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Information of relevance on Evaluation Trials for West Greenland humpback whales (including general non species specific issues)

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ABSTRACT
This paper briefly discusses SLA development for the Greenlandic multi-species fishery with need expressed in terms of edible products across all species, but the main focus is on Evaluation (and Robustness) Trials for the development of a SLA for West Greenland humpback whales. The Scientific Committee has previously agreed to provide management advice on the West Greenland feeding aggregation by treating this as an independent stock, and this view is compared with recently published papers on stock structure. The trial structure used for SLA development for ENP gray whales is briefly discussed, and a rough outline for a suggested structure for West Greenland humpback whales is provided based on the gray whale trials and a recent assessment of West Greenland humpback whales. Information on abundance estimates and biological parameters are also given.

ON NEED ENVELOPES AND SLA DEVELOPMENT

The need envelopes in the Evaluation and Robustness Trials for ENP gray whales and BCB bowhead whales were expressed as fixed blocks in relation to the two species. Greenland, on the other hand, would like to express the possible future development in need as envelopes on the total need of edible products from large whales. By expressing need in terms of edible products it should be easier to obtain a high need satisfaction on a sustainable basic through a multi-species fishery. Should, for one reason or the other, the strike limit on an important species suddenly decline this system should provide the best opportunity for maintaining a relatively high need satisfaction through a shift of quotas to other species, if possible.

An absence of fixed need envelopes that are constrained at levels relatively close to current strike limits do not make SLA development easier, and the AWMP group needs to decide on a way forward. One (but certainly not the best) option would be to develop SLAs under a worst case scenario, i.e., by setting the envelope for each species to the total need. This, however, is likely unproductive because it will prevent that SLAs are optimised to the most likely development in need for the different species. [Please note that there is no problem in having the sum of need of the envelopes across all species being much larger than the total need of the envelope expressed in edible products. When the SLAs are applied we just need to ensure that the sum of strike limits across the species do not exceed total need. This may be done by the development of multi-species allocation functions (see Witting 2001 for an initial discussion on this), or more simply, and maybe even more practical, by simply continuing something like the current approach where Greenland, for each quota year, explicitly states how they would like to have their total need distributed among the different species.]

A better method would be to include the potential for easy retuning as a direct selection criterion in the development process. This could be done by having expected need envelopes for each species to which the initial versions of the SLAs would be tuned, and by having other trials with significantly higher need envelopes (perhaps even the total need envelope per species) where performance of the same SLA, but likely with a different tuning, is tested (or the same tuning if the SLA in itself is sufficient flexible and clever). The winning SLA is then not necessarily the procedure that performs best on the expected need trials, but instead the SLA that performs best on the expected and high need trials together. By choosing such a procedure, the AWMP group should have the best option for providing the most satisfactory advice in the future, even in cases where the actual need for a species would suddenly jump beyond the expected need envelope. In such cases, we may just have to apply another tuning of the SLA, a tuning that may already have been tested within the larger more unlikely need space. Alternatively, should a retesting of the new tuning be required, we would at least have ensured that we have a procedure that is sufficiently flexible to cope with the new situation.

STOCK STRUCTURE

The Scientific Committee has previously agreed to provide management advice on the West Greenland feeding aggregation of humpback whales by treating this as an independent stock (IWC 2008). The abstracts given below from recent papers on stock structure in North Atlantic humpback whales confirm that this approach should be precautionary.

Stevick et al. 2006: Population spatial structuring on the feeding grounds in North Atlantic humpback whales

