SC/63/Rep. 2

Report of the 2011 AWMP Workshop with a focus on eastern gray whales[1]

Contents

[1] NB: Due to EndNote problems the references are not yet complete – we are working on this and will put up a final version. In addition Annex G (Trial specifications is being updated and will be circulated separately).

1. INTRODUCTORY ITEMS

The Workshop was held at the Southwest Fisheries Science Center, La Jolla, California, USA, from 28 March – 1 April 2011. The list of participants is given as Annex A.

1.1 Convenor's opening remarks

Donovan welcomed the participants to the meeting and thanked Weller and the Southwest Fisheries Science Center for hosting the meeting and making the local arrangements.

He recalled that at its last Annual Meeting, the Scientific Committee had agreed that it would hold a workshop on matters related to the AWMP with an emphasis on:

(1) preparing to complete an *Implementation Review* of eastern gray whales at the 2011 Annual Meeting, with the focus on the proposed Makah hunt and the Pacific Coast Feeding Group (PCFG);
(2) evaluating progress on the sex ratio assessment method for common minke whales off West Greenland to ensure that a decision on its suitability or not can be taken at the 2011 Annual Meeting;
(3) making progress on developing SLAs for the Greenlandic hunts with a focus on fin whales and common minke whales.

Given the availability of personnel and the travel distances involved, it has been agreed that the primary focus of the workshop will be on Item (1) which will be discussed from 28 March – 31 March. Greenlandic participants will join the workshop via Skype (or similar) on 1 April to discuss progress with Items (2) and (3).

1.2 Election of Chair

Donovan was elected Chair.

1.3 Appointment of rapporteurs

Allison, Brandon, Butterworth and Punt acted as rapporteurs, with assistance from the Chair.

1.4 Adoption of Agenda

The adopted agenda is shown in Annex B.

1.5 Documents available

The new documents considered by the workshop were SC/M11/AWMP1-6 as shown in Annex C.

2. *IMPLEMENTATION REVIEW* OF EASTERN GRAY WHALES

2.1 Brief review of discussions at 2010 Annual Meeting

At the 2010 Annual meeting (IWC, 2011), it had been agreed that the information on stock structure and hunting presented, although some of it had not met the Data Availability Guideline requirements (IWC, 2004) for the 2010 review, warranted the development of trials as part of a new *Implementation Review* in 2011 to evaluate the performance of *SLA*s for hunting in the Pacific Northwest, with a primary focus on the PCFG (Pacific Coast Feeding Group, see Fig 1). It also agreed that the 2010 *Review* had shown that the population as a whole was in a healthy state but that over the next few years, further work should be undertaken to investigate the possibility of structure on the northern feeding grounds, especially in the region of the Chukotkan hunts.

In terms of general guidance for the 2011 *Implementation Review*, it had been agreed that:

(1) a future *SLA* for the hunt in the Pacific should include a feedback mechanism;
(2) the best estimate of current (1+) abundance for the PCFG was 200, based on the estimates in SC/62/BRG32.
(3) a 'low' value of 150 should also be considered in trials (this is below the CI in SC/62/BRG32, as it would be informative about the performance of a *SLA* and reflect uncertainties that may not have been captured in SC/62/BRG32);
(4) an important component would be determination of the relative availability of PCFG and non-PCFG whales to the hunters for the hunting period and area, taking into account interannual variability;
(5) the level of need (in the form of a need envelope) will be provided to the SWG by the USA along with any domestic regulations for the hunt;
(6) a range of MSYR values similar to that considered for the development of the *Gray Whale SLA* should be considered, taking into account the most recent assessment.

While all of these were considered during the present Workshop, in some cases different approaches were taken; in such cases the rationale is highlighted in the report.

It had also been agreed that the following would assist in the trial development process:

(1) collection/analysis of genetic data that would allow more robust comparison of such data from animals in the northern and southern feeding areas;

(2) collection/analysis of genetic data from Kodiak Island to California to further examine the probable range of the PCFG;

(3) collection/analysis of genetic data to compare further animals seen in only one year with animals that are frequently seen within the hunting area;

(4) collection/analysis of additional information (including telemetry data) on the relative temporal 'availability' of PCFG animals within the hunting area (e.g. by month);

(5) provision of an updated analysis of any additional data to obtain the most recent abundance estimate for the PCFG at the time of the 2011 *Implementation Review*.

Fig. 1. To come. A map showing place names and regions used throughout the report

2.2 New information available with a focus on the PCFG

2.2.1 Stock structure and movements

SC/M11/AWMP2 reported on large feeding aggregations of gray whales documented near Ugak Bay off the northeast coast of Kodiak Island, Alaska. In 2002, 2003 and 2005, vessel surveys were conducted off Ugak Bay to photo-identify gray whales and to determine their foraging habits and prey consumption. Eighty-four unique gray whales were identified from photographs taken near Ugak Bay from 2002 to 2005. Seventeen of these whales were matched to gray whales photographed in the Pacific Northwest from northern California to southeast Alaska, an area used by a portion of the eastern Pacific gray whale population referred to as the PCFG. The timing of these sightings indicated that some of the gray whales seen at Kodiak Island spend time in the summer months foraging south of Alaska and that the home range of gray whales in the PCFG can extend from northern California to Kodiak Island. Seven gray whales sighted around Kodiak Island in 2002-2003 returned and were identified there in 2005, which may indicate some level of site fidelity. It is believed that these movements are driven by food availability (and see Item 2.2.4).

In discussion, it was noted that the majority of the PCFG whales matched off Kodiak Island were known from photographs off northern Vancouver Island. In general, the probability of matching whales between different sub-areas of the PCFG range decreases with the distance between sub-areas (SC/62/BRG32). The inter-annual variability in abundance in the area also provides support for the idea of movement amongst areas within the PCFG (and perhaps beyond) driven by prey availability, as does the telemetry data discussed below.

Mate summarised the results on the tagging in March 2005 of 17 mothers with calves tagged in Laguna Ojo de Liebre[2] with Argos satellite-monitored radio tags ((Mate and Urbán-Ramirez, 2006). The tagged whales passed the Makah Usual and Accustomed Area (U&A)[3] in early- to mid-May. Two were north of Bering Straits by mid-June, moving through the spring ice lead. Three whales, which had spent 4+ months feeding in the Chukchi Sea, had moved south through Bering Straits within four days of each other in mid-November, suggesting an environmental cue for migration. One of those whales spent an extended period near Kodiak before heading farther south.

Mate also noted that in autumn 2009, 17 of 18 Argos-tagged whales in the PCFG area were known from the Cascadia Research Collective photo-identification catalogue (John Calambokidis, pers.comm.) to have PCFG histories for up to 20 years[4]. The movements in the Pacific Northwest were extensive for some whales. One of the known individuals moved to all of its previously known areas from over 15 years in less than one month of telemetry data. All six of the tagged whales migrating to Laguna Ojo de Liebre travelled at the same speed. The arrival times at this lagoon came in three non-over-lapping 'waves', which each involved three weeks in Baja California. The north-bound migrations were at similar speeds, with the exception of one whale which paused for a week at San Miguel Island. The return to the PCFG was as early as mid-February and mid-March. Returning PCFG-tagged whales returned to the north was as far as Icy Bay, Alaska. One adult male tagged off of Crescent City did not migrate south during the following winter-spring-summer.

In discussion, it was noted that there was high variability in the migratory behaviour of the tagged animals (e.g. some PCFG animals migrated past the Makah U&A without stopping, while one did not migrate south at all).

Weller and Mate summarised information on movements of western gray whales from the Okhotsk Sea to the eastern North Pacific based on evidence from satellite tagging, photo-identification and genetic studies. A

[2] formerly known as Scammon's Lagoon.

[3] i.e. the expected hunting area minus the Strait of Juan de Fuca (see Item 2.3.1)

[4] This catalogue of over 1,000 eastern gray whales identified in US and Canadian waters from California to Alaska focuses on the whales in the PCFG area during the summer, but also includes gray whales identified in the spring during their northward migration to the Bering and Chukchi Seas.

western gray whale was satellite tagged on 4 October 2010 off the east coast of Sakhalin Island, Russia[5]. It was tracked for over 4 months traveling from the Okhotsk Sea to the eastern North Pacific off the west coast of the USA.[6] For the first 68 days, the whale remained within the coastal waters of Sakhalin Island. Subsequent travel from the eastern coast of Kamchatka across the Bering Sea was directed, at high speed, and across deep water to the shallow Bering Sea shelf (without sea mounts as a means of navigation). The movements across the Gulf of Alaska were also across open water (this is quite different from the typical nearshore navigation of migratory eastern gray whales) to a location some 25 km off the northwest Washington coast (56km south of the Makah U&A). Subsequent locations were 20km offshore during south-bound travel to the central Oregon coast; transmissions stopped when the animal was off Siletz Bay on 5 February 2011.

The tagged whale, a 14-year old male nicknamed 'Flex', was first photo-identified on the Sakhalin feeding ground as a calf in 1997; it has subsequently been observed in multiple years off Sakhalin during the summer feeding season. As part of a broader effort to understand his movements, his photographs were compared to the Cascadia Research Collective catalogue. This resulted in a confirmed match between Sakhalin Island and Vancouver Island. Flex was sighted April 2008 in the Barkley Sound area off the west side of Vancouver Island and then during July of 2008 off Sakhalin Island.

The Workshop was pleased to hear that a comprehensive comparison of the western (Russia-U.S. program) and eastern gray whale photo catalogues is now underway to identify additional matches and the results of this comparison will be presented at the 2011 Annual Meeting. The Workshop noted that there were two western gray whale catalogues and that a comparative study of these carried out under the auspices of the IUCN Western Gray Whale Advisory Panel[7] had found that whilst the catalogues were broadly the same, there were some individuals in the IBM catalogue that were not found in the Russia-US program (and vice-versa) and it **encouraged** inclusion of these individuals in the comparison with the eastern catalogue.

In addition to the above, Lang *et al*. (2010) found that two individuals from the western population, sampled off Sakhalin in 1998 and 2004, matched the microsatellite genotypes, mtDNA haplotypes, and sexes of two whales sampled off southern California in 1995. The Workshop was pleased to hear that a genetic comparison of the entire Russia-U.S. western gray whale genetic data set with the most recent data set for eastern gray whales is now underway to identify additional inter-area matches. Results of this work will be presented at the 2011 Annual Meeting.

The Workshop **agreed** that the question of the relationship between western gray whales and the PCFG (specifically the Makah U&A) warrants further consideration once the results of the genetic and photo-identification comparisons are discussed at the 2011 Annual Meeting (and see Item 2.3.2). It also **recommended** further tagging of both eastern (particularly PCFG) and western gray whales following appropriate protocols (e.g. see Weller et al. 2010), to further elaborate movements of these animals relative to existing and proposed hunting areas.

SC/M11/AWMP4 presented data on the stock structure of gray whales using feeding grounds in the eastern North Pacific, with a special focus on evaluating differences between the PCFG and whales feeding north of the Aleutians. MtDNA control region sequences and microsatellite genotypes (8 loci) were generated for samples collected from individual gray whales within the southern (n=100) and northern (n=106) feeding areas. Significant mtDNA differentiation was found when the subset of samples representing individuals sighted over two or more years within the seasonal range of the PCFG (northern California to southern Alaska between 1 June and 30 November) (n=71) were compared to the combined set of samples collected from the northern feeding area(s) (F_{ST}=0.01, p=0.005; Fisher's exact test, p=0.008) as well as when the PCFG samples were compared to only those samples which were collected off Chukotka, Russia (n=71, F_{ST}=0.01, p=0.012; Fisher's exact test, p=0.030). No significant differences were found for any of the comparisons utilizing microsatellites. While the number of mtDNA haplotypes found in the PCFG stratum (n=23) was slightly lower than that found in the northern strata (n=27 in Chukotka, n=32 for all samples collected north of the Aleutians), measures of both mtDNA haplotype and microsatellite diversity were similar across all strata compared. Although the lack of nuclear differentiation indicates that gray whales from different feeding regions may be interbreeding, the significant differences in mtDNA haplotype frequencies suggest that use of at least some feeding areas is influenced by matrilineal fidelity and that the PCFG whales show some demographic independence from whales feeding north of the Aleutians.

The Workshop thanked Lang for undertaking this work that also responded to recommendations presented at the 2010 Annual Meeting (see Item 2.1).

[5] http://www.iwcoffice.org/sci_com/pressreleaseWGW.htm
[6] http://mmi.oregonstate.edu/Sakhalin2010
[7] http://www.iucn.org/wgwap/wgwap/task_forces/photo_id_task_force/

In discussion, it was noted that the high number and diversity of mtDNA haplotypes are consistent with both internal recruitment and external immigration from the broader population. However, the differences in mtDNA haplotype frequencies are consistent with internal recruitment having been greater than external immigration. It was noted that quantitative estimates of external recruitment rates are not possible at present with the available genetics data. The Workshop **encourages** data collection and analysis along these lines (e.g. relatedness analyses) in the future.

SC/M11/AWMP5 summarised research conducted by NOAA Fisheries' National Marine Mammal Lab and the Makah Tribe within the Makah U&A during summer and autumn 1993-2009. This study area constitutes a small portion of the PCFG range. The number of gray whale observations per hour of research effort in the Makah U&A was variable by year and month. Site fidelity of individuals was assessed through examination of minimum residency time and annual capture histories from photographs. On average, individual whales utilizing the Makah U&A are observed for a small portion of the June-November feeding season. Most gray whales were seen in only one year; individuals sighted in multiple years averaged periods of 2.2 years between sightings in the study area. A discovery curve analysis did not suggest that gray whales exclusively use the Makah U&A during the summer and autumn feeding season. Together, these results suggest that most gray whales sighted in the U&A survey area do not have strong fidelity to this area. This conclusion supports the conclusion of SC/62/BRG32 that most gray whales seen in the Makah U&A have fidelity to a region that is larger than U&A.

2.2.2 Abundance and trends

At the 2010 Annual Meeting, the focus was on examination of the southbound census data series for the total eastern gray whale population (Laake et al., 2009) and the mark-recapture abundance estimates for the PCFG area (SC/62/BRG32). Those estimates are discussed under Item 2.3. The discussion of new information focussed on the consideration of calf counts since at the 2010 Annual Meeting, the AWMP SWG had recommended that calf count data continue to be collected, and reviewed during future *Implementation Reviews*. The Workshop thanked the authors for the new information given in SC/M11/AWMP5 that is described below.

SC/M11/AWMP3 presented updated calf counts from shore-based surveys of northbound eastern North Pacific gray whales for 2001-2010. Estimates of the total number of northbound calves were 256, 842, 774, 1528, 945, 1020, 404, 553, 312 and 254 for the 10 consecutive surveys. Over this period, annual estimates averaged 4.1% of the total abundance as estimated by Laake *et al.* (2009). The estimates from 2001-2010 represent the most recent of a 17-year time series of surveys from this site and include both the highest (1528 calves in 2004) and the lowest (254 calves in 2010) estimates in this series. Average ice cover for the Bering Sea explains roughly 70% of the interannual variability in estimates of northbound calves the following spring

The Workshop noted that the 2010 estimate of calf production (254 calves) was the lowest in the series. Discussion of whether these data should be used in conditioning is found under Item 2.3.7.

2.2.3 Catch data

The Workshop reviewed the current catch series (IWC, 2011 SC report Annex E Appendix 3). The commercial catches taken between 1846-1909 have been updated since the 2004 *Implementation* (IWC, 2005) following Reeves and Smith (2010) and Reeves *et al*. (2010), and applying an estimated loss rate factor.

The recent (1930-2009) catch series (i.e. that used in the *Implementation Review*) is similar to that used in the 2004 *Implementation* except that the new series includes an estimate of the gray whale catches taken off California from 1932-37 by the floating factory *California* (~326 whales) and of USSR aboriginal catches between 1944-47 (~72 whales). Fig 1 shows the approximate positions of catches since 1930 (the year in which the gray whale operating model commences).

The Workshop confirmed that the new catch series should be used in this *Implementation Review* (see Table 1)

Annex D summarises information on recent bycatches and ship strikes. Bycatches were not included in the 2004 *Implementation* as they were a very small percentage of the total eastern gray whale population, however, the Workshop **agreed** that they should be included in future, especially given the size of the PCFG. Table 2 summarises the available information.

2.2.4 Feeding ecology

SC/M11/AWMP2 reported that faecal samples collected near feeding gray whales off Kodiak Island, Alaska contained a variety of invertebrate species but were dominated by the presence of cumaceans, likely of the genus *Diastylopsis*. The whales were foraging in waters averaging 95m deep (range 85-104 m), which are thought to be some of the deepest foraging locations known for gray whales south of the Bering Sea. As is also true in the southern regions of the PCFG (*e.g.* British Columbia, Washington, Oregon), whales foraging south of the Aleutian Islands appear to opportunistically feed on a wide variety of prey as compared to the amphipod dominated diet exhibited by whales feeding in Arctic waters.

Table 1

Historical catches of eastern north Pacific gray whales for use in the *Implementation* trials.

