SC/67B/REP/07 Rev1

Fifth Rangewide Workshop on the Status of North Pacific Gray Whales

IWC

INTERNATIONAL WHALING COMMISSION

Fifth Rangewide Workshop on the Status of North Pacific Gray Whales[1]

1. INTRODUCTORY ITEMS

1.1 Convenors' opening remarks
The Workshop was held at the Granite Canyon Laboratory (Big Sur, California) of the Southwest Fisheries Science Center from 28-31 March 2018. The list of participants is given as Annex A. Brownell welcomed the participants and explained the history of the facility, which has been used for almost five decades to census gray whales during their southbound migration. Donovan and Punt (co-convenors) noted that the primary tasks of the workshop were to review the results of the modelling work identified at the Fourth Workshop and SC67a, to examine the new proposed Makah Management Plan (submitted by the USA on gray whaling off Washington state and to update as possible (and develop a workplan for) updating the scientific components of the Conservation Management Plan (CMP) for western gray whales.

1.2 Election of Chair
Donovan and Punt were elected Chairs (Donovan chaired from the 28-30 March and Punt on 31 March).

1.3 Appointment of rapporteurs
Calambokidis, Cooke, Lang, Punt, Reeves, Scordino and Weller served as rapporteurs.

1.4 Adoption of Agenda
The Adopted agenda is given as Annex B.

1.5 Documents and data available
The documents available to the meeting are listed in Annex C. Annex D summarizes the terminology used to designate breeding stocks and feeding aggregations.

2. PROGRESS ON 'NON-MODELLING' RECOMMENDATIONS AND NEW DATA

2.1 Updated information from co-operative genetics studies
Bickham presented the results of a multi-authored study of SNPs using samples from approximately 50 whales feeding off Sakhalin Island ('western' gray whales) and approximately 100 whales from the Mexican wintering grounds (assumed 'eastern' gray whales); the full study was to be presented at SC67a. The methods used are described in DeWoody *et al.* (2017). Bickham stated that a finished version of the paper will be presented at the 2018 IWC SC meeting. The authors believe that the results will have implications for prioritising the various stock structure hypotheses being modelled in the Rangewide Review (see below).

Multiple duplicate biopsies were found within both the Sakhalin and Mexico sample sets, but none were shared between the two localities. SNP genotypes were also presented for two mitochondrial and two sex-linked loci (Zfx and Zfy). One of the sex-linked SNPs (ZFY_342) had an apparent fixed heterozygosity in the Mexican whales and thus only the second locus could be used for determining the sex of the whales. The Workshop noted that whilst there is no single explanation of this, one possibility is that there was a translocation (duplication) of the Y-linked SNP to the X or to an autosome.

Bickham also presented the results of the STRUCTURE analyses for the SNPs. In the cases with locality as a prior and without locality as a prior, $K = 2$ genomes (or populations) was the best solution; the plot with geography as a prior showed better differentiation with one predominating in the east (Mexico) and the other predominated in the west (Sakhalin). All eastern samples showed admixed ancestry (including some with predominantly the "western" genome) but the western samples showed a much higher proportion of admixture including individuals of nearly 'pure' eastern and western genomes. He also presented results for an analytical approach called Landscape and Ecological Associations (LEA)[2]. The LEA analysis also identified K = 2 genomes but with greater separation. In the Sakhalin sample set the western genome still predominated but there were both individuals with pure western and others with pure eastern genomes as well as admixed individuals. The more equal proportions

[1] Not all attendees have had a chance to comment on this final version although much of the report was agreed at the Workshop itself.

[2] http://membres-timc.imag.fr/Olivier.Francois/LEA/tutorial.htm

of western and eastern genomes in the Sakhalin samples was consistent with an Mxy estimate of genetic similarity (the Sakhalin sample set had a notably higher variance for genetic relatedness between paired samples than was observed in the Mexican sample set).

The authors of the working paper concluded that the Sakhalin population might be comprised of two types of individuals representing two breeding stocks (i.e., two different genomes), along with individuals of mixed ancestry (admixture). The proportions of the two genomes are vastly different in the two sample sets.

The Workshop **agreed** that incorporating photo-id data into the genetic results will greatly improve interpretation of stock structure and movements and **recommended** that the genetic dataset should be examined comparing whales seen only once off Sakhalin with those whales seen in multiple years.

Lang gave a brief update of her work on SNPs, using the next-generation sequencing approach ddRAD. She is analysing approximately 200 gray whales representing approximately equal sample sizes of PCFG (Pacific Coast Feeding Group), western gray whales, and Northern Feeding Group whales. She expects to present the results of at the 2019 gray whale *Implementation Review.*

The Workshop **welcomed** news from Bickham that a request to the government of Japan to obtain gray whale samples for genetics studies (including of the possible extant western breeding stock).

It was noted that the extent of mixing of gray whales in the past had probably fluctuated in response to changes in sea ice (glacial versus interglacial periods). Bickham responded that additional genome sequencing was planned and that the reconstruction of the historical demography of western and eastern gray whales is one goal of that study. Analyses may reveal associations with the climate cycles of the Pleistocene.

2.2 Updated information from photo-identification studies including consolidation of WGW catalogues

SC/MP/CMP/02 reviewed the results of long-term photo-identification studies conducted between 2002-2017 off northeast Sakhalin Island by the Joint Monitoring Program of two oil and gas companies[3]. The photo-identification catalogue resulting from this work contains 283 identified individual gray whales, including: (a) 175 whales that use the Sakhalin Island feeding area on a regular annual, (b) 27 occasionally-sighted whales (recorded at intervals greater than 3 years), and (c) 71 individuals that have been recorded only once. Forty-eight of the one-time visitors were recorded as calves, excluding the nine calves first identified in 2017. There are 29 identified mothers and 127 whales first identified as calves in the catalogue. Six mother-calf pairs were identified in 2017, along with three unpaired calves. Whale no. KOGW127 (aka "Agent"), was identified as a calf in 2005 and was first recorded as a mother in 2017 at the age of 12 years. Agent was satellite tagged in 2011 and her winter migration was tracked to the Gulf of Alaska before the transponder stopped working (Mate et al., 2015).

Drone-based photography was incorporated into the joint-programme field program in 2017. In most cases, the drone was used at an average distance of about 800 m from shore with a standard altitude of 8 meters. The range of the drone presently in use is 2.5 km from the shore. With the collection of aerial photographs from drones, a new body aspect ("back") was added to the photo-identification catalogue. Also, a new supplemental catalogue of drone-collected video was created for 35 individuals.

The catalogues of the ENL-SEIC joint programme and the Russian Gray Whale Programme (previously the Russia-US programme) were last cross-matched using data available through 2011. At that time, the two Sakhalin photo-identification catalogues contained a total of 222 whales, of which 186 were common to both. Seventeen whales were found only in the Russian Gray Whale Programme catalogue and 19 only in the ENL-SEIC catalogue (IUCN, 2013). An updated catalogue comparison, under the auspices of the IWC, is being discussed as is the concept of a common shared catalogue and database.

In discussion, the Workshop **agreed** on the importance of the long-term nature of the research programmes being conducted off Sakhalin. The concept of a common catalogue and database was welcomed and several measures to ensure data compatibility were mentioned, including the important step to standardize reporting of effort and protocols used to designate calves versus yearlings. It was further mentioned that sighting histories of whales photo-identified off Kamchatka should be evaluated to determine patterns of annual occurrence. Finally, the availability of a shared catalogue and regular updating of such was highlighted with respect to the research component of the hunt management plan proposed for the Makah hunt.

2.3 Gray whales off Korea

SC/M18/CMP/04 reported the possible occurrence of a gray whale off Korea in 2015. Video footage of what appears to be a gray whale was uploaded on YouTube in 2015[4]. The whale was swimming near a port facility in

[3] Exxon Neftegas Limited (ENL) and Sakhalin Energy Investment Company (SEIC)

[4] https://www.youtube.com/watch?v=dJ4J7luGgcE

Samcheok, on the east coast of Korea. While the poor quality of the video prevented positive identification to species, some features of the whale suggest that it was a gray whale. Additional information is being sought to confirm the species identification. If this sighting was indeed of a gray whale, it would be the first record from Korea since 1977. The Workshop thanked D. Yasutaka Imai for alerting Kim to the existence of this video.

3. UPDATING SCIENTIFIC ASPECTS OF THE CMP

Donovan reported recent progress on the "Rangewide Review of the Status of North Pacific Gray Whales" and the 'Western Gray Whale Conservation Management Plan' (CMP). Since 2004, the IUCN and IWC have emphasized the need for a comprehensive international CMP to mitigate anthropogenic threats facing gray whales throughout their range in the western North Pacific. This CMP was initiated at an IUCN-convened international workshop in Tokyo in summer 2008 (IUCN 2009). A draft of the CMP was completed in 2010 (Brownell *et al.* 2010) and this was endorsed by both the IWC and IUCN. The first successes of the CMP included completion of a telemetry project conducted off Sakhalin and a Pacific-wide photo-identification catalogue comparison. The results of these projects showed that some of the whales sighted off Sakhalin in the summer migrate east, across the Pacific, reaching portions of the North American coast between British Columbia, Canada and the wintering lagoons off Baja California, Mexico. In light of this new information, the IWC has been engaged in the present rangewide review.

In support of the CMP initiative, in 2014 a 'Memorandum of Cooperation Concerning Conservation Measures for the Western Gray Whale Population' (the MoC), was signed by Japan, Russian Federation and the USA. In 2016, the memorandum was signed by Mexico and the Republic of Korea and Prof. Hidehiro Kato of the Tokyo University of Marine Science and Technology was appointed as coordinator of the memorandum. It is hoped that in time the other remaining range states will also sign the memorandum.

3.1 Review of existing sections

The Workshop noted that the work to complete the computing specifications, especially taking into account the new Makah Management Plan, meant that there was insufficient time to update the CMP sections, also recognising that this could best be completed after the modelling results became available, ideally at SC67b. Attention was drawn to the updated seasonal maps[5] and participants were asked to send any comments or suggestion for modification to Donovan and Reeves.

The Workshop **recommended** that the Scientific Committee considers establishing a small drafting group comprised of at least the national co-ordinators of the MoC, Reeves (IUCN) and Donovan be convened to meet intersessionally (e.g. at IUCN headquarters) to provide an updated version of the plan after SC67b.

3.2 Consideration of future stakeholder workshop

An important component of the CMP effort is the need for a stakeholder workshop (tentatively forecast to occur in 2019) that helps to finalize the CMP and develops a strategy for its implementation (IWC, 2017b). The workshop, which would be co-sponsored by IWC, IUCN and the signatories to the Memorandum of Cooperation, should be broad-based and include representatives of national and local governments, industry (e.g. oil and gas, fishing, shipping and tourism), IGOs and NGOs. Objectives of this meeting should include: (1) review and updating of the CMP taking into account any new scientific results from the rangewide workshops, (2) establish a stakeholder Steering Group to monitor CMP implementation, (3) arrange for a coordinator of the CMP and (4) establish a work plan and consider funding mechanisms to implement the actions of the plan. The IWC has a Voluntary Fund for Conservation, to which donations can be specifically directed towards the gray whale CMP and related work. It is expected, however, that after the first year of CMP implementation, range states will contribute the necessary funds to advance the conservation actions listed in the plan. The Workshop welcomed the support offered by IUCN with respect to organising the stakeholder workshop.

4 UPDATE ON MODELLING FRAMEWORK AND RUNS

4.1 Progress of modelling since SC67a including validation

4.1.1 General progress, including validation

Punt informed the Workshop that code implementing the specifications agreed at the 4th Rangewide Workshop and modified during SC67a had been written and used to condition the reference trials based on stock hypotheses 3a, 3e and 5a, along with the sensitivity tests that implement stock hypotheses 3b and 6b.

[5] https://iwc.int/western-gray-whale-cmp

Brandon summarized progress on validating the code implementing the operating model and the conditioning process. SC/M18/CMP/03 provides an update on code validation, including a brief overview of the code and input files, and a list of verification steps taken to date. The main focus of the validation process has been on the FORTRAN procedures necessary for the conditioning phase. Conditioning the operating model is the first and most computationally expensive phase of the Rangewide modelling effort because this code involves the bulk of calls to numerical methods to estimate parameters given model fits to the data. To this end, the conditioning code has been checked against the mathematical and statistical model specifications, to ensure that the procedures as implemented are consistent with the specifications (see Annex D for the specifications of the Rangewide model). Likewise, diagnostic output from the code has been checked against expected values. No errors in the coding were identified.

4.1.2 Modelling related to the proposed Makah management plan

Punt informed the Workshop that code implementing the Makah Management Plan (Annex X) had been developed and initial results presented to the March 2018 AWMP meeting. However, Brandon has yet to validate this code. The code implementing the Makah Management Plan needs to be validated prior to SC67b.

During the Workshop, the Makah Management Plan was clarified/updated as shown below.

(1) It was clarified that the hunt will be stopped if the PCFG 10-yr strike limit less number of PCFG-designated animals drops below 1 or if the PCFG 10-yr female strike limit less number of PCFG-designated females drops below 1. The initial implementation only stopped the hunt only when these differences were less or equal to zero.
(2) It was agreed to incorporate an ‘unknown identity’ component for landed whales because it may not be possible to obtain a useable photograph of landed as well as struck and lost whales (although at a lower probability).
(3) It was agreed to allowing for the fact that the amount that unidentified whales count towards the PCFG 10-year strike limit will be updated based on available data rather than always being assumed to be 0.4. The error associated with the estimate of the proportion of PCFG whales in even-year hunts needs to be accounted for (see Item 4.4.1).

4.2 Review of stock hypotheses

The Workshop reviewed how the three baseline stock hypotheses (3a, 3e and 5a) and the two stock hypotheses considered as tests of sensitivity (3b and 6b) had been implemented, noting that some of the ‘limited’ movements (light arrows in Annex E) had been omitted from the baseline hypotheses, but would be considered in tests of sensitivity (e.g. the PCFG in sub-area BSCS). The omission of the associated links was due to lack of mixing data to allow the links to be modelled. It was also noted that that there are no data (abundance estimates, mixing proportions, catches) for some of the sub-area (e.g. the OS sub-area), which implies that the results will be identical no matter how such regions are treated in the modelling.

The Workshop noted that the current implementation of hypothesis 5a did not include the WBS in the SKNK sub-area. This is because there was currently no basis to specify a mixing proportion for WBS vs WFG animals in the sub-area. Cooke provided abundance estimates by breeding stock / feeding group (see Item 4.3.1), which means that it is no longer necessary to specify mixing proportions for the SKNK sub-area.

The Workshop **agreed** that stock hypotheses 3a and 5a would form the references for the analyses as they appear to be most plausible, while trials would also be conducted for stock hypotheses 3b, 3c, 3e and 6b. Annex E shows the final stock hypotheses considered in the trials graphically, while Annex D, Table 2 shows the resulting mixing matrices. The γ values in Annex D, Table 2 indicate parameters that are estimated during the model fitting process.

4.2.1 Plausibility of stock hypothesis 6b

SC/M18/CMP/01 aimed to reopen discussion on the plausibility of the stock hypotheses previously considered as high priority for modelling, with special emphasis on stock hypothesis 6b. Stock hypothesis 6b assumes that the WBS has no fidelity to wintering ground and uses both wintering grounds in both Asia and Mexico. SC/M18/CMP/01 argued that this hypothesis was elevated to high priority due to discussions regarding the movements of humpback whales and the social aggregating hypothesis of Clapham and Zerbini (2015). This hypothesis involves humpback whales learning of new wintering grounds, likely through hearing other humpback whales, and temporarily immigrating. SC/M18/CMP/01 argued that this hypothesis does not apply well to gray whales because they are much quieter than humpback whales and there is a large distance between the distribution of WBS and eastern breeding stock whales (as portrayed by hypothesis 6b) preventing communication between whales. Furthermore, humpback whales and gray whales have very different breeding behaviour, with humpback whales aggregating on modified leks (Clapham and Zerbini 2015). There does not appear to be a functional benefit for WGW to justify shifting their migration to go to wintering grounds in Mexico instead of Asia given the extra 4,000 km of travel required (Villegas-Amtmann *et al*., 2015). Furthermore, it does not appear likely that the WBS used both wintering grounds without fidelity prior to commercial whaling given that whaling occurred off Japan and Korea during a period when the whales using the Mexican wintering grounds were depleted. Bickham et al. (2013) has also presented arguments based on genetics on why hypothesis 6b has low plausibility. SC/M18/CMP/01 also suggested that hypothesis 3e has low plausibility because it assumes that WBS whales occur in their historical feeding range but do not use the Piltun Lagoon area of Sakhalin Island, which has proved to be an important feeding area since the mid-1980s. It is more likely that if the WBS exists, that this breeding stock would spend at least some time feeding near Piltun Lagoon. SC/M18/CMP/01 concluded the trials based on stock hypotheses other than 3a and 5a should be sensitivity tests.

In discussion, it was noted that gray whales that feed off Sakhalin and traditionally used wintering grounds in the western North Pacific could be driven to occasionally use migratory routes and wintering areas in the Eastern North Pacific. While the Rangewide model does not explicitly account for breeding so does not incorporate information on when or where whales breed, this hypothesis could provide an explanation for the observations of Sakhalin whales in the eastern North Pacific. There is evidence showing that whales from the same feeding groups migrate together; both Sakhalin and PCFG whales have been photographically identified in the same groups and in localized areas while on migratory routes (Weller et al. 2012, Calambokidis and Perez 2017). This could provide a mechanism by which whales that feed together, but have traditionally used different wintering areas, could learn new migratory routes.

Although the possibility that gray whales use multiple wintering grounds could not be ruled out, the Workshop **agreed** that stock hypotheses 6b would be considered as a sensitivity test. It was also **agreed** that stock hypothesis 3e would be considered a sensitivity test.