Abstract: Population spatial structuring among North Atlantic humpback whales *Megaptera novaeangliae* on the summer feeding grounds was investigated using movement patterns of identified individuals. We analysed the results from an intensive 2-year ocean-basin-scale investigation resulting in 1658 individuals identified by natural markings and 751 individuals by genetic markers supplemented with data from a long-term collaborative study with 3063 individuals identified by natural markings. Re-sighting distances ranged from $<$ 1 km to $>$ 2200 km. The frequencies (F) of resighting distances (D) observed in consecutive years were best modelled by an inverse allometric function (F=6631D$^{1.24}$, r^2=0.984), reflecting high levels of site fidelity (median re-sighting distance $<$ 40 km) with occasional long-distance movement (5% of re-sightings $>$ 550 km). The distribution of re-sighting distances differed east and west of 45°W, with more long-distance movement in the east. This difference is consistent with regional patterns of prey distribution and predictability. Four feeding aggregations were identified: the Gulf of Maine, eastern Canada, West Greenland and the eastern North Atlantic. There was an exchange rate of 0.98% between the western feeding aggregations. The prevalence of long-distance movement in the east made delineation of possible additional feeding aggregations less clear. Limited exchange between sites separated by as little as tens of kilometers produced lower-level structuring within all feeding aggregations. Regional and temporal differences in movement patterns reflected similar foraging responses to varying patterns of prey availability and predictability. A negative relationship was shown between relative abundance of herring and sand lance in the Gulf of Maine and humpback whale movement from the Gulf of Maine to eastern Canada.

Stevick et al. 2003: Segregation and migration by feeding ground origin in North Atlantic humpback whales

Abstract: Results from a large-scale, capturerecapture study of humpback whales *Megaptera novaeangliae* in the North Atlantic show that migration timing is influenced by feeding ground origin. No significant differences were observed in the number of individuals from any feeding area that were re-sighted in the common breeding area in the West Indies. However, there was a relationship between the proportion (logit transformed) of West Indies sightings and longitude (r^2 = 0.97, $F_{1,3}$ = 98.27, P = 0.0022) suggesting that individuals feeding farther to the east are less likely to winter in the West Indies. A relationship was also detected between sighting date in the West Indies and feeding area. Mean sighting dates in the West Indies for individuals identified in the Gulf of Maine and eastern Canada were significantly earlier than those for animals identified in Greenland, Iceland and Norway (9.97 days, t_{179} = 3.53, P = 0.00054). There was also evidence for sexual segregation in migration; males were seen earlier on the breeding ground than were females (6.63 days, t_{105} = 1.98, P = 0.050). This pattern was consistently observed for animals from all feeding areas; a combined model showed a significant effect for both sex (F_1 = 5.942, P = 0.017) and feeding area (F_3 =4.756, P=0.0038). The temporal difference in occupancy of the West Indies between individuals from different feeding areas, coupled with sexual differences in migratory patterns, presents the possibility that there are reduced mating opportunities between individuals from different high latitude areas.

Heide-Jørgensen and Laidre 2007: Autumn space-use patterns of humpback whales (*Megaptera novaeangliae*) in West Greenland

Abstract: Five humpback whales were tagged with satellite transmitters on their summer feeding grounds in West Greenland in August between 2002 and 2005. Tracking durations lasted between 13 and 111 days and the locations obtained from the whales provided the first insight on the autumn distribution patterns of this species in West Greenland. Whales demonstrated a consistent pattern of rapid and long-distance movements along the West Greenland coast separated by longer-term, focal area use where feeding occurred. Humpback whales in West Greenland feed on capelin (*Mallotus villosus*), sand eels (*Ammodytes sp.*), and krill and these three prey species require different foraging strategies. Generally whales showed high affinity to the coast due to shallow aggregations of capelin. However some use of offshore regions was detected, likely due to concentrations of sand eels. One whale crossed Baffin Bay to Baffin Island, an area not known to support humpback whales. The rapid movements of humpback whales between feeding sites in Greenland and Canada may be a response to variable and dynamic prey resources throughout the summer and autumn seasons.