Year	South			PCFG Jun-Nov			PCFG Dec-May			North			Total		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
1930	0	0	0	0	0	0	0	0	0	23	24	47	23	24	47
1931	0	0	0	0	0	0	0	0	0	5	5	10	5	5	10
1932	5	5	10	0	0	0	0	0	0	5	5	10	10	10	20
1933	30	30	60	0	0	0	0	0	0	8	7	15	38	37	75
1934	30	30	60	0	0	0	0	0	0	36	30	66	66	60	126
1935	55	55	110	0	0	0	0	0	0	16	28	44	71	83	154
1936	43	43	86	0	0	0	0	0	0	50	62	112	93	105	198
1937	0	0	0	0	0	0	0	0	0	12	12	24	12	12	24
1938	0	0	0	0	0	0	0	0	0	32	32	64	32	32	64
1939	0	0	0	0	0	0	0	0	0	19	20	39	19	20	39
1940	0	0	0	0	0	0	0	0	0	56	69	125	56	69	125
1941	0	0	0	0	0	0	0	0	0	38	39	77	38	39	77
1942	0	0	0	0	0	0	0	0	0	60	61	121	60	61	121
1943	0	0	0	0	0	0	0	0	0	59	60	119	59	60	119
1944	0	0	0	0	0	0	0	0	0	3	3	6	3	3	6
1945	0	0	0	0	0	0	0	0	0	25	33	58	25	33	58
1946	0	0	0	0	0	0	0	0	0	14	16	30	14	16	30
1947	0	0	0	0	0	0	0	0	0	11	20	31	11	20	31
1948	0	0	0	0	0	0	0	0	0	7	12	19	7	12	19
1949	0	0	0	0	0	0	0	0	0	10	16	26	10	16	26
1950	0	0	0	0	0	0	0	0	0	4	7	11	4	7	11
1951	0	0	0	0	0	0	1	0	1	5	8	13	6	8	14
1952	0	0	0	0	0	0	0	0	0	17	27	44	17	27	44
1953	0	0	0	0	0	0	6	4	10	15	23	38	21	27	48
1954	0	0	0	0	0	0	0	0	0	14	25	39	14	25	39
1955	0	0	0	0	0	0	0	0	0	22	37	59	22	37	59
1956	0	0	0	0	0	0	0	0	0	45	77	122	45	77	122
1957	0	0	0	0	0	0	0	0	0	36	60	96	36	60	96
1958	0	0	0	0	0	0	0	0	0	55	93	148	55	93	148
1959	1	1	2	0	0	0	0	0	0	73	121	194	74	122	196
1960	0	0	0	0	0	0	0	0	0	58	98	156	58	98	156
1961	0	0	0	0	0	0	0	0	0	77	131	208	77	131	208
1962	4	0	4	0	0	0	0	0	0	55	92	147	59	92	151
1963	0	0	0	0	0	0	0	0	0	68	112	180	68	112	180
1964	15	5	20	0	0	0	0	0	0	75	124	199	90	129	219
1965	0	0	0	0	0	0	0	0	0	71	110	181	71	110	181
1966	15	11	26	0	0	0	0	0	0	80	114	194	95	125	220
1967	52	73	125	0	0	0	0	0	0	109	140	249	161	213	374
1968	41	25	66	0	0	0	0	0	0	48	87	135	89	112	201
1969	39	35	74	0	0	0	0	0	0	50	90	140	89	125	214
1970	0	0	0	0	0	0	0	0	0	71	80	151	71	80	151
1971	0	0	0	0	0	0	0	0	0	57	96	153	57	96	153
1972	0	0	0	0	0	0	0	0	0	61	121	182	61	121	182
1973	0	0	0	0	0	0	0	0	0	97	81	178	97	81	178
1974	0	0	0	0	0	0	0	0	0	94	90	184	94	90	184
1975	0	0	0	0	0	0	0	0	0	58	113	171	58	113	171
1976	0	0	0	0	0	0	0	0	0	69	96	165	69	96	165
1977	0	0	0	0	0	0	0	0	0	87	100	187	87	100	187
1978	0	0	0	0	0	0	0	0	0	94	90	184	94	90	184
1979	0	0	0	0	0	0	0	0	0	58	125	183	58	125	183
1980	0	0	0	0	0	0	0	0	0	53	129	182	53	129	182
1981	0	0	0	0	0	0	0	0	0	36	100	136	36	100	136
1982	0	0	0	0	0	0	0	0	0	57	111	168	57	111	168
1983	0	0	0	0	0	0	0	0	0	46	125	171	46	125	171
1984	0	0	0	0	0	0	0	0	0	59	110	169	59	110	169
1985	0	0	0	0	0	0	0	0	0	54	116	170	54	116	170
1986	0	0	0	0	0	0	0	0	0	46	125	171	46	125	171
1987	0	0	0	0	0	0	0	0	0	48	111	159	48	111	159
1988	0	0	0	0	0	0	0	0	0	43	108	151	43	108	151
1989	0	0	0	0	0	0	0	0	0	61	119	180	61	119	180
1990	0	0	0	0	0	0	0	0	0	67	95	162	67	95	162
1991	0	0	0	0	0	0	0	0	0	67	102	169	67	102	169
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year	South			PCFG Jun-Nov			PCFG Dec-May			North			Total		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	21	23	44	21	23	44
1995	0	0	0	0	0	0	0	0	0	48	44	92	48	44	92
1996	0	0	0	0	0	0	0	0	0	18	25	43	18	25	43
1997	0	0	0	0	0	0	0	0	0	48	31	79	48	31	79
1998	0	0	0	0	0	0	0	0	0	64	61	125	64	61	125
1999	0	0	0	0	0	0	0	1	1	69	54	123	69	55	124
2000	0	0	0	0	0	0	0	0	0	63	52	115	63	52	115
2001	0	0	0	0	0	0	0	0	0	62	50	112	62	50	112
2002	0	0	0	0	0	0	0	0	0	80	51	131	80	51	131
2003	0	0	0	0	0	0	0	0	0	71	57	128	71	57	128
2004	0	0	0	0	0	0	0	0	0	43	68	111	43	68	111
2005	0	0	0	0	0	0	0	0	0	49	75	124	49	75	124
2006	0	0	0	0	0	0	0	0	0	57	77	134	57	77	134
2007	0	0	0	0	1	1	0	0	0	50	81	131	50	82	132
2008	0	0	0	0	0	0	0	0	0	64	66	130	64	66	130
2009	0	0	0	0	0	0	0	0	0	59	57	116	59	57	116
Total	**330**	**313**	**643**	**0**	**1**	**1**	**7**	**5**	**12**	**3,715**	**5,345**	**9,060**	**4,052**	**5,664**	**9,716**

Table 2
Bycatch/ship strike summary (for explanation and details see Annex D)

Region	Average Annual Kill
North	N/A
PCFG: Dec-May	2
PCFG: June-Nov	1.4
South: Dec-May	3.4

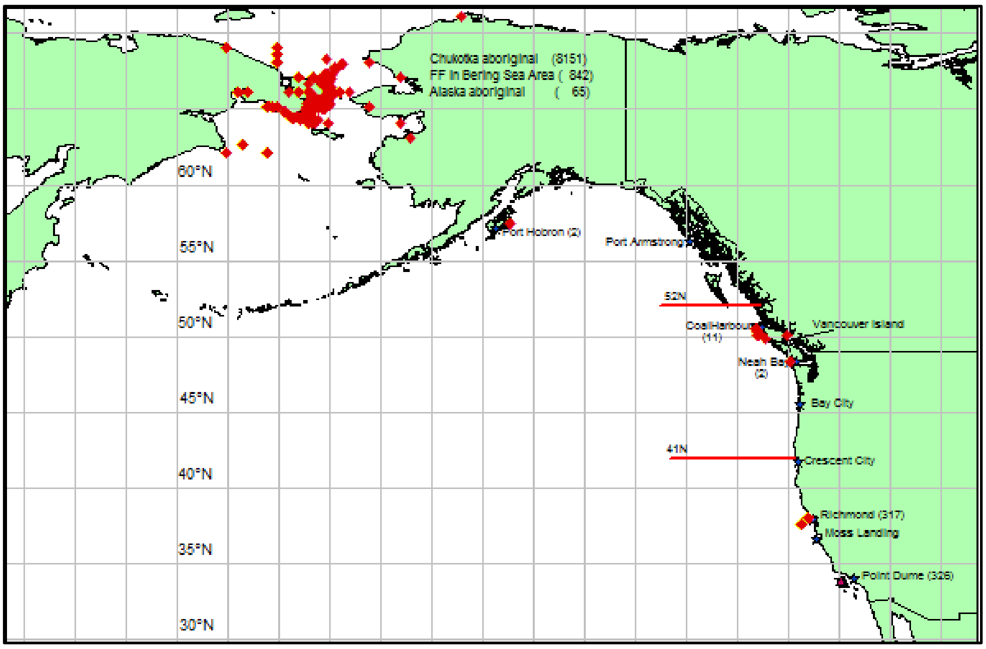

Fig. 2. Distributions of gray whale direct catches post-1930. The symbols show the approximate areas and the catch sizes are shown in parentheses (Cherry, I presume these include struck-and-lost animals).

2.3 Development of trial structure

SC/M11/AWMP1 outlined an age-, sex- and stock-structured operating model which could form the basis for the operating models used for the *Implementation Review*. The operating model was parameterised to represent the 'north' and 'PCFG' stocks of eastern gray whales. The likelihood used to update the prior distributions is based upon estimates of absolute (1+) abundance from surveys at Granite Canyon, California (Laake et al., 2009) and photographic identification data for Northern California to Southeast Alaska (SC/62/BRG32). SC/M11/AWMP1 identified a potential set of *Implementation Trials* intended to capture the key uncertainties associated with the likely performance of proposed *Strike Limit Algorithms* for the hunts off Russia ('north' area) and in the PCFG area.

Fig. 3 outlines the basic structure of the operating model and how the strike limits are implemented for the two hunts (northern and PCFG).

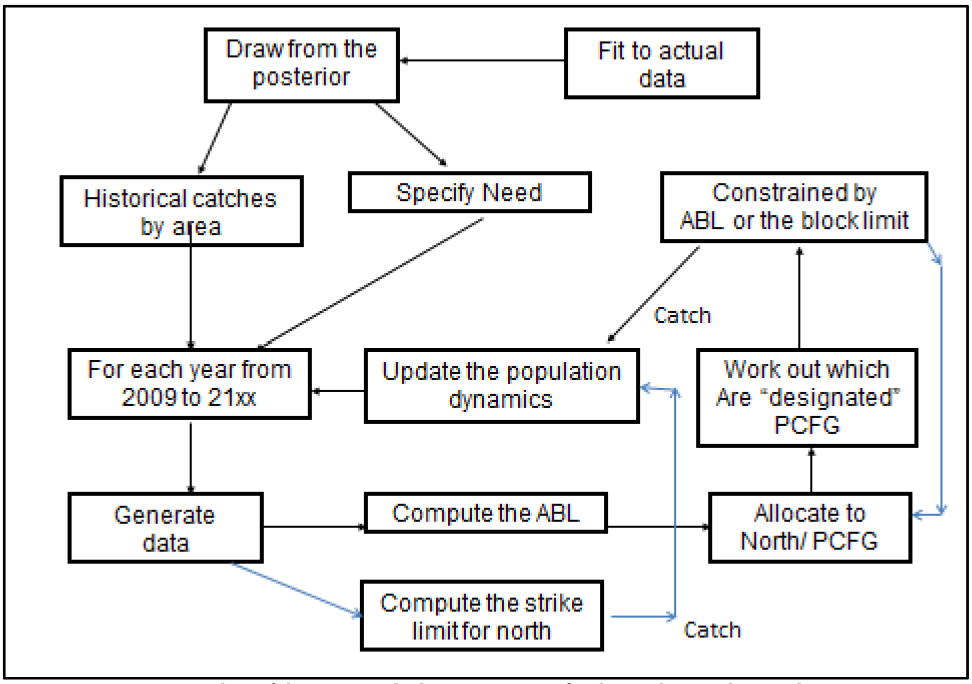

Fig. 3. Outline of the steps used when testing SLA for the northern and PCFG hunts

2.3.1 Proposed Makah management regimes/s and associated issues

SC/M11/AWMP6 presented the Makah Tribe's proposed whale hunt, in order to inform the set of implementation trials. A detailed description of the Makah Tribe's proposed hunt is provided in Annex D. In summary, the Makah Tribe's need envelope is 35 strikes per five-year block quota (seven strikes, three struck and lost, or five landed annually, or 20 landed per five year block) throughout the 100-year period. The hunt area is restricted to an area within the Makah's adjudicated usual and accustomed fishing and hunting grounds (U&A; Fig. 1) in Northwest Washington. The U&A includes both the Strait of Juan de Fuca and the Pacific Ocean but the hunt will be prohibited in the Strait of Juan de Fuca due to the large portion of PCFG whales photographed in that area. Likewise, the hunt will be limited to 1 December - 31 May to target migrating ('north') whales. Despite time and area restrictions, it is possible that the hunt may still accidentally take PCFG whales. Therefore, to provide additional protection to PCFG whales, the Makah Tribe proposes to use an Allowable Bycatch Limit (ABL) of PCFG whales. The ABL uses the equation (rounded down to the nearest whole number) for potential biological removal (PBR – (Wade, 1998)) based on the minimum estimate of PCFG gray whales between Oregon and Southern Vancouver Island. Struck and lost whales between 1 December and 30 April will not count against the ABL (i.e. these are assumed to be 'northern' whales). However, all struck and lost whales during May will be assumed to be from the PCFG. Photographs of each landed whale will be compared to a catalogue of known PCFG whales. Landed whales who match the catalogue of known PCFG whales will count against the ABL. When the number of PCFG strikes (lost in May or landed) is equal to the ABL, the hunt will be concluded for the year.

The Workshop was informed that as part of the U.S. domestic regulations, a harvested whale would be assumed to have been taken to from the PCFG (and count toward the ABL) if it was matched with the National Marine Mammal Laboratory catalogue **(how does this relate to the Cascadia catalogue?)** for whales photographed south of Alaska between 1 June and 30 November. The Workshop noted that this could lead to a false positive rate (i.e. 'north' whales being considered to be PCFG whales) and that the rate of false positives would increase over time because 'north' whales ('stragglers' in the terminology of SC/62/BRG32) would continue to be added to the catalogue if they were ever photographed south of Alaska between 1 June and 30 November.

The 1 June – 30 November period was chosen for the PCFG definition because few if any whales are migrating through the 41-52°N region. SC/63/BRG32 showed that whales seen after 1 June were more likely to be seen multiple times, in multiple years and multiple areas than whales seen before 1 June. The Table 3 shows a similar pattern in classifying whales based on the month of their first sighting and whether they were seen again in a future year. A chi-square test rejects (P=2E-13) the null hypothesis of a constant probability across all months but not for the months June-October (P=0.08) where the largest residuals were for June which had the highest percentage resighted.

Table3

Whales seen in the PCFG (41-52°N) from March-October 1998-2008 classified by the month of their first sighting and whether they were sighted again in a future year. The remaining months each had six or fewer sightings and were excluded.

	Resighted in a future year		
Month of first sighting	No	Yes	Total
March	29	6	35
April	43	3	46
May	90	18	108
June	57	78	135
July	90	72	162
August	60	42	102
September	29	22	51
October	24	22	46
Total	422	263	685

The Workshop **agreed** that, for most of the trials, the ABL would be updated annually based on the estimate of abundance obtained three years before the year for which an ABL is calculated. This time-lag reflects the time it takes to process and analyse the photo-ID data. The Workshop also **agreed** that the U.S. domestic phase-out rule should be implemented in the trials; this is equivalent to setting the ABL to zero if no abundance estimate has become available for eight years. The Workshop was advised that the PBR (the basis for the ABL) is set at zero if no abundance estimates have become available for eight years (note that this is stricter than the proposed IWC phase-out rule which begins to take effect after ten years and does not lead to a complete closure until 15 years (ref)).

Thus, the overall application of the Makah management regime is as follows:

(1) Compute the ABL
(2) Strike an animal
(3) If the animal is struck-and lost in December-April:
  a. If the total number of struck and lost animals is 3, stop the hunt.
  b. Go to step (2).
(4) If the animal is struck-and lost in May:
  a. If the total number of struck and lost animals is 3, stop the hunt.
  b. Add one to the number of whales counted towards the ABL
  c. Check whether the ABL is reached; if so stop
  d. Go to step (2).
(5) If the animal is landed and is matched to the catalogue:
  a. Add one to the number of whales counted towards the ABL
  b. Check whether the ABL is reached; if so stop
  c. Check whether the total number of landed whales equals 5; if so stop
  d. Check whether the total number of struck animals equals the need of 7; if so stop.
  e. Check whether the number of landed whales for the current five-year block equals 20; if so stop
  f. Go to step (2).
(6) If the animal is landed and does not match any whale in the catalogue:
  a. Check whether the total number of landed whales equals 5; if so stop
  b. Check whether the total number of struck animals equals the need of 7; if so stop.
  c. Check whether the number of landed whales for the current five-year block equals 20; if so stop
  d. Go to step (2).

2.3.2 Stock structure hypothesis

The Workshop **agreed** that the trials would consider three geographic regions. The 'north' area is north of 52^0N (roughly northern Vancouver Island; Fig. 1), the PCFG area is between 41°N and 52°N, and the 'south' area is south of 41°N. It **agreed** that the trials would consider two stocks ('PCFG' and 'north'). The Workshop noted that some PCFG whales would be found outside of the PCFG area at various times during the year. However, this is not problematic since the historical catches north of 52°N occurred well north of 52°N (Fig. 3) and future catches will either occur in the Bering Sea or in the Makah U&A.

The boundaries for the PCFG area were chosen: (1) because samples used for the genetic analysis were taken from whales across this range; and (2) SC/62/BRG32 showed movements of whales seen during the spring throughout 41-52^{0}N as well. It was agreed that the whales seen within 41-52°N during 1 June – 30 November will be used to estimate the abundance for the region. However, the proposed management regime with respect to PBR/ABL is predicated on the estimated abundance for a smaller region (Oregon to Southern Vancouver Island).

In relation to western gray whales, the Workshop **agreed** that, in the light of ongoing analyses and the conditions of the DAA, the current *Implementation Review* would not consider the possibility and implications of catches of western gray whales during harvest in the north or the PCFG area (see Item 2.2.1). However, it **recommended** that the results of the comparisons of existing western gray whale catalogues (both genetic and photographic) to eastern gray whale catalogues collected off the west coast of North America be presented at the 2011 Annual Meeting, and that the available data be examined to determine the relative probability of unintentionally harvesting a western gray whale. The Workshop noted that a new *Implementation Review* would likely be triggered if evidence suggested that WNP gray whales were exposed to either hunt (Russian or Makah).

2.3.3 *Abundance estimates (incl. frequency) and relationship to stock structure hypotheses*
The Workshop **agreed** that abundance estimates would be generated for the southbound migration using the same approach as the 2004 *Implementation*, and that it would be assumed that these estimates include all whales (PCFG and north). It also **agreed** that for most of the trials, abundance estimates would be generated annually for the PCFG area. The abundance estimates for the PCFG area would be based on either the 41°-52°N region (1 June- 30 November) or the Oregon – Southern Vancouver Island area (for ABL calculations).

It was noted that it would be expected that the CVs for the abundance estimates would decline over time as an increased amount of data would allow improved estimation of time-invariant parameters such as the annual survival rate. However, the Workshop **agreed** that the rate of change in the CV would be hard to quantify and moreover, the extent of additional variance was sufficiently high that this factor would be inconsequential. Finally, the Workshop noted that abundance estimates are correlated temporally given the analysis methods on which they are based and **agreed** that the abundance estimates for the trials would include this correlation.