4.3 Confirm final data sets

4.3.1 Removals (direct and incidental)

IWC (2018) referenced records of gray whale deaths from entanglement/entrapment, ship strike, and unknown causes in Japan from 1982 until the present (Nakamura *et al.,* 2017). A small group (Scordino, Reeves, Brownell) met to confirm and update what had been stated previously on removals in Japan (and elsewhere), recalling that the adult that 'died off Hokkaido in 1996' was killed deliberately (Brownell, 1999).

The Workshop **endorsed** the conclusions of the small group as summarised below.

(1) Of the six gray whales reported as beached in Japan between 1990 and 2016 but with cause of death undetermined, some proportion should be assumed to have died from either entanglement/entrapment or ship strike. The under-reporting factor (usually x4 but with sensitivities of x10 and x20; Annex D, tables 8 and 9) used in the model to convert observed mortality to true mortality in the case of bycatch and ship strike would account for this.

(2) There was no reason to believe there had been any change in fishing effort (e.g. set net fishing) in Japan between 1930 and 1982. Therefore, the removal rate from 1982 to the present should be extended back to 1930 for modelling purposes.

(3) Finally, with respect to commercial set gillnet fishing in California prior to 1981, as noted last year (IWC, 2018), a seabass fishery operated in northern Mexico and southern California prior to the 1980s (e.g. landing 412,000 pounds of black seabass and 873,000 pounds of white seabass in 1953; Marine Fisheries Branch, 1956). In fact, this fishery was active and overall fishing effort 'fairly constant' from before 1930 until the early 1980s (Vojkovich and Reed, 1983). There was no observer effort in this fishery before 1981, nor was an official stranding record of cetaceans maintained in California before that time. However, a coordinated reporting system for stranding was established in the early 1960s under the auspices of the American Society of Mammalogists, and stranded gray whales were regularly reported. For example, 24 dead gray whales were reported as stranded in California between 1960 and 1968, of which seven were confirmed or suspected of having been either entangled in fishing gear or struck by a ship; Brownell, 1971). A gray whale that stranded at Ocean Beach, California, on 19 February 1953 was missing its flukes and bore 'several gashes' on the body – all suggestive of an entanglement death (Robert Orr, pers. comm. to R. Brownell, April 1964).

At last year's workshop, it was assumed that set gillnet fishing effort for halibut in California declined linearly from 1982 to no effort in 1975. To model the effect of this assumption, it was decided to assign all records of gray whales recorded as injured or killed in halibut or other set gillnet fisheries to a single fishery and modelled separately from all other California fisheries. It was also decided to examine both a low case that assigned no deaths to set gillnet fisheries and a high case that considered all bycatch reports related to gillnet, set gillnet, net, and halibut fisheries in California as if they came from a single fishery (IWC, 2018). A recently found publication (Bureau of Commercial Fisheries, 1936) reported that both set gillnets and trammel nets were used in the 1930s in California for halibut and white seabass fishing. Based on this new information, the Workshop **agreed** to drop the assumption that fishing effort declined linearly to zero from 1982 to 1975 and therefore there was no reason to evaluate high and low scenarios as a way of accounting for bycatch in California prior to 1975.

Set gillnetting effort off California changed markedly in 1991 due to regulations passed in November 1990 intended to eliminate gillnet fishing within 3 n.miles of the mainland and within 1 n.mile of any offshore island in southern California by 1994 (Barlow *et al.*, 1994). To address this, a second set gillnet fishery was added to the model starting in 1991 and the set gillnet fishery described in the preceding paragraph was modelled as having ended in 1990.

Table 1

Abundance estimates (1+) for the WFG feeding aggregation and the western breeding stock

Year	Group	Hypothesis	Estimate	SD	CV
1995	WFG	3a/3c/3e/6b	75.1	3.8	0.051
1995	WBS	3b	25.8	7.3	0.282
1995	WFG	3b	75.5	3.3	0.043
1995	WBS	3e	30.0*	15.0	0.500
1995	WBS	5a	26.6	6.9	0.259
1995	WFG	5a	47.8	7.7	0.160
1995	WBS+WFG	5a	74.4	3.9	0.052
1995	WBS/(WBS+WFG)	5a	0.358	0.093	0.259
2015	WFG	3a/3c/3e/6b	199.8	5.4	0.027
2015	WBS	3b	63.8	15.8	0.248
2015	WFG	3b	198.9	5.7	0.029
2015	WBS	3e	30.0*	15.0	0.500
2015	WBS	5a	64.4	14.0	0.218
2015	WFG	5a	135.6	14.1	0.104
2015	WBS+WFG	5a	200.0	5.7	0.029
2015	WBS/(WBS+WFG)	5a	0.322	0.069	0.200

* Guestimate because the WBS cannot be distinguished given the available information.

4.3.2 Abundance estimates

There were no updates to the estimates of abundance for the PCFG or the ENP stock. New abundance estimates for western gray whales had been presented to the last WGWAP meeting (Cooke *et al*., 2017), which will also be presented to the SC67b. Estimates for the WFG were extracted at the Workshop that would correspond to the stock structure hypotheses listed in Annex E (table 1). The larger estimates for the WFG correspond to the hypothesis that all whales visiting SE Kamchatka and/or Sakhalin belong to the WFG, while the smaller ones correspond with the hypothesis that only whales that visit Sakhalin belong to the WFG (regardless of whether these individuals also visit Kamchatka).

For the hypotheses where a proportion of the WFG belongs to the western breeding stock (WBS), this proportion is highly uncertain (and could be zero) even though the estimate for the total WFG is reasonably precise. The estimates of the numbers of WFG animals in each of the two breeding stocks are, therefore, highly negatively correlated. In these cases, the multi-stock model uses as inputs the estimate of the total WFG and the estimated proportion of this that belongs to the WBS.

Table 2

Mixing proportions for use in the trials

Sub-area	Season	Stock / Feeding aggregation	Mixing proportion
EJPJ	All	WBS/NFG	0.33
SEA	Feeding	PCFG	0.57[1]
SEA	Migration	PCFG	0.1[2]
SEA	Migration	WGW	0.002[3]
BCNC	Feeding	PCFG	0.93
BCNC	Feeding	WGW	0
BCNC	Migration	PCFG	0.28
BCNC	Migration	WGW	0.002
CA	Feeding	PCFG	0.60
CA	Feeding	WGW	0
CA	Migration	PCFG	0.1
CA	Migration	WGW	0.002[3]

1: Not used in the conditioning as no bycatch is recorded for the SEA sub-area during the feeding season.

2: Assumed value owing to lack of data to estimate mixing proportions.

3: Set to the value calculated for BCNC by Moore and Weller 2013)

4.3.3 Mixing proportions

Table 2 lists the updated mixing proportions. The mixing proportion for the EJPJ sub-area is unchanged from that specified at the 4th Rangewide Workshop because none of whales encountered recently in this sub-area had adequate photographs to allow for matching (Table 3).

Table 3

Updated information on matches between whales encountered off Japan and those photographed off Sakhalin (D. Weller, SWFSC).

Date	Location and source	Conclusion
April 2016	Shizuoka, beached	no useable photos/no match
February 2017	Kanagawa, sighting	poor quality video only/no match
April 2017	Chiba, sighting	poor quality video only/no match
March 2017	Aogashima, sighting	no useable photos/no match
February 2018	Aogashima, sighting	no useable photos/no match

New mixing proportions were calculated for PCFG whales by sub-area for the winter/spring (migrating) and summer/fall (feeding) seasons (Table 4). The sub-regions of the BCNC region used for the analysis were northern Oregon, southern Washington, and northern Washington because they were thought to have the least chance of bias in calculated mixing proportions. Updated data through 2015 based on matches to the PCFG catalogue were used. There was considerable discussion about how to calculate the mixing rate for the Oregon-Washington outer coast area due to a dramatic change in proportion of PCFG whales in northern Washington from surveys in early April 2015. Those surveys identified a large number of whales in a previously poorly sampled area that had very few PCFG whales. Identifications in spring 2015 (heavily influenced by these April surveys) reduced the overall proportion of PCFG whales based on pooled proportions through 2015 to 24% (it had been 36% based on data through 2014). To provide a value less influenced by these two days of surveys, the proportions of PCFG whales were averaged over sub-region and month to compute an overall average of 28% (an average of the eight values presented in Table 4.

Table 4

Proportion of PCFG whales by region and month for cells with >10 IDs; complete through 2015 for OR-WA Jan to May (no Dec data)

Region	Jan	Feb	Mar	April	May
NWA	0.09		0.09	0.10	0.41
SWA			0.38	0.21	0.33
NOR					0.63

Mean of above cells for OR to WA: **Unweighted = 28%**, Pooled = 24%

Mean of above for just N WA: Unweighted = 17%, Pooled = 20%

The Workshop **agreed to** adopt 28% for the proportion of PCFG whales in the BCNC sub-area during the migrating season for the bulk of the trials, and that sensitivity would be evaluated to 17%. This value is obtained by restricting the analysis of mixing rates of PCFG whales during the winter/spring to just northern Washington where the hunt would occur (based on the unweighted average of the 4 months where there were at least 10 photo-IDs, table 4). Pooling all 622 photo-IDs for December to May would result in a rate of 20%, although this approach weights values towards periods with more photo-IDs.

Considering some of the uncertainty around the estimate for the portion of PCFG whales present in the spring off the Washington-Oregon coast and the variation by location, month, and year, the Workshop **agreed** the current best estimate of 28% to be +-20% (8-48%) for the true PCFG mixing rate. The rationale for the choice is that very different results would be obtained in different areas such as 1) the recently sampled zone north of Tatoosh Island in the early spring where migrating whales appear to gather in some years where recent efforts revealed almost no PCFG whales, compared to 2) areas along the Northern Washington Coast or for example in Barkley Sound that are feeding areas for PCFG whales and where their proportion compared to migrating whales would be highest.

4.4. Confirm final trial structure and conditioning

4.4.1 Changes to the trials specifications, including stock structure

Annex D lists the specifications for the model that will form the basis for drawing final conclusions regarding the implications of alternative stock structure hypotheses and of the implementation of the Makah management plan. The specifications (see also Annex D and Table 5 and 6) reflect changes to how the stock hypotheses are implemented as well as how the abundance estimates for the western Pacific are used in conditioning. The Workshop also agreed that the following additional changes will be made the trials specifications:

(1) the base-case survival rate for animals aged 1 and older would be assumed to be 0.98, which reflects the estimates obtained by Cooke (ref) and Punt and Wade (2012); the values used in previous trials was 0.95;

(2) the SET1 and SET2 fleets (set gillnets off California in the feeding and migration seasons) would be split between 1990 and 1991 given the changes in regulations in the associated fisheries that appear to have changed bycatch rates;
(3) the survey plan for the California counts were updated to reflect the current plan (two surveys in every five-year block); and
(4) the periods used to calculate average bycatch rates to infer bycatch prior to the establish of monitoring networks into the future as generally but the earliest and most recent five years, but a longer period is specification for sub-areas (e.g. EJPJ and SI) with limited data (Annex D, table 3)

Evaluation of the Makah Management Plan requires specification of the probability of photographing a landed or struck and lost whale, as well as the probability of correctly deciding that such a whale is from the PCFG or the WFG. In addition, it is necessary to specify the probability of striking and losing a whale and assigning a sex to an animal for which a match has been made. These probabilities are specified as follows:

(1) *Probability of obtaining a photograph of sufficient quality to allow it to be matched to the catalogue*. For struck and lost whales, this probability is estimated to be a 0.6 for winter/spring and 0.8 for summer/fall (due less favourable light and weather in winter/spring compared to summer/fall). For landed whales, it is estimated to be 0.9 for all seasons.
(2) *Probability of struck and lost*. The review of the Makah whale *SLA* concluded in 2013 was based on a value for this probability of 0.5, which was informed by two strikes that occurred during the Makah 1999 hunt in which one strike resulted in a landing and the other contacted the whale but did not penetrate the skin. The Workshop agreed to retain the assumption of a 50% struck and lost rate for hunts during the winter and spring. It was decided that hunts occurring during the summer and fall were much less likely to have struck and lost due to better weather conditions and more predictive movement behaviours of whales in the normal feeding depths of PCFG whales. The Workshop therefore agreed that the struck and lost rate for summer and fall hunts would be 0.1 and that sensitivity would be explored to a value of 0.5.
(3) *False positive rate for PCFG (i.e. probability of a non-PCFG being identified as from the PCFG given a good quality photograph*). The probability that a non-PCFG whale might be falsely identified as a PCFG whale is estimated to be 0.05. Normally, there is a near 100% confidence for matches that are identified to Cascadia's PCFG catalogue because these are double checked and photographs of poorer quality where there is some ambiguity are treated as Poor Quality and not used. The value of 0.05 is based on the assumption that a slightly different set of circumstances would exist for comparison of a whale struck or landed because there would be pressure to try to match regardless of the quality of the photograph and it would be hard to justify not reporting as a match something where there was a relatively high degree of confidence (i.e. 95% confident of the match to a PCFG whale).
(4) *False negative rate for PCFG* (i.e. *i.e. probability of a PCFG whale not being identified as such given a good quality photograph*). This probability is estimated to be 0.25 for a hunt in the winter/spring, and zero for a hunt in summer since all struck whales are assumed to be of the PCFG. This value of 0.25 accounts for several factors, including whales only seen in fewer in two years in the PCFG because of a combination of being young, not being photographed, and the one year lag in available catalogue. In addition, there could be a matcher error in missing a match due to things like changed markings.
(5) *False positive rate for WFG (i.e. probability of a non-WFG being identified as from the WFG given a good quality photograph*). This probability is estimated to be 0.01 based on the WFG catalogue being smaller and more well-known. Also, it is suspected that the matcher would likely only declare a match when there was a high level of confidence given the infrequent rate of these matches.
(6) *False negative rate for WFG* (i.e. *i.e. probability of a WFG whale not being identified as such given a good quality photograph*). On the assumption that calves and lactating mothers will not be hunted, the proportion of huntable WFG whales that would not be known as WFG whales if taken during the spring northward migration was estimated using the population model fit to the Sakhalin and Kamchatka photo-id data. An animal that has been seen off Sakhalin is assumed to be a WFG animal if seen or taken in the eastern North Pacific. An animal seen off eastern Kamchatka but not Sakhalin is not assumed to be a WFG animal, because it might be an NFG animal. The estimated proportion, averaged across the posterior distribution of the population trajectory, was 4-5% depending on the hypothesis. These estimates used data through 2011 only, that being the last season for which the catalogues were cross-matched. If only a single catalogue were used, the rate would be higher. The values used in the trials are: stock hypotheses 3a, 3c, 3e, and 6b: 0.041; stock hypothesis 3b: 0.040; stock hypothesis 5a: 0.049.
(7) *Probability of not assigning a sex to a struck and lost animal that has been identified to the PCFG.*
    a. This probability is estimated at 19% for the feeding season based on 81% of encounters of PCFG whales from June-Nov through 2015 for the Oregon and Washington outer coast having known sex. For those with known sex in this sample 58% were female and 42% male, but this could be

biased by some directed sampling toward females so the sex ratio should be treated as 50:50 in the management plan.

b. This probability is estimated at 27% for the migrating season based on 73% of encounters of PCFG whales from Dec-May through 2015 for the Oregon and Washington outer coast having known sex. For those with known sex in this sample 46% were female and 54% were male. This male-biased sex ratio is in the opposite direction of the bias from intentionally sampling females, which suggests males are actually more abundant and available in the spring off the Oregon and Washington outer coast likely as a result of females with calves migrating later and being less available in spring. Given the bias for trying to sample known females, it is likely that the sex ratio in spring is likely closer to 60:40 male:female. If hunters avoid taking mothers with calves it would further reduce the chances of taking a female.

Estimates of the proportion of PCFG whales used in the Makah management plan for assigning a struck unidentified whale in the winter/spring hunt are subject to uncertainty due to for example shifting proportions based on sampling differences and these should be considered subject to a bias (which depends on trials) that ranges from -0.1 to 0.1.

Table 5

Factors considered in the model scenarios. The bold values are the base-levels and the values in standard font form the basis for sensitivity analyses.