ASSESSMENT

The latest assessment paper on humpback whales off West Greenland is Witting (2011), which used recent abundance estimates, historical catches starting from 1664, and an age and sex-structured population model to examine if the population dynamics of West Greenland humpback whales is best described by density regulated growth or by selection-delayed dynamics (earlier referred to as inertia dynamics). As for ENP gray whales (Witting 2003), there was substantial statistical support for the acceptance of selection delayed dynamics and the rejection of density regulated growth. It was estimated that the abundance declined from a population dynamic equilibrium of 2,900 (90% CI:1,800-5,900) individuals in 1664 to a minimum with 1,300 (90% CI:230-5,100) individuals in 1927. With an assumed annual post 2010 catch of ten whales per year, the model estimated that the population would increase to a projected 2020 estimate of 5,200 (90% CI:2,40-9,000) individuals. The 2011 depletion ratio was estimated to 1.4 (90% CI:0.68-3.1), with an annual growth rate of 5.5% (90% CI:$2.6 - 7.6$%) is the absence of harvest.

Biological parameters

There is no estimate of the age of the first reproductive event (a_m) for humpback whales in West Greenland. There are, however, several estimates from other areas (Clapham 1992; Gabriele et al. 2007; Robbins 2007; Ramp 2008). For North Atlantic humpback whales, Ramp (2008) estimated a_m to exceed 12 years in the Gulf of St. Lawrence, Clapham (1992) estimated it to a range from five to seven years for humpbacks in the Gulf of Maine, and a later estimate from this area obtained an average estimate of seven years, ranging from five to 13 (Robbins 2007).

Density dependence operates on the birth rate (b) in the assessment model, but the age of the first reproductive event is also known as one of the more responsive life-history parameters to density-dependent effects (e.g., Eberhardt and Siniff 1977; Gaillard et al. 2000). The assessment model applied the estimate of Clapham (1992) as a uniform prior form five to seven years of age to the density regulated and selection delayed models. For the exponential model it applied the later estimate from the Gulf of Maine ranging from five to 13 years of age (Robbins 2007).

There is no estimate of the birth rate for humpback females in West Greenland, but estimates exist for other areas. Gabriele et al. (2007) found that adult females in Alaska typically give birth every second to third year, with a documented range from one to six, and a mode every second year. Robbins (2007) found a comparable range for humpbacks in the Gulf of Maine, with a mean estimated annual birth rate of 0.57 and a process variance of 0.042 for 201 adult in the south-west of the area. The 2011 assessment applied the latter estimate as an informative beta prior on the birth rate ($a = 2.741$, $b = 2.111$). As for a_m, for density regulated growth and selection-delayed dynamics, the prior on the birth rate should reflect the expected range for the average birth rate among the individuals in a population that increases at its maximum growth rate. As West Greenland humpbacks are estimated to increase at a rate faster than humpbacks in the Gulf of Maine (Clapham et al. 2003; Heide-Jørgensen et al. 2008), the applied prior may be in the lower range of the true value.

Larsen and Hammond (2004) estimated an annual survival rate (p) of 0.957 (SE=0.028) for humpback whales off West Greenland. This is similar to estimates of 0.951 (SE=0.010) and 0.960

(SE=0.008) for the Gulf of Maine feeding aggregation of humpbacks (Buckland 1990; Barlow and Clapham 1997), and an estimate of 0.963 (95% CI:0.944-0.978) for humpbacks in the central North pacific (Mizroch et al. 2004).

In the Gulf of Maine, calf survival was estimated at 0.664 (95% CI:0.517-0.784), and yearly adult survival at 0.991 (95% CI:0.919-0.999) when excluding animals younger than five years of age (Robbins 2007). From age zero to five, yearly survival was found to increase by an approximate straight line. The 2011 assessment applied a linear increase in the relative survival rate from age zero to age five plus: $\{0.67, 0.74, 0.80, 0.87, 0.93, 1.00\}$.

The posterior estimates of the biological parameters from the 2011 assessment is given in Table 1.

M		r	msyr	p	b	a_m	msyl
	$x_{.5}$	.055	-	.98	.81	7.3	-
	$x_{.05}$	.026	-	.96	.51	5.2	-
E	$x_{.95}$	.076	-	.99	.97	12	-
	$x_{.5}$	.059	.048	.98	.79	5.8	.64
	$x_{.05}$	.029	.021	.95	.48	5.1	.55
D	$x_{.95}$	.081	.068	.99	.97	6.9	.69
	$x_{.5}$	.051	-	.98	.76	5.9	-
	$x_{.05}$	.016	-	.95	.38	5.1	-
S	$x_{.95}$	.079	-	.99	.97	6.9	-

Table 1: **Parameter estimates** for the short-term exponential (E), the short term density regulated (D), and the long-term selection-delayed (S) models in Witting (2011). Estimates are given by the median ($x_{.5}$) and the 90% credibility interval ($x_{.05}$ - $x_{.95}$) of the posterior distributions [$r = r_{max}$ for D and S].