2.3.4 Mixing
Mixing in the context of these trials relates not just to mixing of stocks in the three areas, but in particular to the relative probability of whaling in the Makah U&A taking a PCFG whale given the number of PCFG and north whales. Given available data, the Workshop **agreed** that the relative frequency of PCFG whales during the proposed whaling period (December & January – May) could be estimated as the fraction of PCFG whales to total whales in photographs during March - May (Annex E).

There are many uncertainties associated with the estimate that 20.3% of the whales in the U&A are PCFG whales, especially if this estimate is to be used as an estimate of the relatively probability of future harvesting (rather than photographing) of PCFG vs north whales. The Workshop therefore **agreed** that sensitivity tests would need to be conducted to examine alternative values (see Item 2.3.8)

The Workshop noted that some of the uncertainty associated with the estimate of the relative vulnerability of the PCFG vs north whales in the Makah U&A during the proposed harvesting period could be reduced given data from the hunt. The AWMP SWG should monitor the split of the catch between PCFG and north whales if hunting occurs and will need to conduct an *Implementation Review* if the observed value is outside of the tested range. The Workshop **recommended** that the photographic data for 2009 should be analysed to refine the estimate in Annex D and estimate the extent of inter-annual variation. It was **agreed** that if the estimate can be updated, it will be reviewed by the Steering Group (see Item 2.5) and the trial specifications updated.

2.3.5 Biological parameters, including MSYR
The Workshop reviewed the prior distributions for the biological parameters given in SC/M11/AWMP1; those were largely based on decisions made during the 2004 *Implementation*. It revised (increased) the lower bound for *K* for the north stock so that the upper bound of the prior for 1968 abundance of this stock did not exceed the lower bound of the prior for *K*. It replaced the U[5,9] prior for the age-at-maturity in SC/M1/AWMP1 by U[6,10] to reflect recent information on actual ages-to-maturity for western gray whales (Bradford et al., 2010). The Workshop **agreed** that the values for the age-at-maturity, maximum fecundity and non-calf mortality would

be the same (i.e. perfectly correlated) for the PCFG and north stocks. The Workshop noted that the upper bound of the prior for the 1968 abundance of the PCFG stock was lower than the lower bound of the prior for *K* for this stock. However, it did not change either bound because until the trials are conditioned, it is not clear which is the most appropriate to change.

In relation to $MSYR_{1+}$, the Workshop noted that the previous trials had been based on a most likely estimate of 3.5%, with a range of 1.5 – 5.5% explored in the *Evaluation Trials* and that these values were based on the results of the then most recent assessment. The Workshop **agreed** to change the most likely value for $MSYR_{1+}$ for the north stock to 4.5% as this is the posterior median from the most recent assessment of this stock (Punt and Wade, in press; this assessment used the revised southbound abundance estimates from Laake *et al*. (2009) and explicitly modelled the 1999-2000 mortality event). The Workshop also **agreed** that the *Evaluation Trials* would consider values for $MSYR_{1+}$ for north stock of 2% and 6%, which reflect rounding of the 90% posterior intervals from the Punt and Wade (in press) assessment of 2.2% - 6.4%.

In common with the trials on which the 2004 *Implementation* was based, SC/M1/AWMP1 had assumed an increasing survey bias over 1967-2002(?07). The Workshop **agreed** to retain this specification given the focus on the PCFG stock, but highlighted that this matter should be addressed at the next *Implementation Review*.

In relation to the PCFG stock, the Workshop recognised that the available time-series of abundance estimates is insufficient to estimate MSYR. It **agreed** to consider two scenarios: (a) $MSYR_{1+}$ for the PCFG stock is the same as that for the north stock and there is no immigration (this is unlikely given the data but provides a conservative lower bound), and (b) a lower value of $MSYR_{1+}$ but with some immigration.

With respect to the latter, Annex F provides estimates of the number of new recruits to the PCFG stock. Interpretation of these estimates is difficult because new recruits could reflect ‘discovery’ of PCFG whales into the catalogue, immigration and/or PCFG births. Based upon Annex F, the Workshop **agreed** that a conservative estimate of the annual number of PCFG calves is 6, which, when subtracted from the recruitment in the most recent years (which should not reflect the discovery process) leads to an estimate of the annual number of immigrants into the PCFG stock of 4. Given this, the Workshop **agreed** to conduct trials with 2, 4 and 6 immigrants each year.

The **agreed** priors are shown in Table 3.

Table 3

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[6, 12]
K_{1+}^{N}	U[16,000, 70,000]
K_{1+}^{PCFG}	U[100, 500]
Maximum pregnancy rate, f_{max}	U[0.3, 0.6]
Additional variation (population estimates), CV_{add}, in 1968	U[0, 0.35]
1968 abundance, P_{1968}^{N}	U[8,000, 16,000]
1968 abundance, P_{1968}^{PCFG}	U[50, 300]
Catastrophic mortality	U[0.2,1.0]

2.3.6 Other

Part of the Makah harvest regime involves comparing photographs of landed whales with the appropriate catalogue. This can lead to either:

(1) ‘false negatives’ with probability p_1 i.e. a PCFG whale is not matched with the catalogue; and/or
(2) ‘false positives’ with probability p_2 i.e. a north whale is matched with the catalogue.

The Workshop **agreed** the probability p_1 was near zero because nearly all PCFG whales (and many 'stragglers') are in the catalogue. One of the robustness tests considers the possibility that the abundance estimates for the PCFG area are negatively biased by some 50% so p_1=0.5 given there are several sources of potential negative bias (Annex E); the specific choice of 50% is arbitrary. The probability of a false positive can be estimated from the photo-ID data for 1998-2005. Of 444 animals sighted between 1 June and 30 November, 206 were never resighted. Given that the number of north whales is approximately 20,000, this leads to a value for p_2 of 0.01. It was agreed that robustness trials should be developed to consider a scenario in which p_2 increases from 0.01 in 2010 to 0.05 in 2110 to reflect the continual addition of photographs (and hence photographs of non-PCFG whales) to the catalogue.

The Makah harvest regime treats struck-and-lost whales differently from landed whales (see Item 2.3.1). It is therefore necessary for the operating model to 'know' whether a whale is struck-and-lost or landed. This is achieved by conducting a Bernoulli trial with probability η for each struck whale to determine whether it is struck-and-lost or landed. There are few data directly pertaining to the value for η. The Workshop considered information for the Russian hunt, the few strikes in the PCFG and the hunts for bowhead whales in Alaska. Given the differences amongst hunts, it **agreed** that at present, the best direct information was that of two animals struck in 1999 of which one was lost; i.e. η is 0.5. It also **agreed** that the *Evaluation Trials* should consider sensitivity to this value (0 and 0.75).

In relation to future incidental catches (see Item 2.2.3), the Workshop **agreed** the that incidental catch in each of the four spatio-temporal strata ('north', 'PCFG June-November', 'PCFG December – May', 'south') in future year *y* would be computed multiplying the ratio of the average annual number of incidental catches over 200x-y (Table 3) to the average population size over that period by the population in year *y*.

For trials in which abundance estimates for the PCFG area are only available every fifth year (because photo-ID estimates only become available every fifth year), the value p_1 is defined as the ratio of the number of 5+ animals to 1+ animals.

2.3.7 Conditioning

The trials will be conditioned using the estimates of 1+ abundance from the southbound counts (Laake *et al.* 2009) and those for the PCFG area from the open model for the area between 41^0N and 52^0N (see Annex F). The Workshop considered two additional potential data sources: adult survivorship and calf counts. The estimate of survival from the photo-ID analysis could potentially be used to update the prior for adult survival but as it includes both mortality and emigration, the Workshop **agreed** that it would not provide sufficient information to warrant use for the current trials other than in a qualitative sense. There are three options with respect to the calf count data: (1) not to use the data; (2) use the estimates as absolute numbers of calves; or (3) use the estimates of the trends in calf numbers. Options (2) and (3) would require estimation of a third additional variance parameter. Given that the operating model is deterministic, the output would not be expected to match the calf counts well (high additional variance). The Workshop therefore **agreed** that the average number of calves from the counts should be compared with the average number of calves in the operating model over the same number of years and not included formally when conditioning the trials.

The PCFG area is quite small compared to the total number of ENP gray whales, many aspects of evaluating trial performance would relate to small quantities and rare events. While a larger Monte Carlo sample derived from the conditioning (currently 100 simulations per trials) would be preferable, increasing the number of simulations requires prohibitive amounts of computing time. However, Givens suggested that a smoothed bootstrap approach might enable the Working Group to greatly enrich the conditioning set with very little additional computing time (the cpu time would be many orders of magnitude less than would be required simply to increase the number of simulations). The Workshop Group recognised the potential advantages of such an approach but noted that any smoothed bootstrap approach would likely be quite *ad hoc* and that the effect of generating additional sets of parameters using a smoothed bootstrap on the results was unknown. It therefore **agreed** that Givens would investigate the method initially on only a few trials and report back to the Steering Group (see Item 2.5). If the results from the smoothed bootstrap and the ordinary conditioning differed importantly, then a correspondingly large conditioning set obtained from the standard approach would need to be generated in these test cases to determine whether the smoothed bootstrap was offering improved data for analysis or if the difference was attributable to undesirable effects of the approximations employed by the smoothed bootstrap approach. Subsequently, the Steering Group would consider whether the smoothed bootstrap extension to the current approach is worthwhile.

2.3.8 Proposed final trial structure and specifications

The Workshop noted that unlike previous *Implementations*, that for the PCFG was for a 'small' population (previously referred to as a 'Type 3 Fishery'). Punt and Breiwick (2002) had examined the performance of *SLA*s for Type 3 Fisheries using a stochastic model with both environmental and demographic variability. The Workshop noted that demographic uncertainty would be largely inconsequential even for a population of 200. However, it **agreed** that the lowest number of mature females during the 100-year projection period should be included in the standard set of summary statistics so that an evaluation of the potential for depensation could be made (see item 2.4). Moreover, the set of trials (Tables 4 and 5) includes cases in which there is environmental variability in the form of mortality events.

Based on the above considerations, the Workshop **agreed** to the following specifications for the base-case trials:

(1) Two stocks (PCFG, north)
(2) Four spatio-temporal strata (south, north, PCFG [Dec-May], PCFG [June-Nov])
(3) Split of catch to stock
    a. South: 1% PCFG; 99% north
    b. PCFG [Dec-May]: 20.3% PCFG; 79.7% north
    c. PCFG [Jun-Nov]; 100% PCFG
    d. North: 0% PCFG
(4) The split of the catch to stock is deterministic in the past but stochastic in the future.
(5) The probability of a PCFG whale being classified as north is 0.
(6) The probability of a north whale being classified as PCFG is 0.01.
(7) 50% of struck are lost.
(8) Selectivity to be 1+.
(9) All catches occur prior to May[8].
(10) $MSYL_{1+}$ = 0.6; $MSYR_{1+}$=4.5%.

Tables 4 and 5 summarise the *Evaluation* and *Robustness* Trials on which the *Implementation Review* will be based. The full specifications for the trials are provided in Annex E.

Table 4

The *Evaluation Trials*. Values given in bold type show differences from the base case trial.

Trial	Priority	Description	*MSYR*$_{1+}$ North	*MSYR*$_{1+}$ PCFG	Final Need	Survey freq.	Survey Bias	Future Survey CV
GE01	1	Base case	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE02	1	$MSYR_{1+}$ = 1%; Immigration = 2	4.5%	**1%**	340 / 7	10 / 1	**0.5→1***	Base
GE03	1	$MSYR_{1+}$ = 1%; Immigration = 4	4.5%	**1%**	340 / 7	10 / 1	**0.5→1***	Base
GE04	1	$MSYR_{1+}$ = 1%; Immigration = 6	4.5%	**1%**	340 / 7	10 / 1	**0.5→1***	Base
GE05	1	$MSYR_{1+}$ = 2%; Immigration = 2	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE06	1	$MSYR_{1+}$ = 2%; Immigration = 4	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE07	1	$MSYR_{1+}$ = 2%; Immigration = 6	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE08		$MSYR_{1+}$ = 2%; Difficult	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	**½ CV_{est}**
GE09		$MSYR_{1+}$ = 2%; Immigration = 2; Difficult	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	**½ CV_{est}**
GE10		High need	4.5%	4.5%	**530 / 7**	10 / 1	1	Base
GE11		*MSYR*$_{1+}$ = 2%; high need	**2%**	**2%**	**530 / 7**	10 / 1	**0.5→1***	Base
GE12		$MSYR_{1+}$ = 2%; Immigration = 2; High need	**2%**	**2%**	530 / 7	10 / 1	**0.5→1***	Base
GE13	1	*MSYR*$_{1+}$ = 2%	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE14	1	*MSYR*$_{1+}$ = 6%	**6%**	**6%**	340 / 7	10 / 1	1	Base
GE15		GE01 + 3 episodic events[&]	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE16		All PCFG whales; $\delta = 0$; ϕ_{fut}=1.000	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE17		All PCFG whales; $\delta = 0$; ϕ_{fut}=0.600	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE18		Struck & Lost (0%)	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE19		Struck & Lost (75%)	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE20		All PCFG catches in May	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE21		Struck & Lost (0%)	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE22		Struck & Lost (75%)	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE23		All PCFG catches in May	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE24		$MSYR_{1+}$ = 2%; Immigration = 2; Struck & Lost (0%)	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE25		$MSYR_{1+}$ = 2%; Immigration = 2; Struck & Lost	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base

[8] This is assumption is conservative because it will lead to the highest assessed risk to the PCFG stock. In principle, it would be desirable to model to relative probability of strikes by month but no data are available to make any estimates. Sensitivity is explored to the assumption that all of the catches occur in April.

		$MSYR_{1+}$	$MSYR_{1+}$	Final	Survey	Survey	Future Survey
	(75%)						
GE26	$MSYR_{1+}$ = 2%; Immigration = 2; All PCFG catches in May	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE27	Stochastic events 10% every 5 years[&]	4.5%	4.5%	340 / 7	10 / 1	1	Base
GE28	Stochastic events 10% every 5 years[&]	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base
GE29	$MSYR_{1+}$ = 1%; Immigration = 2; Stochastic events 10% every 5 years[&]	4.5%	**1%**	340 / 7	10 / 1	1	Base
GE30	$MSYR_{1+}$ = 1%; Immigration = 2; Stochastic events 10% every 5 years[&]	**2%**	**2%**	340 / 7	10 / 1	**0.5→1***	Base

*To be adjusted based on initial analyses

& The average value for adult survival needs to be adjusted to ensure the population is table for these trials

+ The provided CV is half of the true value.

Table 5

The *Robustness Trials*.

Trial	Priority	Description	$MSYR_{1+}$ North	$MSYR_{1+}$ PCFG	Final Need	Survey freq.	Survey Bias	Future Survey CV
GR01		5 year surveys	4.5%	4.5%	340 / 7	10 / 5	1	Base
GR02		Difficult 2%+5yr surveys	2%	2%	340 / 7	10 / 5	0.5→1*	½ CV_{est}
GR03		Linear decrease in *K*	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR04		Linear increase in PCFG *K* ; decrease for North K	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR05		Linear decrease in PCFG *K* ; increase for North K	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR07		Linear increase in *M*	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR08		Linear increase in PCFG *M*	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR09		Linear increase in north *M*	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR10		All PCFG whales; ϕ_{PCFG}=1.000; MSYR = 2%	2%	2%	340 / 7	10 / 1	0.5→1*	Base
GR11		All PCFG whales; ϕ_{PCFG}=0.000	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR12		Perfect detection; p_1 = 0; p_2 = 0;	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR13		Perfect detection; p_1 =0; p2=0.01-0.05	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR14	1	Survey bias PCFG + p_1 = 0.5	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR15	1	Survey bias PCFG + p_1 = 0.5	2%	2%	340 / 7	10 / 1	0.5→1*	Base
GR16	1	Correlation (draw for N; same quantile in the range for PCFG)	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR17	1	Correlation (draw for N; same quantile in the range for PCFG)	2%	2%	340 / 7	10 / 1	0.5→1*	Base
GR18	1	Pulse migration in 1999 (equal propn to $\tilde{S}$); 3 unepisodic event of 75 years	4.5%	4.5%	340 / 7	10 / 1	1	Base
GR18	1	Pulse migration in 1999 (equal propn to $\tilde{S}$); 3 unepisodic event of 75 years	2%	2%	340 / 7	10 / 1	0.5→1*	Base

*To be adjusted based on initial analyses

Factors	Other Levels (Reference levels shown bold and underlined)
MSYR $_{1+}$	2%, **<u>4.5%</u>**, 6%
Immigration rate	**<u>0, 2</u>**, 4, 6
Proportion of PCFG whales in PCFG area	0, **<u>0.203</u>**, 1
Struck and lost are	0, **<u>50%,</u>** 100%
Northern need in final year (linear change from 150 in 2009)	**<u>340</u>**, 530
Historic survey bias	**<u>None,</u>** Increasing between 1967 to 2002 from 0.5→1 50% (PCFG only)
Survey CV	**<u>BaseCase,</u>** ½ CV_{est}
Future episodic events	**<u>None</u>**, 3 events occur between yrs 1-75 (with at least 2 in yrs 1-50) in which 20% of the animals die; events occur every 5 years in 10% of the animals die
Time dependence in *K*	**<u>Constant</u>**, Halve linearly over 100yr
Time dependence in natural mortality, *M* *	**<u>Constant,</u>** Double linearly over 100yr
Timing of harvest	**<u>April</u>, May**
Parameter correlations	Yes, **<u>No</u>**
Probability of mismatching north whales	0, **<u>0.01</u>**, 0.01-0.05
Probability of mismatching PCFG whales	**<u>0</u>**, 0.5
Frequency of PCFG surveys	**<u>Annual</u>**, 5-year

2.4 Presentation of results and performance statistics

The Workshop reviewed the performance statistics considered during the 2004 *Implementation.* Given the objectives for the current *Implementation Review*, the Workshop **agreed** to the following modifications to the performance statistics (see Section D of Annex G for the complete listings):

(1) The plots of population size (statistics D6 and D7) as well as the D8 statistic should be produced for the population size when (a) there are only incidental catches and (b) when there are incidental catches and catches due to the hunt in the north area.
(2) The trajectory plots (statistics D6 and N8) should be produced for all simulations and not just simulations 1 and 2.
(3) The minimum population numbers (in mature females) [statistic D9] should be included in the standard summary table.
(4) The standard tabular summary should not include the N12, D10 and R1 statistics as these statistics are not very meaningful for the current set of trials.
(5) Two new statistics N13 and N14 which summarize the number of landings and struck and lost animals were introduced.
(6) A new catch variation statistic (N15) was added.
(7) A summary of the reasons for stopping the hunt (reaching the block quota, reaching the ABL, exceeding the limit on struck-and-lost animals) should be provided.