Factor	Levels
Model fitting related	
Stock hypothesis	**3a,** 3b, 3c, 3e, **5a,** 6b
$MSYR_{1+}$ (western)	As for WFG
$MSYR_{1+}$ (north)	**4.5%**, 5.5%, Estimated (common); estimate (separately)
$MSYR_{1+}$ (WFG)	**4.5%** Estimated (common); estimate (separately)
$MSYR_{1+}$ (PCFG)	2%, **4.5%**, 5.5%, Estimated (common); estimate (separately)
Mixing rate (migration season in BCBC	**0.28**, 0.17, 1.00
Immigration into the PCFG	0, 1, **2**, 4
Bycatches and ship strikes	Numbers dead + M/SI, **dead x 4**; dead x 10; dead x 20
Pulse migrations into the PCFG	10, **20**, 30
Projection-related	
Additional catch off Sakhalin (mature female)	0, 1
Catastrophic events	**None**, once in years 0 – 49, and once in years 50-99
Northern need in final year (from 150 in 2014)	**340**
Struck and lost rate	**(0.1; odd-years; 0.5 even years),** 0.5 all years
Future effort	**Constant**, Increase by 100% over 100 years
Probability of a photo (struck and lost whales)	**0.8; odd-years; 0.6 even years**
Probability of a photo (landed whales)	**0.9**
Probability of false positive rate PCFG	**0.05**, 0.1
Probability of false negative rate PCFG	**0.25**
Probability of false positive rate WFG	**0.01**
Probability of false negative rate WFG	**0.041 (stock hypotheses 3a, 3c, 3e, 6b);** 0.040 (stock hypothesis 3b); **0.049 (stock hypothesis 5a)**
Probability of a sex assignment given a PCFG match	**0.81**

4.4.2 Base-case trials and sensitivity tests

The 4th Rangewide workshop specified a series of trials. However, it had not been possible to implement all of these trials during the intersessional period. The Workshop reviewed the set of trials and made the following changes (trial numbers relate to revised numbering system):

(1) stock hypothesis 3e is now treated as a sensitivity test as it is a variant of stock hypothesis 5a (with no WBS animals in the SI sub-area);
(2) a new sensitivity test (18C) based on stock hypothesis 3c has been added as agreed at the 4th Rangewide workshop (IWC, 2018);
(3) the sensitivity test exploring a higher proportion of WBS whales in sub-area SI (3B) involves increasing the estimates of abundance for the WBS by 50% and correspondingly reducing the estimates of abundance for the WFG;
(4) the trials involving PCFG whales in the BSCS sub-area (12A/B) are based on assuming that all PCFG whales are in the BSCS sub-area. The assumption will be conservative given that most PCFG whales are located elsewhere when the aboriginal hunt off Chukotka occurs;
(5) the trials involving WFG whales in the BSCS sub-area (13A/B) are based on assuming that all WFG whales are in the BSCS sub-area. The assumption will be conservative given that most WFG whales are located elsewhere when the aboriginal hunt off Chukotka occurs;

(6) the trials exploring the sensitivity of how the California set gillnet catches were modelled (trials 14 and 15 in Table 8 of IWC (2018)) were dropped as the approach for modelling the SET1 and SET2 fleets was modified (see Item 4.3.1);
(7) the trials with MSYR estimated and a higher pulse were dropped as these trials are unlikely to be informative (trials 14A/B and 8A/B examine these factors individually);
(8) variants of trials 5A/B and 16A/B (trials 18A/B and 19A/B) that have net immigration of 1 to the PCFG were added because the assumption of zero immigration into the PCFG is unlikely given the results of Lang and Martien (2012);
(9) trials 7A/B and 16A/B exclude the PCFG abundance estimates for 1998-2002 as a low pulse would not allow the model to mimic these data – this change in model specifications mimics the adoption in the trials used to evaluate the *SLA* for a Makah hunt by IWC (2013) of a time-varying survey bias;
(10) trials 22A/B have been added to examine the future consequences of a catastrophic events in the NFG – these events occurs randomly once in the first 50 years and randomly once in the second 50 years, with a magnitude equivalent to that of the mortality event in 1999/2000; and
(11) trials 23A/B and 24A/B have been added to explore sensitivity to the struck and lost rate for a Makah hunt in the feeding season, and the false negative rate for a Makah hunt in summer.

Table 6

Final trial specifications

Trial	Description/stock hypothesis	PCFG or WFG in BSCS	MSYR$_{1+}$ North	MSYR$_{1+}$ PCFG	MSYR$_{1+}$ WFG	PCFG Imm.	PCFG Pulse	Bycatch	Condition?
Base-case trials									
0A	Reference 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
0B	Reference 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
Sensitivity tests									
1A	Lower MSYR PCFG 3a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
1B	Lower MSYR PCFG 5a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
2A	Higher MSYR PCFG and North 3a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
2B	Higher MSYR PCFG and North 5a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
3A	Lower WBS in Sakhalin 5a (Hyp 3e)	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
3B	Higher WBS in Sakhalin 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4A	PCFG mixing based on Northern WA only 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4B	PCFG mixing based on Northern WA only 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
5A	No PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
5B	No PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
6A	Higher PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
6B	Higher PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
7A	Lower Pulse into PCFG 3a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
7B	Lower Pulse into PCFG 5a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
8A	Higher pulse into PCFG 3a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
8B	Higher pulse into PCFG 5a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
9A	Bycatch=Dead + MSI 3a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
9B	Bycatch=Dead + MSI 5a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
10A	Bycatch x 10 3a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
10B	Bycatch x 10 5a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
11A	Bycatch x 20 3a	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
11B	Bycatch x 20 3e	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
12A	PCFG in BSCS 3a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
12B	PCFG in BSCS 5a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13A	WFG in BSCS 3a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13B	WFG in BSCS 5a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 3a	No		**Estimated**		2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 5a	No		**Estimated**		2	20	D x 4	Yes
15A	MSYR1+ estimated (by FA) 3a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
15B	MSYR1+ estimated (by FA) 5a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
16A	Lower PCFG immigration and higher bycatch 3a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes

Trial	Description/stock hypothesis	PCFG or WFG in BSCS	MSYR$_{1+}$			PCFG		Bycatch	Condition?
			North	PCFG	WFG	Imm.	Pulse		
16B	Lower PCFG immigration and higher bycatch 5a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes
17A	MSYR estimated and lower pulse 3a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes
17B	MSYR estimated and lower pulse 5a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes
18A	Stock hypothesis 3b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18B	Stock hypothesis 6b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18C	Stock hypothesis 3c	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
19A	Lower PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
19B	Lower PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
20A	Lower PCFG immigration and higher bycatch 3a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
20B	Lower PCFG immigration and higher bycatch 5a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
21A	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
21B	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
22A	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
22B	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
23A	Summer S&L rate = 0.5 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
23B	Summer S&L rate = 0.5 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
24A	PCFG false negative rate = 0.1 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
24B	PCFG false negative rate = 0.1 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
25A	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
25B	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes

4.4.3 Conditioning statistics

The Workshop reviewed the diagnostic plots for evaluating the conditioning developed for the trials specified at the 4th Rangewide Workshop. The Workshop **agreed** that the following plots should be produced for each trial and provided to the Intersessional Steering Group for review:

(1) The estimates of absolute abundance (with 90% sampling intervals) and the median, 50% and 90% intervals for the time-trajectory of the model estimates of 1+ population size.
(2) The time-trajectory of the model estimates of the number of mature females.
(3) The distributions (median, 50% and 90% intervals) for the generated mixing proportions and those for the model-predicted mixing proportions.
(4) The distribution for the net immigration rate from the NFG to the PCFG and the target value (black vertical bar).
(5) The estimates of average bycatch over the period for which reporting is considered adequate [Annex D, table 3] (with 90% sampling intervals) and the median, 50% and 90% intervals for the model-estimate of the average bycatch over the period.
(6) The distributions (median, 50% and 90% intervals) for the generated survival rates for PCFG whales and those for the model-predicted survival rates for PCFG whales.
(7) The time-trajectories of removals, including the recorded removals (adjusted for under-reporting) and the bycatch inferred for the years for which reporting is not considered adequate.

4.4.4 Projection scenarios

Previous projections for the Sakhalin population (J. Cooke in Reeves *et al.*, 2005) considered a scenario in which there is future bycatch of 1.5 mature females off Japan based on inferences from bycatch at that time. The Workshop noted that observed bycatch off Japan has declined since then. The Workshop **agreed** that a projection scenario with 1 mature female taken each year in the EJPJ sub-area should to be conducted.

In addition, the Workshop **agreed** that, if possible, projections should be conducted for the current Makah *SLA*, although it was recognised this may not be feasible to achieve before 67b.

The Workshop noted that care needs to be taken to compare the results from the previous *Implementation Review* with those based on the Rangewide review because the population structure hypotheses have changed and the Rangewide review has more fully accounted for bycatch and its uncertainty.

4.4.5 Performance statistics

4.4.5.1 TIME-TRAJECTORIES OF POPULATIONS

The results of the model fits and the projections will be summarized by time-trajectories of 1+ numbers of breeding stock / feeding group and by sub-area

4.4.5.2 MAKAH MANAGEMENT PLAN

The results of the projections to evaluate the performance of the Makah management plan will be based on the standard statistics used by the Committee to evaluate the performance of Strike Limit Algorithms

(1) D1. Final depletion of 1+ and mature female numbers by breeding stock / feeding group (median, lower 5th and upper 5th percentiles)
(2) D8. Rescaled final depletion: P_T/P_0 (1+ and mature female numbers by breeding stock / feeding group; median, lower 5th and upper 5th percentiles) where P_0 is number of 1+ / mature female animals had there been no future Makah hunts.
(3) D10. Relative increase. The ratio of the 1+ and mature population size after 10 and 100 years to that at the start of the projection period by breeding stock / feeding group (median, lower 5th and upper 5th percentiles)
(4) N9. Need satisfaction. The proportion of the total number of requested strikes that were taken over the first 10 years and the entire 100-year period (median, lower 5th and upper 5th percentiles).

Results are provided for both 10 and 100 years for the D10 and N9 statistics because (a) the Makah management plan current only operates for 10 years, and (b) previous evaluations of the performance of management procedures (RMP and AWMP) have considered performance over 100 years. Population-related statistics should be also be provided for the case there is no future Makah hunt (only bycatch and hunting off Chukotka).

5. WORKPLAN

Before / during 67b

(1) Update the code for the operating model (Punt)
(2) Validate any changes to the historical (conditioning) component of the operating model (Brandon)
(3) Conduct conditioning and distribution of conditioning diagnostics to the Steering Group (Punt)
(4) Review of the conditioning results (Steering Group)
(5) Code the revised Makah management plan and the associated testing code (Punt)
(6) Validate the revised Makah management plan and the associated testing code (Brandon)
(7) Conduct the projections and assemble the projection results (Punt)

After 67b

(1) Complete drafting of the CMP.

6. ADOPTION OF REPORT

The co-chairs thanked Brownell and his colleagues for the excellent and historic facilities provided at the laboratory in the beautiful setting of Granite Canyon (complete with gray whales migrating by). The report was adopted by email.

References

Barlow, J., Baird, R.W., Heyning, J.E., Wynne, K., Manville, A.M., Lowry, L.F., Hanan, D., Sease, J. and Burkanov, V.N. 1994. A review of cetacean and pinniped mortality in coastal fisheries along the west coast of the USA and Canada and the east coast of the Russian Federation. *Rep. Int. Whaling Commn. (special issue)* 15: 405-26.

Bickham, J.W., Dupont, J.M. and Broker, K. 2013. Review of the status of the western North Pacific gray whale; stock structure hypotheses, and recommendations for methods of future genetic studies. Paper SC/65a/BRG16 presented to the IWC Scientific Committee, June 2013, Jeju Island, Republic of Korea (unpublished). 12pp. [Paper available from the Office of this Journal].

Brownell, R.L. 1971. Whales, dolphins and oil pollution. pp.255-76. *In*: Straughan, D. (eds). *Biology and Bacteriology*. Allan Hancock Foundation, University of Southern California, Los Angeles, USA. 426pp.

Brownell, R.L., Jr. and Kasuya, T. 1999. Western gray whale captured off western Hokkaido, Japan. Paper SC/51/AS25 presented to the IWC Scientific Committee, May 1999, Grenada, WI (unpublished). 7pp. [Paper available from the Office of this Journal].

Bureau of Commercial Fisheries. 1936. The commercial fish catches of California for the year 1935. *Fish Bull.* 49. [Available at: *http://content.cdlib.org/view?docId=kt4c6003q0&query=&brand=calisphere*].

Calambokidis, J. and Perez, A. 2017. Association of PCFG gray whales on migration. Paper SC/A17/GW02 presented to the Fourth Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales, April 2017, La Jolla, CA, USA (unpublished). 10pp. [Paper available from the Office of this Journal].

Clapham, P.J. and Zerbini, A.N. 2015. Are social aggregation and temporary immigration driving high rates of increase in some Southern Hemisphere humpback whale populations? *Mar. Biol.* 162: 625-34.

Cooke, J.G., Weller, D.W., Bradford, A.L., Sychencko, A.O., Burdin, A.M., Lang, A.R. and Brownell, R.L., Jr. 2017. Population assessment update for Sakhalin gray whales, with reference to stock identity. Paper SC/67a/NH11 presented to the IWC Scientific Committee, May 2017, Bled, Slovenia (unpublished). 9pp. [Paper available from the Office of this Journal].

Dewoody, J.A., Fernandez, N.B., Bruniche-Olsen, A., Antonides, J.D., Doyle, J.M., San Miguel, P., Westerman, R., Vertyankin, V.V., Godard-Codding, C. and Bickham, J.W. 2017. Characterization of the gray whale (*Eschrichtius robustus*) genome and a genotyping array based on single nucleotide polymorphisms in candidate genes: update of SC/66b/DNA04. Paper SC/67a/SDDNA02 presented to the IWC Scientific Committee, May 2017, Bled, Slovenia (unpublished). 3pp. [Paper available from the Office of this Journal].

IUCN. 2013. Report of the Western Gray Whale Advisory Panel at its thirteenth meeting. . [Available at: *http://www.iucn.org/wgwap/wgwap/meetings/wgwap_13/*].

International Whaling Commission. 2018. Report of the Scientific Committee. *J. Cetacean Res. Manage. (Suppl.)* 19:1-101.

Lang, A.R. and Martien, K.K. 2012. Update on the use a simulation-based approach to evaluate plausible levels of recruitment into the Pacific Coast Feeding Group of gray whales. Paper SC/64/AWMP4 presented to the IWC Scientific Committee, June 2012, Panama City (unpublished). 34pp. [Paper available from the Office of this Journal].

Marine Fisheries Branch. 1953. The marine fish catch of Californiafor the years 1953 and 1954, California department of Fish and Game. *Fish Bull.* 102. [Available at: *https://bit.ly/2ElCndz*].

Mate, B.R., Ilyashenko, V.Y., Bradford, A.L., Vertyankin, V.V., Tsidulko, G.A., Rozhnov, V.V. and Irvine, L.M. 2015. Critically endangered western gray whalesmigrate to the eastern North Pacific. *Biol. Lett.* 11: 20150071. 4pp.

Moore, J. and Weller, D. 2013. Probability of taking a western North Pacific gray whale during the proposed Makah hunt. *NOAA, US Dep. Commer.* Memo NMFS-SWFSC-506: 13pp. [Available from: Protected Resources Division, NOAA, 8901 La Jolla Shores Drive, La Jolla, CA 92037-1022, USA].

Nakamura, G., Yoshida, H., Morita, H., Ito, K., Bando, T., Mogoe, T., Miyashita, T. and Kato, H. 2017. Status report of conservation and researches on the western North Pacific gray whales in Japan, May 2016 - April 2017. Paper SC/67a/CMP02 presented to the IWC Scientific Committee, May 2017, Bled, Slovenia (unpublished). 8pp. [Paper available from the Office of this Journal].

Punt, A.E. and Wade, P.R. 2012. Population status of the eastern North Pacific stock of gray whales in 2009. *J. Cetacean Res. Manage.* 12(1): 15-28.

Reeves, R.R., Brownell, R.L., Burdin, A., Cooke, J.C., Darling, J.D., Donovan, G.P., Gulland, F.M.D., Moore, S.E., Nowacek, D.P., Ragen, T.J., Steiner, R.G., VanBlaricom, G.R., Vedenev, A. and Yablakov, A.V. 2005. Report of the Independent Scientific Review Panel on the Impacts of Sakhalin II Phase 2 on Western North Pacific Gray Whales and Related Biodiversity. 123pp.

Reeves, R.R., Smith, T.D. and Josephson, E.A. 2008. Observations of western gray whales by ship-based whalers in the 19th century. *J. Cetacean Res. Manage.* 10(3): 247-56.

Villegas, S., Schwartz, L.K., Sumich, J.L. and Costa, D.P. 2015. A bioenergetics model to evaluate demographic consequences of disturbance in marine mammals applied to gray whales. *Ecosphere* 6(10, art. 183): 1-19.

Vojkovich, M. and Reed, R.J. 1983. White seabass, *Atractoscion nobilis,* in California-Mexico waters: Status of the fishery. *CalCOFI Rep.* 24: 79-83.

Weller, D.W., Klimek, A., Bradford, A.L., Calambokidis, J., Lang, A.R., Gisborne, B., Burdin, A.M., Szaniszlo, W., Urban, J., Unzueta, A.G., Swartz, S. and Brownell Jr., R.L. 2012. Movements of gray whales between the western and eastern North Pacific. *Endanger. Species Res.* 18: 193-9.

Annex A

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Annex B

Agenda

1. Introductory items
    - 1.1 Convenor's opening remarks
    - 1.2 Election of Chair
    - 1.3 Appointment of rapporteurs
    - 1.4 Adoption of Agenda
    - 1.5 Documents and data available
2. Progress on 'non-modelling' recommendations and new data
    - 2.1 Updated information from the co-operative genetics studies
    - 2.2 Updated information from photo-identification studies including consolidation of WGW catalogues
    - 2.3 Gray whales off Korea
3. Updating scientific aspects of the CMP
    - 3.1 Review of existing sections
    - 3.2 Consideration of future stakeholder workshop
    - 3.3
4. Update on modelling framework and runs
    - 4.1 Progress on modelling since SC/66b, including validation
        - 4.1.1 General progress, including validation
        - 4.1.2 Modelling related to the proposal Mkah management plan
    - 4.2 Review of stock hypothesis
    - 4.3 Confirm final data sets
        - 4.3.1 Removals (direct and incidental)
        - 4.3.2 Abundance estimates
        - 4.3.3 Mixing proportions
    - 4.4 Confirm final trial structure and conditioning
        - 4.4.1 Changes to the trial specifications, including stock structure
        - 4.4.2 Base-case trials and sensitivity tests
        - 4.4.3 Conditioning statistics
        - 4.4.4 Projection scenarios
        - 4.4.5 Performance statistics
5. Work plan
6. Adoption of Report

Annex C
List of Documents

SC/M18/CMP

1. Scordino, J. and Bickham, J. Plausibility of stock structure hypothesis 6b
2. Tyurneva, O.Y., Takovlev, Y.M., Vertyankin, V.V. van der Wolf, P. and Scott, M.J. Lomg-term photo-identification studies of gray whales (*Eschrichtius robustus*) offshore northeast Salhalin Island, Russia, 2002-2017.
3. Brandon, J. IWC Gray Whale Rangewide Model: Code Validation for the 2018 Workshop.
4. Kim, H.W. and Sohn, H. Possible occurrence of gray whale off Korea in 2015.

Annex D

Terminology Used with Respect to Stock Structure Hypotheses

Breeding stocks. There are up to two extant breeding stocks: Western (WBS) and Eastern (EBS).

*Feeding groups or aggregations**. There are up to three feeding groups or aggregations. There is dispersal between the PCFG and North Feeding Group (NFG), but the Western Feeding Group (WFG) is demographically independent of the other two feeding groups (i.e. there is no permanent movement of animals from the NFG or PCFG to the WFG).