ABUNDANCE DATA

Agreed abundance estimates for West Greenland humpback whales are listed in Table 2. Other abundance information include a 2007 estimate of 4,365 (CV:0.20) humpback whales in Canadian waters, with a comparison with a 1981 survey indicating that humpbacks in Newfoundland waters may have increased with an annual rate of approximately 8.2% (NAMMCO 2010, 2011).

ENP GRAY WHALE TRIALS

In order to inform on earlier approaches taken by the AWMP group on the construction of Evaluation Trials for SLA development on a single stock, in this section I briefly summaries the (initially) adopted trial structure for ENP gray whales.

The table in Figure 1 list the Evaluation Trials, and Figure 2 the Robustness Trials, that were adopted for ENP gray whales in 2004, and Figure 3 list the priors of the conditioning. This structure was to a large degree based on the assessments performed by the Wade (2002), Butterworth et al. (2002) and Punt and Butterworth (2002), and to a smaller degree on Witting

Year	I_a	I_b	N
1984	138 (54)	–	–
1988	231 (70)	357 (16)	–
1989	–	355 (12)	–
1991	–	376 (19)	–
1992	–	348 (12)	–
1993	873 (53)	–	–
2005	1,218 (38)	–	–
2007	–	–	3,270 (50)

Table 2: **Abundance** estimates from West Greenland with CV in parenthesis (given in %). I_a is an index series from aerial surveys. I_b is an index series of mark-recapture estimates, and N a fully corrected line transect survey from 2007. Data from Larsen and Hammond (2004), Heide-Jørgensen et al. (2008).

(2003). We should note that only very few of the trials (the few inertia trials) aimed at reconstructing the complete historical trajectory of the population, while the majority of the trials were concerned only with the dynamics on an intermediate time-scale that was initiated in 1930. We may also note that Wade (2002) provided a msyr estimate of 3.5% (95% CI: 2.1 – 6.8%), and that the base case msyr in the trials was 3.5%, with a minimum estimate of 1.5%.

SUGGESTED TRIALS

A way forward with the construction of Evaluation Trials for West Greenland humpback whales is to follow the approach for ENP gray whales, and base the majority of the trials on a density regulated model applied at an intermediate time-scale, with an initial age-structure at equilibrium and an initial abundance not a carrying capacity. The gray whale trials were initiated in 1930, and the short-term density regulated model in Witting (2011) in 1980. The initial starting year is likely not that essential, and it could be earlier than 1980. If later than 1940, we would generally avoid the problem with uncertain historical catches because there were basically no annual caches from 1940 to 1970, even with West Indies catches included. As for the gray whale case, a few long-term Evaluation Trials based on selection delayed dynamics could also be adopted.

The only major uncertain component of this approach relates to the estimate of carrying capacity and current depletion because the available data will not provide an upper limit on the estimate of carrying capacity. The density regulated model of the 2011 assessment provided only an approximate estimate of the lower 5th percentile of the carrying capacity of $2,900$ individuals. Given a pre-whaling abundance in dynamic equilibrium, the selection delayed model of the 2011 assessment estimated a pre-whaling abundance of 2,900 (90% CI:1,800-5,900) individuals in 1664, but this abundance is not comparable with a present day carrying capacity for a density regulated model. The carrying capacity of a density regulated model is a initial condition in the selection delayed model, which predicts that the carrying capacity in an exploited population below the historical equilibrium will increase. Hence, we expect a higher carrying capacity today than the 2,900 (90% CI:1,800-5,900) estimate, and this coincides with a lower 5th percentile of 2,900 individuals as estimated by the density regulated model. The West Greenland humpback trials that were used for the testing on the interim procedure (Figure 4) circumvented this problem by assuming a current deletion at either 0.2, 0.5 or 0.8. It is suggested that this method is applied again, with the median value representing the base case, although the explicit choices of current depletion could be discussed. Nevertheless, and upper estimate of 0.8, is likely applicable as an upper estimate given that the population is currently estimated to increase at an annual rate of 5.5% (90% CI:2.6 – 7.6%).

Relating to the msyr of the Evaluation Trials we note that the base case for ENP gray whales followed the point estimate for that population, that the estimate for the low production trials was 0.6% lower than the 2.5th percentile of the estimate from the assessment, and that the high production trials were 1.6% lower than the 97.5th percentile of the assessment estimate. A similar approach (although based on the 90% CI), would suggest 4.8%, 1.5% and 5.5% for humpback whales in West Greenland. With the humpback whale case being more data poor than the gray whale case, it might be argued that the base case trial for West Greenland humpbacks is adjusted down to the 3.5% of the base case trial for gray whales.

Nearly all gray whale Evaluation Trials assumed a msyl of 0.6, a single trial assumed 0.8, and two an integrated approach with msyl ranging from 0.4 to 0.8, with the msyr ranging from 1.5 to 5.5%. A similar approach, could be adopted for West Greenland humpbacks, and it should be discussed whether the integrated approach is preferable over trials with the msyl fixed at 0.4 or 0.8.

The need envelopes to be considered should not be smaller than flat ten, and they should include also a medium and high option. A final settlement for this will have to reflect and agreed approach by the AWMP group relating to an overall need envelope on edible products across all species of large whales and, dependent upon this agreement, a discussion with the Greenlandic delegation relating to an expected and a maximal possible envelope.

A survey frequency of ten years was assumed in most of the gray whale Evaluation Trials, although the frequency of five years was assumed in ten trials, and a variable interval in a trial with strategic surveys. It is unclear (to me right now) why the high frequency of trials with five year intervals was applied to the gray whale. Because a five year survey interval is likely in the high end of what can be expected in Greenland, it is recommended that only few five year interval Evaluation Trials are constructed for West Greenland humpbacks. But a few should be included to see if more frequent surveys can enhance performance, and it is also recommended that one trial with strategic surveys intervals is adopted.

The gray whale Evaluation Trials also included more specific trials relating to, e.g., the 00/99 die off, episodic events, survey bias, and underestimated abundance estimate CVs. The inclusion of such specific trials will have to be discussed specifically in relation to West Greenland humpbacks. Hence, in conclusion, it is suggested that the base set of the Evaluation Trials for West Greenland humpback whales is constructed over the following parameter space, with bold numbers relating to the base case: msyr $[1.5\%, \mathbf{3.5}\%, 5.5\%]$, msyl $[0.4, \mathbf{0.6}, 0.8]$, current depletion $[0.2, \mathbf{0.5}, 0.8]$, survey interval $[5, \mathbf{10}, \text{strategic}]$, and with the setting of the need envelopes waiting further discussion.

Robustness Trials for West Greenland humpback whales could include the general Robustness

Trials for gray whales, such as relating to density dependence on the mature component of the population, survey frequency, strategic surveys, time dependence in different parameters, and and a delayed density dependent feedback.

Table 2

A summary of the *Evaluation Trials*. Full details are given in Appendix 3. Values given in bold type show differences from the base case trial.

Trial	Description	Model	$MSYR_{1+}$	$MSYL_{1+}$	Final Need	Survey freq.	Survey bias Historic	Survey bias Future	Future Survey CV
GE01	Base case	D	3.5%	0.6	340	10	1	1	Base
GE02	Low need i.e. constant need	D	3.5%	0.6	**150**	10	1	1	Base
GE03	Future +ve bias	D	3.5%	0.6	340	**5**	1	**1→1.5 in yr 25**	Base
GE04	Future -ve bias	D	3.5%	0.6	340	**5**	1	**1→0.5 in yr 25**	Base
GE05	Underestimated CVs	D	3.5%	0.6	340	10	1	1	**½ CV_{est}**
GE07	$MSYL_{1+}$ = 0.8	D	3.5%	**0.8**	340	10	1	1	Base
GE08	5 year surveys	D	3.5%	0.6	340	**5**	1	1	Base
GE09	$MSYR_{1+}$ = 1.5%	D	**1.5%**	0.6	340	10	**0.5→1**	1	Base
GE10	$MSYR_{1+}$ = 5.5%	D	**5.5%**	0.6	340	10	1	1	Base
GE11	Bad data	D	3.5%	0.6	340	10	1	**1→1.5 in yr 25**	**½ CV_{est}**
GE12	Difficult 1.5%	D	**1.5%**	0.6	340	10	**0.5→1**	**1→1.5 in yr 25**	**½ CV_{est}**
GE12a	Difficult 1.5%+5yr surveys	D	**1.5%**	0.6	340	**5**	**0.5→1**	**1→1.5 in yr 25**	**½ CV_{est}**
GE14	High need	D	3.5%	0.6	**530**	10	1	1	Base
GE14a	High need + 5yr surveys	D	3.5%	0.6	**530**	**5**	1	1	Base
GE16	$MSYR_{1+}$ = 1.5%; high need	D	**1.5%**	0.6	**530**	10	**0.5→1**	1	Base
GE20	$MSYR_{1+}$ = 5.5%; high need	D	**5.5%**	0.6	**530**	**5**	1	1	Base
GE21	Integrated	D	**U[1.5,5.5%]**	*U[.4-.8]*	340	10	1	1	Base
GE21a	Integrated + 5yr surveys	D	**U[1.5,5.5%]**	**U[.4-.8]**	340	**5**	1	1	Base
GE23	Strategic surveys; high need	D	3.5%	0.6	**530**	**Strategic**	1	1	**CV_{true}=0.1 + base case value**
GE24	Inertia Model	**I**			340	10	1	1	Base
GE27	GE24 + future –ve bias	**I**			340	**5**	1	**1→0.5 in yr 25**	Base
GE30	GE24 +hist. bias+high need	**I**			**530**	10	**0.5→1**	1	Base
GE33	GE01 + ignore low est.	D	3.5%	0.6	340	10	1	1	Base
GE34	GE04 + ignore low est.	D	3.5%	0.6	340	**5**	1	**1→0.5 in yr 25**	Base
GE37	GE16 + ignore low est.	D	**1.5%**	0.6	**530**	10	**0.5→1**	1	Base
GE38	GE24 + ignore low est	**I**			340	10	1	1	Base
GE41	GE01 + 40% die in 99/00	D	3.5%	0.6	340	10	1	1	Base
GE42	GE04 + 40% die in 99/00	D	3.5%	0.6	340	**5**	1	**1→0.5 in yr 25**	Base
GE45	GE16 + 40% die in 99/00	D	**1.5%**	0.6	**530**	10	**0.5→1**	1	Base
GE46	GE24+40% die in 99/00	**I**			340	10	1	1	Base
GE49	GE01 + 3 ep.events	D	3.5%	0.6	340	10	1	1	Base
GE50	GE09 + 3 ep.events	D	**1.5%**	0.6	340	10	**0.5→1**	1	Base

Figure 1: Gray whale Evaluation Trials from IWC (2004).

The *Robustness Trials.*

Trial No.	Factor	Basic trials (Table 2)	Factor Level
GR01	A: Density dependence	1, 9, 24	Density dependence on mature (GE trials use 1+)
GR04	E: Survey frequency	9, 14, 16, 20	a) 15 yrs
		16, 24	b) 5 yrs
GR05	F: Strategic surveys	1, 9	a) Yes + CV = base case value
		1, 9, 30	b) Yes + CV_{true}=0.1+ base case value
GR06	G: Survey bias time dependence	1	a) Historic bias: 1.5 constant; Future bias: decreasing (1.5→1)
		1	b) Historic bias: 0.5 constant; Future bias: increasing (0.5→1)
		12	d) Future bias: increasing from 1→1.5 in year 25 and then decreasing →1 in year 100
		14	e) Future bias: increasing from 1→1.5 in year 25 and constant thereafter
GR08	I: Historic catch bias)	14, 16	a) 0.5 (1940-70 catches under-reported) + survey bias adjustment as necessary
		24	b) Pre 1943 aboriginal catch (Table 1b) decreased by 50% (sla is given basecase catches)
		24	c) Commercial catch 1846-99 increased by 50% (the *sla* is given the basecase catches)
		24	d) Commercial catch 1846-99 decreased by 50% (the *sla* is given the basecase catches)
GR09	K: Time dependence in *K*	1, 9, 10	a) *K* halves linearly over 100 years
		1, 9, 10	b) *K* doubles linearly over 100 years
		1	c) *K* sinusoidal from base value in year 0 to maximum of 150% in year 40 (Fig 1a)
		1	d) Tent *K: K* doubles linearly from years-50 to 0 and halves from years 0 to 50 (Fig1b)
		1, 9	e) *K* halves linearly over 100 years + strategic surveys
GR10	L: Time dependence in *MSYR*	10	a) Resilience (*A*) halves linearly over 100 years
		9	b) Resilience (*A*) doubles linearly over 100 years
		1, 8	c) Resilience steps 2½%→1%→2½% every 33 yrs over 100 years
		1, 8	d) Resilience steps 2½%→1%→2½% every 33 yrs over 100 years in sync with *M* (compute MSYR first) – if it is practical halve *M* for each age class
		1	e) *K* and *A* halve linearly over 100 years
		1	f) *K* and *A* vary as tent (see GR09(d))
GR11	M: Time dependence in *M*	1, 9, 24	a) Natural mortality *M* halves linearly over 100 years
		1, 9, 10, 24	b) *M* doubles linearly over 100 years
GR15	$MSYL_{1+}=0.9$	1, 9, 10	See [1]
GR17	Q: 20 year time lag	9, 10	20 year time lag
GR18	R: Historic catch sex ratio	24	50:50 catch sex ratio from 1600-1964. The *sla* is given the basecase sex ratio.
GR19	S: Survival rate	1, 9, 10	1+ natural survival rate S_{1+}=0.95
GR20	Final need	1, 9, 10	a) Final need = 700
		1, 9, 10	b) Final need = 1,000
GR21	T: Different sex ratio at start	1	Sex ratio in initial (1930) population = 70%males,30%females (50:50 used in base case).

[1] For trials GR15-1 and 10 the model could not be conditioned with MSYL=90% so values of 85% (GR15-1) and 80% (GR15-9) were used.

[6] 'H' operates in the idealised case when the parameters of the common control programme are known exactly and it is simply one possible way to interpret the Commissions' advice given in 1994 (International Whaling Commission, 1995). It cannot therefore be used as an *SLA* since this perfect knowledge is not available for the actual, as opposed to the simulated gray whale stock.

Figure 2: Gray whale Robustness Trials from IWC (2004).

A.8 Conditioning

The method for conditioning the trials (i.e. selecting the 100 sets of values for the parameters a_m, S_0, S_{1+}, K^{1+}, A and z) is based on a Bayesian assessment of the eastern North Pacific stock of gray whales (Punt and Butterworth, 2002; %%23397%% Wade, 2002 %%21366%%). The algorithm for conducting the Bayesian assessment is as follows:

(a) Draw values for the parameters S_{1+}, f_{max}, a_m, $MSYR_{1+}$, $MSYL_{1+}$, K^{1+}, P_{1968}, CV_{sch} (the CV associated with the mean school size estimation error in 1968[1]), CV_{add} (the additional variance for the estimate of 1+ abundance in 1968), CV_{add2} (the additional variance associated with the calf counts) and B_c (the calf count bias) from the priors in Table 2. For most trials, it is not necessary to draw values for $MSYR_{1+}$ and $MSYL_{1+}$ because the values for these quantities are pre-specified rather than being determined during the conditioning process.

Table 2 The prior distributions for the eastern north Pacific stock of gray whales.

Parameter	**Prior distribution**
Non-calf survival rate, S_{1+}	U[0.95, 0.999]
Age-at-maturity, a_m	U[5, 9]
K^{1+}	U[0, 70,000]
$MSYL_{1+}$	U[0.4, 0.8]
$MSYR_{1+}$	U[0.01, 0.1]
Maximum pregnancy rate, f_{max}	U[0.3, 0.6]
Additional variation (population estimates), CV_{add}, in 1968	U[0, 0.35]
School size variation, CV_{sch}, in 1968	$U[\max_t(CV^{obs}_{sch,t})/2,\ 1.5*\max_t(CV^{obs}_{sch,t})]$ (see [1])
1968 abundance, P_{1968}	$\ell n P_{1968} = N(\ell n 12{,}921; (0.075^2 + CV^2_{add} + CV^2_{sch}))$
Additional variation (calf counts), CV_{add2}	U[0.2, 0.6]
Calf survey bias, B_c	$\ell n B_c \sim U[-\infty, \infty]$ (see [2])

[2] This is the non-informative prior for a scale parameter. The values of CV^{obs}_{sch} are given in Table 3a.

Figure 3: Gray whale conditioning priors from IWC (2004).

Table 1 A summary of the trials used to evaluate measures to provide interim advice for fin, humpback and bowhead whales off West Greenland.

Key: N2008 or N2002 – fixed number of animals assumed in either 2008 or 2002; *d* – fixed level of assumed depletion in 1970; MSYR/MSYL – fixed values for maximum sustainable yield rate and level, respectively; Need – assumed level of need.

Fin and humpback trials

Trial	N2008	*d*	MSYR	MSYL	Need	Trial	N2008	*d*	MSYR	MSYL	Need
F01	2900	0.2	2%	60%	20	H01	2500	0.2	4%	60%	10
F02	2900	0.5	2%	60%	20	H02	2500	0.5	4%	60%	10
F03	2900	0.8	2%	60%	20	H03	2500	0.8	4%	60%	10
F04	2900	0.2	1%	60%	20	H04	2500	0.2	2%	60%	10
F05	2900	0.5	1%	60%	20	H05	2500	0.5	2%	60%	10
F06	2900	0.8	1%	60%	20	H06	2500	0.8	2%	60%	10
F07	1900	0.2	2%	60%	20	H07	1300	0.2	4%	60%	10
F08	1900	0.5	2%	60%	20	H08	1300	0.5	4%	60%	10
F09	1900	0.8	2%	60%	20	H09	1300	0.8	4%	60%	10
F10	1900	0.2	1%	60%	20	H10	1300	0.2	2%	60%	10
F11	1900	0.5	1%	60%	20	H11	1300	0.5	2%	60%	10
F12	1900	0.8	1%	60%	20	H12	1300	0.8	2%	60%	10
F13	800	0.2	2%	60%	20	H13	600	0.2	4%	60%	10
F14	800	0.5	2%	60%	20	H14	600	0.5	4%	60%	10
F15	800	0.8	2%	60%	20	H15	600	0.8	4%	60%	10
F16	800	0.2	1%	60%	20	H16	600	0.2	2%	60%	10
F17	800	0.5	1%	60%	20	H17	600	0.5	2%	60%	10
F18	800	0.8	1%	60%	20	H18	600	0.8	2%	60%	10
F22	2900	0.5	2%	50%	20	H22	2500	0.5	4%	50%	10
F23	2900	0.5	2%	80%	20	H23	2500	0.5	4%	80%	10
F24	1900	0.5	2%	80%	20	H24	1300	0.5	4%	80%	10
F25	2900	0.5	2%	60%	40	H25	2500	0.5	4%	60%	20
F26	1900	0.5	2%	60%	40	H26	1300	0.5	4%	60%	20

Figure 4: Trials used for providing interim advice for West Greenland humpback whales. From IWC (2009).

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