The Workshop also **agreed** that results be presented for the *SLA* for PCFG hunt in which the ABL is ignored.

2.5 Recommendations and Workplan prior to 2011 Annual Meeting

(1) Finalise the specifications for the trials [10 April 2011]
    a. Provide updated abundance estimates and the associated variance-covariance matrix
    b. Specify how temporal autocorrelation in the abundance estimates will be modelled [Jeff Laake]
(2) Refine the estimates of PCFG / north mixing (Annex D) based on the 2009 photo-ID data [15 May 2011].
(3) Code the trials [23 April 2011]
(4) Validate the code [15 May 2011]
(5) Givens to provide code to generate parameter vectors [8 May 2011].
(6) Condition the trials [15 May 2011]
(7) Run the trials and assemble the outputs

The Workshop established a Steering Group comprising Allison, Butterworth, Donovan, Givens, Laake, Punt, Weller to guide the work.

3. PROGRESS WITH GREENLANDIC MATTERS

3.1 Consideration of sex ratio method in the light of comments at the 2010 Annual Meeting

At the 2010 Annual Meeting, the SWG stated that, despite considerable effort, it was still not possible to conclude whether or not the statistical method proposed by Schweder and Witting to provide a lower confidence interval value for the current West Greenland minke whale abundance using sex ratio data, could be used to provide management advice. The SWG had agreed that it would no longer prioritise development of the sex ratio approach unless a comprehensive final analysis could be endorsed at the 2011 Scientific Committee meeting. It had noted that the 'transformation strategy' outlined by Butterworth could provide a promising basis for estimation in the short time remaining.

At the present Workshop, Butterworth reported on his intended work on the 'transformation' method. His plan is to focus initially on a simple case in which the sex ratio data are analysed using an age-aggregated population model. The model is to be transformed in a manner that should not impact maximum likelihood estimates (MLEs) for data sets in which the sex ratio of catches changed over time in the direction anticipated given imbalance in the sex distribution of past catches, but should also yield such MLEs in cases where the trends in the observed ratio are in the opposite direction as a result of data fluctuations. If successful, this will render likelihood profile based approaches for confidence interval estimation possible in such circumstances.

The Workshop **emphasised** the need for any specific proposal for such an approach to be accompanied by the results of simulation testing which confirmed satisfactory estimation performance, noting the views of the SWG expressed in 2010.

3.2. Consideration of multi-species issues

In Greenland, a multispecies hunt occurs and the expressed 'need' is for 670 tonnes of edible products from large whales for West Greenland; this involves catches of common minke, fin, humpback and bowhead whales. The flexibility among species is important to the hunters and satisfying 'subsistence need' to the extent possible is a critical component management. Last year, the SWG noted that the development of a combined approach to calculate strike limits for more than one species has not been previously attempted.

The Workshop agreed that this matter should be deferred until single species management approaches had been developed further. These would provide the necessary basis to extend to multi-species considerations, such as need being expressed on a species-combined rather than a species-specific basis.

3.3 Consideration of *SLA* development by species

3.3.1 Fin whales

The Workshop agreed that the first step is to define the operating models for trials for prospective *SLA*s and that these should be based on the existing *Implementation Simulation Trial* framework for North Atlantic fin whales [REF]. This should be reviewed and if necessary refined to incorporate more detail particularly with respect to stock structure and other recent information on West Greenland fin whales. Witting **agreed** to report new data and suggestions for such operating model refinements to the next Annual Meeting.

3.3.2 Minke whales

The Workshop agreed that a similar approach to that described under Item 3.3.1 was applicable for West Greenland common minke whales; Witting **agreed** to report similarly to the next Annual Meeting.

3.3.3 Humpback whales

The Scientific Committee has previously agreed [REF] to provide management advice on the West Greenland feeding aggregation of humpback whales by treating this as an independent stock. The Workshop thanked Witting for undertaking to provide an updated single-stock assessment for the West Greenland humpback whale aggregation to the next Annual Meeting to provide a framework from which to develop operating models for simulation trials.

3.3.4 Bowhead whales

The Workshop noted that the Scientific Committee still has to finalise its view of the stock structure of bowhead whales in the western North Atlantic. Witting advised that he plans to table an updated assessment under the assumption that this is a single stock at the next Annual Meeting.

3.4 Progress following the 2010 recommendations with respect to conversion factors

Witting advised that he hopes to be able to table further information on this topic at the next Annual Meeting.

3.5 Recommendations and workplan (Greenland)

The following workplan was agreed, with all items due for report at the next Annual meeting:

1) Analyses using the transformation approach to address the potential utility of catch sex-ratio information to assess the abundance of West Greenland minke whales (Butterworth, Brandão).
2) Provision of new data and proposed refinements (pertinent to West Greenland) of existing RMP *IST* frameworks for North Atlantic fin and minke whales (Witting).
3) Updated single stock assessments of the West Greenland humpback whale aggregation and the western North Atlantic bowhead whale population (Witting).

4. OTHER MATTERS

4.1 Progress with work on the Aboriginal Whaling Scheme and specifications for carrying out *Implementations* and *Implementation Reviews*

Donovan reported that a draft would be circulated at the 2011 Annual Meeting and that it would *inter alia* take into account the applicability of the DAA to multi-year *Implementation Reviews.*

5. ADOPTION OF REPORT

Donovan thanked all of the participants for their hard work and co-operative attitude in what had proved to be a scientifically challenging and enjoyable workshop. He particularly thanked the rapporteurs for their prompt drafting, Dave Weller for the excellent organisation and Jeff Laake and his wife for the evening barbecue.

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Annex A

List of Participants

USA
J. Bickham (by phone on 28 March 2011)
J. Brandon
A. Lang
J. Laake
J. Scordino
D. Weller

DENMARK
L. Witting (by Skype on 1 April 2011)

INVITED PARTICIPANTS
D. Butterworth
G. Givens
B. Mate
A. Punt

IWC
C. Allison
G. Donovan

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 available

2. IMPLEMENTATION REVIEW OF EASTERN GRAY WHALES
2.1 Brief review of discussions at 2010 Annual Meeting
2.2 New information available with a focus on the PCFG
2.2.1 *Stock structure and movements*
2.2.2 Abundance and trends
2.2.3 Catch data
2.2.4 Feeding ecology
2.3 Development of trial structure
2.3.1 *Proposed Makah management regimes/s and associated issues*
2.3.2 *Stock structure hypothesis*
2.3.3 *Abundance estimates (incl. frequency) and relationship to stock structure hypotheses*
2.3.4 *Mixing*
2.3.5 *Biological parameters, including MSYR*
2.3.6 *Other*
2.3.7 *Conditioning*
2.3.8 *Proposed final trial structure and specifications*
2.4 Presentation of results and performance statistics
2.4.1 *Review of existing performance statistics*
2.4.2 Suggested modifications
2.4.3 Proposed final presentation of results and performance statistics
2.5 Recommendations and Workplan prior to 2011 Annual Meeting

3. PROGRESS WITH GREENLANDIC MATTERS
3.1 Consideration of sex ratio method in light of comments at the 2010 Annual Meeting
3.2 Consideration of multi-species issues
3.3 Consideration of SLA development by species
3.3.1 Fin whales
3.3.2 Common minke whales
3.3.3 Humpback whales
3.3.4 Bowhead whales
3.4 Progress following the 2010 recommendations with respect to conversion factors
3.5 Recommendations and workplan

4. OTHER MATTERS
4.1 Progress with work on the Aboriginal Whaling Scheme and specifications for carrying out *Implementations* and *Implementation Reviews*

5. ADOPTION OF REPORT

Annex C

Bycatch and Ship strikes of Gray Whales on US West Coast 1990-2010 and in British Columbia 1990-1995

JONATHAN SCORDINO AND BRUCE MATE

Stranding databases and human interaction databases maintained by NOAA Fisheries Northwest Regional Office and Southwest Regional Office were reviewed to determine past impacts on gray whales from fisheries bycatch and ship strikes. Data supplied in Baird *et al.* (2002) was used to estimate human caused mortality (other than hunting) in British Columbia. All bycatch data used for this analysis is reported in Table 3 and ship strike data in Table 4. Bycatch and ship strikes were binned by time period (June-November and December-May) and reporting region (Table 1) for the time period of 1990-2010 for US waters and 1990-1995 in Canadian waters. These time frames were used because stranding networks were well established at this time and data was consistently available for the reported regions. We next divided the number of observations by the number of years in which there was effort to report ship strikes and fisheries bycatch (Table 2). All unique records incidents of bycatch or ship strike were used for this analysis even if a whale was successfully disentangled and had little reported damage from a ship strike. We felt that conservatively including these animals was appropriate because not all whales that are reported as disentangled are actually fully disentangled. Furthermore, including whales thought to be rescued in the analysis will help buffer the effect of whales that were struck or bycaught and not reported. There were 15 whales that were recorded in the bycatch database multiple times.

We found the total human interactions as 1.4 whales per year from June-November and 5.4 whales per year from December-May (Table 2). Whales south of the proposed PCFG boundaries during June-November and a whale bycaught just north of the PCFG boundary are likely members of the PCFG and thus all June-November incidental takes are thought to be of PCFG whales. Based on the finding that 20% of whales observed in the time period of December-May between 41N and 52N are PCFG whales (Calambokids *et al.* 2010) and the assumption that 1% of whales south of the 41N in the migratory period are PCFG whales, it is possible that an additional 0.43 PCFG whales are bycaught or ship struck making an annual mortality of 1.83 PCFG whales per year.

Bycatch during the reported period is predominately in gillnet and pot fisheries (Figure 1). Many of the entanglements reported as “unknown” gear types that were described as ropes that could have been from pot fisheries.

Reported human interactions are likely biased low. Baird *et al.* (2002) concluded that the rate of bycatch is 27% of stranded gray whales based on a sample size of 15 whales that were closely examined. If conclusions of Baird *et al.* (2002) are correct then there would have been about 11 gray whales stranding in British Columbia due to interactions with fishing gear from 1990-1995 rather than the four reported in Table 1.

Mortalities due to fisheries bycatch may be decreasing through time, this trend is most apparent with net fisheries (Figure 2). Bycatch due to pot fisheries does not have an apparent pattern of increase or decrease with time (Figure 3). The observed trend in declining bycatch in net fisheries is likely due to changes in gear used, seasonality and number of participants in net fisheries that are known to incidentally catch whales. Many of the fisheries known to cause marine mammal mortality in the US have mitigation plans to reduce mortality, with the exception of crab pot fisheries. Combined with the increased capacity of stranding networks in both the US and Canada to disentangle large cetaceans it is very likely that the number of fatally bycaught gray whales will decrease to low numbers in the future.

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Table 1

The number of observed bycatch and ship strike incidents recorded by region for the noted period of years. These time periods were used due to the availability of data and because stranding networks were fully operational. All whales from Tables 3 and 4 were included for the years of 1990-2010 except whales noted to be seen in more than one year.

Region	June-Nov	Dec-May	Total	Years of observation
BC Bycatch	1	3	4	1990-1995
WA Bycatch	9	7	16	1990-2010
WA Ship Strike	2	7	9	1990-2010
OR Bycatch	2	9	11	1990-2010
OR Ship Strike	0	0	0	1990-2010
CA PCFG Bycatch	3	4	7	1990-2010
CA PCFG Ship Strike	0	1	1	1990-2010
CA South Bycatch	6	39	45	1990-2010
CA South Ship Strike	2	29	31	1990-2010

Table 2

The observed annual rate of gray whales fisheries bycatch and ship strikes is listed by region and for the migratory and feeding time periods. Data are applicable for 1990-2010 in US water and 1990-1995 in British Columbia.

Region	June-Nov	Dec-May	Total
BC Bycatch	0.2	0.6	0.8
WA Bycatch	0.45	0.35	0.8
WA Ship Strike	0.1	0.35	0.45
OR Bycatch	0.1	0.45	0.55
OR Ship Strike	0	0	0
CA PCFG Bycatch	0.15	0.2	0.35
CA PCFG Ship Strike	0	0.05	0.05
CA South Bycatch	0.3	1.95	2.25
CA South Ship Strike	0.1	1.45	1.55
Total	1.4	5.4	6.8

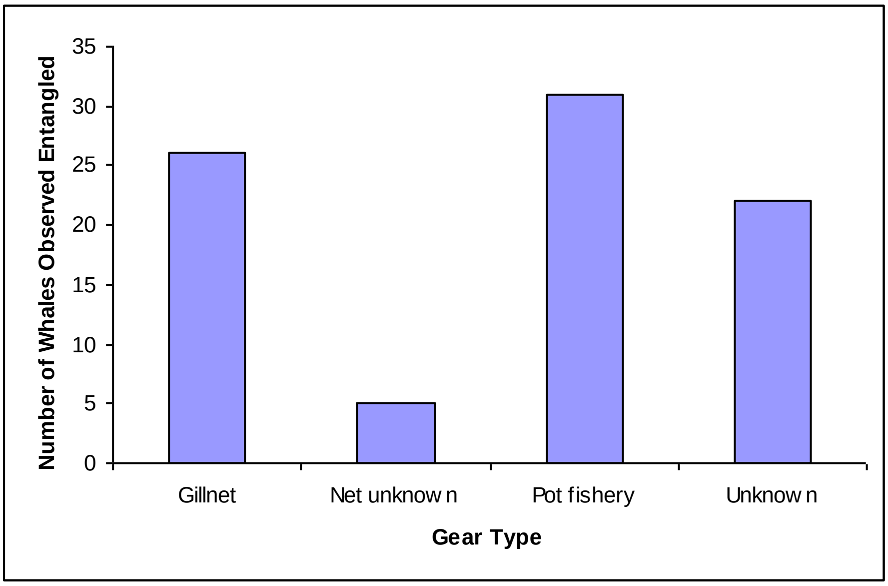

Fig. 1: Number of entanglement per fishing gear type from 1990-2010 in California, Oregon, and Washington and from 1990-1995 in British Columbia.

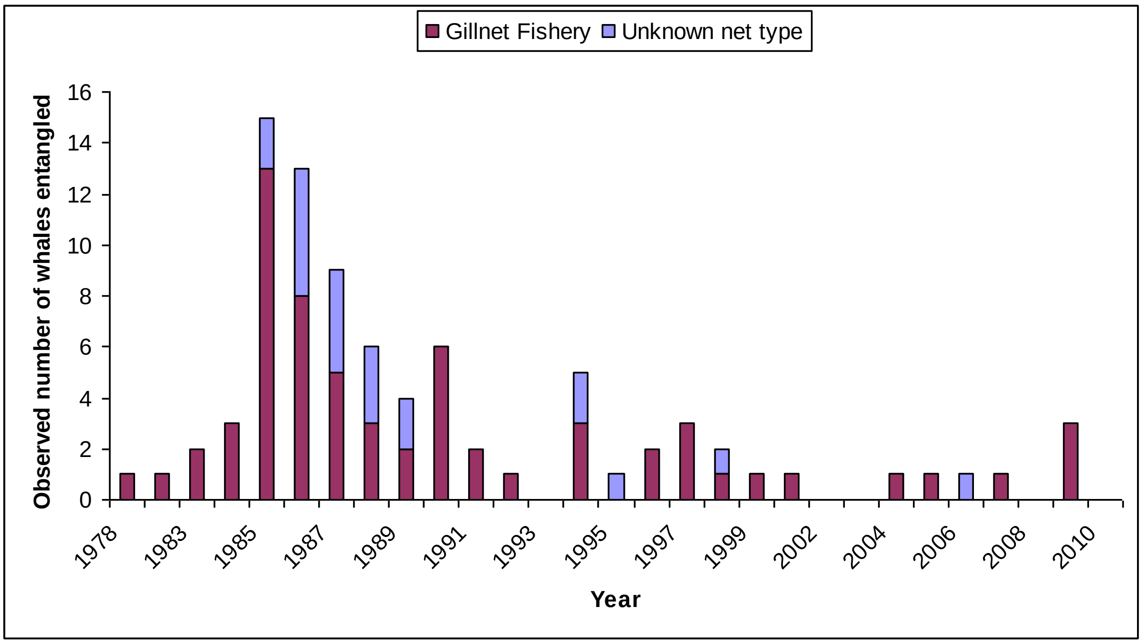

Fig. 2. Gray whales observed to be entangled in net fishery gear by year. Gillnet entanglements are specifically noted. Disentangled gray whales are included because it is not known for sure that these animals were fully disentangled.

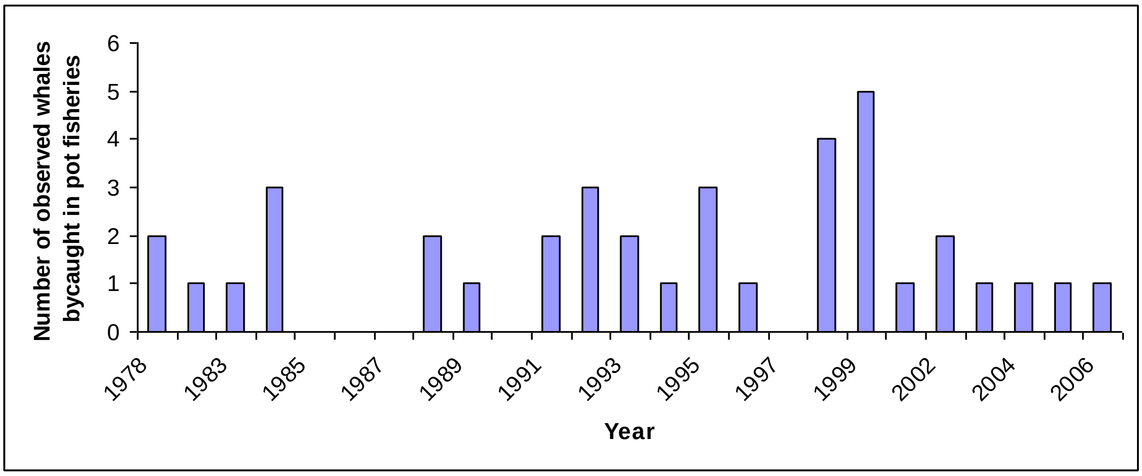

Fig.3. Gray whales observed to be entangled in pot fishery gear by year. Disentangled whales are included because it is not known for sure that these animals were fully disentangled.