	Feeding groups or aggregations	Abbreviation	Definition (may vary with hypothesis)
1	Western Feeding Group	WFG	Animals that feed regularly (define?) off Sakhalin Island* according to photo-identification data
2	Pacific Coast Feeding Group	PCFG	Animals that feed regularly (define?) in the PCFG area according to photo-identification data
3	North Feeding Group	NFG	Animals found in other feeding areas (and for which there is relatively little information including photo-ID)

* May need revising with regard to Southern Kamchatka animals given Justin's paper.

Sub-areas. The model includes 11 geographical sub-areas that are used to explain the movements of gray whales (breeding stocks and feeding groups) in the North Pacific and two 'latent sub-areas' used to link model predictions to observed indices of abundance.

	Sub-area	Abbreviation
1	Vietnam-South China Sea	VSC
2	Korea and western side of the Sea of Japan	KWJ
3	Eastern side of the Sea of Japan and the Pacific coast of Japan	EJPJ
4	Northeastern Sakhalin Island	SI
5	Southern Kamchatka and Northern Kuril Islands*	SKNK
6	Areas of the Okhotsk Sea not otherwise specified	OS
7	Northern Bering and Chukchi Sea	BSCS
8	Southeast Alaska	SEA
9	British Columbia to Northern California	BCNC
10	California	CA
11	Mexico	M
12	Latent sub-area	Calif-3
13	Latent sub-area	BC-BCA-3

* New at this workshop – replaces the old East Kamchatka and Kuril Islands to recognise the information from telemetry and photo-ID.

Annex E

Specifications of the rangewide model

A. Basic concepts and stock structure

The aim of the projections is to explore the population consequences of various scenarios regarding anthropogenic removals of gray whales, with a view to informing future conservation and management. The model distinguishes 'breeding stocks' and 'feeding aggregations'. Breeding stocks are demographically and genetically independent whereas feeding aggregations may be linked through dispersal of individuals[6], though perhaps at very low rates for some combinations of feeding aggregations. Each breeding stock / feeding aggregation is found in a set of sub-areas, each of which may have catches (commercial, aboriginal or incidental), proportions of breeding stock / feeding aggregation mixing[7] in those sub-areas, observed bycatch rates[8], estimates of survival rates, and indices of relative or absolute abundance. Removals may be specified to sets of months during the year for some sub-areas if the various feeding aggregations are not equally vulnerable to catches throughout the year for those sub-areas. The trials capture uncertainty regarding stock structure and MSYR, as well as uncertainty regarding bycatch and immigration.

The region concerned, the North Pacific, is divided into 11 sub-areas (Fig. 1). The model also includes several 'latent' sub-areas used to link model predictions to observed indices of abundance. These are denoted, WFG, WBS, WST, CA-3 and BCNC-3. There are up to two extant *breeding stocks* (Western and Eastern). The Eastern breeding stock consists of up to three *feeding aggregations* depending on the stock structure hypothesis: Western Feeding Group (WFG), Pacific Coast Feeding Group (PCFG) and North Feeding Group (NFG). There is dispersal between the PCFG and the NFG, but the WFG is demographically independent of the other two feeding aggregations (i.e. there is no *permanent* movement of animals from the NFG or PCFG to the WFG or vice-versa).

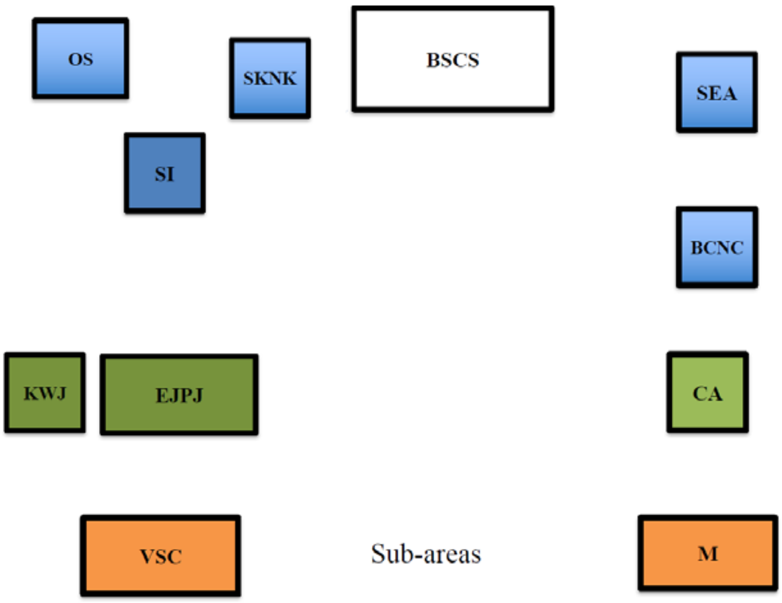


Fig. 1. The sub-areas in the model.

The trials consider five stock structure hypotheses

(1) *Hypothesis 3a*. Although two breeding stocks (Western and Eastern) may once have existed, the Western breeding stock is assumed to have been extirpated. Whales show matrilineal fidelity to feeding grounds, and the Eastern breeding stock includes three feeding aggregations: PCFG, NFG, and WFG.

---

[6] The term 'dispersal' is used here in the sense of 'effective dispersal', and refers to permanent movement of individuals among feeding aggregations. Such individuals become part of the feeding aggregation to which they move and contribute to future reproduction.

[7] Mixing is defined here as two feeding aggregations that overlap at some time on the feeding grounds, but do not exchange individuals.

[8] Bycatch is understood to include mortality or 'serious' injury from entanglement or entrapment in fishing gear (or debris) and ship strikes.

(2) *Hypothesis 3b*. Identical to hypothesis 3a, except that NFG whales do not feed off SKNK. In addition, a Western breeding stock exists that overwinters in VSC and feeds in the OS (but not SI) and SKNK. Thus, SKNK is used by both the WFG whales and the whales of the Western breeding stock.
(3) *Hypothesis 3c*. Identical to 3a, except that on occasion whales migrating between the Sakhalin feeding region and Mexico travel through the BSCS sub-area
(4) *Hypothesis 3e*. Identical to hypothesis 3a, except that the Western breeding stock is extant and feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula. All of the whales feeding off Sakhalin overwinter in the eastern North Pacific
(5) *Hypothesis 5a*. Identical to hypothesis 3e except that the whales feeding off Sakhalin include both whales that are part of the extant Western breeding stock and remain in the western North Pacific year-round, and whales that are part of the Eastern breeding stock and migrate between Sakhalin and the eastern North Pacific
(6) *Hypothesis 6b*. This hypothesis assumes that the WFG does not exist, but that whales feeding in the SI sub-area represent an extant Western breeding stock that utilizes two wintering grounds (VSC and M). This hypothesis differs from hypothesis 5a, in that 1) all removals off China and Japan are assumed to be Western breeding stock animals, and 2) the abundance estimates for Sakhalin are assumed to relate only to the Western breeding stock.

B. **Basic dynamics**

The population dynamics are based on the standard age- and sex-structured model, which has formed the basis for the evaluation of *Strike Limit Algorithms* for eastern North Pacific gray whales, i.e.:

$$
\begin{aligned}
N^{m/f,i,j}_{t+1,0} &= 0.5B^{i,j}_{t+1} && a=0 \\
N^{m/f,i,j}_{t+1,a} &= (N^{m/f,i,j}_{t,a-1} + I^{m/f,i,j}_{t,a-1} - C^{m/f,i,j}_{t,a-1})\, S_{a-1}\, \tilde{S}^{i,j}_t && 1 \le a \le x-1 \quad \text{(B.1)} \\
N^{m/f,i,j}_{t+1,x} &= ((N^{m/f,i,j}_{t,x} + I^{m/f,i,j}_{t,x} - C^{m/f,i,j}_{t,x}) S_x + (N^{m/f,i,j}_{t,x-1} + I^{m/f,i,j}_{t,x-1} - C^{m/f,i,j}_{t,x-1})\, S_{x-1})\, \tilde{S}^{i,j}_t && a = x
\end{aligned}
$$

where $N^{m/f,i,f}_{t,a}$ is the number of males / females of age *a* in feeding aggregation *j* of breeding stock *i* at the start of year *t*; $C^{m/f,i,f}_{t,a}$ is the number of anthropogenic removals of males / females of age *a* in feeding aggregation *j* of breeding stock *i* during year *t* (whaling/incidental catches are assumed to take place in a pulse at the start of each year); S_a is the annual survival rate of animals of age *a* in the absence of catastrophic mortality events (assumed to be the same for males and females):

$$
S_a = \begin{cases} S_0 & \text{if } a = 0 \\ S_{1+} & \text{if } 1 < a \end{cases} \tag{B.2}
$$

S_0 is the calf survival rate; S_{1+} is the survival rate for animals aged 1 and older; $\tilde{S}^{i,j}_t$ is the amount of catastrophic mortality (represented in the form of a survival rate) for feeding aggregation *j* of breeding stock *i* during year *t* (catastrophic events are assumed to occur at the end of the year after mortality due to anthropogenic removals, whaling and non-catastrophic natural causes and dispersal; in general $\tilde{S}^{i,j}_t$ =1, i.e. there is no catastrophic mortality); $B^{i,j}_{t+1}$ is the number of births to feeding aggregation *j* of breeding stock *i* during year *t*; $I^{s,m/f}_{t,a}$ is the net dispersal of female/male animals of age *a* into feeding aggregation *j* of breeding stock *i* during year *t*; and *x* is the maximum (lumped) age-class (all animals in this and the *x*-1 class are assumed to be recruited and to have reached the age of first parturition). *x* is taken to be 15.

C. **Births and density-dependence**

Density-dependence is assumed to be a function of numbers of animals aged 1 and older by feeding ground relative to the carrying capacity by feeding ground. The density-dependence component for feeding aggregation *j* of breeding stock *i* is the sum of the density-dependence components by feeding aggregation weighted by the proportion of animals from feeding aggregation *j* of breeding stock *i* that are found on each feeding ground, i.e.:

$$
F(i,j,t) = \sum_A \psi^{A,i,j} \left(X^{A,i,j} (N^{1+,A}_t / K^{1+,A})^z \right) / \sum_A \psi^{A,i,j} X^{A,i,j} \tag{C.1}
$$

where z is the degree of compensation; $\psi^{A,i,j}$ indicates whether sub-area A impacts density-dependence for feeding aggregation j of breeding stock i, N_t^{1+A} is the number of 1+ animals on feeding ground A at the start of year t:

$$N_t^{1+,A} = \sum_i \sum_j X^{A,i,j} \sum_{a=1}^{x} (N_{t,a}^{m,i,j} + N_{t,a}^{f,i,j}) \tag{C.2}$$

K^{1+A} is the carrying capacity for feeding ground A:

$$K^{1+,A} = \sum_i \sum_j X^{A,i,j} \sum_{a=1}^{x} (N_{-\infty,a}^{m,i,j} + N_{-\infty,a}^{f,i,j}) \tag{C.3}$$

$X^{A,i,j}$ is the proportion of animals of feeding aggregation j of breeding stock i that are found in feeding ground A[9] (Tables 1 and 2).

The number of births at the start of year t for feeding aggregation j of breeding stock i, $B_t^{i,j}$, is given by:

$$B_t^{i,j} = b_t^{i,j}\, N_t^{f,i,j} \tag{C.4}$$

where $N_t^{f,i,j}$ is the number of mature females in feeding aggregation j of breeding stock i at the start of year t:

$$N_t^{f,i,j} = \sum_{a=a_m}^{x} N_{t,a}^{f} \tag{C.5}$$

a_m is the age-at-maturity (the convention of referring to the mature population is used here, although this actually refers to females that have reached the age of first parturition); $b_t^{i,j}$ is the probability of birth/calf survival for mature females:

$$b_t^{i,j} = \max(0, b_K\{1 + A^{i,j}(1 - F(I, j, t))\}) \tag{C.6}$$

b_K is the average number of live births per year per mature female at carrying capacity; and $A^{i,j}$ is the resilience parameter for feeding aggregation j of breeding stock i.

D. **Immigration (dispersal)**

The numbers dispersing into feeding aggregation j of breeding stock i, include contributions from pulse migration as well as diffusive dispersal:

$$I_{t,a}^{s,j,i} = I_{t,a}^{1,s,j,a} - I_{t,a}^{2,s,j,a} \tag{D.1a}$$

$$I_{t,a}^{1,s,j,i} = \sum_{k \neq j} \delta^{k,j,i} N_{t,a}^{s,i,k} \left(\frac{N_t^{f,i,k}}{N_{-\infty}^{f,i,k}}\right)^{\tilde{\lambda}} + \sum_{k \neq j} \Omega_y^{k,j,i} \frac{N_{t,a}^{s,i,k}}{\sum_{a=1}^{x} (N_{t,a}^{m,i,k} + N_{t,a}^{f,i,k})} \tag{D.1b}$$

$$I_{t,a}^{2,s,j,i} = \sum_{k \neq j} \delta^{j,k,i} N_{t,a}^{s,i,j} \left(\frac{N_t^{f,i,j}}{N_{-\infty}^{f,i,j}}\right)^{\tilde{\lambda}} + \sum_{k \neq j} \Omega_y^{j,k,i} \frac{N_{t,a}^{s,i,j}}{\sum_{a=1}^{x} (N_{t,a}^{m,i,j} + N_{t,a}^{f,i,j})} \tag{D.1c}$$

---

[9] It is usually the case that $\sum X^{A,i,j} = 1$. However, for gray whales, this is not necessarily the case because removals can take place in the various sub-areas at different times. What is then important is the relative values of the $X^{A,i,j}$ among feeding aggregations for a given feeding ground.

where $\delta^{k,j,i}$ is the rate of dispersal from feeding aggregation *k* to feeding aggregation *j* of breeding stock *i*; λ is a factor to allow for density-dependence in the dispersal rate (set to 2); and $\Omega_y^{k,j,i}$ is the number of animals that disperse in year *y* from feeding aggregation *k* to feeding aggregation *j* of breeding stock *i* in a pulse.

E. **Anthropogenic removals**

The catch by feeding aggregation, sex and age is the sum of the catch over fleet (see Table 3 for fleet definitions), i.e.:

$$C_{t,a}^{m/f,i,j} = \sum_k C_t^{m/f,k} \frac{\alpha_a^k X^{A_k,i,j} N_{t,a}^{m/f,i,j}}{\sum_{i,j,a} \alpha_a^k X^{A_k,i,j} N_{t,a}^{m/f,i,j}} \tag{E.1}$$

where $C_t^{m/f,k}$ is the catch of males/females by fleet *k* during year *t*; A_k is the sub-area in which fleet *k* operates; and α_a^k is the relative vulnerability of animals of age *a* to harvest by fleet *k*. The values for the catches by fleet and sex are either pre-specified (Table 4[10]) or computed using Equation E.2. for the years for which actual estimates are not available:

$$C_{t,a}^{m/f,k} = \lambda^k E_t^k \sum_{i,j,a,m/f} \alpha_a^k X^{A,i,j} N_{t,a}^{m/f,i,j} \tag{E.2}$$

where E_t^k is a measure of the effort by fleet *k* during year *t* (Table 5) and λ^k is the catchability coefficient for fleet *k*.

F. Initializing the parameter vector

The numbers at age in the pristine population are given by:

$$\begin{aligned} N_{-\infty,a}^{m/f,i,j} &= 0.5\, N_{-\infty,0}^{i,j} \prod_{a'=0}^{a-1} S_{a'} && \text{if } a < x \\ N_{-\infty,x}^{m/f,i,j} &= 0.5\, N_{-\infty,0}^{i,j} \prod_{a'=0}^{x-1} S_{a'} / (1-S_x) && \text{if } a = x \end{aligned} \tag{F.1}$$

The value for $N_{-\infty,0}^{i,j}$ is determined from the value for the pre-exploitation size of the 1+ component of feeding aggregation *j* of breeding stock *i* using the equation:

$$N_{-\infty,0}^{m,i,j} = K^{1+,i,j} / \left(\sum_{a=1}^{x-1} \left(\prod_{a'=0}^{a-1} S_{a'} \right) + \frac{1}{1-S_x} \prod_{a'=0}^{x-1} S_{a'} \right) \tag{F.2}$$

where $K^{1+,i,j}$ is the carrying capacity (in terms of the 1+ population size size) for feeding aggregation *j* of breeding stock *i*:

$$K_t^{1+,i,j} = \sum_{a=1}^{x} (N_{-\infty,a}^{m,i,j} + N_{-\infty,a}^{f,i,j}) \tag{F.3}$$

$N_{-\infty,a}^{m/f,i,j}$ is the number of animals of age *a* that would be in feeding aggregation *j* of breeding stock *i* in the pristine population.

The model is based on the assumption that the age-structure at the start of year τ is stable rather than that the population was at its pre-exploitation equilibrium size at some much earlier year. The determination of the age-structure at the start of year τ involves specifying the effective 'rate of increase', γ, that applies to each age-class. There are two components contributing to γ, one relating to the overall population rate of increase (γ^+) and the other to the exploitation rate due to all forms of anthropogenic removal. Under the assumption of knife-edge recruitment to the fishery at age a_r, only the γ^+ component (assumed to be zero following Punt and Butterworth

[10] The bycatches for 2016 are set equal to those for 2015 as data on bycatch for 2016 are not finalized at present.

[2002]) applies to ages a of a_r or less. The number of animals of age a at the start of year τ relative to the number of calves at that time, $N^*_{\tau,a}$, is therefore given by the equation:

$$N^*_{\tau,a} = \begin{cases} 1 & \text{if } a = 0 \\ N^*_{\tau,a-1}\, S_{a-1} & \text{if } a \le a_r \\ N^*_{\tau,a-1}\, S_{a-1}\,(1-\gamma) & \text{if } a_r < a < x \\ N^*_{\tau,x-1}\, S_{x-1}(1-\gamma)/(1-S_x\,(1-\gamma)) & \text{if } a = x \end{cases} \tag{F.4}$$

where B_τ is the number of calves in year τ and is derived directly from equations C.1 and C.6.

$$B_\tau = \left(1 - \left[1/(N^f_\tau b_K) - 1\right]/A\right)^{1/z} \frac{K^{1+}}{N^{1+,*}_\tau} \tag{F.5}$$

The effective rate of increase, γ, is selected so that if the population dynamics model is projected from year τ to a year Ψ, the size of the 1+ component of the population in a reference year Ψ equals a value, P_Ψ.

G. **Conditioning**

The parameters of the model are: (a) the carrying capacity of each stock, (b) the population size for each stock at the start of 1930 (expressed relative to carrying capacity), (c) MSYR by stock, (d) annual survival under 'normal' conditions, (e) maturity as a function of age, (f) the impact of the mortality event in the eastern Pacific in 1999 and 2000, (g) selectivity, (h) the rate of dispersal between the NFG and the PCFG, (i) the parameters of the mixing matrices, (j) the catchability coefficients that determine bycatch by fleet (Eqn E.2), and (k) the extent of additional variation for each abundance index. Some of these parameters are pre-specified:

(1) MSYR (except for trials 14, 15, and 17);
(2) Annual survival under 'normal' conditions (base-case 0.98);
(3) Maturity as a function of age (a logistic function of age, with an age-at-50%-first-parturition of 8 years and a minimum age-age-at-first parturition of 3 years); and
(4) Selectivity (Table 3).

Under the assumption that the estimates of abundance for a sub-area (Table 6) are log-normally distributed, the negative of the logarithm of the likelihood function is given by:

$$-\ell nL = \ell n\sqrt{\mathrm{Det}[V]} + 0.5\sum_k (\ell\,\mathrm{n}\,\underline{N}^{A,obs} - \ell\,\mathrm{n}\,\underline{N}^{A})[V^{-1}](\ell\,\mathrm{n}\,\underline{N}^{A,obs} - \ell\,\mathrm{n}\,\underline{N}^{A})^T \tag{G.1}$$

where $N^{A,\mathrm{obs}}_t$ is the survey estimate of abundance for sub-area A during year t; and V is the sum of the variance-covariance matrix for the abundance estimates plus an additional variance term (assumed to be independent of year). Note that the abundance estimates for the western areas (Table 6a) depend on the stock hypothesis under consideration.

The data on the proportion of each stock (Tables 6a and 7) in each sub-area are modelled under the assumption that the proportions are normally distributed, i.e.:

$$-\ell nL = \sum_i \sum_A \sum_t \tfrac{1}{2(\tau^{i,A}_t)^2} (p^{i,A}_t - p^{i,A,\mathrm{obs}}_t)^2 \tag{G.2}$$

where $p^{i,A}_t$ is the model-estimate of the proportion of the animals in sub-area A that are from feeding aggregation i of the Eastern breeding stock; $p^{i,A,\mathrm{obs}}_t$ is the observed proportion of animals in in sub-area A that are from feeding aggregation i of the Eastern breeding stock; and $\tau^{i,A}_t$ is the standard error of $p^{i,A,\mathrm{obs}}_t$.

The (non-zero) bycatches by sub-area for the first five years for which data are available are assumed to be log-normally distributed, and the model is fitted to the average bycatch by sub-area over a pre-specified set of years (the years for which detection and reporting of entanglements, ship strikes, and strandings in general was relatively good; Table 3), i.e.:

$$-\ell \mathrm{n}L = \sum_{A} \frac{1}{2\sigma_{BC}^2}\left(\ell \mathrm{n}C^{I,A,\mathrm{obs}} - \ell \mathrm{n}\hat{\bar{C}}^{I,A}\right)^2 \tag{G.3}$$

where $C^{I,A,\mathrm{obs}}$ is the observed average annual bycatch from sub-area *A* over the pre-specified period, $\hat{\bar{C}}^{I,A}$ is the average over this period of the model-estimate of the bycatch from sub-area *A*, and σ_{BC} is the standard error of the logarithms of the observed bycatches.

A penalty is imposed on the average number of animals moving permanently from the NFG into the PCFG between 2001 and 2008, i.e.:

$$-\ell nL = \frac{1}{2\sigma_I^2}\left(\tilde{I} - \frac{\delta^{\mathrm{m/f,north},West}}{8}\sum_{t=2001}^{2008}\sum_{s=m/f}\sum_{a=1}^{x} I_{t,a}^{s,\mathrm{East,north}}\right)^2 \tag{G.4}$$

where $\tilde{I}$ is the pre-specified average number of immigrants into the PCFG from the NFG, and σ_I is a weighting factor.

The estimates of survival for PCFG whales (Calambokidis *et al.*, 2017) are assumed to be normally distributed, i.e.:

$$-\ell \mathrm{n}L = \frac{1}{2\sigma_{S,1}^2}(S^{\mathrm{obs},1} - \hat{S}^1)^2 + \frac{1}{2\sigma_{S,2}^2}(S^{\mathrm{obs},2} - \hat{S}^2)^2 \tag{G.5}$$

where $S^{\mathrm{obs},1} = 0.917$, $\sigma_{L,1} = 0.0142$, $S^{\mathrm{obs},2} = 0.967$, $\sigma_{L,2} = 0.0066$, $\hat{S}_1$ is the estimate of post-first-year survival for whales that entered in 1998 or earlier, and $\hat{S}_2$ is the estimate of post-first-year survival for whales that entered in 1999 or later.

H. Quantifying uncertainty using bootstrap

A bootstrap procedure is used to quantify uncertainty for a given model specification. Each bootstrap replicate involves:

(1) Generating pseudo time-series of abundance estimates based on the assumption that the abundance estimates are log-normally distributed with means and variance-covariance matrices given by the observed abundance estimates and the reported variance-covariance matrices.
(2) Generating pseudo mixing proportions from beta distributions with means and CVs given by the observed means and CVs.
(3) Generating pseudo bycatch rates by sub-area from log-normal distributions with means of $C^{I,A,\mathrm{obs}}$ and a log standard error of σ_{BC}.
(4) Generating a pseudo immigration rate from the NFG into the PCFG based on a normal distribution (truncated at zero) with mean $\tilde{I}$ and standard error σ_I.
(5) Generating pseudo survival rates from normal distributions.

I. Generation of Data

The actual historical estimates of absolute abundance (and their associated CVs) provided to the *Strike Limit Algorithms* are listed in Table 6. The future estimates of abundance for sub-areas WFG, WST, BCNC-3 and CA-3 (say sub-area *K*) are generated using the formula:

$$\hat{P} = PYw / P^*\beta^2 Yw \tag{I.1}$$

where *Y* is a lognormal random variable *Y*=e$^{\varepsilon}$ where $\varepsilon \sim N(0;\sigma_\varepsilon^2)$ and $\sigma_\varepsilon^2 = \ell n(1+\alpha^2)$; *w* is a Poisson random variable with $E(w) = \mathrm{var}(w) = \mu = (P/P^*)/\beta^2$, *Y* and *w* are independent; *P* is the current total (1+) population size in survey area *K*:

$$P = P_t^K = \sum_i \sum_j \sum_g \sum_{a\geq 1} N_{t,a}^{g,i,j} \tag{I.2}$$

P^* is the reference population level, and is equal to the total (1+) population size in the survey area prior to the commencement of exploitation in the sub-area for which an abundance estimate is to be generated. For consistency with the first-stage screening trials for a single stock (IWC, 1991, 1994), the ratio $\alpha^2:\beta^2=0.12:0.025$, so that $CV^2(\hat{P})=\tau(0.12+0.025P^*/P)$. If $\overline{CV}$ is the target CV then $\tau=\overline{CV}^2/(0.12+0.025P_{\rm ref}/P^*)$ where $P_{\rm ref}$ is the population size in a reference year.

An estimate of the *CV* is generated for each estimate of abundance:

$$CV(\hat{P})^2_{\rm est}=\sigma^2\chi^2/n \tag{I.3}$$

where $\sigma^2=\ell n(1+\alpha^2+\beta^2P^*/\hat{P})$, and χ is a random number from a Chi-square distribution with *n* degrees of freedom (where *n*=10 as used for NP minke trials; IWC, 2004).

J. Trials

The factors included in the trials are listed in Table 8 and the trials in Table 9.

K. Management options

The strike limits for the BSCS sub-area are based on the Gray Whale *SLA* (IWC, 2005). The strike limits for the BCNC sub-area based on the Makah Management Plan (Appendix 1) although sensitivity is explored using variant 1 agreed to in 2012 (IWC, 2013; Appendix 2).

Removals due to bycatch are based on the scenarios regarding future trends in effort. Table 8 lists the factors considered in the projections.

L. Output Statistics

The population-size statistics are produced for each breeding stock / feeding aggregation, while the removal-related statistics are for each sub-area.

I.1 Risk

D1. Final depletion: P_T/K (1+ and mature female numbers by breeding stock / feeding group (median, lower 5th and upper 5th percentiles)).

D2. Lowest depletion: $\min(P_t/K):t=0,1,...,T$.

D3. Plots of $\{P_{t[x]}:t=0,1,..,T\}$ where $P_{t[x]}$ is the *x*th percentile of the distribution of P_i. Results are presented for *x* = 5, 50, and 95.

D8. Rescaled final depletion: P_T/P_0 (1+ and mature female numbers by breeding stock / feeding group; median, lower 5th and upper 5th percentiles) where P_0 is number of 1+ / mature female animals had there been no future Makah hunts.

D10. Relative increase. The ratio of the 1+ and mature population size after 10 and 100 years to that at the start of the projection period by breeding stock / feeding group (median, lower 5th and upper 5th percentiles)

I.2 Removal-related

N9. Need satisfaction. The proportion of the total number of requested strikes that were taken over the first 10 years and the entire 100-year period (median, lower 5th and upper 5th percentiles).

R1. Plots of strikes by year for simulations 1-100.

R2. Plots of landed whales by year for simulations 1-100.

R3. Plots of incidental catches by year for simulations 1-100 (median, lower 5th and upper 5th percentiles by year).

L. References

Calambokidis, J., Laake, J. and Pérez, A. Updated analysis of abundance and population structure of seasonal gray whales in the Pacific Northwest, 1996-2015. IWC Document SC/A17/GW5 (68pp).

Durban, J., Weller, D., Lang, A. and Perryman, W. 2013. Estimating gray whale abundance from shore-based counts using a multilevel Bayesian model. IWC Document SC/65a/BRG2 (9pp).

Durbin, J.W., Weller, D.W. and Perryman, W.L. Gray whale abundance estimates from shore-based counts off California in 2014/15 and 2015/2016. IWC Document SC/A17/GW6 (4pp).

International Whaling Commission. 1991. Report of the Sub-Committee on Management Procedures, Appendix 4. Report of the *ad-hoc* trials subgroup. *Rep. int. Whal. Commn* 41: 108-12

International Whaling Commission. 1993. Report of the Scientific Committee, Annex I. Report of the Working Group on Implementation Trials. *Rep. int. Whal. Commn*. 43: 153-96.

International Whaling Commission. 2004. Report of the Sub-Committee on the Revised Management Procedure, Appendix 10. North Pacific minke whale *Implementation Simulation Trial* Specifications. *J. Cetacean Res. Manage. (Suppl.)* 6: 118-29

International Whaling Commission. 2005. Report of the Scientific Committee. *J. Cetacean Res. Manage. (Suppl.)* 7: 1-62.

International Whaling Commission. 2013. Report of the Scientific Committee. *J. Cetacean Res. Manage. (Suppl.)* 14: 1-86.

International Whaling Commission. 2015. Draft Report of the 2nd Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales. IWC Document SC/66a/Rep8 (40pp).

Laake, J.L., Punt, A.E., Hobbs, R., Ferguson, M., Rugh, D. and Breiwick, J. 2012. Gray whale southbound migration surveys 1967-2006: An integrated re-analysis. *J. Cetacean Res. Manage.*12: 287-306.

Moore, J.E. and Weller, D.W. 2013. Probability of taking a western North Pacific gray whale during the proposed Makah hunt. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-SWFSC-506.

Punt, A.E. and Butterworth, D.S. 2002. An examination of certain of the assumptions made in the Bayesian approach used to assess the eastern Pacific stock of gray whales (*Eschrichtius robustus). J. Cetacean Res. Manage*. 4: 99-110.

Table 1

The presence matrices for stock structure hypotheses 3a, 3b, 3c, 3e, 5a and 6b.

[a] Hypothesis 3a (no extant Western breeding stock)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Eastern														
WFG			1	1	1	1			1		1		1	1
North			1			1	1	1	1	1	1	1	1	1
PCFG							1[A]	1	1	1	1	1	1	1

A: Sensitivity test (12) only

[b] Hypothesis 3b (extant Western breeding stock)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	1	1		1								
Eastern														
WFG				1	1	1			1		1		1	1
North			1				1	1	1	1	1	1	1	1
PCFG								1	1	1	1	1	1	1

[c] Hypothesis 3c (no extant Western breeding stock; WFG in BSCS)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Eastern														
WFG			1	1	1	1	1		1		1		1	1
North			1			1	1	1	1	1	1	1	1	1
PCFG								1	1	1	1	1	1	1

[d] Hypothesis 3e (extant Western breeding stock; WFG in EJPJ)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	1	1		1								
Eastern														
WFG			1	1	1	1			1		1		1	1
North						1	1	1	1	1	1	1	1	1
PCFG								1	1	1	1	1	1	1

[e] Hypothesis 5a (Western breeding stock in SI)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	1	1	1	1								
Eastern														
WFG			1	1	1	1			1		1		1	1
North						1	1	1	1	1	1	1	1	1
PCFG							1[A]	1	1	1	1	1	1	1

A: Sensitivity test (12) only

[f] Hypothesis 6b (no Western feeding group)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	1	1	1	1			1		1		1	1
Eastern														
North						1	1	1	1	1	1	1	1	1
PCFG								1	1	1	1	1	1	1

Table 2

The mixing matrices for stock structure hypotheses 3a, 3b, 3e, 5a and 6b. The γs denote the estimable parameters of the catch mixing matrix and the χs denote values that are varied in the tests of sensitivity.

[a] Hypothesis 3a (no extant Western breeding stock)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Eastern														
WFG			1	1	1	1			γ_6		γ_3		γ_6	1
North			γ_1			1	1	1	1	1	1	1	1	1
PCFG							1^A	γ_8^B	γ_7	γ_2	γ_4	γ_5	γ_7	1

A: Sensitivity test (12) only
B: Sensitivity test (9) only

[b] Hypothesis 3b (extant Western breeding stock)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	γ_1	1										
Eastern														
WFG				1	1	1			γ_6		γ_3		γ_6	1
North			1			1	1	1	1	1	1	1	1	1
PCFG								1	γ_7	γ_2	γ_4	γ_5	γ_7	1

[c] Hypothesis 3c (extant Western breeding stock; WFG in BSCS)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1												
Eastern														
			1	1	1	1	1		γ_6		γ_3		γ_6	1
North			γ_1			1	1	1	1	1	1	1	1	1
PCFG								1	γ_7	γ_2	γ_4	γ_5	γ_7	1

[d] Hypothesis 3e (extant Western breeding stock; WFG in EJPJ)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	γ_1	1		1								
Eastern														
WFG			1	1	1	1			γ_6		γ_3		γ_6	1
North						1	1	1	1	1	1	1	1	1
PCFG								1	γ_7	γ_2	γ_4	γ_5	γ_7	1

[e] Hypothesis 5a (Western breeding stock in SI)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	γ_1	1	1	1								
Eastern														
WFG			1	1	1	1			γ_6		γ_3		γ_6	1
North						1	1	1	1	1	1	1	1	1
PCFG							1^A	γ_8^B	γ_7	γ_2	γ_4	γ_5	γ_7	1

A: Sensitivity test (12) only
B: Sensitivity test (9) only

[f] Hypothesis 6b (no Western feeding group)

Breeding stock/ Feeding Aggregation	Sub-area													
	VSC	KWJ	EJPJ	OS	SI	SKNK	BSCS	SEA (J-N)	SEA (D-M)	BCNC (J-N)	BCNC (D-M)	CA (J-N)	CA (D-M)	M
Western	1	1	1	1	1	1			γ_6		γ_3		γ_6	1
Eastern														
North						1	1	1	1	1	1	1	1	1
PCFG								1	γ_7	γ_2	γ_4	γ_5	γ_7	1

Table 3

Fleets included in the population dynamics model, the associated selectivity patterns, and the years for which detection and reporting of entanglements, ship strikes, and strandings in general was relatively good. The columns "Years (hindcast)" and "Years (forecast)" denote the ranges of years used to infer bycatch rates respectively before and after the first year for which detection and reporting of entanglements, ship strikes, and strandings in general was relatively good