Table 3

Ship strikes as documented by NOAA Fisheries from the early 1970s through 2010. If a bycatch was reported twice in the same day one of the reports was deleted. The column labeled 41N – 52N denotes if ship strike event occurred in the waters known to be used by the PCFG. The ship strike code is: 1 – cause of death diagnosed as ship strike; 2 – cause of death suspected to be a ship strike; 3 – whale free swimming but injured and likely to die; 4 – whale free swimming, injured from a ship strike, and may die; 5 – whale stuck by a boat is free swimming and unlikely to die and; 6 – the whale was last seen alive and its status is unknown.

Date	Location	41N - 52N	LEN (cm) or age-class	Sex	Ship Strike Code
11-Apr-85	Long Beach Peninsula, WA	Yes	Unknown	Male	1
21-Jan-87	Oceano, CA	No	610	Female	2
14-Feb-87	Ventura River, CA	No	437	Male	1
20-Apr-87	Seal Beach, CA	No	Subadult	Female	1
02-May-87	Fort Baker, CA	No	1150	Female	1

Date	Location	41N - 52N	LEN (cm) or age-class	Sex	Ship Strike Code
11-Jan-88	Tiburon, CA	No	800	Female	1
3-Apr-91	Novato, CA	No	1223	Unknown	2
13-Apr-91	Richmond, CA	No	963	Unknown	2
17-Apr-91	Newark, CA	No	1143	Unknown	2
6-Apr-93	Oceanside, CA	No	1067	Unknown	1
14-May-94	Pismo Beach, CA	No	1943	Unknown	2
2-Jan-95	Anacapa Island, CA	No	Unknown	Unknown	4
7-Mar-95	Point Loma, CA	No	Unknown	Unknown	5
4-Apr-95	Richmond, CA	No	1219	Unknown	6
11-Sep-95	Copalis Beach, WA	Yes	Unknown	Unknown	1
14-Apr-97	Grayland, WA	Yes	Unknown	Male	2
2-Jan-98	San Pedro, CA	No	1219	Unknown	4
7-Jan-98	Crescent City, CA	Yes	447	Unknown	3
17-Mar-98	Grays Harbor, WA	Yes	Unknown	Female	1
24-Apr-98	Point Loma, CA	No	914	Unknown	3
24-Apr-98	Point Loma, CA	No	610	Unknown	3
30-Apr-98	Stinson Beach, CA	No	1240	Unknown	2
23-Jan-99	Coronado Island, CA	No	762	Unknown	4
19-Dec-99	Muir Beach, CA	No	1222	Unknown	2
9-Jan-01	San Luis Obisbo, CA	No	366	Unknown	3
18-Apr-03	San Francisco, CA	No	790	Unknown	1
19-Apr-05	Whidbey Island, WA	Yes	Yearling	Male	2
8-Dec-05	Marrowstone Island, WA	Yes	Yearling	Male	2
1-Feb-06	Santa Barbara, CA	No	914	Unknown	4
10-Feb-06	San Pedro, CA	No	876	Unknown	1
24-Mar-06	San Diego, CA	No	914	Unknown	4
20-Apr-06	San Francisco, CA	No	1400	Unknown	2
1-Jun-07	Golden Gate NRA, CA	No	950	Unknown	2
7-Oct-07	San Pedro, CA	No	792	Unknown	2
7-Feb-08	Huntington Beach, CA	No	517	MALE	6
1-Mar-08	Offshore San Diego, CA	No	Unknown	Unknown	6
4-Apr-09	Ilwaco, WA	Yes	Subadult	Male	2
5-Apr-09	Sunset Beach, CA	No	853	MALE	6
27-Apr-09	Whidbey Island, WA	Yes	Adult	Male	2
1-May-09	El Segundo, CA	No	Calf	Unknown	6
9-Sep-09	La Push, WA	Yes	1400	Unknown	4

Table 4

Whales documented to be bycaught by NOAA Fisheries and Canadian stranding networks (Baird *et al*. 2002). The column repeat uses the same letter of the alphabet to mark bycatch reports that are likely the same whale. If a bycatch was reported twice in the same day one of the reports was deleted. The column labeled 41N – 52N denotes if bycatch event occurred in the waters known to be used by the PCFG. Bycatch code is: 1 – cause of death diagnosed as entanglement; 2 – cause of death may be due to entanglement; 3 – disentanglement efforts initiated and only partly unsuccessful, final status of the individual is unknown; 4 – disentanglement efforts initiated and fully successful or whale was able to free itself; 5 – free swimming with entangling gear, final status unknown and; 6 – status of the whale is unknown, last seen alive. Whales noted as disentangled were not included on the analysis of bycatch per year.

Date	Repeat	City, State/Province	41N - 52N	Entanglement	Bycatch Code
14-Sep-78		Neah Bay, WA	Yes	Gillnet	1
5-May-81		Newport, OR	Yes	Unknown	4
30-May-81		Neah Bay, WA	Yes	Gillnet	4
1-Apr-83		China Beach, BC	Yes	Unknown	1
17-May-83		Estevan Point, BC	Yes	Gillnet	1
9-Dec-83		Rancho Palos Verdes, CA	No	Gillnet	1
2-Jan-84		Gig Harbor, WA	Yes	Unknown	4
18-Feb-84		Rancho Palos Verdes, CA	No	Gillnet	3
21-Mar-84		Huntington Beach, CA	No	Gillnet	1
24-Apr-84		Boundary Bay, BC	Yes	Unknown	1
5-May-84		Cayucos, CA	No	Gillnet	1
4-Jan-85	a	Dana Point, CA	No	Gillnet	3
10-Jan-85	a	Santa Cruz Island, CA	No	Gillnet	6
15-Jan-85	a	Camp Pendleton, CA	No	Gillnet	1
28-Jan-85	a	Santa Cruz Island, CA	No	Unknown	1
28-Jan-85		Mexico	No	Gillnet	4
29-Jan-85		Port Hueneme, CA	No	Gillnet	6
7-Feb-85		Vandenburg Air Force Base, CA	No	Gillnet	6
14-Feb-85		Huntington Beach, CA	No	Unknown	1

Date	Repeat	City, State/Province	41N - 52N	Entanglement	Bycatch Code
15-Feb-85		Huntington Beach, CA	No	Gillnet	6
23-Feb-85		Huntington Beach, CA	No	Gillnet	4
25-Feb-85		Anacapa Island, CA	No	Pot fishery	6
12-Mar-85		San Diego, CA	No	Gillnet	6
12-Mar-85		Seal Beach, CA	No	Unknown	6
25-Mar-85		San Pedro, CA	No	Gillnet	4
30-Mar-85	b	Catalina Island, CA	No	Net Unknown	6
30-Mar-85		Oxnard, CA	No	Net Unknown	1
31-Mar-85	b	Catalina Island, CA	No	Gillnet	6
31-Mar-85		Ventura, CA	No	Gillnet	1
4-Apr-85		San Diego, CA	No	Gillnet	1
8-Apr-85		La Jolla, CA	No	Gillnet	6
17-Apr-85		San Diego, CA	No	Gillnet	6
23-Apr-85		Eureka, CA	No*	Pot fishery	4
12-May-85		Pigeon Point, CA	No	Unknown	1
18-Jul-85		San Pedro, CA	No	Gillnet	1
29-Jan-86		San Diego, CA	No	Gillnet	6
11-Feb-86		Malibu, CA	No	Net Unknown	6
24-Feb-86		Malibu, CA	No	Gillnet	3
4-Mar-86		Newport Beach, CA	No	Pot fishery	6
10-Mar-86		Huntington Beach, CA	No	Gillnet	3
31-Mar-86		Santa Barbara, CA	No	Gillnet	4
1-Apr-86		Santa Barbara, CA	No	Unknown	4
2-Apr-86		Oceanside, CA	No	Unknown	4
2-Apr-86		Santa Barbara, CA	No	Gillnet	4
10-Apr-86		Santa Barbara, CA	No	Unknown	4
15-Apr-86		Santa Barbara, CA	No	Unknown	2
25-Apr-86		Malibu, CA	No	Unknown	4
25-Apr-86		Long Beach, CA	No	Gillnet	3
25-Apr-86	c	Malibu, CA	No	Net Unknown	6
27-Apr-86		Encinitas, CA	No	Net Unknown	6
27-Apr-86		Refugio State Beach, CA	No	Net Unknown	6
27-Apr-86	c	Refugio State Beach, CA	No	Net Unknown	6
1-May-86		Monterey, CA	No	Net Unknown	6
28-Dec-86		San Pedro, CA	No	Gillnet	6
31-Dec-86	d	San Pedro, CA	No	Gillnet	3
6-Jan-87	d	Palos Verdes, CA	No	Gillnet	6
22-Jan-87	e	Rancho Palos Verdes, CA	No	Gillnet	7
30-Jan-87	e	Palos Verdes Estates, CA	No	Gillnet	1
5-Feb-87		Malibu, CA	No	Gillnet	3
6-Feb-87		San Pedro, CA	No	Net Unknown	1
5-Mar-87	f	Newport Beach, CA	No	Pot fishery	6
5-Mar-87	f	Rancho Palos Verdes, CA	No	Pot fishery	6
2-Apr-87		Oceanside, CA	No	Net Unknown	4
5-Apr-87		Oxnard, CA	No	Unknown	4
6-Apr-87		Oceanside, CA	No	Gillnet	4
10-Apr-87		Malibu, CA	No	Gillnet	6
12-Apr-87		Malibu, CA	No	Unknown	4
17-Apr-87		Carlsbad, CA	No	Gillnet	1
12-Aug-87		Point Loma, CA	No	Net Unknown	3
19-Nov-87		Point Loma, CA	No	Net Unknown	6
16-Jan-88		Seal Beach, CA	No	Net Unknown	3
28-Jan-88		San Diego, CA	No	Pot fishery	4
10-Mar-88		Coronado, CA	No	Gillnet	4
16-Mar-88	g	San Diego, CA	No	Gillnet	6
16-Mar-88		Long Beach, CA	No	Unknown	6
17-Mar-88		San Pedro, CA	No	Net Unknown	1
18-Mar-88	g	San Onofre Area, CA	No	Gillnet	6
18-Mar-88		Rancho Palos Verdes, CA	No	Net Unknown	6
19-Mar-88		Seal Beach, CA	No	Pot fishery	4
22-Mar-88		Seal Beach, CA	No	Pot fishery	4
4-Aug-88		Cape Scott, BC	Yes	Unknown	1
22-Oct-88		Long Beach, CA	No	Gillnet	3
22-Jan-89		Santa Cruz Island, CA	No	Net Unknown	1
5-Mar-89	h	Avilla Beach, CA	No	Unknown	6
11-Mar-89	h	Cambria, CA	No	Unknown	6
14-Mar-89	i	Dana Point, CA	No	Unknown	6
20-Mar-89	i	Santa Barbara, CA	No	Unknown	4
22-Mar-89		Newport Beach, CA	No	Gillnet	1

Date	Repeat	City, State/Province	41N - 52N	Entanglement	Bycatch Code
11-Apr-89		Rancho Palos Verdes, CA	No	Unknown	6
15-Apr-89		Camp Pendelton, CA	No	Net Unknown	1
4-May-89		Long Beach, CA	No	Gillnet	4
15-Feb-90		Laguna Beach, CA	No	Gillnet	1
16-Feb-90		Santa Barbara, CA	No	Unknown	6
27-Mar-90		Santa Barbara, CA	No	Gillnet	6
15-Apr-90		Long Beach, CA	No	Gillnet	6
21-May-90		Santa Cruz, CA	No	Gillnet	1
11-Jun-90		Kitasu Bay, Swindle Island, BC	No*	Gillnet	1
23-Jul-90		Neah Bay, WA	Yes	Gillnet	1
2-Jan-91		Bodega Bay, CA	No	Unknown	1
10-Mar-91		Ventura, CA	No	Gillnet	6
23-Mar-91		Cleland Island, BC	Yes	Gillnet	4
26-Sep-91			No	Unknown	4
30-Dec-91		Bodega Head, CA	No	Unknown	1
26-Feb-92	j	Point Loma, CA	No	Pot fishery	1
5-Mar-92		San Diego, CA	No	Pot fishery	4
5-Mar-92	j	Cardiff-By-The-Sea, CA	No	Pot fishery	1
28-Mar-92		Santa Barbara, CA	No	Gillnet	6
10-Feb-93		Rancho Palos Verdes, CA	No	Pot fishery	4
28-Jun-93		Neah Bay, WA	Yes	Unknown	2
26-Jan-94		Coronado, CA	No	Net Unknown	2
21-Mar-94		Newport Beach, CA	No	Unknown	6
3-Apr-94		Mendocino, CA	No	Gillnet	6
17-Apr-94		Dare Point, BC	Yes	Gillnet	1
5-May-94		Port San Juan, BC	Yes	Net unknown	1
11-Sep-94		Smith River, CA	Yes	Gillnet	6
6-Mar-95		Malibu, CA	No	Pot fishery	4
10-Mar-95		Summerland, CA	No	Net Unknown	2
11-Apr-95		Queets, WA	Yes	Unknown	2
13-Apr-95		Santa Barbara, CA	No	Pot fishery	4
1-Apr-96		Crescent City, CA	Yes	Pot fishery	1
2-Apr-96	k	Huntington Beach, CA	No	Pot fishery	5
5-Apr-96	k	Montecito, CA	No	Gillnet	4
27-Apr-96		Summerland, CA	No	Gillnet	1
27-Apr-96		Summerland, CA	No	Gillnet	1
2-May-96		Eureka, CA	No *	Pot fishery	4
16-Mar-97		Mexico	No	Pot fishery	6
26-Mar-97	l	El Capitan State Park, CA	No	Gillnet	5
7-Apr-97	l	Goleta, CA	No	Gillnet	5
14-Apr-97		Trinidad, CA	Yes	Pot fishery	6
12-May-97		Anacapa Island, CA	No	Gillnet	4
24-May-97		Vandenburg Air Force Base, CA	No	Gillnet	1
3-Mar-98	m	San Pedro, CA	No	Net Unknown	6
18-Mar-98	m	San Pedro, CA	No	Net Unknown	6
8-Jul-98		Wreck Creek, WA	Yes	Gillnet	1
23-Oct-98		San Pedro, CA	No	Unknown	3
30-Nov-98		San Diego, CA	No	Pot fishery	4
4-Mar-99	n	Rancho Palos Verdes, CA	No	Gillnet	6
14-Mar-99	n	Rancho Palos Verdes, CA	No	Gillnet	6
24-Jun-99		Port Hueneme, CA	No	Pot fishery	1
15-Jul-99		Grayland, WA	Yes	Pot fishery	1
5-Aug-99		Crescent City, CA	Yes	Pot fishery	4
1-Feb-00	o	San Diego, CA	No	Pot fishery	6
16-Mar-00	o	San Clemente, CA	No	Unknown	6
27-Mar-00		Malibu, CA	No	Unknown	6
30-Mar-00		Long Beach, CA	No	Gillnet	1
10-Jun-00		Aptos, CA	No	Unknown	6
24-Apr-02		Isla Vista, CA	No	Unknown	6
14-May-02		Rancho Palos Verdes, CA	No	Unknown	6
3-Aug-02		Ocean Shores, WA	Yes	Unknown	1
31-Jan-03		Morro Bay, CA	No	Pot fishery	6
25-Mar-03		San Mateo Point, CA	No	Pot fishery	6
20-Apr-03		Cape Lookout, OR	Yes	Pot fishery	1
18-May-03		Clinton, WA	Yes	Pot fishery	4
20-May-03		Mukilteo, WA	Yes	Unknown	4
10-Jul-03		Ocean City, WA	Yes	Unknown	1
17-Jan-04		La Jolla, CA	No	Pot fishery	3
18-Jan-04		Driftwood SP, OR	Yes	Unknown	1

Date	Repeat	City, State/Province	41N - 52N	Entanglement	Bycatch Code
24-Mar-04		Half Moon Bay, CA	No	Pot fishery	6
12-Apr-04		Tillamook, OR	Yes	Pot fishery	6
20-May-04		Cape Elizabeth, WA	Yes	Pot fishery	2
29-May-04		Ocean City, WA	Yes	Pot fishery	6
13-Aug-04		Point Loma, CA	No	Gillnet	6
19-Sep-04		Driftwood Beach SP, OR	Yes	Unknown	2
21-Feb-05		Depoe Bay, OR	Yes	Pot fishery	6
8-Mar-05		Long Beach, CA	No	Gillnet	4
26-Apr-05		Grayland, WA	Yes	Unknown	2
6-Jul-05		Horsefall Beach, OR	Yes	Unknown	2
25-Aug-05		Cape Flattery, WA	Yes	Unknown	4
23-Apr-06		Cape Lookout, OR	Yes	Net unknown	6
14-May-06		Lakeside, OR	Yes	Pot fishery	6
29-May-06		Grays Harbor, WA	Yes	Pot fishery	1
2-Apr-07		Rancho Palos Verdes, CA	No	Gillnet	6
20-Apr-07		Newport, OR	Yes	Pot fishery	6
26-Jul-07		Seattle, WA	Yes	Unknown	6
16-Apr-08		Eureka, CA	No *	Pot fishery	6
31-Jan-09		Point Loma, CA	No	Pot fishery	6
25-Mar-09		Seal Beach, CA	No	Gillnet	6
24-Jun-09		Neah Bay, WA	Yes	Gillnet	4
21-Jul-09		Trinidad Head, CA	Yes	Gillnet	6
16-Apr-10		Gearhart, OR	Yes	Unknown	1
7-May-10		Newport, OR	Yes	Pot fishery	6

Annex D

Description of Makah Tribe's Proposed Whale Hunt

MAKAH TRIBAL COUNCIL

The Makah Tribe's hunt of ENP gray whales would harvest up to five (5) whales per year with limitations imposed by a combination of tribal and United States federal regulations. The hunt would be restricted in time and area to target whales migrating to or from the summer feeding grounds in the Bering-Chukchi-Beaufort Seas. The hunt would also include a feedback mechanism to limit the impacts to whales that feed during the spring, summer and autumn in coastal waters of the Pacific coast of North America from northern California to southeast Alaska (the "Pacific Coast Feeding Group," or PCFG),[9] particularly those animals that demonstrate inter-annual site fidelity to the coast of Washington state and Southern Vancouver Island. The parameters of the hunt for purposes of the gray whale SLA trials are as follows.

A. Need Envelope.

Five (5) whales per year for the entire 100-year period covered by the SLA trials. Under the current five-year ASW quota period for ENP gray whales (2008-2012) and the bilateral agreement between the United States and the Russian Federation, up to 20 whales may be taken by the Makah Tribe, with a maximum of five (5) whales taken in any one year.

B. Area of the Hunt.

The hunt will be limited to the portion of the Makah usual and accustomed area (U&A) in the Pacific Ocean. The striking of a whale will be prohibited outside an area bounded by the following line:

> Beginning at the northwestern tip of Cape Flattery running to the Tatoosh Island Lighthouse; from the Tatoosh Island Lighthouse to the buoy adjacent to Duntze Rock; from the buoy adjacent to Duntze Rock following a straight line to Bonilla Point on Vancouver Island but stopping at the Exclusive Economic Zone (EEZ); tracking the EEZ boundary westward to 125° 44'00" longitude; south along 125° 44'00" longitude to 48° 02'15" latitude; east along 48° 02'15" latitude to shore; and then track the shoreline northward to point of origin at Cape Flattery.

C. Time of the Hunt.

The striking of a whale will be prohibited between June 1 and November 30 of any calendar year.

D. PCFG Bycatch Limits.

The Tribe will provide for detailed photographic monitoring of all landed whales. As soon as practicable after a successful hunt, in consultation with scientists from NOAA's National Marine Mammal Laboratory (NMML), the Tribe will compare photographs of the landed whale with the NMML photo-identification catalog for the PCFG, which includes any gray whale that has been photographed from northern California to southeast Alaska between June 1 and November 30 in any year.

The Tribe will cease hunting in a calendar year if, based on this photographic analysis, suspension of the hunt is necessary to prevent the number of whales harvested from the PCFG catalog from exceeding an annual allowable bycatch level (ABL) for that year. The ABL for the PCFG will be calculated by applying Equation 1 to the most recent estimate of the number of gray whales demonstrating inter-annual site fidelity between June 1 and November 30 in the Oregon to Southern Vancouver Island (ORSVI) gray whale survey area:

$$ABL = N_{min}(ORSVI) * 0.5R_{max} * F_r \qquad (1)$$

The minimum population (N_{min}) is calculated from an abundance estimate according to Equation 2.

$$N_{min} = N/\exp(0.842*[\ln(1+CV(N)^2)]^{½}) \qquad (2)$$

In Equation 1, the maximum theoretical or estimated net productivity rate at a small population size (R_{max}) is fixed at 0.04. The recovery factor (F_r) is fixed at 1.0. The minimum population is based on the most recent abundance estimate for gray whales demonstrating inter-annual site fidelity between June 1 and November 30 in the ORSVI survey area.

[9] The Standing Working Group on the Aboriginal Whaling Management Procedure agreed to this term in its 2010 report (Annex E to the report of the Scientific Committee).

E. Strike Limits; Struck and Lost.
The hunt will be limited to seven (7) strikes and three (3) struck and lost whales in any calendar year.

F. Other Limits.
The striking of a whale calf or any whale accompanied by a calf will be prohibited.

A whale that is struck and lost between May 1 and May 31 will be presumed to be a member of the PCFG and will count toward the ABL for that calendar year unless photographs of the whale, when compared with the NMML photo-identification catalog, demonstrate that it is not a member of the PCFG.

Annex E

Encounter probability of PCFG whales prior to 1 June

J. LAAKE

SC/62/BRG32 provided a brief summary of the sighting data prior to 1 June from NWA, the portion of the Makah U&A on the outer coast where hunting would take place. Here I provide more of the details such that available data are better understood. Weather conditions during the spring make it difficult to collect sightings data so the amount of available data is not large. From 1998-2008, whales were only sighted on 10 days during the spring in NWA from March through May with 4 whales sighted in March, 6 in April and 64 in May. The 10 dates were spread across 1999 (1 day), 2000 (2 days), 2002 (1 day), 2005 (1 day), 2006 (3 days) and 2008 (2 days). Of the 74 whales sighted on the 10 dates but 45 were sighted on the single date in 1999 and the next largest was 14 during 2006, so there is insufficient data to evaluate annual variation or even differences across months. Of the 74 whales sighted only one was sighted on multiple days and that was in different years. With these limitations in mind a single pooled estimate of the encounter probability of a PCFG whale in spring of 0.203 (15/74) was computed and reported in SC/62/BRG32.

From PCFG	March	April	May
No	4	3	52
Yes	0	3	12

Annex F

Abundance Estimates, Immigration, Non-PCFG whales

J. LAAKE

The estimates of abundance from the open population models in BRG32 contain both PCFG and non-PCFG whales in the one year they are present. Because many more non-PCFG whales entered in 1999-2001 than later, this hid an increase in the abundance of PCFG whales that was occurring. During discussion this created concern that the estimates were not correct because we expected abundance to increase with the average annual addition of 20 whales into the PCFG (new whales that were resighted later). Upon reviewing the abundance estimator for the POPAN open model, it also became clear that it was not adequate for situations with individual covariates and with splitting the whales into cohorts based on time of first sighting.

For all of these reasons, a better approach is a method that is similar to the method used by Calambokidis et al (2004). All whales are assumed to be seen if they are in the defined region during 1 June-30 Nov. Whales may not be seen in subsequent years but it is assumed that this only occurs because they are not in the region. Thus, the estimate of new whales that enter in a year are those that are seen (none are missed) and thus all individual covariate values are known. If a whale enters in a year but is not seen then it is not in the catalog that is used to define the ABL. Presumably if a whale is part of the PCFG then it will eventually be seen but not necessarily in the first year it was there. Thus, this approach may lead to an underestimate of the abundance of PCFG whales due to these undiscovered whales.

The standard Jolly-Seber estimator of abundance can be expressed as:

$$\hat{N} = \frac{n}{\hat{p}} = \frac{u+m}{\hat{p}} \quad ,$$

where n=u+m, n is the number seen which is composed of new animals (u=unmarked) and previously seen animals (m=marked), and $\hat{p}$ is the estimate of the sighting probability. For the PCFG we are assuming that any new whale is sighted and we are only interested in estimating the abundance of whales that will remain part of the PCFG which is portion of the new whales that do not permanently emigrate from the PCFG. We can modify the estimator for year j as follows:

$$\hat{N}_j = u_j \phi_j + \frac{m_j}{\hat{p}_j} \quad ,$$

where ϕ_j is the first year survival rate of "new" whales. When ϕ and p contain whale specific covariates like minimum tenure (Calambokidis et al. 2004) the estimator is:

$$\hat{N}_j = \sum_{i=1}^{u_j} \hat{\phi}_{ij} + \sum_{i=1}^{m_j} 1/\hat{p}_{ij} \qquad .$$

To obtain an abundance estimate for 2008, I assumed that the parameter for first year survival intercept in 2008 was the same as in 2007. A variance-covariance matrix for the abundance estimates can be constructed using the variance estimator in Borchers et al(1998) for a Horvitz-Thompson type estimator with an adaptation for the first component of the abundance estimator for prediction of number of new whales that do not permanently emigrate. The estimates of ϕ and p were constructed from a model fitted to the observed encounter histories of whales photographed at survey sites between Northern California to Northern British Columbia (41-52N) and a smaller region from Oregon to Southern Vancouver Island (42-49N). The models examined in BRG32 were fitted with the only difference being that minimum tenure values were not scaled by subtracting off the median value in each year. A substantially better fit was achieved by not scaling the covariates. For both regions, the best model was one that had different first year survival probabilities for each year and first year survival was an increasing function of the minimum tenure of each new whale in its first year. Survival in subsequent years was always held constant. The best model for p included variation across years and whales were more likely to be seen in a subsequent year if they had a longer tenure in the previous year. Those relationships were the same as described by Calambokidis et al. (2004) and in BRG32. The parameter estimates on the logit scale are given in Tables 1-2 and the abundance estimates in Tables 3-4.

By constructing the abundance estimates in this fashion, the estimate should never be greater than the number of whales in the catalog and because the ABL is based on an estimate of abundance of the number of whales in the catalog that are still alive and remaining in the PCFG, there should not be any false negatives. However, some whales in the catalog are not part of the PCFG because they never return to the PCFG during 1 June -30 November. As the catalog grows the false positive rate will grow. The estimate of the number of these "stragglers" (transients) in the catalog is the sum of the probabilities that the new whales do not remain (1-survival after first year seen). An estimate of the average number of immigrants to the PCFG, is the average number of new whales that remain in the PCFG less the number that enter as calves. In making that computation, 1998 is excluded because all whales are new by definition at the beginning of the data time series. Also, we excluded "new" whales that had been in the catalog prior to 1998. There were 6,4 and 2 of those in 1999-2001 respectively and none afterward. The average observed number of calves was about 3 per year but much of the sighting effort occurs after when weaning has completed. To acknowledge this, we assume the actual number was 6 and 50% were seen. The average total number of new whales added to the PCFG was 17 and if we assume 6 were calves, then 11 new non-calves are annually entering the PCFG. However, the initial estimates of recruitment may include discovery of whales that entered the PCFG earlier but were not seen and may also reflect a pulse of recruitment related to the large mortality event in 1999-2000. A more reasonable estimate of recruitment would be the average of the last 5 years which is 10 and if we subtract t 6 calves that yields an estimate of 4 whales externally recruited each year into the PCFG.

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Table 1.

Parameter estimates on logit scale for ϕ and p from model fitted to NCA-NBC data. Constant post-first year survival is 1/(1+exp(-2.7848))=0.942. $\hat{\phi}_{ij}$=1/(1+exp(-β_j + 0.0226 mt_i) where β_j is the first year estimate for year j and mt_i is the minimum tenure of the whale in its first year. Values of $\hat{p}_{ij}$ are constructed in a similar fashion.

	Estimate	SE
Phi:(Intercept)	2.7848	0.1579
Phi:cohort1998:firstyr	-2.2006	0.3220
Phi:cohort1999:firstyr	-4.4283	0.3472
Phi:cohort2000:firstyr	-2.9382	0.3464
Phi:cohort2001:firstyr	-3.8518	0.3434
Phi:cohort2002:firstyr	-3.0099	0.3375
Phi:cohort2003:firstyr	-2.3343	0.6205
Phi:cohort2004:firstyr	-3.7499	0.4544
Phi:cohort2005:firstyr	-3.3921	0.5459
Phi:cohort2006:firstyr	-4.7682	1.1275
Phi:cohort2007:firstyr	-3.8246	0.6401
Phi:firstyr:minimum tenure	0.0226	0.0038
p:1999	0.1423	0.2544
p:2000	0.2794	0.2306
p:2001	0.5150	0.2151
p:2002	1.4493	0.2650
p:2003	0.3688	0.1840
p:2004	0.6976	0.1875
p:2005	-0.1871	0.1725
p:2006	0.1749	0.1774
p:2007	-0.3233	0.1799
p:2008	0.6203	0.2341
p:minimum tenure previous year	0.0185	0.0020

Table 2
Parameter estimates on logit scale for ϕ and p from model fitted to OR-SVI data. . Constant post-first year survival is 1/(1+exp(-2.9249))=0.949. . $\hat{\phi}_{ij}$=1/(1+exp(-β_j + 0.0224 mt_i) where β_j is the first year estimate for year j and mt_i is the minimum tenure of the whale in its first year. Values of $\hat{p}_{ij}$ are constructed in a similar fashion.

	Estimate	SE
Phi:(Intercept)	2.9249	0.2204
Phi:cohort1998:firstyr	-2.5465	0.4062
Phi:cohort1999:firstyr	-3.4584	0.5006
Phi:cohort2000:firstyr	-2.7452	0.5149
Phi:cohort2001:firstyr	-4.0420	0.4031
Phi:cohort2002:firstyr	-2.5783	0.4362
Phi:cohort2003:firstyr	-2.3532	0.6385
Phi:cohort2004:firstyr	-3.3191	0.4842
Phi:cohort2005:firstyr	-3.7371	0.5835
Phi:cohort2006:firstyr	-3.9375	0.7739
Phi:cohort2007:firstyr	-4.0703	0.6509
Phi:firstyr:minimum tenure	0.0224	0.0046
p:1999	-0.1135	0.3119
p:2000	-0.3085	0.2576
p:2001	0.9053	0.2724
p:2002	-0.2451	0.2119
p:2003	0.2330	0.1937
p:2004	-0.1677	0.1910
p:2005	-0.0338	0.1829
p:2006	-0.0700	0.1924
p:2007	0.0427	0.2095
p:2008	0.4650	0.2531
p:minimum tenure in previous year	0.0185	0.0023

Table 3
PCFG (41-52N) abundance estimates and standard error, number recruited (immigrants + calves) and number of non-PCFG whales that entered the catalog each year.

Year	N	Std Error	Recruited	Non-PCFG
1998	104	4.6		19
1999	122	10.0	15	54
2000	146	10.5	29	21
2001	170	10.4	28	35
2002	198	7.7	31	26
2003	204	12.8	16	5
2004	206	11.9	13	19
2005	205	17.8	12	10
2006	188	15.6	1	7
2007	186	19.7	6	16
2008	194	17.0	18	30
Avg			17	22

Table 4
OR-SVI (42-49°N) abundance estimates, number recruited (immigrants + calves) and number of non-PCFG whales that entered the catalog each year.

Year	N	Std Error
1998	65	3.9
1999	78	8.8
2000	90	11.7
2001	113	8.0
2002	137	14.3
2003	153	13.1
2004	160	15.5
2005	162	15.9
2006	154	16.0
2007	153	16.1
2008	154	15.3

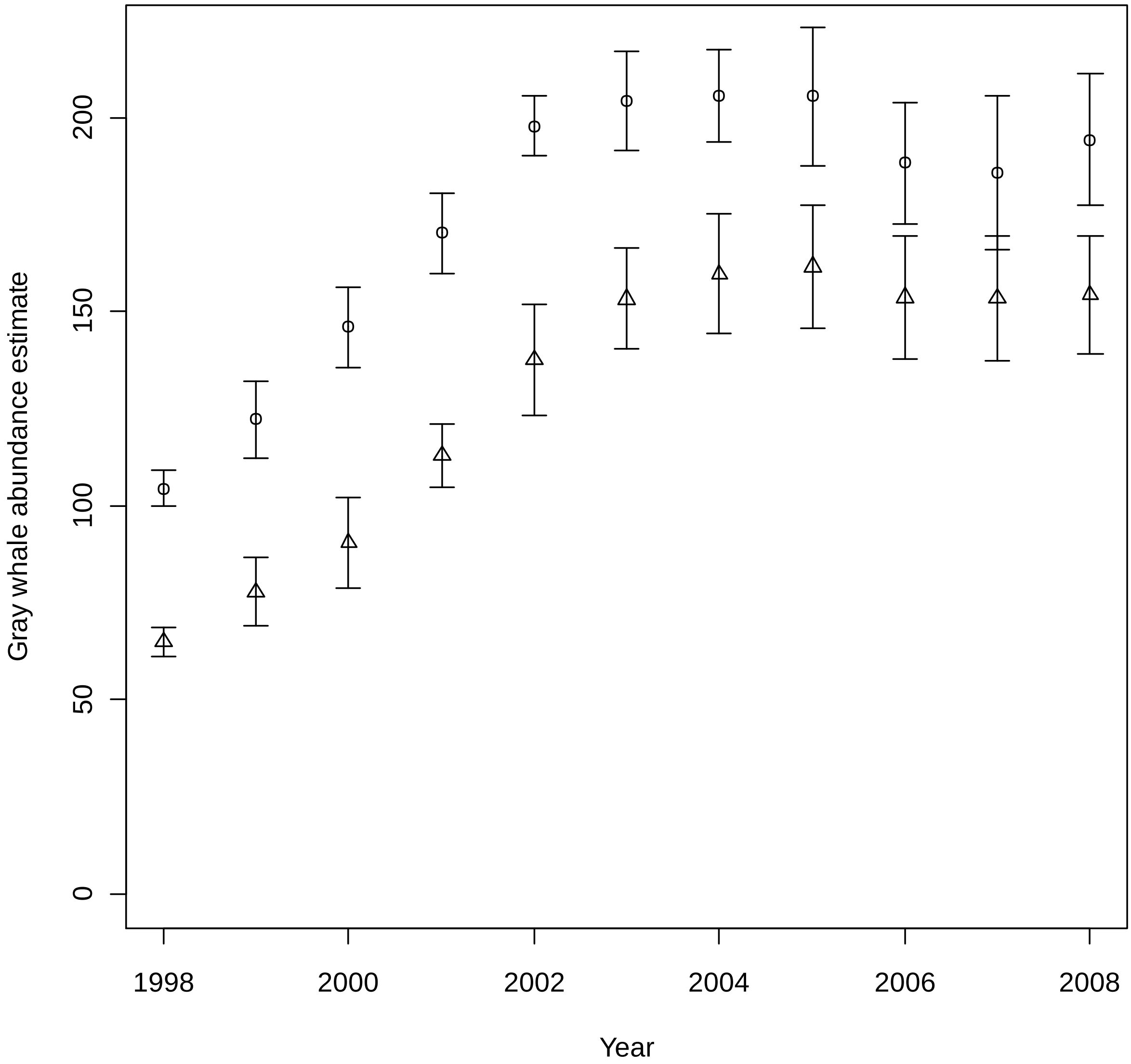

Fig. 1. Plot of PCFG (41-52°N) (circle) and OR-SVI (42-49°N) (triangle) abundance estimates from 1998-2008 with +/- 1 standard error bars.

Annex G, the Trial Specifications Annex will be made available separately

Annex G
Trials Specifications (to be read in conjunction with SC/63/AWMP4)

This document outlines a set of trials to evaluate the performance of *SLA*s for hunting in the Pacific Northwest, with a primary focus on the PCFG (Pacific Coast Feeding Group). The operating model assumes the two groups (the 'north' group and the PCFG) are separate stocks.

A. The population dynamics model

The underlying population dynamics model is deterministic, age- and sex-structured, and based on a two-stock version of the Baleen II model (Punt, 1999).

A.1 Basic dynamics

Equation A1.1 provides the underlying 1+ dynamics.

$$\begin{aligned}
R^{s,m/f}_{t+1,a+1} &= (R^{s,m/f}_{t,a} + I^{s,m/f}_{t,a} - C^{s,m/f}_{t,a})\,\tilde{S}^s_t\, S_a + U^{s,m/f}_{t,a}\,\tilde{S}^s_t\, S_a\,\delta_{a+1} && 0 \le a \le x-2 \\
R^{s,m/f}_{t+1,x} &= (R^{s,m/f}_{t,x} + I^{s,m/f}_{t,x} - C^{s,m/f}_{t,x})\,\tilde{S}^s_t\, S_x + (R^{s,m/f}_{t,x-1} + I^{s,m/f}_{t,x-1} - C^{s,m/f}_{t,x-1})\,\tilde{S}^s_t S_{x-1} && \\
U^{s,m/f}_{t+1,a+1} &= U^{s,m/f}_{t,a}\,\tilde{S}^s_t\, S_a\,(1-\delta_{a+1}) && 0 \le a \le x-2
\end{aligned} \tag{A1.1}$$

$R^{s,m/f}_{t,a}$ is the number of recruited males/females of age a in stock s at the start of year t;

$U^{s,m/f}_{t,a}$ is the number of unrecruited males/females of age a in stock s at the start of year t;

$C^{s,m/f}_{t,a}$ is the catch of males/females of age a from stock s during year t (whaling is assumed to take place in a pulse at the start of each year);

δ_a is the fraction of unrecruited animals of age a-1 which recruit at age a (assumed to be independent of sex and stock);

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):

$$S_a = \begin{cases} S_0 & \text{if } a = 0 \\ S_{1+} & \text{if } 1 < a \end{cases} \tag{A1.2}$$

S_0 is the calf survival rate;

S_{1+} is the survival rate for animals aged 1 and older;

$\tilde{S}^s_t$ is the amount of catastrophic mortality (represented in the form of a survival rate) for stock s during year t (catastrophic events are assumed to occur at the start of the year before mortality due to whaling and natural causes; in general $\tilde{S}^s_t$ =1, i.e. there is no catastrophic mortality);

$I^{s,m/f}_{t,a}$ is the net migration of female/male animals of age a into stock s 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 for these trials.

Catastrophic mortality is assumed to be zero (i.e., $\tilde{S}^s_t = 1$) except for the north stock for 1999 and 2000 when it is assumed to be equal to the parameter $\tilde{S}$. This assumption reflects the large number of dead ENP gray whales observed stranded along the coasts of Oregon and Washington during 1999 and 2000 relative to annual numbers stranding there historically (Gulland et al., 2005; Brownell et al., 2007). The mortality event is assumed to have only impact the north stock because the abundance estimates for the PCFG stock increased when the mortality event occurred in contrast to those for the north stock which declined substantially.

Immigration only occurs from the north stock to the PCFG stock and only animals aged 1+ immigrate. The annual number of animals immigrating is given by $I_t = \bar{I}\, N^{\text{north},1+}_t / 20000$ where $\bar{I}$ is the hypothesized recent average number of individuals recruiting into the PCFG from the north stock (i.e., 2, 4 or 6). The annual number of immigrants by age and sex is given by:

$$I_{t,a}^{s,m/f} = I_t \frac{N_{t,a}^{\text{north},m/\text{f}}}{\sum_{a=1}^{x}(N_{t,a}^{\text{north,m}} + N_{t,a}^{\text{north,f}})} \tag{A1.3}$$

A.2 Births

The number of births to stock *s* at the start of year *t*+1, B_{t+1}^{s}, is given by:

$$B_{t+1}^{s} = b_{t+1}^{s} N_{t+1}^{s,f} \tag{A2.1}$$

$N_t^{s,f}$ is the number of mature females in stock *s* at the start of year *t*:

$$N_t^{s,f} = \sum_{a=a_m}^{x} (R_{t,a}^{s,f} + U_{t,a}^{s,f}) \tag{A2.2}$$

a_{m} is the age-at-maturity (the convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition);

b_{t+1}^{s} is the probability of birth/calf survival for mature females:

$$b_{t+1}^{s} = b_{-\infty}\{1 + A^s(1-(D_{t+1}^{s}/D_{-\infty}^{s})^{z^s})\} \tag{A2.3}$$

$b_{-\infty}$ is the average number of live births per year per mature female in the pristine (pre-exploitation) population;

A^s is the resilience parameter for stock *s*;

z^s is the degree of compensation for stock *s*;

D_t^s is the size of the component of stock *s* in year *t* upon which the density-dependence is assumed to act; and

$D_{-\infty}^{s}$ is the pristine size of the component of stock *s* upon which the density-dependence is assumed to act.

The number of female births, $B_t^{s,f}$, is computed from the total number of the births during year *t* according to the equation:

$$B_t^{s,f} = 0.5\, B_t^{s} \tag{A2.4}$$

The numbers of recruited/unrecruited calves is given by:

$$\begin{aligned} R_t^{s,f} &= \pi_0\, B_t^{s,f} & R_t^{s,m} &= \pi_0\,(B_t^s - B_t^{s,f}) \\ U_t^{s,f} &= (1-\pi_0)\, B_t^{s,f} & U_t^{s,m} &= (1-\pi_0)(B_t^s - B_t^{s,f}) \end{aligned} \tag{A2.5}$$

π_0 is the proportion of animals of age 0 which are recruited (0 for these trials).

For the trials $D_t^s = N_t^{s,1+}$ and $D_{-\infty}^{s} = K^{s,1+}$ because density-dependence is assumed to act on the 1+ component of the population and affects fecundity and infant survival. $N_t^{s,1+}$ and $K^{s,1+}$ are defined according to the equations:

$$N_t^{s,1+} = \sum_{a=1}^{x}(R_{t,a}^{s,f} + U_{t,a}^{s,f} + R_{t,a}^{s,m} + U_{t,a}^{s,m}) \qquad K^{s,1+} = \sum_{a=1}^{x}(R_{-\infty,a}^{s,f} + U_{-\infty,a}^{s,f} + R_{-\infty,a}^{s,m} + U_{-\infty,a}^{s,m}) \tag{A2.6}$$

A.3 Catches

The historical (*t*<2010) catches by stratum (north, south, PCFG December – May, and PCFG June – November) are taken to be equal to the reported catches (Table 1). The historical catches are allocated to stocks in fixed proportions as follows:

(1) North area catches: all north animals;
(2) PCFG area catches in December – May: PCFG animals with probability ϕ_{PCFG} (base-case value 0.203, as determined by the photo-ID data);
(3) PCFG area catches in June – November: all PCFG animals; and
(4) South area catches: PCFG animals with probability ϕ_{south} (base-case value 0.01, as determined by relative abundance).

The future catches by stratum are incidental catches and the catches arising from application of the *SLA*s. Subsistence catches are only assumed to occur in the north and the PCFG area from December – May. The sex-ratio of future catches is assumed to be 50:50. The catches are allocated to stock as outlined above, except that the subsistence catches from the PCFG area in June – November are modelled individually. Thus, the catch from the PCFG area is allocated to the PCFG stock based on a Bernoulli trial with probability:

$$\frac{\sum_{m/f}\sum_{a'} R^{PCFG,m/f}_{y,a'}}{\delta\sum_{m/f}\sum_{a''} R^{north,m/f}_{y,a''} + \sum_{a''} R^{PCFG,m/f}_{y,a''}} \tag{A3.1}$$

where δ is the relative probability of harvesting a PCFG versus a north animal had the sizes of the two populations been the same. δ is calculated from ϕ under the assumption that the number of PCFG animals is 200 and north animals is 20000, i.e:

$$\delta = (200/\phi - 200)/20000 \tag{A3.2}$$

The incidental catches by stratum for the historical period are computed using the equation: [CHANGES HERE]

$$C^{I/s}_{y} = \begin{cases} 0.5\left\{p^I - \frac{p^I - 1}{69}[y-1999]\right\}\bar{C}^I & \text{if } y \le 1999 \\ \bar{C}^I & \text{otherwise} \end{cases} \tag{A3.3}$$

$C^{I/s}_{y}$ is the incidental catch of animals of sex *s* during year *y*;

$\bar{C}^I$ is the mean catch in the stratum (see Table 2).

The catches from the PCFG and north stocks are then allocated to age and size using the formula:

$$C^{s,m}_{t,a} = C^{s,m}_{t} R^{s,m}_{y,a} / \sum_{a''} R^{s,m}_{y,a''}; \quad C^{s,f}_{t,a} = C^{s,f}_{t} R^{s,f}_{y,a} / \sum_{a''} R^{s,f}_{y,a''}; \tag{A3.4}$$

The probability of not identifying a PCFG whale as such, is p_2, (base-case value 0) while the probability of incorrectly identifying a north whale as a PCFG whale is, p_1,(base-case 0.01). If the survey frequency is not annually, p_2 is defined as:

$$p_{2,t} = 1 - \frac{\sum_{a \ge SF} (R^{\mathrm{PCFG,m}}_{t,a} + R^{\mathrm{PCFG,f}}_{t,a} + U^{\mathrm{PCFG,m}}_{t,a} + U^{\mathrm{PCFG,f}}_{t,a})}{\sum_{a \ge 1} (R^{\mathrm{PCFG,m}}_{t,a} + R^{\mathrm{PCFG,f}}_{t,a} + U^{\mathrm{PCFG,m}}_{t,a} + U^{\mathrm{PCFG,f}}_{t,a})} \tag{A3.5}$$

where SF is the survey frequency for the PCFG area.

A.4 Recruitment

The proportion of animals of age *a* that would be recruited if the population was pristine is a knife-edged function of age at age 0, i.e.:

$$\pi_a = \begin{cases} 0 & \text{if } \; a = 0 \\ 1 & \text{otherwise} \end{cases} \tag{A4.1}$$

The (expected) number of unrecruited animals of age *a* that survive to age *a*+1 is $U^{s,m/f}_{t,a} S_a$. The fraction of these that then recruit is:

$$\delta_{a+1} = \begin{cases} [\pi_{a+1} - \pi_a]/[1-\pi_a] & \text{if } 0 \le \alpha_a < 1 \\ 1 & \text{otherwise} \end{cases} \tag{A4.2}$$

A.5 Maturity

Maturity is assumed to be a knife-edged function of age at age a_m.

A.6 Initialising the population vector

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

$$
\begin{aligned}
R^{s,m/f}_{-\infty,a} &= 0.5\;\; N^{s}_{-\infty,0}\;\; \pi_a \prod_{a'=0}^{a-1} S_{a'} && \text{if}\quad 0 \le a < x \\
U^{s,m/f}_{-\infty,a} &= 0.5\;\; N^{s}_{-\infty,0}\;\; (1-\pi_a) \prod_{a'=0}^{a-1} S_{a'} && \text{if}\quad 0 \le a < x \\
R^{s,m/f}_{-\infty,x} &= 0.5\;\; N^{s}_{-\infty,0} \prod_{a'=0}^{x-1} \frac{S_{a'}}{(1-S_x)} && \text{if}\quad a = x
\end{aligned}
\qquad \text{(A6.1)}
$$

$R^{s,m/f}_{-\infty,a}$ is the number of animals of age a that would be recruited in the pristine population;

$U^{s,m/f}_{-\infty,a}$ is the number of animals of age a that would be unrecruited in the pristine population; and

$N^{s}_{-\infty,0}$ is the total number of animals of age 0 in the pristine population.

The value for $N^{s}_{-\infty,0}$ is determined from the value for the pre-exploitation size of the 1+ component of the population using the equation:

$$
N^{s}_{-\infty,0} = K^{s,1+} \Big/ \left(\sum_{a=1}^{x-1} \left(\prod_{a'=0}^{a-1} S_{a'} \right) + \frac{1}{1-S_x} \prod_{a'=0}^{x-1} S_{a'} \right) \qquad \text{(A6.2)}
$$

It is well-known that it is not possible to make a simple density-dependent population dynamics model consistent with the abundance estimates for the eastern north Pacific stock of gray whales (Reilly, 1981; 1984; Cooke, 1986; Lankester and Beddington, 1986; Butterworth *et al.*, 2002). This is why recent assessments of this stock (e.g. Punt and Wade, in press) have been based on starting population projections from a more recent year (denoted as τ) than that in which the first recorded catch occurred. The trials are therefore based on the assumption that the age-structure at the start of τ=1930 is stable rather than that the population was at its pre-exploitation equilibrium size at the start of 1600, the first year for which catch estimates are available. The choice of 1930 for the first year of the simulation is motivated by the fact that the key assessment results are not sensitive to a choice for this year from 1930-1968 (Punt and Butterworth, 2002; Punt and Wade, in press). Note that even though the operating model ignores the catch data for 1600-1929, these catches are nevertheless provided to the *SLA* for the north area.

The determination of the age-structure at the start of 1930 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. Under the assumption of knife-edge recruitment to the fishery at age 1, only the γ^+ component (assumed to be zero following Punt and Butterworth, 2002) applies to ages a of age 0. The number of animals of age a at the start of τ =1930 relative to the number of calves at that time, $N^{s,*}_{\tau,a}$, is therefore given by the equation:

$$
N^{s,*}_{\tau,a} = \begin{cases} 1 & \text{if } a = 0 \\ N^{s,*}_{\tau,a-1}\, S_{a-1}(1-\gamma^+) & \text{if } a \le 1 \\ N^{s,*}_{\tau,a-1}\, S_{a-1}\,(1-\gamma^s) & \text{if } 1 < a < x \\ N^{s,*}_{\tau,x-1}\, S_{x-1}(1-\gamma^s)\,/\,(1-S_x\,(1-\gamma^s)) & \text{if } a = x \end{cases} \qquad \text{(A6.3)}
$$

B^{s}_{τ} is the number of calves in year τ (=1930) and is derived directly from equations A2.1 and A2.3 (for further details see Punt, 1999):

$$
B^{s}_{\tau} = \left(1 - \left[1/(N^{s,f}_{\tau} b_{-\infty}) - 1\right]/A^{s}\right)^{1/z^{s}} \frac{D^{s}_{-\infty}}{D^{s,*}_{\tau}} \qquad \text{(A6.4)}
$$

$D^{s,*}_{\tau}$ is the number of animals in the density dependent component of the population relative to the number of births at that time (see equation A2.6).

The effective rate of increase, γ, is selected so that if the population dynamics model is projected from 1930 to 1968, the size of the 1+ component of the population (both stocks) in 1968 equals a pre-specified value, P_{1968} .

A.7 z and A

A^s, z^s and S_0, are obtained by solving the system of equations that relate *MSYL*, *MSYR*, S_0, S_{1+}, f_{max} a_m, A^s and z^s, where f_{max} is the maximum theoretical pregnancy rate (Punt, 1999).

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+}, $\tilde{S}$, K_{1+}^N, K_{1+}^{PCFG} A^N, A^{PCFG}, z^N, and z^{PCFG}) is based on a Bayesian assessment of the eastern North Pacific stock of gray whales (Punt and Butterworth, 2002; Wade, 2002). The algorithm for conducting the Bayesian assessment is as follows:

(a) Draw values for the parameters S_{1+}, f_{max}, a_m, K_{1+}^N, K_{1+}^{PCFG}, P_{1968}^N, P_{1968}^{PCFG}, $\tilde{S}$, CV_{add}^N (the additional variance for the estimate of 1+ abundance Carmel, California in 1968), CV_{add}^{PCFG} (the additional variance for the estimate of 1+ abundance from North California to Southeast Alaska in 1968 – had such a survey taken place) from the priors in Table 3. 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.

(b) Solve the system of equations that relate $MSYL^s$, $MSYR^s$, S_0, S_{1+}, f_{max}, a_m, A^s and z^s to find values for S_0, A^s and z^s.

(c) Calculate the likelihood of the projection for each area, given by

$$-\ell nL = 0.5\ell n\,|\,\mathbf{V}+\Omega\,| + 0.5\sum_i\sum_j(\ell nN_i^{obs} - \ell n\hat{P}_i^{1+})[(\mathbf{V}+\Omega)^{-1}]_{i,j}(\ell nN_j^{obs} - \ell n\hat{P}_j^{1+}) \quad \text{(A8.1)}$$

N_i^{obs} is the i^{th} estimate of abundance[1] (Tables 4a, 4b),

$\hat{P}_i$ is the model-estimate corresponding to N_i^{obs},

$\mathbf{V}$ is the variance-covariance matrix for the abundance estimates, and

Ω is a diagonal matrix with elements given by $E(CV_{add,t}^2)$:

$$E(CV_{add,t}^2) = \eta(0.1+0.013P^*/\hat{P}_t) = CV_{add}^2\,\frac{0.1+0.013P^*/\hat{P}_t}{0.1+0.013P^*/\hat{P}_{1968}} \quad \text{(A8.2)}$$

(d) Steps (a) – (c) are repeated a large number (typically 1,000,000) of times.

(e) 100 sets of parameters vectors are selected randomly from those generated using steps (a) – (c), assigning a probability of selecting a particular vector proportional to its likelihood. The number of times steps (a) – (c) are repeated is chosen to ensure that each of the 100 parameter vectors are unique.

The expected value for the estimate of abundance of the north area is taken to the total abundance (PCFG and north stocks combined) while the abundance estimates for the PCFG area are assumed to pertain to the PCFG stock.

B. Data generation

B.1 Absolute Abundance Estimates

The historic (t<2010) abundance estimates (and their CVs) are provided to the *SLA* and are taken to be those in Tables 4a, 4c. Future estimates of absolute abundance (and their estimated CVs) are generated and provided to the *SLA* once every F years during the management period (starting in year 2011 where F=10 for the northern area and F=1 for the PCFG area). The CV of the abundance estimate (CV_{true}) may be different from the CV provided to the *SLA* (further details are provided below).

The survey estimate, $\hat{S}$, may be written as:

$$\hat{S} = B_A PY\,w/\mu = B_A\,P^*\,\beta^2\,Y\,w \quad \text{(B1.1)}$$

B_A is the bias (the bias for the bulk of the simulations for the north area is 1 while the bias for PCFG area is generated from $\ell nB_A \sim N(-0.335, 0.112)$ – this bias reflects the difference between the abundance estimates on which the ABL is based [which pertain to Oregon to Southern Vancouver Island] and the abundance of the entire stock];

P is the current total 1+ population size ($= N_t^{1+}$); (B1.2)

Y is a lognormal random variable: $Y = e^\phi$ where: $\phi \sim N[0;\sigma_\phi^2]$ and $\sigma_\phi^2 = \ell n(1+\alpha^2)$ (B1.3)

[1] The shore-based abundance estimate for year y/y+1 is assumed to pertain to abundance at the start of year y+1.

w	is a Poisson random variable, independent of Y, with $E(w) = \text{var}(w) = \mu = (P / P^*) / \beta^2$; and	(B1.4)
P^*	is the reference population level (the pristine 1+ population, $= K^{1+}$).	

Note that under the approximation $CV^2(ab) = CV^2(a) + CV^2(b)$,

$$E(\hat{S}) = B_A P_t \text{ and } CV^2_{true}(\hat{S}) = \alpha^2 + \beta^2 P^* / P \quad \text{(B1.5)}$$

[2]The steps used in the program to generate the abundance estimates and their CVs are given below.

The *SLA* is provided with estimates of CV_{est} (the estimation error associated with factors considered historically) for each future sightings estimate.

The estimate of $CV_{est,t}$ is given by:

$$\hat{C}V_{est,t} = \sqrt{\sigma_t^2 (\chi_n^2 / n)} \qquad \sigma_t^2 = \ell n(1 + E(CV^2_{est,t})) \quad \text{(B1.6)}$$

$E(CV^2_{est,t})$ is the sum of the squares of the actual CVs due to estimation error:

$$E(CV^2_{est,t}) = \theta^2 (a^2 + b^2 / w\beta^2) \quad \text{(B1.7)}$$

χ_n^2	is a random number from a χ^2 distribution with n (=19; the value assumed for the single stock trials for the RMP) degrees of freedom;
a^2, b^2	are constants and equal to 0.02 and 0.012 respectively;

The relationship between CV_{est} and CV_{true} is given by:

$$\eta = [E(CV^2_{true}) - E(CV^2_{est})] / (0.1 + 0.013 P^* / P) \quad \text{(B1.8a)}$$

where η is a constant known as the additional variance factor. The value of η is based on the population size and CVs for 1968 (for consistency with the way the CV for P_{1968} is generated in Table 3):

$$\eta = CV^2_{add} / (0.1 + 0.013 P^* / P_{1968}) \quad \text{(B1.8b)}$$

The values of α and β are then computed as:

$$\alpha^2 = \theta^2 a^2 + \eta\, 0.1 , \qquad \beta^2 = \theta^2 b^2 + \eta\, 0.013 \quad \text{(B1.9)}$$

C. Need

The level of need in each year, Q_t , will be supplied to the *SLA*. The need is given by $Q_t = Q_{2010} + \frac{t - 2010}{100}(Q_{2110} - Q_{2010})$ where Q_{2010} (=150/7 for the north and PCFG areas respectively) is the need at the start of the first year in which the AWMP is applied and Q_{2110} is the value 100 years later. The level of need supplied

D. Implementing the Makah harvest regime

Thus, the overall application of the Makah management regime is as follows:

(1) Compute the ABL (Allowable bycatch limit of PCFG whales)
(2) Strike an animal
(3) If the animal is struck-and lost in December-April[3]:

---

[2] The steps used to generate estimates of abundance and their CVs are as follows (steps i) – iii) are part of the conditioning process).

(i) Read in CV_{est} (basecase value= 0.075 = value used to generate the 1968 abundance). Generate values of CV^2_{add} for 1968.

(ii) Set η using equation B1.8b and the value of CV_{add} generated in step i).

(iii) Set θ^2 using equation B1.7a and the values for CV_{est} from step (i) and $w\beta^2 = P / P^* = P_{1968} / P^*$. Set α^2 and β^2 using equation B1.9.

(iv) Generate w (Poisson random variable – see equation B1.4) and ϕ (lognormal random variable – see equation B1.3).

(v) Set abundance estimate $\hat{S}$ using equation B1.1.

(vi) Set $E(CV^2_{est,t})$ using eqn B1.7a.

(vii) Generate $\hat{C}V_{est,t}$ from a χ_n^2 distribution using equation B1.6a.

[3] Whether a whale is struck and lost is determined from a Bernoulli trial with probability 0.5 (base-case).

a. If the total number of struck and lost animals is 3, stop the hunt.
b. If the total number of struck animals equals the need of 7 stop the hunt.
c. Go to step (2).

(4) If the animal is struck-and lost in May:
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 struck and lost animals is 3, stop the hunt.
d. If the total number of struck animals equals the need of 7; stop the hunt.
e. Go to step (2).

(5) If the animal is landed and is matched against the catalogue[4]:
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 total number of struck animals equals the need of 7; stop the hunt.
e. If the number of landed whales for the current five-year block equals 20; stop the hunt
f. Go to step (2).

(6) If the animal is landed and does not match any whale in the catalogue:
a. If the total number of landed whales equals 5; stop the hunt
b. If the total number of struck animals equals the need of 7; stop the hunt.
c. If the number of landed whales for the current five-year block equals 20; stop the hunt
d. Go to step (2).

E. Statistics

The risk- and recovery-related performance statistics are computed for the mature female and for the total (1+) population sizes (i.e. P_t is either the size of the mature female component of the population, N_t^f, or the size of the total (1+) population, N_t^{1+}). P_t^* is the population size in year t under a scenario of zero strikes in the northern and PCFG area (but allowing for incidental catches) over the years $t \geq 2010$ (defined as t=0 below), P_t^{**} is the population size in year t under a scenario of zero strikes in the PCFG area (but allowing for incidental catches and strikes in the north area) over the years $t \geq 2010$ (defined as t=0 below), and K_t^* is the population size in year t if there had never been any harvest.

The trials are based on a 100-year time horizon, but a final decision regarding the time horizon will depend inter alia on interactions between the Committee and the Commission regarding need envelopes and on the period over which recovery might occur. To allow for this, results are calculated for T=20 and 100.

Statistics marked in bold face have previously been considered the more important. Note that the statistic identification numbers have not been altered for reasons of consistency. Hence, there are gaps in the numbers where some statistics have been deleted.

E.1 Risk

D1. Final depletion: P_T / K. In trials with varying K this statistic is defined as P_T / K_t^*.

D2. Lowest depletion: $\min(P_t / K): t = 0,1,...,T$. In trials with varying K this statistic is defined as $\min(P_t / K_t^*):\ t = 0,1,...,T$.

D6. Plots for simulations 1-100 of $\{P_t : t = 0,1,..,T\}$, $\{P_t^* : t = 0,1,..,T\}$, $\{P_t^{**} : t = 0,1,..,T\}$

D7. Plots of $\{P_{t[x]} : t = 0,1,..,T\}$ $\{P_{t[x]}^* : t = 0,1,..,T\}$ and $\{P_{t[x]}^{**} : t = 0,1,..,T\}$ where $P_{t[x]}$ is the xth percentile of the distribution of P_t. Results are presented for x = 5 and x = 50.

D8. Rescaled final population: P_T / P_T^* and P_T / P_T^{**}

D9. Minimum population level in terms of mature females, $\min(P_t):\ t = 0,1,...,T$

D10. Relative increase P_T / P_0

E.2 Need (for PCFG, statistics N1- N12 will be computed for the total number of strikes as well as the number of landed animals)

N1. Total need satisfaction: $\sum_{t=0}^{T-1} C_t / \sum_{t=0}^{T-1} Q_t$

N2. Length of shortfall = (negative of the greatest number of consecutive years in which $C_t < Q_t$) / T

[4] PCFG whales are mismatched as north stock whales with probability p_1 while north stock whales are matched to the catalogue with probability p_2.

N4. Fraction of years in which $C_t = Q_t$

N5. Proportion of block need satisfaction: $\Gamma/(T-h+1)$ where Γ is the number of blocks of h years in which the total catch equals the total need; h is 5 for these trials.

N7. Plot of $\{V_{t[x]} : t = 0,1,T-1\}$ where $V_{t[x]}$ is the xth percentile of the distribution of $V_t = C_t / Q_t$ [catch for the PCFG area]

N8. Plots of V_t for simulations 1-100.

N9. Average need satisfaction: $\frac{1}{T}\sum_{t=0}^{T-1}\frac{C_t}{Q_t}$

N10. AAV (Average Annual Variation): $\sum_{t=-1}^{T-2}|C_{t+1} - C_t| / \sum_{t=-1}^{T-2} C_t$

N11. Anti-curvature: $\frac{1}{T-1}\sum_{t=0}^{T-2}\left|\frac{C_t - M_t}{\max(10, M_t)}\right|$ where $M_t = (C_{t+1} + C_{t-1})/2$

N12. Mean downstep (or modified AAV): $\sum_{t=-1}^{T-2}\left|\min(C_{t+1} - C_t, 0)\right| / \sum_{t=-1}^{T-2} C_t$

N13. Average annual number of animals landed

N14. Average annual number of animals struck and lost.

N15. Ray Plot. For each simulation, make a line plot of cumulative absolute year-to-year quota changes versus time (x-axis). Superimpose all these rays.

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Table 1
Historical catches of eastern north Pacific gray whales

Year	South			PCFG Jun-Nov			PCFG Dec-May			North			Total		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
1930	0	0	0	0	0	0	0	0	0	23	24	47	23	24	47
1931	0	0	0	0	0	0	0	0	0	5	5	10	5	5	10
1932	5	5	10	0	0	0	0	0	0	5	5	10	10	10	20
1933	30	30	60	0	0	0	0	0	0	8	7	15	38	37	75
1934	30	30	60	0	0	0	0	0	0	36	30	66	66	60	126
1935	55	55	110	0	0	0	0	0	0	16	28	44	71	83	154
1936	43	43	86	0	0	0	0	0	0	50	62	112	93	105	198
1937	0	0	0	0	0	0	0	0	0	12	12	24	12	12	24
1938	0	0	0	0	0	0	0	0	0	32	32	64	32	32	64
1939	0	0	0	0	0	0	0	0	0	19	20	39	19	20	39
1940	0	0	0	0	0	0	0	0	0	56	69	125	56	69	125
1941	0	0	0	0	0	0	0	0	0	38	39	77	38	39	77
1942	0	0	0	0	0	0	0	0	0	60	61	121	60	61	121
1943	0	0	0	0	0	0	0	0	0	59	60	119	59	60	119
1944	0	0	0	0	0	0	0	0	0	3	3	6	3	3	6
1945	0	0	0	0	0	0	0	0	0	25	33	58	25	33	58
1946	0	0	0	0	0	0	0	0	0	14	16	30	14	16	30
1947	0	0	0	0	0	0	0	0	0	11	20	31	11	20	31
1948	0	0	0	0	0	0	0	0	0	7	12	19	7	12	19
1949	0	0	0	0	0	0	0	0	0	10	16	26	10	16	26
1950	0	0	0	0	0	0	0	0	0	4	7	11	4	7	11
1951	0	0	0	0	0	0	1	0	1	5	8	13	6	8	14
1952	0	0	0	0	0	0	0	0	0	17	27	44	17	27	44
1953	0	0	0	0	0	0	6	4	10	15	23	38	21	27	48
1954	0	0	0	0	0	0	0	0	0	14	25	39	14	25	39
1955	0	0	0	0	0	0	0	0	0	22	37	59	22	37	59
1956	0	0	0	0	0	0	0	0	0	45	77	122	45	77	122
1957	0	0	0	0	0	0	0	0	0	36	60	96	36	60	96
1958	0	0	0	0	0	0	0	0	0	55	93	148	55	93	148
1959	1	1	2	0	0	0	0	0	0	73	121	194	74	122	196
1960	0	0	0	0	0	0	0	0	0	58	98	156	58	98	156
1961	0	0	0	0	0	0	0	0	0	77	131	208	77	131	208
1962	4	0	4	0	0	0	0	0	0	55	92	147	59	92	151
1963	0	0	0	0	0	0	0	0	0	68	112	180	68	112	180
1964	15	5	20	0	0	0	0	0	0	75	124	199	90	129	219
1965	0	0	0	0	0	0	0	0	0	71	110	181	71	110	181
1966	15	11	26	0	0	0	0	0	0	80	114	194	95	125	220
1967	52	73	125	0	0	0	0	0	0	109	140	249	161	213	374
1968	41	25	66	0	0	0	0	0	0	48	87	135	89	112	201
1969	39	35	74	0	0	0	0	0	0	50	90	140	89	125	214
1970	0	0	0	0	0	0	0	0	0	71	80	151	71	80	151
1971	0	0	0	0	0	0	0	0	0	57	96	153	57	96	153
1972	0	0	0	0	0	0	0	0	0	61	121	182	61	121	182
1973	0	0	0	0	0	0	0	0	0	97	81	178	97	81	178
1974	0	0	0	0	0	0	0	0	0	94	90	184	94	90	184
1975	0	0	0	0	0	0	0	0	0	58	113	171	58	113	171
1976	0	0	0	0	0	0	0	0	0	69	96	165	69	96	165
1977	0	0	0	0	0	0	0	0	0	87	100	187	87	100	187
1978	0	0	0	0	0	0	0	0	0	94	90	184	94	90	184
1979	0	0	0	0	0	0	0	0	0	58	125	183	58	125	183
1980	0	0	0	0	0	0	0	0	0	53	129	182	53	129	182
1981	0	0	0	0	0	0	0	0	0	36	100	136	36	100	136
1982	0	0	0	0	0	0	0	0	0	57	111	168	57	111	168
1983	0	0	0	0	0	0	0	0	0	46	125	171	46	125	171
1984	0	0	0	0	0	0	0	0	0	59	110	169	59	110	169
1985	0	0	0	0	0	0	0	0	0	54	116	170	54	116	170
1986	0	0	0	0	0	0	0	0	0	46	125	171	46	125	171
1987	0	0	0	0	0	0	0	0	0	48	111	159	48	111	159
1988	0	0	0	0	0	0	0	0	0	43	108	151	43	108	151
1989	0	0	0	0	0	0	0	0	0	61	119	180	61	119	180
1990	0	0	0	0	0	0	0	0	0	67	95	162	67	95	162
1991	0	0	0	0	0	0	0	0	0	67	102	169	67	102	169
1992	0	0	0	0	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	0
1994	0	0	0	0	0	0	0	0	0	21	23	44	21	23	44
1995	0	0	0	0	0	0	0	0	0	48	44	92	48	44	92

Year	South			PCFG Jun-Nov			PCFG Dec-May			North			Total		
	M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
1996	0	0	0	0	0	0	0	0	0	18	25	43	18	25	43
1997	0	0	0	0	0	0	0	0	0	48	31	79	48	31	79
1998	0	0	0	0	0	0	0	0	0	64	61	125	64	61	125
1999	0	0	0	0	0	0	0	1	1	69	54	123	69	55	124
2000	0	0	0	0	0	0	0	0	0	63	52	115	63	52	115
2001	0	0	0	0	0	0	0	0	0	62	50	112	62	50	112
2002	0	0	0	0	0	0	0	0	0	80	51	131	80	51	131
2003	0	0	0	0	0	0	0	0	0	71	57	128	71	57	128
2004	0	0	0	0	0	0	0	0	0	43	68	111	43	68	111
2005	0	0	0	0	0	0	0	0	0	49	75	124	49	75	124
2006	0	0	0	0	0	0	0	0	0	57	77	134	57	77	134
2007	0	0	0	0	1	1	0	0	0	50	81	131	50	82	132
2008	0	0	0	0	0	0	0	0	0	64	66	130	64	66	130
2009	0	0	0	0	0	0	0	0	0	59	57	116	59	57	116
Total	**330**	**313**	**643**	**0**	**1**	**1**	**7**	**5**	**12**	**3,715**	**5,345**	**9,060**	**4,052**	**5,664**	**9,716**

Table 2
Average historical incidental catches

Stratum	Average incidental catch
North	0[1]
PCFG [Dec – May]	2
PCFG [Jun – Nov]	1.4[2]
South	3.4

1 – obviously not actually zero, but will be small relative to population size
2 – includes southern whales during June – November as these whales are almost certainly PCFG animals

Table 3
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[6, 12]
K_{1+}^{N}	U[16,000, 70,000]
K_{1+}^{PCFG}	U[100, 500]
Maximum pregnancy rate, f_{max}	U[0.3, 0.6]
Additional variation (population estimates), CV_{add}, in 1968	U[0, 0.35]
1968 abundance, P_{1968}^{N}	U[8,000, 16,000]
1968 abundance, P_{1968}^{PCFG}	U[50, 300]
Catastrophic mortality	U[0.2,1.0]

Table 4a Estimates of absolute abundance (with associated standard errors) for the eastern north Pacific stock of gray whales based on shore counts (source: Laake *et al*, 2010).

Year	Estimate	CV	Year	Estimate	CV
1967/68	13426	0.094	1979/80	19763	0.083
1968/69	14548	0.080	1984/85	23499	0.089
1969/70	14553	0.083	1985/86	22921	0.081
1970/71	12771	0.081	1987/88	26916	0.058
1971/72	11079	0.092	1992/93	15762	0.067
1972/73	17365	0.079	1993/94	20103	0.055
1973/74	17375	0.082	1995/96	20944	0.061
1974/75	15290	0.084	1997/98	21135	0.068
1975/76	17564	0.086	2000/01	16369	0.061
1976/77	18377	0.080	2001/02	16033	0.069
1977/78	19538	0.088	2006/07	19126	0.071
1978/79	15384	0.080			

Table 4b Estimates of absolute abundance (with associated standard errors) for 41^0-52^0N (source: J. Laake, pers. commn).

Year	Estimate	CV	Year	Estimate	CV
1998	104	0.044	2004	206	0.058
1999	122	0.082	2005	205	0.087
2000	146	0.072	2006	188	0.083
2001	170	0.061	2007	186	0.106
2002	198	0.039	2008	194	0.087
2003	204	0.063			

Table 4c Estimates of absolute abundance (with associated standard errors) for the Oregon to Southern Vancouver Island (source: J. Laake, pers. commn).

Year	Estimate	CV	Year	Estimate	CV
1998	65	0.061	2004	160	0.097
1999	78	0.113	2005	162	0.098
2000	90	0.130	2006	154	0.104
2001	113	0.071	2007	153	0.105
2002	137	0.104	2008	154	0.099
2003	153	0.085			