Fleet	Season	Type	Years	Years (hindcast)	Years (forecast)	Selectivity
Northern Bering and Chukchi Sea (BSCSA)	All	Subsistence	N/A			Uniform 1+
WA U&A (feeding) (WAUAF)	June-Nov	Subsistence	N/A			Uniform 1+
WA U&A (migration) (WAUAM)	Dec-May	Subsistence	N/A			Uniform 1+
CA-scientific (migration)	Dec-May	Scientific	N/A			Uniform 1+
Vietnam-South China Sea (VSC)	All	All removals	No removals			
Korea and western side of the Sea of Japan (KWJ)	All	All removals	No removals			
Eastern side of the Sea of Japan and the Pacific coast of Japan (EJPJ)	All	All removals	1982 – 2015	1982 – 2015	1982 – 2015	Uniform 0-5
Northeastern Sakhalin Island (SI)	All	All removals	1982 – 2015	1982 – 2015	1982 – 2015	Uniform 0-5
Southern Kamchatka and Northern Kuril Islands (SKNK)	All	All removals	No removals			
Areas of the Okhotsk Sea not otherwise specified (OS)	All	All removals	No removals			
Northern Bering and Chukchi Sea (BSCSE)	All	Entanglements	1987 – 2015	1987 – 1991	2011 – 2015	Uniform 0-5
Southeast Alaska (SEA1E)	June-Nov	Entanglements	M/SI only	1987 – 1991	2011 – 2015	Uniform 0-5
Southeast Alaska (SEA2E)	Dec-May	Entanglements	1987 – 2015	1987 – 1991	2011 – 2015	Uniform 0-5
British Columbia to Northern California (BCNC1E)	June-Nov	Entanglements	1990 – 2015	1990 – 1994	2011 – 2015	Uniform 0-5
British Columbia to Northern California (BCNC2E)	Dec-May	Entanglements	1990 – 2015	1990 – 1994	2011 – 2015	Uniform 0-5
California (CA1E)	June-Nov	Entanglements	1982 – 2015	1982 – 1986	2011 – 2015	Uniform 0-5
California (CA2E)	Dec-May	Entanglements	1982 – 2015	1982 – 1986	2011 – 2015	Uniform 0-5
Mexico (MEXE)	All	Entanglements	MS/I only	1982 – 1986	2011 – 2015	Uniform 0-5
Northern Bering and Chukchi Sea (BSCSS)	All	Ship strikes	No ship strikes			
Southeast Alaska (SEA1S)	June-Nov	Ship strikes	No ship strikes			
Southeast Alaska (SEA2S)	Dec-May	Ship strikes	1987 – 2015	1987 - 2015	1987 - 2015	Uniform 0+
British Columbia to Northern California (BCNC1S)	June-Nov	Ship strikes	1990 – 2015	1990 – 2015	1990 – 2015	Uniform 0+
British Columbia to Northern California (BCNC1S)	Dec-May	Ship strikes	1990 – 2015	1990 – 2015	1990 – 2015	Uniform 0+
California (CA1S)	June-Nov	Ship strikes	1982 – 2015	1982 – 2015	1982 – 2015	Uniform 0+
California (CA2S)	Dec-May	Ship strikes	1982 – 2015	1982 – 2015	1982 – 2015	Uniform 0+
Mexico (MEXS)	All	Ship strikes	MS/I only	1982 – 2015	1982 – 2015	Uniform 0+
California (SET1)	June-Nov	Set Gillnet	1982 – 1990	1982 – 1990	None	Uniform 0-5
California (SET2)	Dec-May	Set Gillnet	1982 – 1990	1982 – 1990	None	Uniform 0-5
California (SET3)	June-Nov	Set Gillnet	1991 – 2015	None	1991 – 2015	Uniform 0-5
California (SET4)	Dec-May	Set Gillnet	1991 – 2015	None	1991 – 2015	Uniform 0-5

Table 4a

Non-bycatch removals. The BSCS 'fleet' represents the aboriginal catches, the two WAUA 'fleets' represent Makah hunting in the Makah usual and accustomed area, and the CA migration 'fleet' is the scientific catches off California.

Year	Fleet				Year	Fleet			
	BSCS	WAUA Feeding	WAUA Migration	CA Migration		BSCS	WAUA Feeding	WAUA Migration	CA Migration
1930	47	0	0	0	1974	184	0	0	0
1931	10	0	0	0	1975	171	0	0	0
1932	10	0	0	10	1976	165	0	0	0
1933	15	0	0	60	1977	187	0	0	0
1934	66	0	0	60	1978	184	0	0	0
1935	44	0	0	110	1979	183	0	0	0
1936	112	0	0	86	1980	182	0	0	0
1937	24	0	0	0	1981	136	0	0	0
1938	64	0	0	0	1982	168	0	0	0
1939	39	0	0	0	1983	171	0	0	0
1940	125	0	0	0	1984	169	0	0	0
1941	77	0	0	0	1985	170	0	0	0
1942	121	0	0	0	1986	171	0	0	0
1943	119	0	0	0	1987	159	0	0	0
1944	6	0	0	0	1988	151	0	0	0
1945	58	0	0	0	1989	180	0	0	0
1946	30	0	0	0	1990	162	0	0	0
1947	31	0	0	0	1991	169	0	0	0
1948	19	0	0	0	1992	0	0	0	0
1949	26	0	0	0	1993	0	0	0	0
1950	11	0	0	0	1994	44	0	0	0
1951	13	0	1	0	1995	92	0	0	0
1952	44	0	0	0	1996	43	0	0	0
1953	38	0	10	0	1997	79	0	0	0
1954	39	0	0	0	1998	125	0	0	0
1955	59	0	0	0	1999	123	0	1	0
1956	122	0	0	0	2000	115	0	0	0
1957	96	0	0	0	2001	112	0	0	0
1958	148	0	0	0	2002	131	0	0	0
1959	194	0	0	2	2003	128	0	0	0
1960	156	0	0	0	2004	111	0	0	0
1961	208	0	0	0	2005	124	0	0	0
1962	147	0	0	4	2006	134	0	0	0
1963	180	0	0	0	2007	131	1	0	0
1964	199	0	0	20	2008	130	0	0	0
1965	181	0	0	0	2009	116	0	0	0
1966	194	0	0	26	2010	118	0	0	0
1967	249	0	0	125	2011	130	0	0	0
1968	135	0	0	66	2012	143	0	0	0
1969	140	0	0	74	2013	127	0	0	0
1970	151	0	0	0	2014	124	0	0	0
1971	153	0	0	0	2015	125	0	0	0
1972	182	0	0	0	2016	120	0	0	0
1973	178	0	0	0					

Table 4b.

Bycatches. The bycatches in the remaining areas are: VSC (2 in 2011), EJPJ (1 in 1995; 1 in 1970; 1 in 1996; 5 in 2005; 1 in 2007); and SI (2 in 2014)). Values replaced by the predictions of Eqn E.2 are indicated by dashes.

(a) Deaths

Year	Entanglements								Ship strikes								Entanglements	
	BSCS	SEA	SEA	BCN	BCN	CA	CA	MEX	BSCS	SEA	SEA	BCN	BCN	CA	CA	MEX	SET	SET
		Feeding	Migration	Feeding	Migration	Feeding	Migration			Feeding	Migration	Feeding	Migration	Feeding	Migration		Feeding	Migration
1982	-	-	-	-	-	0	1	0	-	-	-	-	-	0	0	0	0	0
1983	-	--	-	-	-	1	2	0	-	--	-	-	-	0	0	0	0	0
1984	-	-	-	-	-	0	3	0	-	-	-	-	-	0	1	0	0	0
1985	-	-	-	-	-	0	6	0	-	-	-	-	-	0	0	0	1	2
1986	-	-	-	-	-	0	1	0	-	-	-	-	-	0	0	0	0	0
1987	1	0	0	-	-	0	2	0	0	0	0	-	-	0	4	0	0	1
1988	0	0	1	-	-	0	1	0	0	0	0	-	-	0	3	0	0.75	0
1989	0	0	0	-	-	0	1	0	0	0	0	-	-	0	0	0	0	2
1990	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1991	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0
1992	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1994	0	0	0	0	2	1	1	0	0	0	0	0	0	0	1	0	0	0
1995	0	0	0	1	1	0	1	0	0	0	0	1	0	0	1	0	0	0
1996	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
1998	1	0	1	1	0	0	1	0	0	0	0	0	1	0	2	0	0	0
1999	2	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
2000	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0
2004	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0.75	0
2005	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0
2006	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
2010	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
2012	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	1	0	4	0	0	0	0	0	1	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.75	0

(b) Serious Injuries

Year	Entanglements								Ship strikes								Entanglements	
	BSCS	SEA	SEA	BCN	BCN	CA1	CA2	MEX	BSCS	SEA	SEA	BCN	BCN	CA	CA	MEX	SET	SET
		Feeding	Migration	Feeding	Migration	Feeding	Migration			Feeding	Migration	Feeding	Migration	Feeding	Migration		Feeding	Migration
1982	-	-	-	-	-	0	1	0	-	-	-	-	-	0	0	0	0	0
1983	-	--	-	-	-	1	2	0	-	--	-	-	-	0	0	0	0	0
1984	-	-	-	-	-	0	3	0	-	-	-	-	-	0	1	0	0	0.75
1985	-	-	-	-	-	0	10.75	0.75	-	-	-	-	-	0	0.14	0	1	4.5
1986	-	-	-	-	-	0	10.25	0	-	-	-	-	-	0	0	0	0	4.5
1987	1.75	0	0	-	-	1.5	5	0	0	0	0	-	-	0	4	0	0	3.5
1988	0	0	1	-	-	0	6	0	0	0	0	-	-	0	4	0	0.75	0
1989	0	0	0	0	0	0	3.5	0	0	0	0	-	-	0	0	0	0	2.75
1990	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0.52	0	0	3.75
1991	0	0	0	0	0	0.75	2.75	0	0	0	0	0	0	0	3	0	0	0
1992	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1994	0	0	0	0	0	1	2.75	0	0	0	0	0	0	0	1	0	0	0
1995	0	0	0.75	1	0	0	2.75	0.75	0	0	0	1	0	0	1.72	0	0	0
1996	0	0	0	0	0	0	3.75	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0.75	0.75	0.75	0	0	1	0	1	0	0	0	0	1.75
1998	1.75	0	1	1	0	0.75	2.5	0	0	0	0	0	2	0	3.56	0	0	0
1999	2	0	0	1.375	0	1	2.5	0	0	0	0	0	0.2	0	1.36	0	0	0
2000	0	0	0	0	0	0.75	3.25	0.75	0	0	0	0	0	0	0	0	0	1
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0
2002	0	0	0	1	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	1	0	0	1.75	0.75	0	0	0	0	0	0	1	0	0	0
2004	1	0.75	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0.75	0
2005	0	0	0	1	0	0	1.5	0	0	0	0	0	0	0	2	0	0	0
2006	0	0	0	0	0	0	1.75	0.75	0	0	0	0	0	0	2.56	0	0	0
2007	1	0	0	0	0	1.5	0	0	0	0	0	0	0	1	0	0	0	0
2008	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0	0
2009	0	0	0.75	0.75	0	0	1.5	0	0	0	0	0.52	1	0	3	0	0	0
2010	0	0	0	0	0	1	2.5	0	0	0	0	0	0	0	1.52	0	0	0
2011	0	1	0	0	0	2	0	0	0	0	0	0	0	1	1.28	0	0	0
2012	2.5	0	0	1.75	0	2	7.75	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	1	0	4	2.5	0	0	0	0	1	0	0	0	0	0	0
2014	0	0	0	0	0	2.5	1.5	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	0	1.5	6	0	0	0	0	0	0	0	1	0	0.75	0

Table 5

Relative effort for the set gillnet fishery off California (J. Carrette, SWFSC, pers commn. Effort is constant at 1 prior to 1981

Year	Effort	Year	Effort	Year	Effort
1981	1.000	1993	1.438	2005	0.428
1982	1.819	1994	0.571	2006	0.365
1983	1.940	1995	0.460	2007	0.401
1984	2.459	1996	0.519	2008	0.384
1985	2.598	1997	0.690	2009	0.304
1986	2.048	1998	0.554	2010	0.358
1987	1.883	1999	0.737	2011	0.370
1988	1.560	2000	0.754	2012	0.324
1989	1.376	2001	0.624	2013	0.278
1990	1.444	2002	0.668	2014	0.265
1991	1.395	2003	0.607	2015	0.419
1992	1.197	2004	0.626		

Table 6a

Abundance estimates (1+) for the WFG feeding aggregation and the western breeding stock (J.G. Cooke, pers. commn)

Year	Group	Stock hypothesis	Estimate	SD	CV
1995	WFG	3a/3c/3e/6b	75.1	3.8	0.051
1995	WBS	3b	25.8	7.3	0.282
1995	WFG	3b	75.5	3.3	0.043
1995	WBS	3e	30.0*	15.0	0.500
1995	WBS	5a	26.6	6.9	0.259
1995	WFG	5a	47.8	7.7	0.160
1995	WBS+WFG	5a	74.4	3.9	0.052
1995	WBS/(WBS+WFG)	5a	0.358	0.093	0.259
2015	WFG	3a/3c/3e/6b	199.8	5.4	0.027
2015	WBS	3b	63.8	15.8	0.248
2015	WFG	3b	198.9	5.7	0.029
2015	WBS	3e	30.0*	15.0	0.500
2015	WBS	5a	64.4	14.0	0.218
2015	WFG	5a	135.6	14.1	0.104
2015	WBS+WFG	5a	200.0	5.7	0.029
2015	WBS/(WBS+WFG)	5a	0.322	0.069	0.200

* Guestimate because the WBS cannot be distinguished given the available information.

Table 6b

Estimates of absolute abundance (with associated standard errors) for the eastern North Pacific stock of gray whales based on shore counts (source: 1967/78-2006/07: Laake *et al*, 2012; 2006/07-2015/16: Durban *et al*, 2013, 2017). These estimates are assumed to pertain to the total number of gray whales.

Year	**Estimate**	**CV**	**Year**	**Estimate**	**CV**
1967/68	13426	0.094	1987/88	26916	0.058
1968/69	14548	0.080	1992/93	15762	0.067
1969/70	14553	0.083	1993/94	20103	0.055
1970/71	12771	0.081	1995/96	20944	0.061
1971/72	11079	0.092	1997/98	21135	0.068
1972/73	17365	0.079	2000/01	16369	0.061
1973/74	17375	0.082	2001/02	16033	0.069
1974/75	15290	0.084	2006/07	19126	0.071
1975/76	17564	0.086	2006/07	20750	0.060
1976/77	18377	0.080	2007/08	17820	0.054
1977/78	19538	0.088	2009/10	21210	0.046
1978/79	15384	0.080	2010/11	20990	0.044
1979/80	19763	0.083	2014/15	28790	0.130
1984/85	23499	0.089	2015/16	26960	0.050
1985/86	22921	0.081			

Table 6c

Estimates of absolute abundance (with associated CVs) for the PCFG feeding aggregation based on mark-recapture analysis (source: Calambokidis et al., 2017).

Year	Estimate	CV	Year	Estimate	CV
1998	126	0.087	2009	208	0.101
1999	145	0.101	2010	200	0.095
2000	146	0.098	2011	205	0.078
2001	178	0.076	2012	217	0.052
2002	197	0.069	2013	235	0.059
2003	207	0.084	2014	238	0.080
2004	216	0.077	2015	243	0.078
2005	215	0.125			
2006	197	0.108			
2007	192	0.136			
2008	210	0.089			

Table 7

Data on mixing proportions (definite and likely matches / non-matches only) to be used when conditioning the models.

Sub-area	Season	Stock / Feeding aggregation	Mixing proportion (assumed SD)
EJPJ	All	WBS/NFG	0.33 (0.1)
SEA	Feeding	PCFG	0.57[1] (0.1)
SEA	Feeding	WFG	0
SEA	Migration	PCFG	0.1[2] (0.1)
SEA	Migration	WFG	0.002[3] (0.05)
BCNC	Feeding	PCFG	0.93 (0.1)
BCNC	Feeding	WFG	0
BCNC	Migration	PCFG	0.28 (0.1)
BCNC	Migration	WFG	0.002 (0.05)
CA	Feeding	PCFG	0.60 (0.1)
CA	Feeding	WFG	0
CA	Migration	PCFG	0.1 (0.05)
CA	Migration	WFG	0.002[3] (0.05)

1: Not used in the conditioning except for the sensitivity test based when the bycatch is based on M/SI as no dead bycatch is recorded for the SEA sub-area during the feeding season.

2: Assumed value owing to lack of data to estimate mixing proportions.

3: Set to the value calculated for BCNC by Moore and Weller (2013)

Table 8

Factors considered in the model scenarios. The bold values are the base-levels and the values in standard font form the basis for sensitivity analyses.

Factor	Levels
Model fitting related	
Stock hypothesis	**3a,** 3b, 3c, 3e, **5a,** 6b
$MSYR_{1+}$ (western)	As for WFG
$MSYR_{1+}$ (north)	**4.5%**, 5.5%, Estimated (common); estimate (separately)
$MSYR_{1+}$ (WFG)	**4.5%** Estimated (common); estimate (separately)
$MSYR_{1+}$ (PCFG)	2%, **4.5%**, 5.5%, Estimated (common); estimate (separately)
Mixing rate (migration season in BCBC	**0.28**, 0.17, 1.00
Immigration into the PCFG	0, 1, **2**, 4
Bycatches and ship strikes	Numbers dead + M/SI, **dead x 4**; dead x 10; dead x 20
Pulse migrations into the PCFG	10, **20**, 30
Projection-related	
Additional catch off Sakhalin (mature female)	0, 1
Catastrophic events	**None**, once in years 0 – 49, and once in years 50-99
Northern need in final year (from 150 in 2014)	**340**
Struck and lost rate	**(0.1; odd-years; 0.5 even years),** 0.5 all years
Future effort	**Constant**, Increase by 100% over 100 years
Probability of a photo (struck and lost whales)	**0.8; odd-years; 0.6 even years**
Probability of a photo (landed whales)	**0.9**
Probability of false positive rate PCFG	**0.05**, 0.1
Probability of false negative rate PCFG	**0.25**
Probability of false positive rate WFG	**0.01**
Probability of false negative rate WFG	**0.041 (stock hypotheses 3a, 3c, 3e, 6b);** 0.040 (stock hypothesis 3b); **0.049 (stock hypothesis 5a)**
Probability of a sex assignment given a PCFG match	**0.81**

Table 9

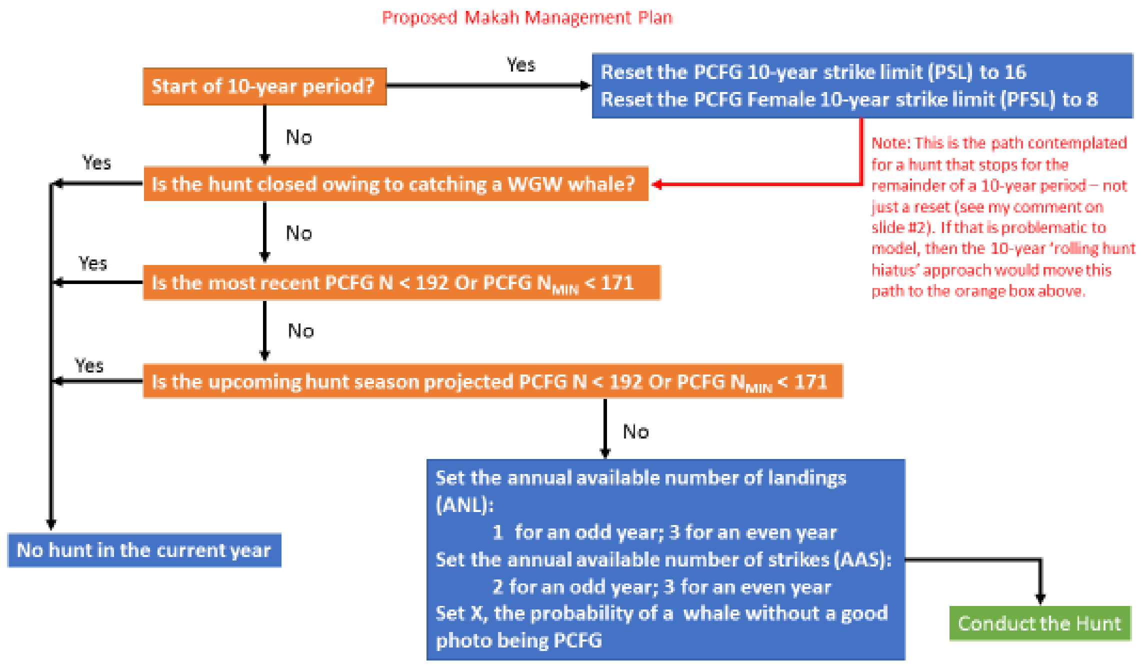
Final trial specifications

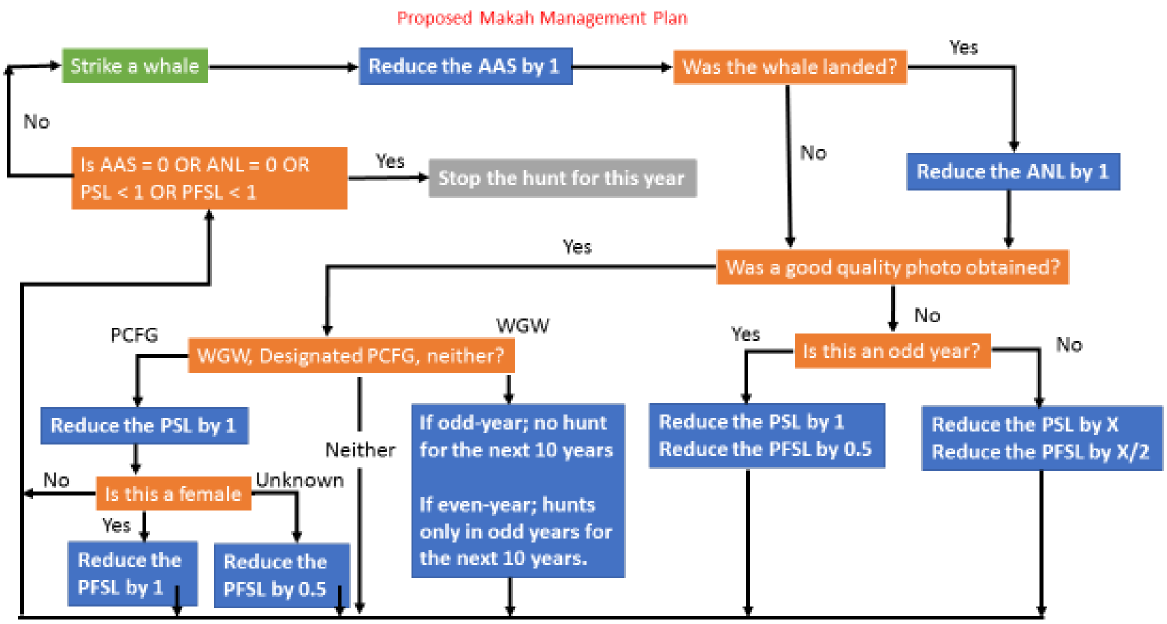
Trial	Description/stock hypothesis	PCFG or WFG in BSCS	$MSYR_{1+}$			PCFG		Bycatch	Conditioning
			North	PCFG	WFG	Imm.	Pulse		
Base-case trials									
0A	Reference 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
0B	Reference 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
Sensitivity tests									
1A	Lower MSYR PCFG 3a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
1B	Lower MSYR PCFG 5a	No	**4.50%**	**2%**	**4.50%**	2	20	D x 4	Yes
2A	Higher MSYR PCFG and North 3a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
2B	Higher MSYR PCFG and North 5a	No	**5.50%**	**5.50%**	**4.50%**	2	20	D x 4	Yes
3A	Lower WBS in Sakhalin 5a (Hyp 3e)	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
3B	Higher WBS in Sakhalin 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4A	PCFG mixing based on Northern WA only 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
4B	PCFG mixing based on Northern WA only 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
5A	No PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
5B	No PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**0**	20	D x 4	Yes
6A	Higher PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
6B	Higher PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**4**	20	D x 4	Yes
7A	Lower Pulse into PCFG 3a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
7B	Lower Pulse into PCFG 5a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	2	**10**	D x 4	Yes
8A	Higher pulse into PCFG 3a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
8B	Higher pulse into PCFG 5a	No	4.50%	4.50%	4.50%	2	**30**	D x 4	Yes
9A	Bycatch=Dead + MSI 3a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
9B	Bycatch=Dead + MSI 5a	No	4.50%	4.50%	4.50%	2	20	**D + MSI**	Yes
10A	Bycatch x 10 3a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
10B	Bycatch x 10 5a	No	4.50%	4.50%	4.50%	2	20	**D x 10**	Yes
11A	Bycatch x 20 3a	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
11B	Bycatch x 20 3e	No	4.50%	4.50%	4.50%	2	20	**D x 20**	Yes
12A	PCFG in BSCS 3a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
12B	PCFG in BSCS 5a	**PCFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13A	WFG in BSCS 3a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
13B	WFG in BSCS 5a	**WFG**	4.50%	4.50%	4.50%	2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 3a	No		**Estimated**		2	20	D x 4	Yes
14A	MSYR1+ estimated (common) 5a	No		**Estimated**		2	20	D x 4	Yes
15A	MSYR1+ estimated (by FA) 3a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
15B	MSYR1+ estimated (by FA) 5a	No	**Est**	**Est**	**Est**	2	20	D x 4	Yes
16A	Lower PCFG immigration and higher bycatch 3a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes
16B	Lower PCFG immigration and higher bycatch 5a (and no 1998-2002 PCFG data)	No	4.50%	4.50%	4.50%	**0**	20	**D x 10**	Yes
17A	MSYR estimated and lower pulse 3a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes
17B	MSYR estimated and lower pulse 5a	No	**Est**	**Est**	**Est**	2	**10**	D x 4	Yes

Trial	Description/stock hypothesis	PCFG or WFG in BSCS	MSYR$_{1+}$			PCFG		Bycatch	Conditioning
			North	PCFG	WFG	Imm.	Pulse		
18A	Stock hypothesis 3b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18B	Stock hypothesis 6b	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
18C	Stock hypothesis 3c	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
19A	Lower PCFG Immigration 3a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
19B	Lower PCFG Immigration 5a	No	4.50%	4.50%	4.50%	**1**	20	D x 4	Yes
20A	Lower PCFG immigration and higher bycatch 3a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
20B	Lower PCFG immigration and higher bycatch 5a	No	4.50%	4.50%	4.50%	**1**	20	**D x 10**	Yes
21A	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
21B	Survival = 0.95; 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
22A	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
22B	Future catastrophic events (once in each of yrs 1-50 & 51-99) - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
23A	Summer S&L rate = 0.5 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
23B	Summer S&L rate = 0.5 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
24A	PCFG false negative rate = 0.1 - 3a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 3a
24B	PCFG false negative rate = 0.1 - 5a	No	4.50%	4.50%	4.50%	2	20	D x 4	No, 5a
25A	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes
25B	PCFG mixing based on Northern WA is 100%	No	4.50%	4.50%	4.50%	2	20	D x 4	Yes

Appendix 1

OUTLINE OF THE MAKAH MANAGEMENT PLAN AND ITS IMPLEMENTATION IN TRIALS





Appendix 2
THE 'RESEARCH WITH VARIANT' (SLA VARIANT 1) OPTION (IWC, 2013).

This option operates as follows:

(1) Update the ABL (Allowable Bycatch Limit of PCFG whales) if this is the start of a new 6-year block as:

$$ABL = N_{MIN} * 0.5 * R_{MAX} * F_R$$

Where:

N_{MIN} is the log-normal 20th percentile of the most recent abundance estimate for the Oregon to Southern Vancouver (OR-SVI) sub-area of the PCFG. The abundance estimates for use in the ABL formula are generated as specified in Section I, except for allowance is made for a bias which differs among simulations but is constant over time between the estimates for OR-V and those for the PCFG, i.e. $\ell n B_A \sim N(-0.335, 0.112^2)$ (IWC, 2012).

R_{MAX} is equal to 0.04;

F_R is equal to 1.0.

(2) Strike an animal
(3) If the total number of struck animals equals the need of 7 stop the hunt.
(4) If the animal is struck-and lost:
  a. if the total number of struck and lost animals is 3, stop the hunt.
  b. go to step (2).
(5) If the animal is landed and is matched against the PCFG catalogue:
  a. add one to the number of whales counted towards the ABL
  b. if the ABL is reached; stop the hunt
  c. if the total number of landed whales equals 5; stop the hunt
  d. if the number of landed whales for the current six-year block equals 24; stop the hunt
  e. go to step (2).
(6) If the animal is landed and does not match any whale in the PCFG catalogue:
  a. if the total number of landed whales equals 5; stop the hunt
  b. if the number of landed whales for the current six-year block equals 24; stop the hunt
  c. go to step (2).

References
IWC. 2012. Report of the Standing Working Group in the Aboriginal Whaling Management Procedure. J. Cetacean Res. Manage. 13 (Suppl.) 130-53.

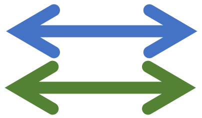
Geographic areas utilized by gray whales are illustrated with colored boxes:

Feeding region

Migratory region

Wintering region

Arrows represent movements between geographic areas, with blue representing movements between feeding regions and green representing migratory movements:

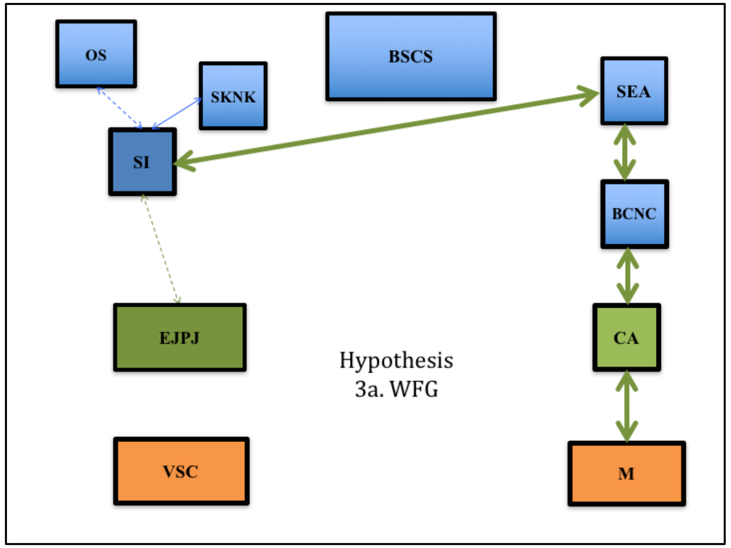


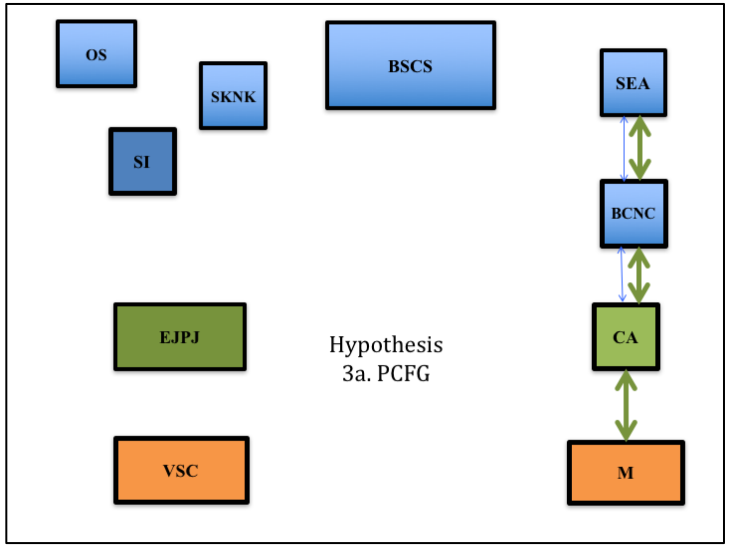
Solid thick lines with arrows denote movements between regions of a significant proportion of individuals using the area

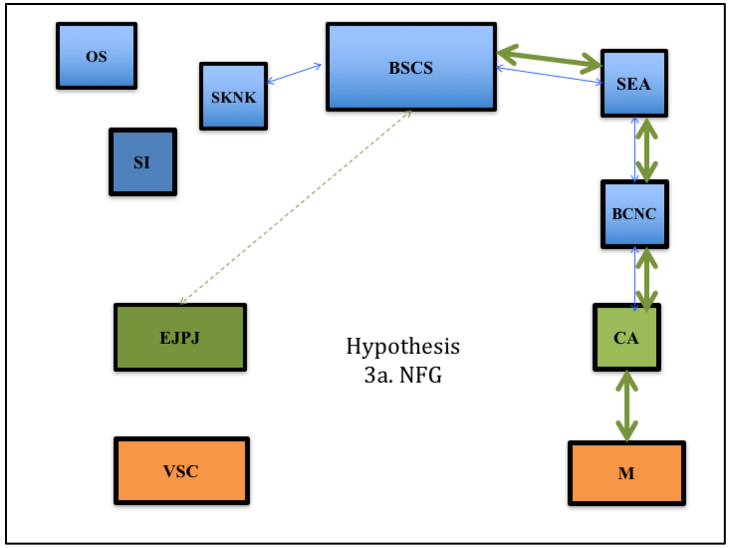
Solid thin lines with arrows denote limited movements between regions

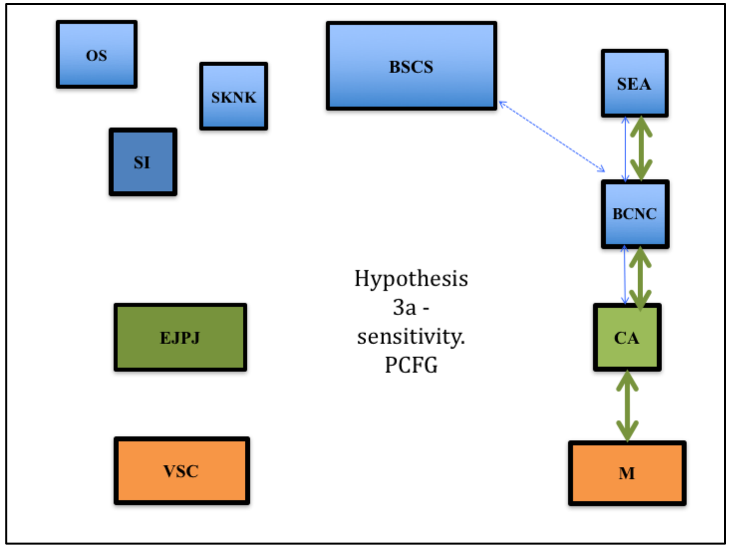
Dashed thin lines with denote occasional movement between regions of small number of individuals

Hypothesis 3a:

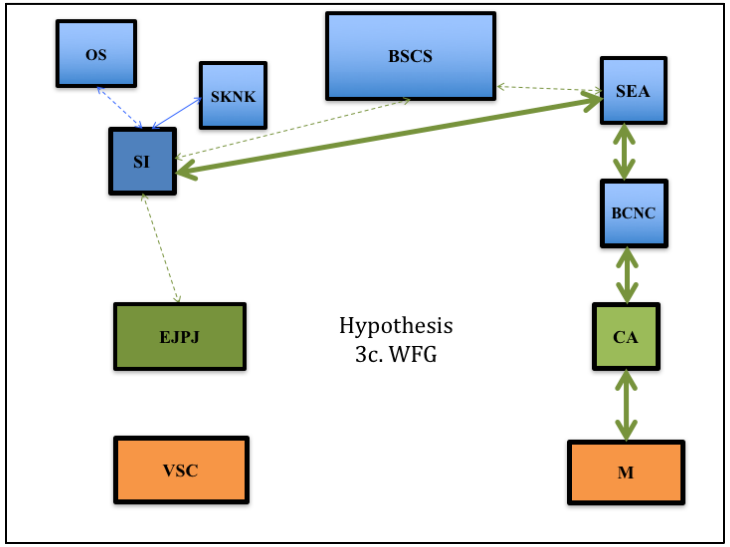


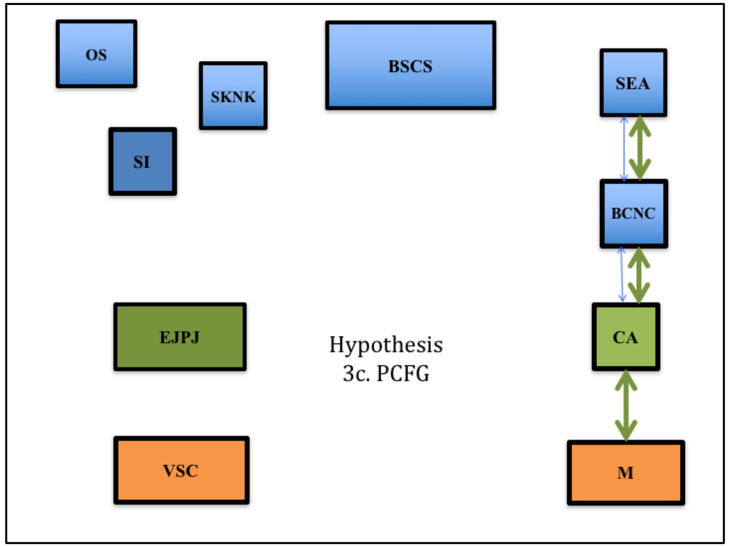


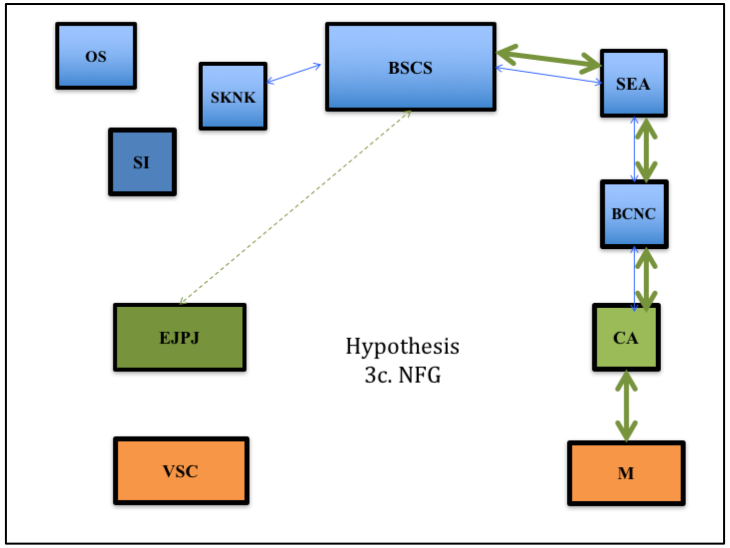




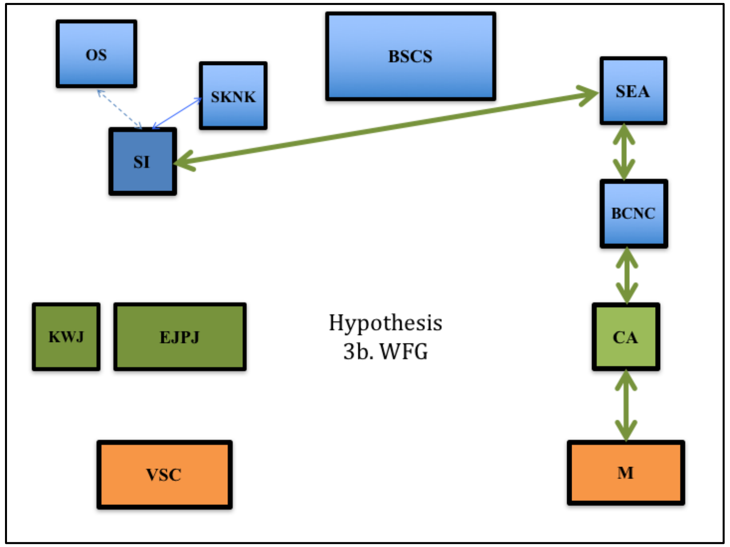
Hypothesis 3c:

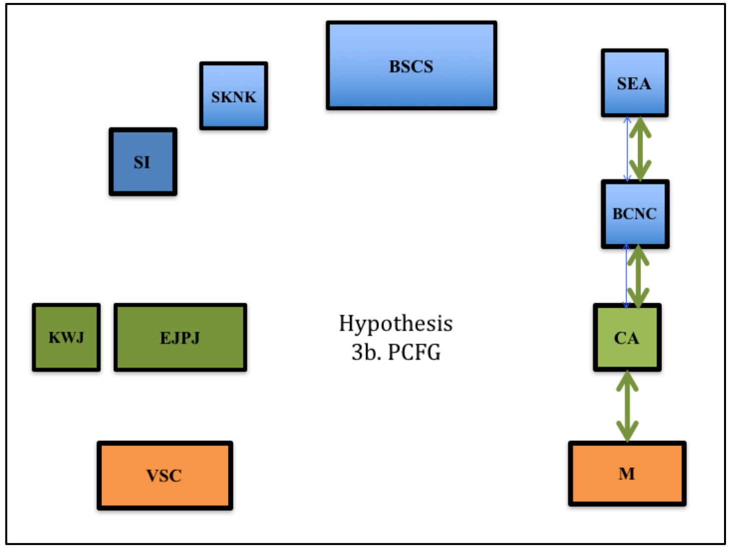


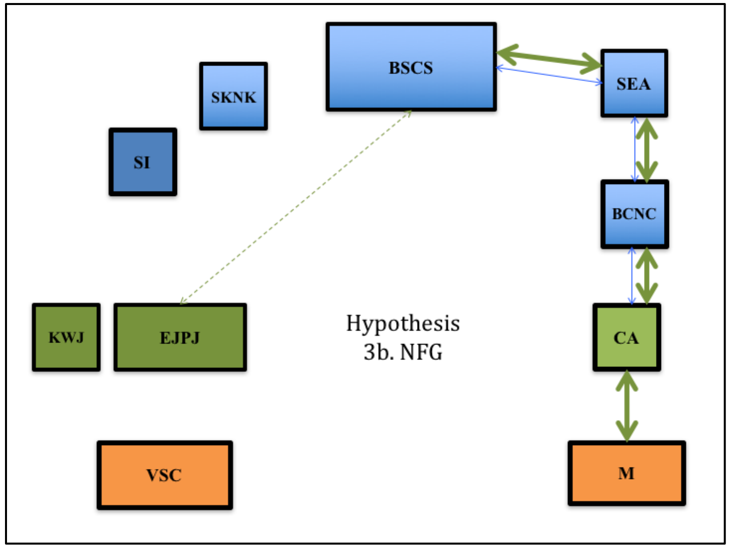


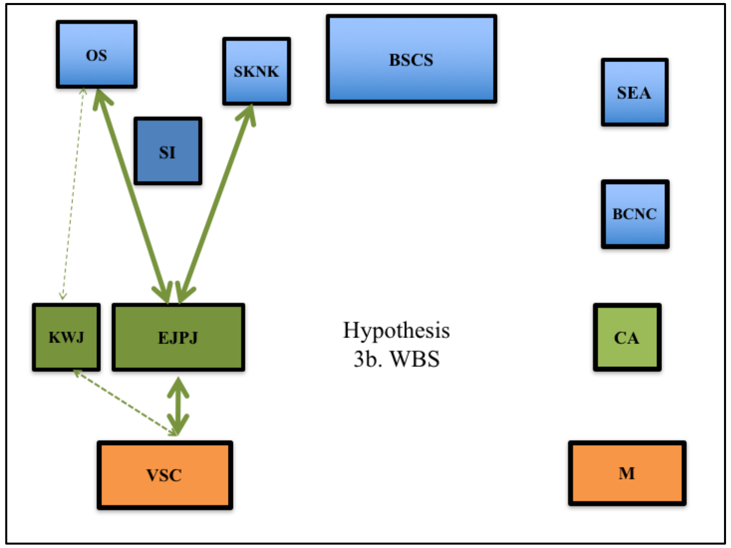


Hypothesis 3b:









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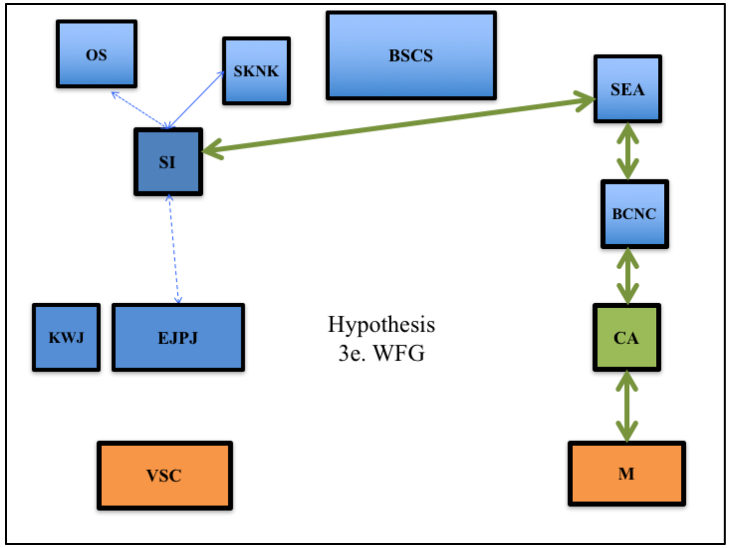
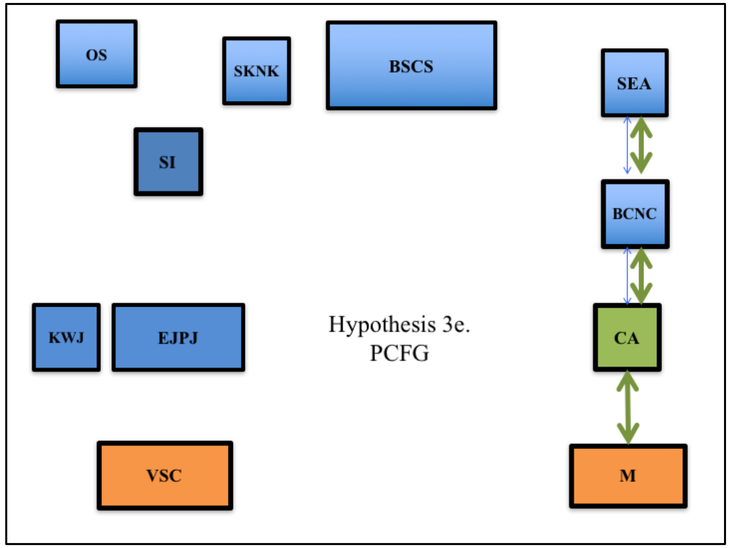
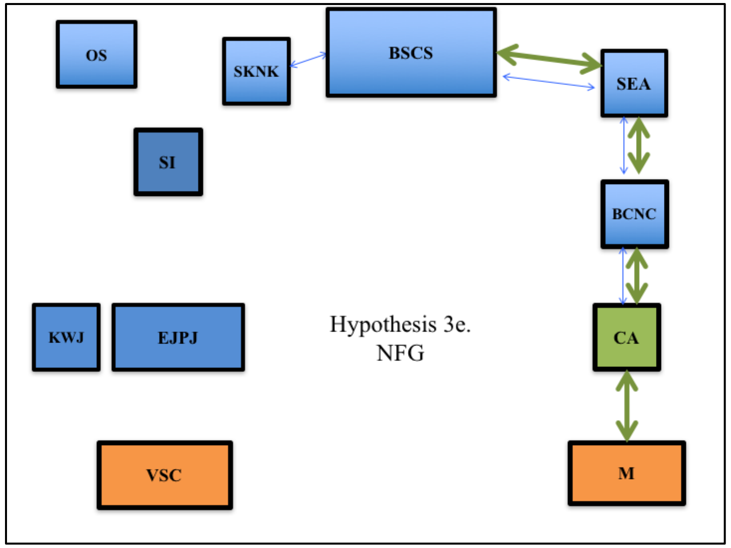
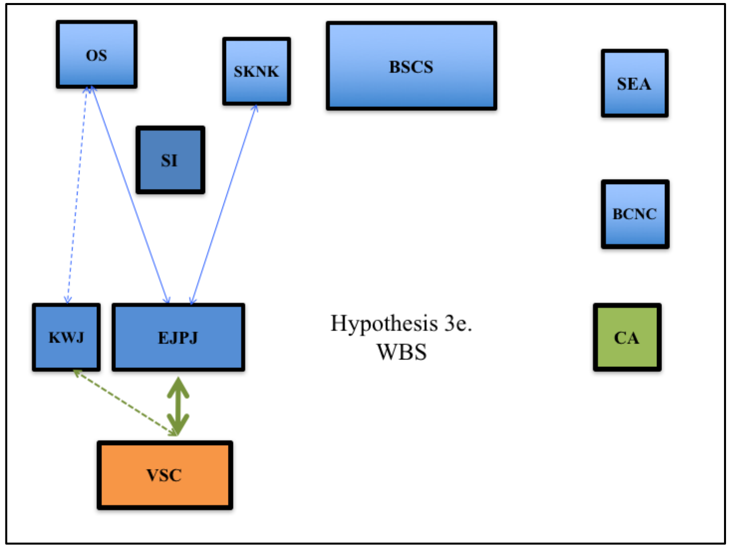
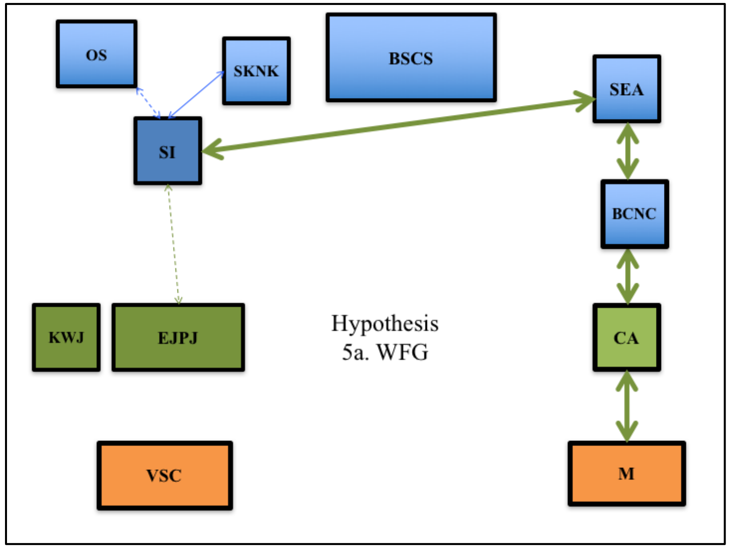


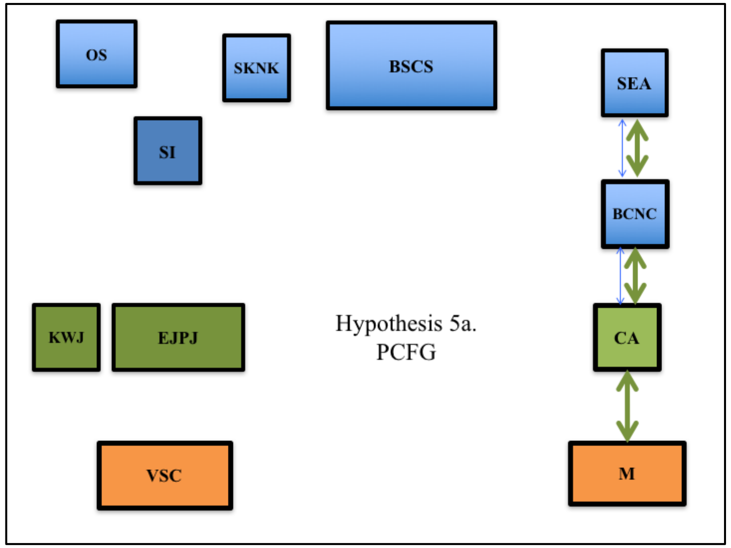


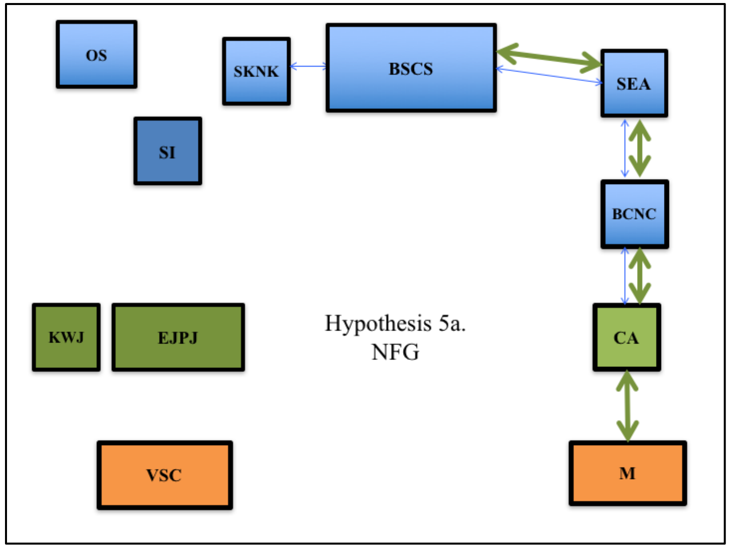


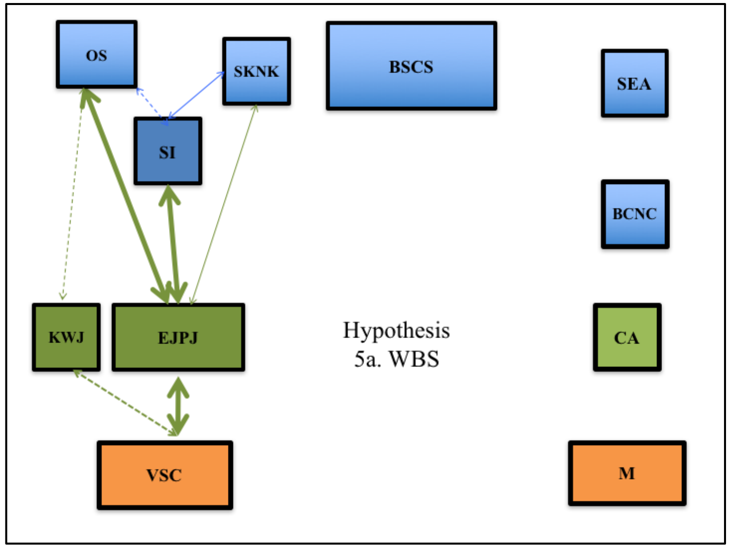


Hypothesis 5a:









Hypothesis 6b: