Report of the Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales

Contents

The Workshop was held at the Southwest Fisheries Science Center, La Jolla California from 8-11 April 2014. The list of participants is given as Annex A.

1. **INTRODUCTORY ITEMS**

1.1 Convenor's opening remarks

Donovan and Punt (co-convenors) welcomed the participants. In particular they thanked the Southwest Fisheries Science Center for hosting the Workshop at its excellent facilities and in particular Dave Weller for co-ordinating the logistics. The objectives of the Workshop were to:

(1) review available information (especially new telemetry, genetics and photo-ID data) and reappraise the population structure and movements of North Pacific gray whales with a focus on examining status;

(2) develop a modelling framework to better assess the status of gray whales and the potential impact of human activities and possible changes in regime or climate – if possible such that some initial runs may be available for the 2014 Annual Meeting of the Scientific Committee.

(3) provide information for updating the IUCN/IWC Conservation Management Plan for western gray whales and develop a mechanism for updating the plan.

1.2 Election of Chair

Donovan was elected chair.

1.3 Appointment of rapporteurs

Reeves co-ordinated production of the report assisted by Donovan, Cooke, Moore, Lang, Weller, Punt and Bradford.

1.4 Adoption of Agenda

The adopted Agenda is provided as Annex B.

1.5 Documents and data available

The list of documents is available as Annex C.

2. SUMMARY OF POPULATION MODELLING APPROACHES THAT HAVE BEEN OR MAY BE RELEVANT FOR NORTH PACIFIC GRAY WHALES

2.1 AWMP (including Pacific Coast Feeding Group or PCFG)

The AWMP trial approach has since 2011 included consideration of the Chukotkan hunt and the potential hunt by the Makah tribe off Washington State (IWC, 2012). The trials considered two plausible 'stocks': 'PCFG' and 'north'. PCFG whales are defined as gray whales observed (i.e. photographed) in multiple years between 1 June and 30 November in the PCFG area (IWC, 2011, p.22). Not all whales seen within the PCFG area (the precise boundaries are somewhat arbitrary as discussed in IWC (2011) at this time will be PCFG whales and some PCFG whales will be found outside of the PCFG area at various times during the year. The geographic regions considered were:

(1) the 'north' area (north of 52°N, i.e. roughly northern Vancouver Island);

(2) the 'PCFG' area (between 41°N and 52°N with the exception of Puget Sound); and

(3) the 'south' area (south of 41°N).

The trials used to evaluate candidate *Strike Limit Algorithms* (*SLA*s) for the PCFG are based on operating models that include the 'north' and PCFG 'stocks', each of which is represented using age- and sex-structured population dynamics models (IWC, 2013). Allowance is made for immigration and emigration between the 'north' group and the PCFG group. The operating model allows for catastrophic mortality in 1999 and 2000 from the 'north' group given the large numbers of gray whales observed stranded along the coasts of Oregon and Washington in those years (Gulland *et al.*, 2005; Brownell *et al.*, 2007). A variety of levels for the annual rate of immigration from the 'north' to the PCFG was considered, along with the possibility of an immigration pulse into the PCFG in 1999 and 2000.

The catches accounted for in the operating model include aboriginal subsistence catches as well as incidental removals. The operating model allocated the catches to four types: (a) catches north of the PCFG area, (b) catches in the PCFG area during December to May, (c) catches in the PCFG area during June – November, and (d) catches south of the PCFG area. All of the catches north of the PCFG area were assumed to be 'north' group whales, the catches from the PCFG area during June – November were all assumed to the PCFG group whales, and the other two types of catches were assumed to be from both stocks.

The values for the parameters of the operating model were estimated using Bayesian methods. Uniform priors were placed on the parameters on the model based on data for the eastern North Pacific stock of gray whales. The data used when fitting the model were the shore-based counts at Granite Point and Yankee Point (Laake *et al.*, 2012) and estimates of abundance based on mark-recapture data (Calambokidis *et al*., 2012; IWC, 2013). It is well-known that it is impossible to develop a model of the eastern North Pacific gray whales which assumes that carrying capacity has been unchanged since the start of commercial whaling, and nevertheless fits the available abundance estimates (Butterworth *et al.*, 2002). Consequently, in terms of providing management advice for present whaling operations, the model projections are initiated in 1930 with the age-structure of a depleted population (IWC, 2013).

The process adopted for developing operating models for commercial whaling (IWC, 2005) and aboriginal subsistence whaling aims to identify a range of uncertainties, including those associated with stock structure, such that future information should reduce rather than increase the range. Consequently, the range of uncertainties considered during trials development should be inclusive. This process has been applied to the western North Pacific minke whales (IWC, in press), the western North Pacific Bryde's whales (IWC, 2008) and the North Atlantic fin whales (IWC, 2009), as well as for eastern gray whales and bowhead whales under the AWMP. Under the RMP, the trials based on the hypotheses developed to encompass the uncertainties are assigned plausibility ranks, and only trials which are not considered 'low plausibility' are used when selecting 'variants' (IWC, 2005). In addition to stock structure hypotheses, the trials include hypotheses related to productivity, to changes over time in carrying capacity and natural mortality, to time-trends in survey bias, and to the quality and quantity of data on which future management advice might be based.

2.2 Western North Pacific (Cooke model)

Cooke summarised the population modelling approach used for assessment of western North Pacific gray whales since 2004. The model has been applied to the group of whales studied on a summer feeding ground off Sakhalin Island. Photo-id data, supplemented with sex determinations from biopsies, collected under the Russia-US programme since 1994 were used to inform the model. The latest assessment was presented in SC/65a/BRG27 (using data through the 2011 season), where details of the model are to be found (see Item 5.1.1.1 for a summary of results).

The population model is stage-structured. The stages include: calves; each of the immature age classes by sex; mature males; and three stages of mature females: pregnant, lactating and resting. The minimum observed time between calvings is two years: the model allows zero or more additional resting years so that calving intervals of three or more years are also possible. The model is individual-based, so that it can be fitted to individual photo-id capture histories. A "capture" in this case means that a whale was photo-identified in a given year as either: (i) a mother with a calf; (ii) a calf with its mother; (iii) a calf on its own; or (iv) any other whale. These were the only categories of animal that were considered to be distinguishable with close to 100% reliability in the field.

The transition probabilities between stages are assumed to depend on various combinations of parameters to be estimated. The transition probabilities can vary between years and between individuals. Availability (sighting probability) can vary between years, stages and individuals. Variations between individuals are modelled by allowing individuals to have additional attributes, and stages in the model are replaced by stage-attribute combinations. Model selection using the AIC criterion is used to determine which parameters are allowed to vary over time.

The results of greatest potential ecological interest are the annual variations in population parameters. The analyses presented in SC/65a/BRG27 found strong indication of inter-annual variability in both calf (post-weaning) survival rates and calving intervals. The variations in these two parameters were significantly correlated with each other subject to a 2-year time lag.

The variations in parameters and the time lags between them potentially provide insights into the impact of external factors on the life cycle. For example, correlations have been identified using a similar model for South Atlantic right whales (Leaper *et al.*, 2006): between right whale calving intervals and environmental variables such as the ENSO (El Niño Southern Oscillation), water temperatures in the South Georgia feeding ground, and reproductive success of other species (fur seals, gentoo penguins) feeding in the same area.

Work is in progress to identify the ecological and climatic variables most strongly correlated with the demographic changes observed in Sakhalin gray whales. Understanding the ecological factors affecting the demography can also provide important background information when interpreting data on the possible impacts of anthropogenic factors such as acoustic disturbance on the feeding ground.

The main reason for using an individual-based model is not that the individual processes are necessarily the focus of interest, but that the longitudinal individual data from photo-id have been found to be extremely informative with respect to population parameters and their variations. In order to make maximal use of these data to draw inferences on population parameters, an individual-based model is required.

An application of the model that also uses data collected from eastern Kamchatka is contained in the latest report of the Western Gray Whale Advisory Panel[1] (iucn.org/wgwap/wgwap/meetings/wgwap_13). Those results were obtained by simply merging the available data sets as if they were from a single study. It is recognised that this is probably not a valid approach, and that it would be desirable, when using data from more than one location, for the model to take account of differences between locations. In the case of Kamchatka and Sakhalin, for example, there may be differences in the relative availability of the different population stages (for example, adults versus subadults). Furthermore, the observations off Kamchatka may include whales that do not “belong” to the group of whales summering off Sakhalin Island.

Work is in progress to extend the model to allow location-specific differences in the relative availability of the different population stages, and to allow data from locations where not all animals necessarily belong to the population of interest.

The Workshop **welcomes** this information and **strongly encourages** the continued development of the approach. It **reiterates** the importance of careful incorporation of all relevant data from Sakhalin and Kamchatka into the model (e.g. IWC, 2013).

3. STOCK STRUCTURE AND MOVEMENTS

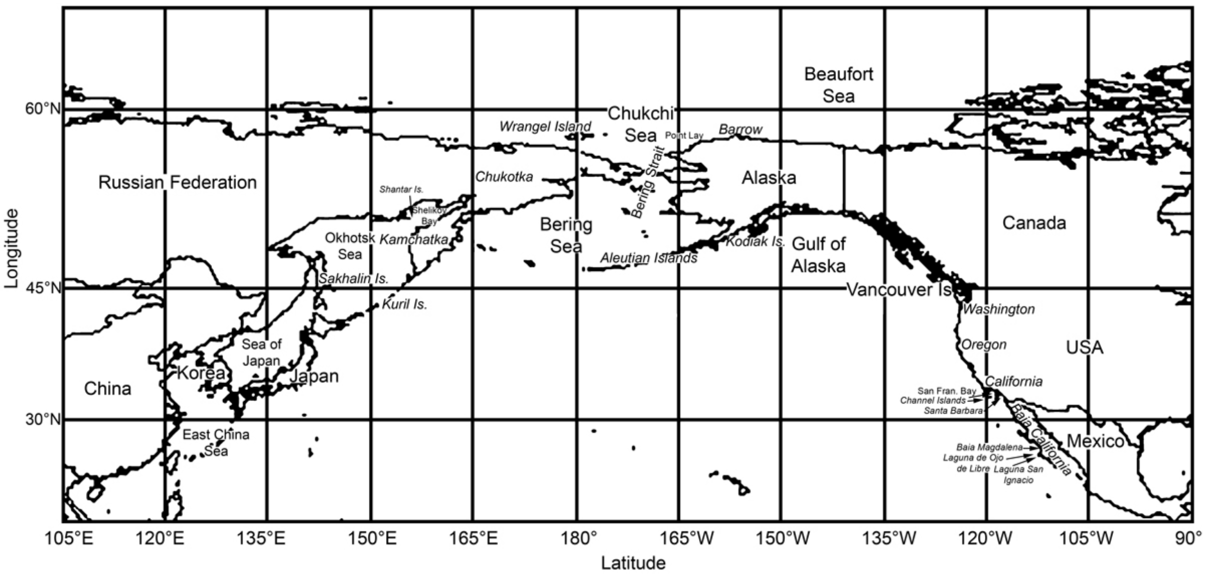

Fig. 1. Map of the North Pacific showing place names in the text.

3.1 Summary of existing hypotheses

Until recently, it was generally believed that there were two separate gray whale stocks in the North Pacific. According to that paradigm, the ‘eastern’ stock winters in Mexican waters, migrates along the North American coast and feeds during the summer and autumn in Arctic waters of Russia (primarily Chukotka) and the USA. This stock is considered to have recovered to around its pre-exploitation level (~20,000 individuals). The greatly depleted ‘western’ stock is considered to feed mainly in waters off Sakhalin Island, migrate along the coasts of Japan and possibly Korea and winter somewhere in the South China Sea (see Fig. 2 for a simple schematic). The AWMP *Implementation* for gray whales which evaluated and agreed the *Gray Whale SLA* (strike limit algorithm) agreed to a single eastern stock (IWC, 2001)

However, during the AWMP *Implementation Review* of eastern North Pacific gray whales in 2010 (IWC, 2011), which examined the subsistence hunts of gray whales off Chukotka and potentially Washington State, the

[1] www.iucn.org/wgwap/wgwap/meetings/wgwap_13

Scientific Committee agreed that there was sufficient evidence to consider the Pacific Coast Feeding Group (PCFG) of gray whales separately for management purposes related to the proposed Makah hunt and this evaluation was completed in 2012 (IWC, 2013), as defined above under Item 2.1.

In an effort to obtain more information about the southern migration route(s) and wintering area(s) of gray whales in the western North Pacific (WNP), a satellite telemetry project was undertaken in 2010 and 2011 by a team of Russian and American scientists (Mate *et al.* 2011). While the objective of the study was to document gray whale movements within the WNP, the three whales tracked for more than a few weeks travelled from the Sakhalin feeding area to the eastern North Pacific (ENP) (see Item 3.2.4).

Lang summarized the stock structure hypotheses put forward at the last IWC Scientific Committee meeting (IWC/65A/Rep 1 Annex I). These hypotheses are focused on the stock identity of the whales that feed off Sakhalin, and they did not address possible stock structure among whales considered part of the eastern North Pacific (ENP) stock. It was suggested that these existing hypotheses should be modified to include Kamchatka, as some data are available from this area. The addition of a model that incorporates multiple migratory routes in the western North Pacific was also proposed.

Fig.2. Schematic of the suspected distribution of what were thought to be two distinct populations of gray whales with little overlap (see text)

3.2 Review of available data and analyses

3.2.1 Genetic data on population structure

A small working group, consisting of Lang, Bickham and Urbán, was formed to summarize the available genetic data and analyses by region. A short summary is included as Table 1 and a full summary in Annex D.

Lang reviewed the results of previous genetic studies of gray whales that were relevant to stock structure. Recent studies investigating whether structure exists among feeding grounds used by ENP gray whales have found significant differences in mtDNA haplotype frequencies when PCFG whales were compared with whales sampled in other regions of the ENP stock's range (PCFG v. Bering and Chukchi Seas, Lang *et al.*, 2014; PCFG v. ENP migratory route, Frasier *et al.* 2011). No significant differences were detected when comparing microsatellite allele frequencies between the PCFG and whales sampled in the Mexican wintering lagoons (D'Intino et al. 2012) or between the PCFG and whales sampled in the Bering and Chukchi Seas (Lang et al. 2014). Structure on the ENP wintering grounds has also been investigated, with small but significant differences in mtDNA haplotype frequencies identified between cows (females with calves) sampled in two of the primary calving lagoons in Mexico and females sampled in other areas (Goerlitz *et al.,* 2003). A subsequent study by Alter *et al.* (2009), however, did not detect significant levels of mtDNA differentiation when comparing whales sampled in the three primary calving lagoons, although a small but significant departure from panmixia was detected between whales in two of the lagoons using microsatellites.

Comparison of whales feeding off of Sakhalin Island, Russia, with whales sampled on ENP feeding grounds and migratory routes have identified significant differences in both mtDNA haplotype and microsatellite allele frequencies (LeDuc *et al.,* 2002, Lang *et al.,* 2011). Between 1995 and 2007, 56 mother-calf pairs were sampled off Sakhalin; males sampled off Sakhalin were assigned as putative fathers for 46 to 50% of these calves (Lang *et al.*, 2010). Meschersky *et al.* (2012) analysed additional mtDNA sequence data, totalling ~2800 bps of sequence and including two protein-coding genes, generated from biopsy samples collected from whales encountered off Sakhalin Island, the eastern coast of Kamchatka, and the Russian Koryak coast as well as from samples collected as part of the aboriginal hunt in the coastal waters of the Chukotka Peninsula. Two sequence variants were found in relatively high frequencies among whales sampled off Sakhalin but only in low frequencies among the Chukotka whales.

Urbán reported that samples have been collected from gray whales in the Mexican lagoons over the last three seasons. Approximately 450 samples have been collected and 300 are being processed for mtDNA. Once produced, these data may provide additional insight into whether structure among lagoons exists.

Ilyashenko noted that approximately 150 samples collected from whales harvested in the Chukotka hunt had been sent to Japan for analysis; data are not currently available. Bickham noted that in addition to the samples analysed in Bickham *et al.* (2013), additional samples collected from whales off Sakhalin in 2012 (n = 20) and 2013 (n = 9) exist.

Lang reported that an analysis of relatedness among whales sampled off Sakhalin is ongoing; the primary objective of this work is to evaluate what proportion of the whales sampled off Sakhalin share a putative mother-offspring relationship with Sakhalin whales known to migrate to the eastern North Pacific. Similar studies to examine relatedness among sampled PCFG whales are also underway and will focus on examining internal recruitment into the group by identifying putative mother-offspring pairs among sampled whales.

Table 1

Summary of available samples of gray whales (not all have been analysed and there may be some overlap between studies included here). For details and further explanation see text and Annex D).

Region	Reference	N*	Years	Months
MEX				
Baja, all three lagoons	Urbán in process	450[1]	2012-2014	Feb-Mar
Baja, Bahia Balenas	Goerlitz *et al.* 2003	2	1996	Mar
Baja, Bahia Magdalena lagoon	Alter *et al.* 2009	32	2001-02, 2005-2006	Feb-Mar
Baja, Offshore, San Jose del Cabo	Goerlitz *et al.* 2009	1	1996	Mar
Baja, Ojo de Liebre lagoon	Alter *et al.* 2009	24	2001-02, 2005-2006	Feb-Mar
Baja, Ojo de Liebre lagoon	Goerlitz *et al.* 2009	14	1997	Feb-Mar
Baja, San Ignacio lagoon	Alter *et al.* 2009	56	2001-02, 2005-2006	Feb-Mar
Baja, San Ignacio lagoon	Goerlitz *et al.* 2009	66	1996, 1997	Feb-Mar
ENP (not specified)	Alter *et al.* 2007	42		
Migration				
CA/OR/WA (89), AK (9), Chukotka (5)	LeDuc *et al.* 2002	104	1979-2000	All
PCFG/South				
Pacific Northwest, (not id'd as PCFG)	Lang *et al.* 2011, pers. comm.	33	1996-2012	May-Nov
Pacific Northwest	Alter *et al.* 2012	16	150-2690 ybp)	?
PCFG				
Pacific Northwest,	Ramakrishnan *et al.* 2001	45		?
Pacific Northwest, PCFG	Lang *et al.* 2014, Lang pers. comm.	134	1996-2012	All but Mar?
Pacific Northwest, PCFG	D'Intino *et al.* 2012	82		Jul-Nov
Pacific Northwest, PCFG	Frasier *et al.* 2011	40	1995-2006	Jul-Nov
Pacific Northwest, PCFG	Steeves *et al.* 2001	16	1995-1996	Jun-Nov
SE AK				
Alaska, Kodiak	Lang pers. com	6	2001, 2005	Jul-Aug
NE CHUKCHI				
Alaska, Barrow	Lang *et al.* 2014, Lang pers. comm.	23	1997-8, 2000, 2002, 2010-1	Jul-Sep
NBS/SCH				
Russia, Chukotka	Kanda *et al.* 2010	7	2008	Jun-Oct
Russia, Chukotka	Meschersky *et al.* 2012	84		
Russia, Chukotka	Ilyashenko pers. comm.	~150		
Russia, Chukotka	Lang *et al.* 2014	75	1994, 2001, 2003-2005	Aug-Nov
Russia, Koryak coast	Meschersky *et al.* 2012	16	2010-2011	
Russia, Koryak coast	Lang *et al.* 2014	17	2010	Jun
SAK				
Russia, Sakhalin Island	Meschersky *et al.* 2012	14	2010-2011	
Russia, Sakhalin Island	Lang reported	155	1995-2007, 2010-2011	Jul-Sep
Russia, Sakhalin Island	LeDuc *et al.* 2002	45	1995-1999	Jun-Oct
Russia, Sakhalin Island	Bickham *et al.* 2013	6	2011	Jun-Oct
Russia, Sakhalin Island	Bickham pers comm.	29	2012-13	Jun-Oct
KAM-E				
Russia, SE Kamchatka	Meschersky *et al.* 2012	17	2010-2011	
Russia, SE Kamchatka	Lang pers. comm.	16	2004, 2010-2011	Jun-Aug
PAC-J				
Japan, Pacific coast	Kanda *et al.* 2010	5	1995-2007	Jan, Apr-May, Jul-Aug
S OF J				
Japan, Sea of Japan coast	Kanda *et al.* 2010	1	1996	May
AS				
China	Lang Pers. Comm.	2*	1996, 2011	Nov-Dec

[1] MtDNA analysis of 300 is underway. *to be added

3.2.2 Osteological data comparing populations
Kato and Nakamura (doc for this meeting) reported initial results of osteological comparisons among five gray whales from Japan (1 mature, 4 immature), one from Korea (Andrews, 1914), one from California (Andrews, 1914) and five additional California specimens (body lengths 9.3–11.7m). They concluded that the specimens from Japan (all from the Pacific coast) were more similar to the California specimens than to the Korea specimen and thus inferred that the feeding range of 'eastern' gray whales has expanded to the coast of Japan (an idea also suggested by Nishiwaki and Kasuya, 1970).

The Workshop welcomed this initial analysis but cautioned against over-interpretation of the results given that (1) the sample size is small and there are the long temporal gaps in timing of collections and (2) the sample includes immature specimens and some skeletal and skull features are known to vary by age or stage. The Workshop **encourages** continuation of this work provided sufficient additional specimens can be identified.

In discussion, it was noted that bone material can also be used for stable isotope and DNA studies (see below).

3.2.3 Individual identification data (photo and genetic)
Research on gray whales in the western North Pacific has been ongoing since 1995, predominantly on the feeding grounds off north-eastern Sakhalin Island and more recently also off south-eastern Kamchatka. These studies monitor gray whales using photo-identification methods. Data have been collected primarily between July and September off Sakhalin, and July and August off Kamchatka. The Sakhalin catalogue contains about 230 whales. The Kamchatka catalogue contains about 155 whales, of which approximately 55% have also been sighted off Sakhalin. In addition to the Sakhalin and Kamchatka catalogues, opportunistic photographs exist for a number of other regions in the Okhotsk Sea, the northern Kuril Islands, Japan and China.

Research on gray whales in the eastern North Pacific has been ongoing since the late 1960s. Photo-identification data useful for analyses of stock structure have been collected in a number of areas including: (1) Baja California, Mexico (Urbán *et al.*, 2013), (2) the north-western USA and southern British Columbia, Canada (~ 41°-52°) (Darling *et al.*, 1984; SC/A14/NPGW03) and (3) around Kodiak Island, Alaska, USA (Gosho *et al.*, 2011).

The photo-catalogue from Mexico includes images obtained primarily between January and April from all of the major wintering lagoons including: (1) Laguna Ojo de Liebre (2001-2003, 2013), (2) Laguna San Ignacio (2005-2013) and (3) Bahia Magdalena (1998-2010, 2012-2013). Altogether, 6,900 individual gray whales have been photo-identified in these three study areas.

The photo-catalogue from the Pacific Northwest (PNW) contains ~1,500 'Pacific Northwest' gray whales identified by a large number of researchers working in US and Canadian waters from California to Alaska, primarily between 1998 and 2013. The PNW catalogue focuses on gray whales that feed during the summer and fall in coastal waters between northern California and the Gulf of Alaska, the PCFG, but also includes some migrating whales identified in the spring (March to May) during their northward passage to high-latitude feeding grounds; there are some but fewer southbound sightings from December to February.

Gray whale photo-identification images have also been collected opportunistically during the past decade off southern California and off Alaska including Southeast Alaska, Kodiak Island and Barrow and vicinity. In addition some photographs are available from St. Lawrence Island and the SE Chukchi Sea (also see Item 3.2.6).

Table 2 provides a summary of the photo-id efforts across the North Pacific.

Ilyashenko reported that he has asked biologists working in Chukotka to try to obtain photographs of harvested gray whales for photo-id work even though this is difficult because carcasses on shore are generally not oriented in a convenient position and their flukes have been trimmed to facilitate towing to shore. This recommendation has also been made by the IWC Scientific Committee (e.g. IWC, 2009).

Results from photo-identification (Urbán *et al.* 2013, Weller *et al.* 2012), genetic (Lang, 2010; Baker *et al.,* 2002), and telemetry studies (Mate *et al.* 2011) have documented spatial and temporal overlap between western and eastern gray whales. Observations include: (1) six whales photo-matched from Sakhalin Island to southern Vancouver Island, (2) two whales genetically matched from Sakhalin to Santa Barbara, California, (3) 13 whales photo-matched from Sakhalin Island to San Ignacio Lagoon, Mexico, and (4) two satellite-tagged whales that migrated from Sakhalin Island to the west coast of North America. Despite this overlap, significant mtDNA and nDNA differences are found between whales in the western North Pacific and those summering in the eastern North Pacific (Lang *et al.*, 2011). Although it is clear that some whales feeding in the western North Pacific during the summer/fall migrate to the west coast of North America during the winter/spring, past and present observations of gray whales in the western North Pacific off Japan, Korea and China during the winter/spring suggest that not all gray whales in the WNP share a common wintering ground (Weller *et al.*, 2013). The possibility that not all whales migrate to the same grounds each winter was also raised.

Table 2.

Photo-identification data for North Pacific gray whales

Location	Photos	Catalogue Size	Years	Season(s)
Mexico Lagoons	Yes	< 7000 IDs	2006-present*;	Primarily January-April
Mexico Offshore	Yes	No catalogue; < 100 IDs	2007-2013	Primarily January-April
California (31-41°N)	Yes	No catalogue; Opportunistic/whale watchers		South and northbound migration
PCFG (41°-52°N)	Yes	> 1500 IDs	Primarily 1980s-2000s*	Primarily June-November Opportunistic year round
Aleutians (52°N)	?	NA	NA	NA
Kodiak	Yes	< 130 IDs	2002-2012 some annual gaps	Primarily August-September
US Bering Sea	Yes	< 10 IDs; Opportunistic (St. Lawrence Island)	2012	August
Chuckchi-Beaufort Sea	Yes	< 40 IDs	2013	August-September
Chukotka	No	NA	NA	NA
East Kamchatka	Yes	< 160 IDs	2004-2012	Primarily July-August
Okhotsk Sea, West of Kamchatka	Yes	No catalogue; Opportunistic	1990s-2000s	NA
Sakhalin	Yes	< 230 IDs	1994-present (no data in 1996)	Primarily July-October
Korea	No	NA	NA	NA
Japan: Pacific	Yes	No catalogue; < 10 IDs	1990s-2000s	NA
Japan: Sea Of Japan	Yes	No catalogue; 1 ID	2014	March-April
China	Yes	No catalogue; 1 ID	2011	November

* Some historic data to 1970s

In view of the evidence that at least some of the whales that summer off Sakhalin migrate to the eastern North Pacific in winter, the Workshop considered that a combined analysis of all available data to place bounds on the proportion of whales that move from Sakhalin to the eastern North Pacific and vice-versa would be useful. The Workshop **recommends** that such an analysis be performed, preferably before SC65b. It **requests** that curators of the different catalogues provide summary data as outlined under Item 10.4, if they have not already done so.

3.2.4 Telemetry data

ENP: MIGRATION AND FORAGING AREAS

The eastern gray whale population numbers around 21,000 whales and the population is censused from shore during its annual south-bound migration past Granite Canyon, central California (Laake *et al.,* 2012; Durban *et al.*, 2013). Mother whales (N=17) tagged by Oregon State University (Mate) in Baja California in April 2005 showed staggered departure times over a period of ~6 weeks. Additional tagging by John Durban *et al.* of whales in San Ignacio Lagoon (N=18) resulted in localized movements in Baja California and southern California. Travel speeds of adult females accompanied by calves were slower going north than single whales traveling south. Mothers with calves also travelled closer to shore than earlier (Phase A) north-bound single whales. Most tagged whales provided very few locations from British Columbia to Unimak Pass (Alaska), probably because wind-generated waves and swells compromised the antenna and saltwater switch. One whale 're-appeared' after a period of more than a week without positions. By that time it was moving northeast along the Russian coast of the Bering Sea and subsequently continued through Bering Straits. The feeding destinations of 7 tagged whales were primarily in the Chukchi Sea between Barrow (Alaska) and Wrangel Island (Alaska), with arrivals to that region starting in mid-June. One tagged whale was killed by hunters in Chukotka. Five additional whales tagged by John Ford *et al.* (2013) in British Columbia remained in coastal waters while migrating north. Six whales tagged by NMML in the Alaskan Chukchi Sea and whales tagged by M.P. Heide-Jørgensen off Chukotka showed localized foraging. Six whales tagged by researchers from Alaska Department of Fish and Game (one off Tuktoyuktuk in Canada and five off Barrow) foraged in the Beaufort Sea, while one tagged off St Lawrence Island moved to the Russian coast during a 65-day track.

The Workshop **welcomes** a report from Ilyashenko that Litovka is planning to tag gray whales off Chukotka this year in collaboration with researchers from Europe.

PCFG: S & N MIGRATIONS, WINTERING AREAS, FORAGING AREAS

Mate *et al.* tagged 35 PCFG whales (see definition under Item 2.1) feeding during late autumn in coastal waters off Oregon and northern California, where whales seem to stage before the south-bound migration. Nineteen whales left the PCFG area with staggered departure dates over a period from late November to early February. Some tagged whales had returned to California waters from Mexico before other PCFG whales arrived in Baja California. There were several such 'waves' of Baja arrivals for each of the three years of tagging.

Table 3

Summary of telemetry information (see text)

Area	Months	Age/sex class	Activity	Time in area	Travel speed	*n*
Animals tagged on eastern side (Mexico) N = 18						
Mexican lagoons	Apr-May	Mothers	suckling	0.5-1.5mo[1]	nominal	17(ENP)
Mexican offshore	May-July	Mothers	Migrate N	weeks	Moderate-fast	
32-41°N		Adults	Migrate N	Days[2]	Moderate-fast	5 (ENP)
41-52°N						
52° - Aleutians						
Kodiak	No info	No info	No info	No info	No info	
US side Bering Sea	Jun-July	Adults	Migrate & forage[3]	3-8days	Moderate-fast	
Chukchi-Beaufort	June-Nov	Adults	Forage[4]	3-4 mo[5]	Slow	Home range
Chukotka	June-Sept	Adults	Forage	0.5-2.0mo[6]	Slow-moderate	Home range
Animals tagged off Sakhalin N = 7						
Sakhalin	Aug-Dec	Adults	Forage	2-2.5mo	slow	
E. Kamchatka	Nov-Jan	Adults	Migrate E	Few days	fast	3
US Bering Sea	Dec-Jan	Adults	Migrate E	Week	fast	3
52° - Aleutians	Dec-Jan	Adults	Migrate S	Two weeks	fast	3
41-52°N	Jan-Feb	Adults	Migrate S	Week	fast	2
Mexican offshore	Jan-Feb	Adults	Migration, ‘Reproduction?’	Month	Directed/ moved between	1
Mexican lagoons						
32-41°N	Mar	Adult	Migrate N	Week	fast	1
41-52°N	Mar	Adult	Migrate N	Week	fast	1
52° - Aleutians	Mar	Adult	Migrate N	Two weeks	fast	1
US Bering Sea	Apr	Adult	Migrate W	Few days	fast	1
Sakhalin	May-Oct	Adult	Forage	5 mo		
Animals tagged on eastern side (PCFG) N= 35						
41-52°N	Nov-Feb	Adults	Migrate S	2 weeks	fast	35
32-41°N						
Mexican offshore	Dec-Mar	Adults	‘Reproduction’	3-10 weeks	Directed/ moved between	17
Mexican lagoons						
32-41°N	Mar-Apr	Adult	Migrate N	Week	Mod. fast	
41-52°N	Mar-Apr	Adult	Migrate N & forage[8]	Week	Mod. fast	
52° - Aleutians	Mar-Apr	Adult	Migrate N &forage	Two weeks	Mod. fast	

[1] added data from Durban; [2] added data from Ford (2013); [3] added data from 1 whale Quakenbush *et al.* (2013); [4] added data from 6 whales Quakenbush *et al.* (2013); [5] added data from NMML; [6] added data from Heide-Jørgensen *et al.* (2011); [7] transmitter stopped so may have been longer (as in previous year); [8] added data from CRC limpet tags, Ford *et al.,* 2013.

Seventeen tagged whales were tracked to the breeding and calving areas of Baja California, where most of them stayed in nearshore waters. Most of the whales began their southward migration near Pt. St. George, CA. However, in 2012 two of them travelled north to the Washington coast before migrating south. Another individual began its southerly migration from Pt. St George but reversed course near San Francisco Bay, CA, and travelled north to the northern Washington coast before again turning south and migrating to Mexico. One healthy-appearing male did not migrate south at all, instead remaining off northern California and Oregon for the duration of the winter, with two extended periods off Pt. St. George in October-February and February-May during its 382 day tracking period.

In Baja California, most whales spent extended time in the area offshore of Ojo de Liebre (ODL) lagoon and two whales passed farther south offshore of San Ignacio Lagoon en route to Magdalena Bay. Locations inside ODL lagoon accounted for 23% of all high-quality locations. No tagged whales had more than 69% of their high-quality locations within the lagoon. Eight of 17 whales did not have any high-quality locations within the lagoon.

Tagged whales arrived at the breeding grounds from late December to early March. Most of them spent an average of 21 days in reproductive areas before heading north on migration. One female and another whale of unknown sex remained in the breeding area for 2.5-3 times as long as other whales. These were likely both females that gave birth and then departed the lagoon area in late February or early March. The observed variability in arrival and departure times indicates that the entire population is never in the lagoon region at the same time. Thus, population estimates based on surveys in the breeding areas will severely underestimate the population if typical ‘closed population’ assumptions are made.

Twelve whales were tracked back to the ‘Pacific Northwest’ following their northbound migration from wintering areas off Baja California. Migratory routes were typically close to shore and followed the coastline. However, some whales in each year travelled directly across the California Bight, through the outer Channel Islands (Santa Rosa and Santa Cruz), rather than following the coastline. Most whales travelled continuously after starting their migration until they reached their destination. However, one whale stopped for 9 days near San Miguel Island in the California Channel Islands (where it was first photographed before the telemetry study) before continuing its journey south. Ford *et al.* (2013) tagged three PCFG whales as they passed Vancouver Island migrating north. These three whales continued north exhibiting similar migratory speed and path as whales not thought to be PCFG whales until their tags stopped working in southeast Alaska.

Rather than migrating to the Bering, Chukchi and Beaufort Seas like the rest of the ENP population, tagged PCFG whales returned on their north-bound migration to traditional PCFG areas, although two went farther north to Icy Bay (60N) for variable periods before working their way farther south. Some of the emphasis in the data on foraging locations in the area of Pt. St. George reflects the large number of tag deployments there (23 out of 35 whales). Six whales recorded locations either inside (or adjacent to) the Makah Tribal U&A Fishing grounds during five months (Feb, Apr, May, Sep, Dec).

It has often been noted that the number of calves found at any one time in the three main Mexican lagoons is smaller than the total estimated calf production. The large proportion of tagged whale locations outside ODL lagoon during the breeding season suggests not only a greater amount of time spent outside the lagoon, but also that most of the population (and probably calves as well) can be outside lagoons at any point in time. In the case of eight whales, none of their good-quality locations were inside the lagoon. If some whales rarely if ever enter the lagoon, and others spend a large percentage of time outside the lagoon, it would be necessary to include offshore surveys to properly characterize the population's distribution during the breeding season. As relatively small areas, lagoons could serve to help drive genetic isolation of the PCFG whales (and possibly also Sakhalin whales) from other eastern gray whales. However, ODL is the largest of the three major lagoons and has peak populations of nearly ten times the estimated number of PCFG whales.

Gray whale calls have been recorded throughout the winter in the Beaufort Sea (Stafford *et al.* 2007), suggesting either that (a) some whales do not migrate or (b) there is considerable variation in the timing of migration into and out of the region, with the turnover ensuring that the area is never 'unused' by gray whales. Moreover, results from tagged PCFG whales provide unequivocal evidence that not all gray whales migrate to Mexico every year.

Re-sight photographs showed that tagged whales, whales that had shed their tags and untagged whales were often together in the Pt. St. George area (especially very late in the season). This mingling suggests that the movements of tagged whales represent, at least to some extent, the movements of some other, untagged whales.

WESTERN GRAY WHALES: N & S MIGRATIONS AND FORAGING AREA

Three of seven gray whales tagged at Sakhalin Island migrated to the ENP after staying at Sakhalin for several months after tagging (the tags on the others stopped transmitting prior to movement away from Sakhalin). They crossed the Bering Sea, using varying routes, timings and entry points through the Aleutian Islands into the Gulf of Alaska. Two of the whales entered the traditional coastal south bound migration route for 'traditional' ENP gray whales from late December to late January. These whales migrated at faster speeds than ENP whales. One male's transmitter was last heard along the Oregon coast in February while migrating south while a female migrated to Baja California where it spent 42 days and passed all three major calving areas before a return northbound. The latter involved a different route across the Bering Sea than the winter migration eastward and southward. The first arrival point on the Russian coast was the western? side of Kamchatka peninsula. The whale continued on to the NE coast of Sakhalin Island in mid-May, passing through what was characterized as heavy ice.

The Workshop **reiterates** the great importance of further telemetry studies, particularly off Sakhalin, Kamchatka and in the northern areas such as Chukotka and **recommends** that such work be undertaken.

3.2.5 Removals data (catch and incidental catch; strandings)

Uni (2008) analysed records of Japanese whaling along with recent sightings, bycatch and strandings data and concluded that although most gray whale catches over the past 400-500 years were in the Sea of Japan (including the Korean peninsula), recent sightings, entrapments and strandings have been mainly along the Pacific coast (although see Nambu, 2008). These data, together with the Korean whaling records (Mizue, 1951), have been interpreted as suggesting two or three 'substocks' of gray whales using different migration routes along either side of the Japanese archipelago and along the Korean Peninsula. There is also some evidence to suggest a wintering area in the Inland Sea of Japan, in addition to the presumed wintering area in southern China (around Hainan Island).

Reeves *et al.* (2008) plotted the approximate positions and dates (i.e. months) of 160 kills and sightings of gray whales by American whalers in the Sea of Okhotsk in the latter half of the 20th century. Gray whales were observed consistently in Shelikhov Bay (Zaliv Shelikhova) and Penzhinskaya Gulf (Penzhinskaya Guba) from early May to the end of August. They were also seen in Gizhiginskaya Bay (North-east Gulf) between mid-May and late August and near Magadan along the north central coast of the Sea of Okhotsk from at least early June to early July and from mid-August to mid or late September. The American whalers apparently did not visit the coastal waters off north-eastern Sakhalin Island where gray whales now congregate to feed throughout the summer.

Brownell reported that the large catches (>1,750 gray whales) by Japanese modern whalers in the East Sea of Korea from 1890-1966, but mainly in the first third of the 20th century (Kato and Kasuya 2002), came at a time when the population of gray whales in the eastern Pacific was seriously depleted as a result of 19th century whaling. This mismatch in the timing of peak catches in the eastern and western North Pacific is consistent with the hypothesis of separate populations. The observation that not all eastern gray whales visit Mexico each year was also noted in this regard.

Whaling data from the eastern North Pacific are generally consistent with the well-known concept of a north-south coastal migration between summering grounds off Chukotka or Alaska and the Mexican wintering grounds. Some shore whaling stations in California operated seasonally in accord with the arrival of southbound migrating gray whales (relatively fat) in December or January and the departure of northbound migrants (relatively thin) from March to early May (Rice and Wolman, 1971; Reeves and Smith, 2010). At some stations, winter/early spring catches comprised mainly gray whales whereas at other seasons humpback whales were the main targets (Reeves and Smith, 2010).

3.2.6 Sightings data

NORTHERN BERING-SOUTHERN CHUKCHI SEAS (NBS/SCH), NORTHERN CHUKCHI SEA (NCH) AND CALIFORNIA (CA) REGIONS

Sue Moore summarised sightings data from aerial surveys in the northern Bering, north-eastern Chukchi and Alaskan Beaufort seas from 1982 to the present; noting a hiatus in broad-scale surveys in the region from 1992-2007 (Clarke *et al.,* 2013). Since 2008, surveys have been conducted from July-October by researchers at the National Marine Mammal Laboratory (NMML) as part of the Aerial Surveys of Arctic Marine Mammals (ASAMM) program[2]. Gray whales are distributed predominantly along the Alaska coast in the north-eastern Chukchi Sea from roughly Point Lay to Barrow, and in the south-central Chukchi Sea southeast of Point Hope (Fig. 4). Many of the whales seen are associated with mud plumes and as a result are designated 'feeding whales'.

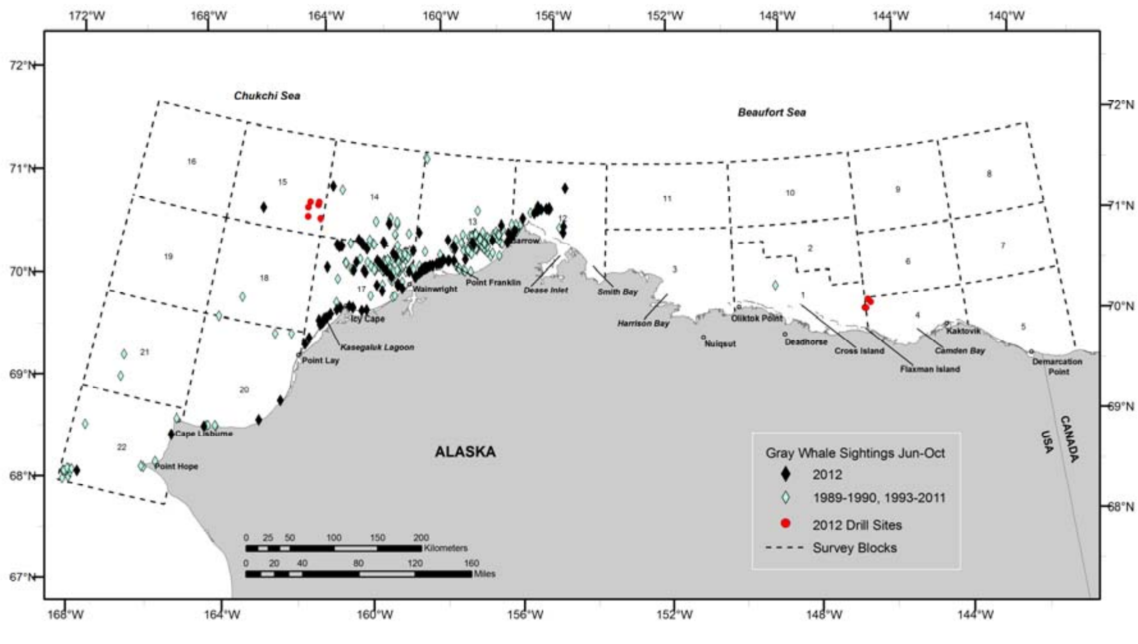

Fig. 4. Gray whale on-transect sightings in 2012, compared to years with light sea ice cover: 1989-1990, 1993-2011. Includes all on-transect sightings from primary and secondary observers. Reproduced with permission from Clarke *et al.,* 2013: fig. 24.

Recent surveys resulted in fewer observations of gray whales feeding near Hanna Shoal than was the case during the 1982-1991period. Female-calf pairs are commonly observed along the Alaska coast with no noticeable change from the 1980s through 2013. In addition to ASAMM sightings, gray whales were routinely observed during

[2] http://www.afsc.noaa.gov/nmml/cetacean/research/caepresearch.php?url=nmmlcaep1405

summer oceanographic cruises that extended into Russian waters between 2009-2013, including two sightings of eleven whales in 2009, north of Wrangel Island (Moore *et al.,* 2014). Together, these sightings confirm the broad distribution of gray whales in the Chukchi Sea, as summarised by Berzin (1984).

In discussion it was noted that with so many calves seen along the Alaska coast, there might be opportunities for photo-identification and/or biopsy sampling there. In 2013, 36 gray whale photo ID's were obtained and 5 gray whales were tagged with satellite transmitters under the NMML-led ArcWEST program[3]; unfortunately, biopsy samples were not obtained. The ArcWEST program will continue for the next 2-3 years, and there may be opportunities to include biopsy sampling in future cruise plans. The Workshop **encourages** the ArcWEST program to collect biopsy samples if at all possible.

Female-calf sightings extend into September, beyond the time when females are generally thought to have weaned their calves. Moore noted that NMML staff had analysed calf sightings specifically, with results presented at the annual Alaska Marine Science Symposium each January. Moore noted that there might be sufficient sighting data from the 1980s to calculate relative abundance indices for comparison to sighting rates from recent (and ongoing) surveys in the 2000s, although the record is not continuous for gray whales in the Chukchi Sea. The Workshop **recommends** that such an analysis is undertaken if the data are found to be sufficient.

Shore-based sighting surveys of northbound gray whale cows with calves have been conducted annually from the Piedras Blancas Light Station, located near San Simeon, CA, since 1994 (Perryman et al. 2012). Weller reported that starting in 2012, photographs for identification of northbound mother-calf pairs passing the site have been collected and images forming this catalogue will be shared with other researchers for comparison to their catalogues. The primary goal of this effort is to identify migrating mother-calf pairs for comparison with gray whales known to be part of the PCFG. Annual additions of calves to the PCFG are thought to be underestimated because some calves are weaned before being photo-identified. This photographic effort may be expanded in 2015 to include the use of a small UAS (unmanned aircraft system) for photo-identification purposes.

MEXICO

Scott noted that records are available of gray whale sightings off Mexico (1970s to present) by tuna purse seine vessel observers of the US NMFS, Inter-American Tropical Tuna Commission and the Agreement for the International Dolphin Conservation Program. Additional sightings have likely been made during research cruises in the eastern tropical Pacific by the US NMFS.

RUSSIA

There have been local reports of distribution of gray whales around some of the whaling villages (e.g. Blokhin, 1986; 1987; 1989; 1990; 1998; Bogoslovskaya *et al.*, 1982; Melnikov, 2008; Melnikov and Bobkov, 1996; Melnikov *et al.*, 1997). Ilyashenko reported that V.V. Melnikov recently observed and filmed more than 20 gray whales near the Shantar Islands in the western Okhotsk Sea. Two gray whales were observed in September 2011 in the Laptev Sea in the central Russian Arctic (Shpak *et al.,* 2013). In addition, two gray whales were documented from a tourist ship near Frans Josef Land off north-western Russia in 2011.

3.2.7 Biological data (e.g. conception date)

Rice and Wolman (1971) provided the most detailed information available on gray whale life history, derived from 316 whales sampled off central California between 1959 and 1970. The authors reported that breeding and calving are seasonal and closely synchronized with timing of the migration. Non-pregnant mature females were found to ovulate regularly in late November and early December, which coincides with the initial phase of the southbound migration. Based on estimates of foetal growth rate, sampled females were determined to have conceived between late November and early January, with a mean conception date of 5 December. Rice and Wolman (1971) found that successive ovulations can occur, separated by a period of about 40 days, indicating that whales can enter oestrus while on the wintering ground. The gestation period is approximately 13 months, with calving occurring mainly from late December to early March on the wintering grounds, although some calves are born during the southbound migration (Shelden *et al*., 2004 – cited in Moore, 2008).

There are no comparable reproductive data for gray whales in the western North Pacific. Andrews (1914) examined 23 gray whales taken during the southbound migration off Ulsan, Korea, and summarised observations made by the whalers working there. Adult females taken off Ulsan in December and January were carrying near-term foetuses, and one of the whales Andrews examined was a foetus measuring 4.76m. Rice and Wolman (1971) reported an average near-term foetus size of 4.62m from the eastern gray whales sampled off central California.

The coincidence in observed foetus size, season, and latitude between Korea and central California (mothers were moving past Korea and central California at the same time of year carrying same-sized fetuses) provides support

[3] http://www.afsc.noaa.gov/nmml/cetacean/researc/caepresearch.php?url=nmmlcaep1407

for the hypothesis that at least historically there were separate populations in the eastern and western North Pacific (Weller *et al.,* 2002).

The Workshop reviewed biological parameter data more fully under Item 6. It was noted that in the past, data on conception dates had proved useful in formulating stock structure hypotheses (e.g. WNP common minke whales). However, the Workshop **agrees** that there are insufficient such data for gray whales to be used in a stock structure context.

3.2.8 Ecology and behaviour
Sue Moore provided a brief summary of information related to gray whale feeding ecology in the northern Bering and southern Chukchi seas (NBS/SCh). A decline in sighting rate of feeding gray whales between the 1980s and 2002 in the NBS (Chirikov Basin) was demonstrated to coincide with a decline in amphipod-prey biomass there over that period (Moore *et al.* 2003). Gray whales are commonly seen feeding in the SCh and five whales tagged there during the 2013 ArcWEST program co-occurred with areas of high benthic-prey biomass. Additional lines of evidence that gray whales alter their behavioral ecology in response to variability in biophysical forcing (e.g. Pacific Decadal Oscillation, sea ice cover) are reviewed in Moore (2008).

There is some evidence that gray whale feeding ecology may vary considerably amongst region; e.g. the PCFG whales feed primarily on a different and larger variety of species that those in more northern seas (Darling *et al.*, 1998).

3.2.9 Other
Scordino suggested that future consideration be given to examining stable isotopes from bone artefacts. Stable isotope analysis could contribute to evaluations of stock structure and movements. Alter *et al.* (2012) evaluated the stable isotopes of bones found in Makah and Quilleute tribal middens from whales hunted 500 to 1,500 years before present compared to the isotopes from migrating whales hunted in the 1970s off California. Those authors assumed that the whales hunted in California during the migratory season represent whales that feed in the Bering, Chukchi and Beaufort seas. They found significant differences in Carbon-13 which suggests that the whales historically hunted by the Makah and Quilleute tribes fed further south than the whales hunted off California, although it was acknowledged that other factors could have caused the observed differences in Carbon-13 values.

Ilyashenko reported that Chukotka whalers (and scientists) have reported seeing more and more dark-skinned gray whales with no or few white marks from skin parasites, which they interpret to mean that these animals do not migrate far south but stay in cold water year-round. The numbers of such animals are not large but are increasing.

Finally, a recent paper by Tsai *et al.* (2014) reported on two specimens of fossil juvenile gray whale from the sea bottom between Taiwan and the Penghu Islands. These fossil specimens are Quaternary in age and of potential value to further assessments of gray whales in the western North Pacific.

3.3 Discussion of possible population structure hypotheses
As noted under Item 3.1, seven possible stock structure hypotheses were put forward at SC/65a (IWC, 2014). The original seven hypotheses focused primarily on evaluating stock structure relative to the whales feeding off Sakhalin, and thus additional variants needed to be added to address stock structure across the entire North Pacific. A small working group was formed to identify additional hypotheses that should be included, and the schematic for each hypothesis was drawn (or re-drawn in the case of the original seven) to incorporate a number of spatial regions[4] (see Annex F) that were identified as areas where data were available that might be valuable in constructing and/or informing the hypotheses. The hypotheses identified at SC/65a retained their original numbering, and additional hypotheses were added as variants of the original seven hypotheses.

A number of key issues were identified during the initial discussion of hypothesis construction and these are considered below.

(1) Should each Mexican lagoon and the region offshore of Baja California be modelled as separate breeding sub-stocks?
Alter *et al.* (2009) compared mtDNA haplotype and microsatellite allele frequencies (*n*=9 loci) between the three major calving lagoons. Significant nuclear differences were found between Laguna San Ignacio and Bahia Magdalena, while the results of the remaining comparisons were not significant. While this finding provides an indication that structure among lagoons could exist, the evidence is equivocal given that most of the comparisons were not significant. Urbán noted that his group has collected approximately 450 samples from all three lagoons

[4] The North Central Pacific was originally included as a region to allow for visualisation of an area on the western migratory route used primarily by Sakhalin whales before they reached the 'common' eastern part of the migratory route along the North American coast (and where they may mate). This region is not included in Annex F as it will not be modelled; trials are informed only by demographic data (e.g. only the demographic data are compared to the model output to determine plausibility).

over the past three seasons, and they are in the process of generating data on mtDNA control region haplotypes for 300 of these samples. The results are expected to be available by the end of the year. As noted earlier, there is evidence from photo-identification and telemetry of animals moving among lagoons and the offshore area within a season.

The Workshop **agrees** that at present, the Mexican wintering grounds will be treated as a single breeding area. However, the possibility that structure between lagoons exists will be reconsidered if needed based on the results of the Urbán study, which incorporates a much larger set of samples than previous studies. No schematic depicting this possibility was constructed.

(2) Should a hypothesis be included that considers the PCFG and feeding regions in the Gulf of Alaska, Bering and Chukchi Seas to represent a single feeding sub-stock?
While not completely ruling out the possibility of a single feeding stock, the Workshop **agrees** to follow the example of the AWMP trials and to include the PCFG as a separate feeding sub-stock. From a management perspective this is the most conservative in that it is more challenging from a conservation standpoint wit respect to future hunting. Thus, although it may be plausible that the PCFG is part of the larger sub-stock that includes feeding areas north of the Aleutians, there is little value at this stage in running additional, less conservative variants. For this reason, no schematic depicting this possibility was constructed.

(3) Should a hypothesis that considers the PCFG to represent a breeding sub-stock be considered?
The results of previous analyses have not found significant nuclear differences when comparing samples collected from PCFG whales with samples collected on the feeding area(s) north of the Aleutians (Lang *et al*., 2014) or with samples collected from whales in the Mexican lagoons (D'Intino *et al*., 2012). These findings are consistent with interbreeding between PCFG whales and those from other feeding areas. However, as the Committee has noted many times in the past, the failure to detect significant differences does not necessarily mean that no differences exist.

There have been some observations of PCFG whales aggregating off northern California during late November to mid-December, which Rice and Wolman (1971) identified as the first breeding period. In principle, this could provide some limited support for a hypothesis that the PCFG may represent a separate breeding sub-stock. However, the Workshop **agrees** that this hypothesis should not be included at this time, recognising that in effect the existing hypothesis of PCFG as a separate feeding stock is sufficient. Analysis of relatedness patterns of PCFG whales by Lang and colleagues is underway, and the inclusion of this hypothesis will be reconsidered in the future if warranted by the results of this work. No schematic depicting this possibility was constructed.

(4) Should a hypothesis be included that considers the whales feeding in the northern Bering-southern Chukchi Seas to be a separate feeding sub-stock from those feeding in the northern Chukchi Sea?
Given that matrilineal fidelity of gray whales to feeding grounds on parts of their range is believed to occur (e.g., off Sakhalin and in the PCFG), it is possible that gray whales exhibit this behaviour throughout their range. However, little is known about whether this behaviour occurs in feeding areas north of the Aleutians. Six whales tagged in 2005 on the Mexican wintering grounds retained their tags through all or part of the subsequent feeding season in the Bering and Chukchi Seas. While some of these whales made wide-ranging movements (e.g., between Barrow and Wrangel Island, and between Barrow and the southern Chukchi Sea), others remained in smaller areas, particularly during the latter part (September and October) of the feeding season (Mate, 2006). Nine gray whales tagged off Chukotka and tracked for variable amounts of time between September and November remained in the western Bering Strait, largely staying within 5km of the Chukotka coast (Heide-Jorgensen *et al.,* 2012). Thus both wide-ranging and more localized movements have been documented in this area. Moore further noted that there are ecological differences between the two regions included in the existing models (NBS/SCH and NCH), which might result in the development of sub-structuring between these regions.

Given the limited data available, the Workshop **agrees** that while it is certainly possible that some sub-structure within the feeding area north of the Aleutians could exist, this hypothesis should not be evaluated as a priority at this time. However, that the Workshop also **recommends** that additional studies (photo-identification, genetics, tagging) should be conducted in these regions, as has been previously recommended by the Scientific Committee. In making this recommendation, the Workshop **recognises** the practical difficulties of working in these areas and also **recognises** the ongoing efforts off Chukotka referred to earlier in the report.

(5) Should the possibility that a Sakhalin whale might be killed in the Chukotka harvest be incorporated in the model(s)?
There is only limited information on this topic, but none of the three whales that were tagged off Sakhalin and migrated into the eastern North Pacific travelled through the area where the Chukotka harvest is conducted. It was also noted that the evidence from the Sakhalin feeding area is that abundance is increasing in the face of the >100 whales that are taken in that harvest each year. Given this the Workshop **agrees** that such a scenario does not

warrant inclusion as a full hypothesis. However, there is some merit in including some options in the context of a sensitivity test.

(6) Should multiple migratory pathways in the western North Pacific be incorporated into the model(s)?
Park (2001) suggested that up to three migratory routes (east coast of the Korean Peninsula, the Pacific coast of Japan, and the east coast of the Sea of Japan) were used by western North Pacific (WNP) gray whales in the past. However, no recent sightings of gray whales off the Korean Peninsula exist, despite shore-based and vessel-based sighting surveys conducted between 2003 and 2011 (Kim *et al.,* 2013). There are 14 records of gray whales from Japan since 1990; the majority of these (*n*=12) are from the Pacific coast of Japan (Weller and Brownell, 2012; Kato *et al.,* 2013). However, only limited genetic (Kanda *et al.,* 2010) and photo-identification (Weller *et al.,* 2008) data are available from these areas, and it is currently not possible to evaluate whether the use of multiple migratory routes led to sub-structuring of the Asian breeding stock in the past. This hypothesis is depicted and described in the schematic 5b (see Annex E). However, given the lack of available data from the Asian migratory routes, the Workshop **agrees** that this hypothesis should be given low priority.

3.4 Recommendations for hypotheses for inclusion in the modelling framework
The Workshop examined the hypotheses described in Annex F. It **agrees** that Hypotheses 1 and 2 (from SC65a) were not consistent with available data and should no longer be considered. It also **agrees** that hypotheses for which little or no data (other than catch records) are available to assess plausibility should be considered to be of low priority for inclusion in the modeling framework (Hypotheses 3b, 3d, 5b, 6a, 6c). Finally, it **agrees** that low priority should be assigned to hypotheses that would be represented in the modelling framework in the same way as other hypotheses (Hypotheses 4a, 4b, 6b, and 6c; see hypothesis 7 for details).

Following this evaluation, the Workshop **recommends** that the following three hypotheses be considered a high priority for inclusion in the initial modeling framework.

Hypothesis 3a
Two breeding stocks (Asia and Mexico) may exist, although the Asian stock may have been extirpated. Whales show matrilineal fidelity to feeding grounds, and the Mexico stock includes three feeding sub-stocks: PCFG, NBS/SCH-NCH-G of AK [hereafter, Northern], and Sakhalin.

Hypothesis 3e
Identical to hypothesis 3a except that the Asian breeding stock is extant and feeds off both coasts of Japan, Korea, and in the northern Okhotsk Sea west of the Kamchatka Peninsula. All whales off Sakhalin overwinter in the eastern North Pacific.

Hypothesis 5a
Identical to hypothesis 3a, except that the whales that feed off Sakhalin include both whales that are part of the Asian stock and remain in the WNP year-round, and whales that are part of the Mexican stock and migrate to the eastern North Pacific (ENP).

Hypothesis 3c should be included as a sensitivity test. This hypothesis incorporates the possibility that a Sakhalin whale may occasionally move through the NBS-SCHK region and thus will have a chance of being taken in the Chukotka harvest.

3.5 Recommendations for future data collection and/or analyses
The practicality and utility of the recommendations presented in SC/A14/NPGW01 were evaluated. One recommendation was to develop Single Nucleotide Polymorphisms (SNP) assays for use with gray whales. These assays would allow integration of genetic data between labs as well as over time, increasing the utility of such data for future analyses. In addition, this approach could be utilized with low-quality samples, such as bone and baleen, which could facilitate analysis of any historic samples identified. The Workshop **recommends** that a SNP panel be developed for use with gray whales and considers this task a high priority for future work. It was noted that while development of SNP assays would be valuable, some analyses, such as evaluating relatedness among sampled animals, would necessitate the identification of several hundred loci. Until such a SNP panel is developed, nuclear analyses of relatedness would likely require that SNP and microsatellite data be combined. Conducting a gray whale genome project, which was one of the recommendations of SC/A14/NPGW01, would allow SNP loci to be identified and would generate data that could be useful in addressing a wide range of questions. However, the cost and utility of such an approach is greater than that required by other methods used to identify SNPs (e.g., Next Generation Sequencing), and thus this approach is considered a lower priority in terms of evaluating stock structure.

Another high priority for future genetic studies of stock structure is to increase the sample numbers and sample coverage for the eastern North Pacific stock of gray whales. While a high proportion of the whales using the Sakhalin feeding ground have been sampled, the proportion of the eastern North Pacific stock that has been sampled is low. In addition, few or no samples have been collected from some parts of the range of eastern North Pacific stock. The Workshop **recommends** additional sampling and photo-identification efforts be conducted in key areas, such as the northern Chukchi, with the goal of evaluating whether additional structure exists on feeding areas used by the ENP stock.

Genetic analyses of samples derived from the bones or baleen of pre-depletion western North Pacific gray whales was also recommended in SC/A14/NPGW01. Few known sources of such specimens have been identified, and finding additional samples would be difficult. It is unlikely that significant progress could be made in the near future. However, a smaller-scale project aimed at reviewing museum collections, archeological literature, and records of whaling station locations would be valuable in evaluating whether such samples exist. For such a project to be successful, it would be beneficial to identify scientists, ideally in countries bordering the range of gray whales in the western North Pacific, to conduct such work. This work should be considered a medium priority task for the future.

The Workshop noted the important contribution of the telemetry information provided and **recommends** further work in all areas, especially off Chukotka, Sakhalin and Kamchatka.

The Workshop **recommends** that existing acoustic data be analyzed for the presence of gray whale calls. Such an analysis would provide valuable information on gray whale distribution as well as on the presence of gray whales north of the Aleutians during winter months, and this work should be considered a medium priority task for the future.

4. REMOVAL DATA (TAKING INTO ACCOUNT DISCUSSIONS UNDER ITEM 2)

4.1 Commercial catches [post 1850]

4.1.1 Western North Pacific

Before the beginning of modern commercial whaling in this region, there was a long but poorly documented history of gray whale exploitation by hand harpoon and netting. In Japan, gray whales were probably hunted by hand harpoon from the late 16th century and they were definitely taken by net whaling beginning in the late 17th century (Omura, 1984). Net whalers took 50-60 gray whales annually from 1675-1890 (Omura, 1984) and between1891-1899 they took at least 44 in Korea (16, 15 and 13 in 1890/91, 1891/92 and 1898/99 respectively; Park, 1987; Kato and Kasuya, 2002) and at least 29 in Japan (Omura, 1984). Japanese net whaling ended around 1900, at approximately the same time that modern whaling companies were being formed.

From the 1840s to mid-1880s, American sailing vessel whalers searched the Okhotsk Sea for bowhead whales and hunted gray whales as secondary targets, taking at least a few hundred in total in that region over an approximately 40-year period (Henderson, 1984; Reeves *et al.,* 2008).

A Russian company based in Haydamak (180km east of Vladivostok) initiated modern whaling in Asian waters. This company operated off the Korean Peninsula in some winters from 1890 until 1904 (Tønnessen, 1973; Kato and Kasuya, 2002). Gray whales that were killed in this operation were transported to Japan. Yablokov and Bogoslovskaya (1984) reported that gray whales were hunted sporadically by Russians near Peter the Great Bay, Russia, during World War II (WWII) but those authors provided no numbers or details on this operation.

The first catch numbers for gray whales by modern commercial whaling listed for Japan by Kato and Kasuya (2002) was of 23+ whales in 1900. However, catching must have started at least a few years earlier - Kato and Kasuya indicate '?' in their Japan catch column for 1898 and see Omura, 1984). Andrews (1914) reported

> Captain Melson was the first whaleman to learn to take 'Devilfish' in Korean waters and it was he who laid the foundation for the winter fishery which has been so successfully prosecuted there by the Japanese for the last fifteen years.

Brownell reported that Andrews visited the Toyo Hogei Ulsan whaling station in January-February 1912, so 15 years earlier would be 1897.

Japanese whaling operations in Korean waters started in 1898 but were limited. In 1909, Toyo Hogei opened a land station at Ulsan that operated for a number of years after Japan annexed Korea in 1910.

Modern whaling operations started in Japan in 1898, but only a few gray whales were taken there after the turn of the century (Kasahara, 1950; Omura, 1984). From at least 1909 onwards, several land stations on the central-eastern and south-eastern coasts of Korea were operated by Japan until 1945 at the end of WWII (Kasahara, 1950; Kato and Kasuya, 2002).

Kasahara (1950) reported that smaller catches were made in western Korea (Yellow Sea) and catches totalling at least 244 from 1911 to 1927 were made in north-eastern Korea (Broughton Bay, 40°N). The catch record is particularly poor and incomplete for the period 1898-1910, which is unfortunate since the available catch record suggests that substantial numbers of gray whales were taken during those years. For example, at least 125 gray whales were taken in 1907 and 193 in 1912, which could mean that significant numbers were also taken in the years before 1907 and from 1907-1911. By the 1930s, total annual catches of western gray whales had declined to fewer than 50 (Kato and Kasuya, 2002).

The only known ‘sizeable’ catches of gray whales after WWII were by Korean whalers off southeastern Korea (Brownell and Chu, 1977). According to Brownell, post-WWII Records of bycatch and direct catches in Japanese waters probably total fewer than 20.

Twentieth century catch data compiled primarily by Bradford and Brownell from published sources are summarised in Table 4. The full Table is given as Annex F.

Fig. 5. Land stations (closed circles) used by modern whaling fleets in Korean waters (taken from Kato and Kasuya, 2002).

Table 4

Twentieth century catches for the western North Pacific by year based upon published sources. For details see Annex F.

Year	China	China?	Japan	Korea	Korea?	Russia	Unknown	Total
1900			2	23				25
1902				9			5	14
1906				59			11	70
1907				125				125
1908				26				26
1909				83	1			84
1910			1	37				38
1911			2	119				121
1912				25			193	218
1913							131	131
1914			19	139				158
1915			9				130	139
1916			1	77				78
1917				66	2			68
1918				101	2		1	104
1919				46				46
1920			10	65				75
1921			2	76				78
1922				38	2			40
1923				27				27
1924				14			4	18
1925				10				10
1926				10		1		11
1927				9			1	10
1928				9				9
1929				11			1	12
1930				30				30
1931				10				10
1932				7				7
1933				1				1
1942				1		1		2
1943				1				1
1945				5				5
1948				9				9
1949		1		4				5
1951				7				7
1952				1				1
1953	4			7				11
1958	1			7				8
1959			1	7				8

1960		1		8				9
1961				3				3
1963				2				2
1964				3				3
1965				4				4
1966				5				5
1968			1					1
1996			1					1
Total	**5**	**2**	**49**	**1326**	**7**	**2**	**477**	**1868**

Although it is known that modern whaling for gray whales in the western North Pacific started in the 1890s and that some catches of gray whales were made in Korean waters, catch data are extremely sparse for years prior to 1904. Because of the likelihood (explained above) that substantial catches were made in at least some years between 1890 and 1910, the Workshop **recommends** that an investigation or investigations be carried out to obtain information on whaling effort (e.g. numbers of vessels, captains, stations) and other aspects (e.g. suspension of effort due to the Sino-Japanese War), by year, that could be used to estimate catches for these years by inference, interpolation or extrapolation using the known catches in 1907 and 1913 as a starting point (see Reeves and Smith, 2010). Such a study will require participation by researchers with appropriate language abilities – i.e. at least Japanese, Russian and Norwegian.

4.1.2 Eastern North Pacific
An agreed catch series for commercial catches and special permit catches of eastern North Pacific gray whales 1846-2009 is available from the IWC SC meeting in 2010 (IWC, 2011; JCRM 12, Suppl., p 145 and Appendix 3).

Ilyashenko reported that he had learned from a Russian fishery agency official in the Russia embassy in North Korea that the whaling catcher boat (as pictured on a postage stamp from 19xx – *fide* RLB) is no longer in operation. Only dolphins are hunted nowadays in North Korea and this hunting is done from military vessels.

4.1.3 Future
The Workshop **agrees** that modelling exercises will assume no commercial catches in the future.

4.2 Aboriginal subsistence catches

4.2.1 Past

WESTERN PACIFIC

There is little information on aboriginal subsistence whaling for western gray whales. Maritime Koryak people along the north-eastern Okhotsk Sea hunted whales, presumably including both bowhead and gray whales (Krupnik, 1984).

EASTERN PACIFIC

The aforementioned catch series agreed in 2010 for the eastern North Pacific (JCRM 12, Suppl., p 145 and Appendix 3) includes aboriginal catches, very crudely estimated from an unpublished compilation of literature by Mitchell and Reeves (in 1990) for 1600 to around the 1940s, and estimated with somewhat more precision thereafter through 2009 from a variety of sources. Reported catches since 2009 will need to be added to update that series.

4.2.2 Future
The current block quota for aboriginal subsistence whaling of gray whales is 744 for 2013-2018 (no more than 140 in any one year). No hunting of gray whales in Alaska is currently permitted and none is planned or foreseen. No hunting by the Makah in Washington State is currently permitted but the Tribe is continuing its efforts to obtain a quota for four removals per year. The Workshop **agrees** that modelling exercises should consider the range of catches used in the AWMP trials (IWC, 2011). Assumptions on allocations of removals will need to be made for the various stock structure hypotheses.

4.2 Incidental catches in fishing gear

4.2.1 Past
Like other cetaceans, gray whales are susceptible to entanglement or entrapment in various types of fishing gear. Several gray whales are known to have died in fishing gear (mainly set nets) in Japan – 1 in 1955, 1 in 1970, and 4 from 2005-2007 (Weller *et al.* 2008). Another died in 1996 from being harpooned and entangled in harpoon lines used to catch Dall's porpoises off Japan.

Based on a collection of digital and film images of gray whales off Sakhalin, Bradford *et al.* (2009) estimated that 20.0% (30 of 150) of whales identified from 1995-2004 had detectable anthropogenic scarring, with 18.7% (n = 28) determined to have been previously entangled in fishing gear at least once. However, Brownell noted that this rate is underestimated as photographs were not available for all areas of each whale.

In the eastern North Pacific, at least tens of gray whale deaths have been documented in gillnets (e.g. for salmon and herring), seine nets, net pens, longlines and pot or trap lines since the 1970s (Heyning and Lewis, 1990; Baird *et al.* 2002; Scordino and Mate, 2011). Carretta noted that about three fishery-related deaths or serious injuries to gray whales are reported in US waters each year. Most documentation is from opportunistic reports rather than systematic fishery observer programs. From 1990-2013 some 18,000 fishing sets were observed in the California offshore drift gillnet fishery (about 15% observer coverage) and inshore set gillnet fishery (5-10% coverage but not observed every year) but only four entanglements of gray whales were documented.

Carretta acknowledged that observed and reported bycatch represents only a fraction of the likely actual bycatch. Punt and Wade (2012), for example, estimated that only 3.9-13% of gray whales that die in a given year end up stranding and being reported. Carretta drew attention to SWFSC data suggesting that only about a quarter of the carcasses of common bottlenose dolphins that die in California each year are recovered, this despite the fact that these dolphins spend about 95% of their time in nearshore waters within 500m of land.

4.2.2 Future

As part of the AWMP *Implementation Review* for eastern gray whales, existing data were reviewed and scenarios of future removals determined (IWC, 2013). The Workshop **agrees** that this approach should be updated (see Item 4.5) for the whole North Pacific. Assumptions on allocations of removals will need to be made for the various stock structure hypotheses.

4.3 Ship strikes

4.3.1 Past

No records are available of ship strike mortality of gray whales in the western North Pacific. However, a small percentage of the whales photo-identified off Sakhalin (n = 3, or 2.0%) showed evidence of having survived at least one vessel strike (Bradford *et al.* 2009).

Laist *et al.* (2001) reported that of the various large whale species reported struck by ships, gray whales were one of the most frequently hit. Carretta reported that in addition to fishery-related deaths and serious injuries, approximately two gray whale deaths and/or serious injuries are attributed to ship strikes each year in US waters. These data reflect the most recent 5-year time period reported in US marine mammal stock assessment reports[5].

4.3.2 Future

As part of the AWMP *Implementation Review* for eastern gray whales, existing data were reviewed and scenarios of future removals determined (IWC, 2013). The Workshop **agrees** that this approach should be updated (see Item 4.5) for the whole North Pacific. Assumptions on allocations of removals will need to be made for the various stock structure hypotheses.

4.5 Recommended time series for use in modelling framework

The Workshop **agrees** that the determination of time series of removals cannot be completed until the work outlined under Item 4 has been reported. For initial runs, this should be agreed at SC65b.

5. ABUNDANCE AND TRENDS

5.1 Review of available data and analyses

5.1.1 Western North Pacific

5.1.1.1 INDIVIDUAL IDENTIFICATION (PHOTO AND GENETIC)

The Russia-US team has been collecting gray whale photo-id data near Piltun lagoon from 1994 to the present. Since 2008, the project has been run solely by the Kamchatka Branch of the Pacific Institute of Geography (Burdin *et al.*, 2013). The IBM team (Institute of Marine Biology, Vladivostok) has been collecting photo-id data off Sakhalin since 2002 as part of the Sakhalin Energy/Exxon Neftegas Limited (ENL) Joint Programme (Tyurneva *et al.*, 2013). Gray whale photo-id data have also been collected off south-eastern Kamchatka since 2006 (Tyurneva *et al*., 2013).

The last time the catalogues were compared (using data through 2011), there was a total of 223 distinct whales in the Sakhalin catalogues, of which 187 were common to both catalogues (IUCN, 2013). Of the 150 distinct whales in the Kamchatka catalogue, 86 were found in at least one of the Sakhalin catalogues.

As of the 2013 season, the Russia-US Sakhalin catalogue contained 225 whales, which is probably more than the total number of whales currently alive in the Sakhalin population. Of these whales, 155 have been sexed genetically from biopsies.

[5] http://www.nmfs.noaa.gov/pr/sars/species.htm

An assessment using the Russia-US data through 2011 was presented in SC/65a/BRG27. Cooke's model had been updated to allow:

(i) individual heterogeneity in sampling probability;
(ii) time lags in the effects of environmental variability on population parameters;
(iii) immigration of 'foreign' whales (i.e. whales whose mothers were not in the Sakhalin population).

The standard AIC criterion for goodness of fit of the model to the data was used to determine which of those new factors were to be included in the final model choice. As in previous assessments, the sampling probability was found to be significantly stage-dependent: highest for mothers with calves and lowest for non-calf immature animals. Allowing, additionally, for individual heterogeneity in sampling probability resulted in a very substantial improvement in the fit of the model to the data, but it had only a small effect on estimates of population size and demographic parameters. Significant inter-annual fluctuations were found in both calving rates and calf survival rates, but no evidence was found of any net trend in these parameters over time. The best fit to the data was obtained by introducing a 2-year time lag into the correlation between calving rates and calf survival rates, i.e. a low (high) calf survival rate from year t to year $t+1$ tends to be associated with a low (high) calving rate in year $t+2$. There was little evidence for immigration: the level of immigration was estimated to be zero or negligible in recent years, but immigration earlier in the period could not be excluded.

As reported by IUCN (2013), the selected model was also fitted to: (a) the Russia-US data set, (b) the combined Russia-US and IBM Sakhalin data set and (c) all three data sets combined (Russia-US, IBM and Kamchatka, but only including whales seen at least once off Sakhalin). Estimates of key population parameters for each of the three data sets are listed in Table 5. The estimates of population size over time are shown in Fig. 6 for (i) the population aged 1+ (i.e. all animals except calves) and (ii) mature females only.

Table 5 – to come from Cooke

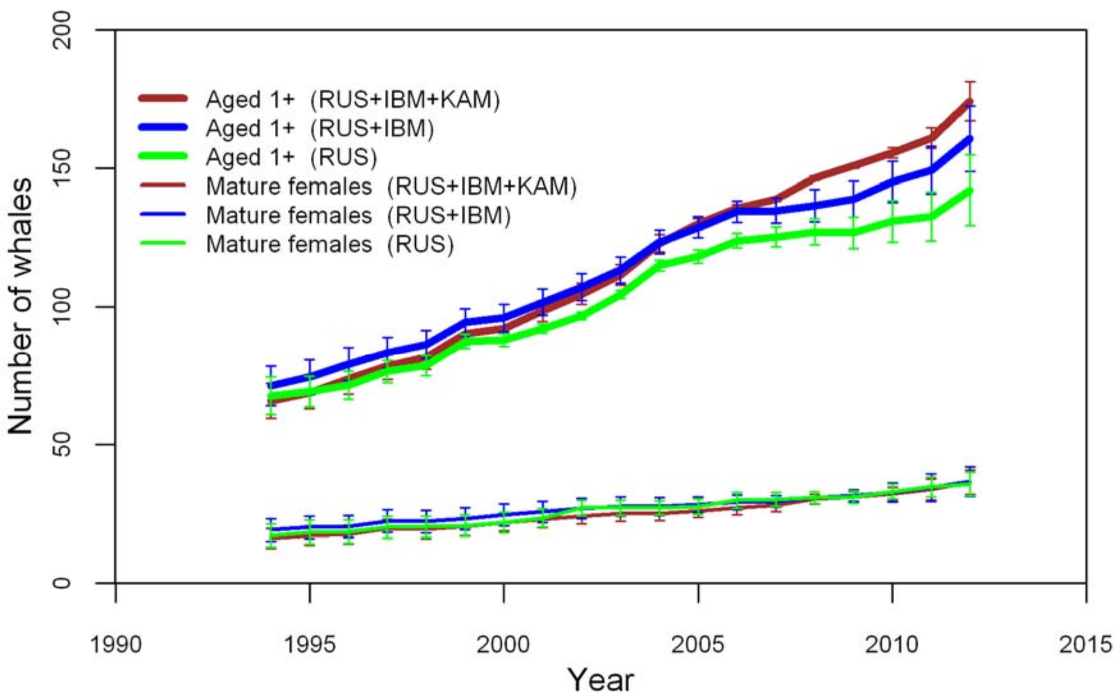

Fig. 6. Estimated population trends for the Sakhalin gray whale population for (i) aged 1+ animals (all animals except calves) and (ii) mature females only, for three data sets: (a) Russia-US(RUS) only; (b) RUS and IBM; (c) RUS, IBM and Kamchatka.

Combining the three data sets without considering potential differences between them may not be a valid approach. In particular, it is noted that relatively few subadult animals are included in the Sakhalin catalogues, and there is an indication that these may be better represented in the Kamchatka catalogue. Work is in progress to extend the model to allow for differences between data sets and locations, and to allow explicitly for the fact that whales were selected on the basis of having been seen at least once off Sakhalin. In the meantime, the estimates of population growth rate (3.4% ± 0.5%) and other demographic parameters obtained from fitting only to the Russia-US data set should be considered the best currently available for the Sakhalin feeding aggregation.

5.1.1.2 SIGHTINGS

The sightings work off Sakhalin Island undertaken as part of the Sakhalin Energy/ENL joint programme (e.g. see summaries in IUCN WGWAP reports) is not designed to estimate abundance but provides information on density and distribution for a portion of each summer season and can be used to examine changes in these by year.

5.1.1.3 PREVIOUS ANALYSES, MODELS AND ASSUMPTIONS (INCLUDING HISTORICAL CATCH SERIES)

An initial effort to model the population dynamics of gray whales in the WNP including historical catch was made by Bradford (2003). Mark-recapture survival estimates, in combination with other life history parameters, were used to calculate a current (1997-2002) population growth rate of gray whales feeding off Sakhalin Island, Russia, which were assumed to represent the western population of gray whales. This growth rate estimate and historical catch data were applied to a 20th century back calculation of the western gray whale population. Bayesian statistics were used to estimate model parameters and indices of population status. A mark-recapture estimate of current (2002) abundance off Sakhalin was treated as a model input to project the population using the backwards method described by Butterworth and Punt (1995). Back calculation results indicated that the western gray whale population should currently be growing at its maximum net recruitment rate, has an undefined carrying capacity, is currently at most between 8-9% of its original size, and has been highly depleted for over half of the 20th century. This assessment can be considered invalidated given the connection between at least some Sakhalin whales and the ENP.

5.1.3 Eastern North Pacific

5.1.3.1 INDIVIDUAL IDENTIFICATION (PHOTO AND GENETIC)

Individual photo-identification data have been collected from the Mexican lagoons and all the way to northern Alaska near Barrow, but mark-recapture abundance estimates have been produced only for the PCFG, defined spatially from 41°-52°N and temporally from 1 June – 30 November. The data, estimation methods and results are described in SC/A14/NPGW03. A collaborative survey effort was conducted from 1998-2012 that covered survey regions between 41°N-52°N (Northern California (NCA) to Northern British Columbia (NBC)). Additional data collected in 1996-1997 with less extensive effort was included to improve the earlier estimates in the time series. The current estimated abundance for 2012 excluding transient whales is 209 (SE=15.4). The annual survival estimate of adults was 0.963 (SE=0.0079) using whales first seen prior to 1999. For whales first seen after 1999, the post first-year survival estimate of adults was 0.905 – a relatively low value which reflects both mortality and permanent emigration from the PCFG by whales that initially entered this population in 1999 or later at the time of or after the 1999-2000 stranding event[6]. Calf survival estimates are first-year survival estimates which can include permanent emigration of calves associated with mothers that were transient and calf mortality within the photo-id season. The calf survival estimates ranged from 0.35 to 0.9 for calves with minimum tenure of 1 to 125 days. The average was 0.54 (SE=0.047).

5.1.3.2 SIGHTINGS

Counts of southbound migrating whales off California at Granite Canyon form the basis of abundance estimation for the eastern North Pacific stock of gray whales. Previous assessments (1967-2007) have estimated detection probability (p) from the detection/non-detection of pods by two independent observers (Laake *et al*., 2012). However, tracking distinct pods in the field can be difficult for single observers, resulting in biased estimates of pod sizes that needed correcting, and matching observations of the same pod by both observers involved key assumptions. Due to these limitations, a new observation approach has been adopted wherein a paired team of observers work together and use a computerized mapping application to track and enumerate distinct pods and tally the number of whales passing during watch periods (Durban *et al.,* 2013). This approach has produced consistent counts over four recently monitored migrations (2006/7, 2007/8, 2009/10 and 2010/11), with an apparent increase in p compared to the previous method. To evaluate p and estimate abundance in these four years, counts from two independent stations of paired observers operating simultaneously were compared using a hierarchical Bayesian 'N-mixture' model to estimate p and abundance without the challenge of matching pods between stations. The overall average detectability po= 0.80 (95% Highest Posterior Density Intervals [HPDI] =0.75-0.85) varied with observation conditions, observer effects and changes in whale abundance during the migration. Abundance changes were described using Bayesian model selection between a parametric model for a normally distributed common migration trend and a semi-parametric model that estimated the time trends independently for each year; the resultant migration curve was a weighted compromise between models, allowing for key departures from the common trend. The summed estimates of migration abundance ranged from 17,820

[6] Darling commented that he was undertaking some analysis to examine the interpretation of the 1999-200 data.

(95% HPDI = 16,150-19,920) in 2007/8 to 21,210 (95% HPDI = 19,420-23,230) in 2009/10, consistent with previous estimates and indicative of a stable population.

5.1.3.3 PREVIOUS ANALYSES, MODELS AND ASSUMPTIONS (INCLUDING HISTORICAL CATCH SERIES)

Population models including historical catch have been constructed for the ENP as a single stock by Punt and Wade (2010) and for the PCFG as a plausible stock by Punt and Moore (2013). Punt and Wade (2010) constructed an age- and sex-structured population dynamics model which was fitted using Bayesian methods to data on the catches and abundance estimates for the ENP stock. They concluded that this stock was at its optimum sustainable population (OSP) level with probability 0.884. Punt and Moore (2013) constructed a deterministic, age- and sex-structured model that consisted of two groups (the 'north' group and the PCFG), which were assumed to be separate for purposes of the analysis, but with possible immigration (permanent movement) between them. With variants of the model, the probability that the PCFG was at OSP ranged from 0.35 on the low end (models F and G) to 0.88 on the high end. They concluded that additional data were needed to obtain better empirical estimates of bycatch mortality and net annual immigration rates, and to reduce uncertainty in Maximum Sustainable Yield Rate (MSYR) and Maximum Net Productivity Level (MNPL) that would potentially improve inferences about the likelihood of the PCFG being at OSP.

5.1.4 Consideration of integrated approach taking into account discussions under Item 2

The Workshop **agrees** that initially, a simple modelling approach will be used that will take into account the above information on abundance and trends (see Item 8). The Workshop also **recommends** that the existing ASAMM data should be analysed to examine trends in relative abundance over the longest period possible to assist in the modelling exercise.

6. POPULATION PARAMETERS

6.1 Review of available data and analyses

A number of biological parameters have been estimated for North Pacific gray whales or could be estimated from currently available data. These estimates are both model-derived and empirical and are summarised in Table 6. Abundance estimates from data collected off California have been used a number of times to model eastern gray whale population dynamics (Cooke, 1986; Lankester and Beddington, 1986; Punt and Butterworth, 2002; Reilly, 1981; Wade, 2002). The model-derived parameter estimates presented in Table 6 reflect the recent modelling effort by Punt and Wade (2012).

6.2 Consideration of integrated approach taking into account discussions under Item 2

The Workshop **agrees** that for the initial modelling purposes, the same values as used in the AWMP trials will be used for the eastern side of the North Pacific; for the western North Pacific, the values from Sakhalin can be used. This will need to be revisited by the Scientific Committee at a later stage.

7. HUMAN ACTIVITIES (OTHER THAN DIRECT REMOVALS) THAT MAY (OR MAY IN THE FUTURE) AFFECT STATUS

7.1 Habitat degradation and modification e.g. by climate change

Sue Moore briefly summarised the impact of climate change on gray whale Arctic habitats, especially the dramatic loss of volume and seasonal areal extent of sea ice Jeffries *et al.,* 2013. Compared to the 1980s, the Pacific Arctic sector (NBS/SCh) is now ice-free roughly 1-2 weeks earlier each spring, and sea ice forms there about 3-4 weeks later each autumn. So gray (and other baleen) whales have 1-1.5 months longer to feed in ice-free habitat. In addition, the loss of sea ice appears to be accompanied by an increase in primary production in the Pacific Arctic sector[7], which may result in more prey for gray and other baleen whales. Finally, a step-change in inflow of Pacific water through the Bering Strait (50% increase in volume, 2001-2011) may be transporting prey (especially krill) into the SCh and NCh gray whale habitats.

Ilyashenko reported that hunters in Chukotka are having difficulty hunting gray whales because the whales stay farther offshore as ice cover declines (ice is now often >10km offshore in northern Chukotka).

7.2 Industrial activities

The dramatic reduction of sea ice in the Arctic has been accompanied by an upsurge in industrial activities in the Pacific Arctic sector (NBS/SCh), particularly with regard to commercial shipping and oil and gas exploration. Commercial ship passage between Europe and China can be roughly 12 days shorter along the Northern Sea Route (NSR) compared to a route through the Suez Canal. However, because great uncertainties remain regarding

[7] http://www.arctic.noaa.gov/report12/primary_productivity.html

reliable transit along the NSR, it remains unclear whether the NSR is likely to develop into a major shipping artery. This matter was covered extensively at the IWC Arctic Impacts workshop (cite report). Oil and gas exploration, including seismic surveys and destinational ship transits, will increase the risks of ship strikes (especially at narrow passages such as Bering Strait) and toxic spills (including oil) and bring more underwater noise to the region. These matters were also discussed at the Arctic Impacts workshop and are also discussed at annual meetings of the SC/E group (ref. SC 65a).

Table 6
Biological parameter information by sub-area

Parameter	Mexico lagoons	32-41° (CA)	41-52° (PCFG)	Kodiak	Chukotka	East Kamchatka	Sakhalin
First-year calf survival	Photo data available, Urbán *et al.*	0.711 (90% PI=0.423-0.950)[2] Punt and Wade, 2012					
Post-weaning calf survival			Mark-recapture estimates available, Calambokidis *et al.*; Photo data available Darling *et al.*.			Photo data available Tyurneva *et al.*	0.67 (SE=0.07)[2]- Cooke *et al.*, 2013; 0.717 (95% CI=0.579-0.824)[1] Bradford, 2011[1]
Non-calf survival	Photo data available, Urbán *et al.*.	0.981 (90% PI=0.957-0.997)[2] Punt and Wade, 2012	0.963 (SE=0.0079)[2] - SC/A14/NPGW03; Photo data available, Darling *et al.*	Photo data available? Wynne *et al.*.		Photo data available Tyurneva *et al.*	0.975 (SE=0.005)[2] Cooke *et al.*, 2013; 0.973 (95% CI=0.954-0.984)[1]-Bradford 2011
Age at sexual maturity		9 med (6-12)[1] both sexes Rice and Wolman (1971), Rice (1990)			7 med (6-8)[1] (females), Blokhin and Tiupeleyev 1987; Catch data available, Blokhin *et al.*		
Age at first reproduction	7 (n=1)[1] Swartz *et al.*.					Photo data available? Tyurneva *et al.*	11.5 (SE=1.1)[2] Cooke *et al.*, 2013; 7, 9, 10, 11 (*n*=4) Bradford *et al.*
Pregnancy rate	0.48 (95% CI=0.463-0.498)[1], Jones and Swartz, 1990; Hormone data available, Urbán *et al.*	0.46[1] Rice and Woman (1971)	Biopsy data available Calambokidis *et al.*		0.44[1]- Blokhin 1984a, 1987; Catch data available, Blokhin *et al.*		
Calving interval	2.11 (SD=0.4)[1] (1972-1982) – Jones,1990; 2.44 (SD=0.61)[1] (2006-2013), Urbán *et al.*		Photo data available Calambokidis *et al.*, Darling *et al.*			Photo data available Tyurneva *et al.*	2.9 (SE=0.18), 2.7 (SE=0.16), or 2.5 (SE=0.13)[1] (1995-2003) Bradford *et al.*. 2008; Photo data available, Weller *et al.*.
Sex ratio	0.564 male (neonate)[1] IWC 1993[3]	0.5 male (foetal) and 0.625 male (neonate)[1,3]- Rice (1990); 0.52 male (all age classes)[1] and 0.506 male (foetal)[1] Rice and Wolman (1971)	Photo data available Calambokidis *et al.*, Darling *et al.*.		Catch data available, Blokhin *et al.*		0.61 male (SE=0.05) (neonate)[2] Cooke *et al.*. 2013 0.591 male (calf)[1] Lang *et al.*.
Conception date		5 Dec mean (late Nov – early Jan)[1] - Rice and Wolman 1971					
Calving date	27 Jan med (late Dec – early Mar)[1]- Rice *et al.*. 1981						

[1]Observed or estimated from data (includes mark-recapture); [2]Population dynamics model-based estimate; [3]Attributed to Jones and Swartz 1983, but this value was not reported there; [4]Combines fetuses and neonates from breeding, migration, and feeding areas

As in the case of Item 7.1, the Workshop recognised that this agenda item also applies to non-Arctic portions of the gray whale's range (certainly including Sakhalin Island and coastal regions of Korea, Japan and China). A number of anthropogenic threats to gray whales in the western North Pacific give cause for concern. For instance, incidental takes in fishing gear throughout the range may pose a threat to gray whales as discussed under Item 4.3. Near-shore industrialization and shipping congestion throughout the migratory corridor(s) represent additional risks by increasing the likelihood of exposure to pollutants and ship strikes as well as a general degradation of the habitat. Finally, the summer feeding area off Sakhalin Island is a region rich with offshore oil and gas reserves. Two major offshore oil and gas projects now directly overlap or are in near proximity to this important feeding area, and more development is planned there and in other parts of the Okhotsk Sea that include the migratory routes of these whales. Operations of this nature have introduced new sources of underwater noise, including seismic surveys, as well as increasing ship traffic and the risk of oil spills. Considerable information has been published in reports of the IWC SC, the report of the 2008 IUCN rangewide workshop, and various reports by the IUCN gray whale panels (see http://www.iucn.org/wgwap/).

7.3 Other

Military activities, research and tourism have also increased in the Arctic and elsewhere in the gray whale's range but no new information on these issues was presented at this Workshop.

7.4 Consideration of how these may be incorporated into a modelling framework

In an ecological context, the impacts of human activities on gray whales must be incorporated as an additional level of habitat variability coupled to that of climate change. The whales experience 'one habitat', which reflects the combined outcome of 'natural' variability and human activities. With regard to gray whale population structure and status, the potential for increased lethal takes (by ship strike) and habitat alteration and degradation (by increased offshore activities) in the Pacific Arctic sector is recognized, but for now impossible to quantify. The Workshop **agrees** that further consideration as to how to incorporate these factors into the modelling framework should take place after the initial simple modelling has been undertaken (see Item 8).

8. DEVELOP MODELLING APPROACH/SCENARIOS

The development of a population dynamics model for North Pacific gray whales will necessarily be an iterative process. The first step is to develop an age- and sex-aggregated model which includes multiple stocks (two or three depending on the hypothesis under consideration). The aim for developing this model will be primarily to understand whether sufficient data are available to justify the various stock structure hypotheses and whether parameterization of the model based on the associated hypotheses can provide reasonable fits to the data. The data included in the first step model will be the catches by area and month and the trends in 1+ abundance for the Sakhalin feeding area, the PCFG and the counts off southern California. The model will mimic the assumptions regarding how catches off North America and Chukotka are allocated to breeding stock.

The estimable parameters of the first step model will be the initial sizes of each breeding stock, the rate of increase of each stock in the limit of zero population size, and the levels of immigration and emigration into and out of the PCFG. The proportion of each stock which is found in each area will initially be pre-specified, but some of these parameters will be treated as estimable in the second and subsequent steps. The first step model should initially try to start the model projections for the system at unfished equilibrium. However, the fits to the data may be very poor unless allowance is made, for example, for changes in carrying capacity over time. Consequently, model runs should be produced when the model is initialized in a more recent year. The first step model should explore assumptions regarding the dynamics prior to the 1990s of the whales that feed off Sakhalin.

The results of the initial model fits will be reviewed by the Scientific Committee and this review may lead to refinement of the stock structure hypotheses, including rejection of some hypotheses which are clearly inconsistent with the available data.

The second step in the modelling process, assuming that the Scientific Committee considers the first phase a success, would be to extend the model to include age and sex structure and to include data on mixing proportions based on telemetry and genetics data. Subsequent steps may be required depending on how well it is possible to mimic the available data, and to explore the impact of future catches and other human activities.

The Workshop established an intersessional working group with members Punt (chair), Bradford, Cooke, Donovan, Lang, Mate and Weller to develop a set of model specifications for the first step in the modelling process.

9. WORKPLAN UP TO 2014 IWC ANNUAL MEETING AND BEYOND

9.1 Prior to SC65b

Develop the mathematical specifications for an age- and sex-structured model and identify data gaps (Punt, with help from the intersessional working group).

9.2 During SC65b

(1) Implement the age- and sex-structured model for one hypothesis as a proof-of-concept (Punt).

(2) Refine the specifications of the age- and sex-structured model.

(3) Develop detailed terms of reference for the 2nd workshop.

9.3 After SC65b

Use the age- and sex-structured model to explore the remaining hypotheses.

10. RECOMMENDATIONS

10.1 Conduct a preliminary comparison of photographically and genetically identified gray whales in Mexico, off central California and in the PCFG with a focus on mothers and calves.

Objectives

(1) Improve assessment of internal recruitment to the PCFG by identifying PCFG whales known to have given birth in Mexico (would increase the sample size of known PCFG mothers).
(2) Improve estimates of calf survival for PCFG whales by identifying mothers with calves on wintering grounds and during migration and determining whether the calves were ever sighted again.
(3) Improve determination of the number of known reproductive PCFG females that have been biopsied. This would come about two ways: 1) the comparison would reveal some biopsied PCFG whales that were not previously known to be reproductive females and 2) some PCFG whales that match to Mexico but have not been biopsied in the PCFG may prove to have been biopsied in Mexico.

Tasks

(1) Conduct a rapid comparison of the approximately 1,500 photo-identified gray whale mothers known to have been accompanied by calves in Mexico from 2010-2014 and off central California from 2012-2014 to a subset of the catalogue (maintained by Cascadia Research Collective, CRC) consisting of known PCFG whales photo-identified in multiple years. This work would be carried out by the primary CRC photo-matcher who is familiar with PCFG whales and he/she would examine all Mexico/central California mothers for any that are recognized and then compare any familiar whales to the catalogue to verify the match. When a match is found, the calf of the mother will be compared to the full catalogue (all whales) maintained by CRC.
(2) Conduct a simultaneous comparison by matchers at UABCS of the approximately 50 known PCFG mothers to the 1,500 Mexico mothers with calves. This will both provide an independent check on the comparison above and help explain some of the long gaps between calves observed with PCFG mothers – e.g. the female did have a calf in a given year but it was missed.

10.2 Develop Single Nucleotide Polymorphisms (SNP) assays for use with gray whales

Objectives

The development of a SNP panel be developed for use with gray whales would:

(1) allow integration of genetic data between labs as well as over time, increasing the utility of such data for future analyse;

(2) allow work with low-quality samples, such as bone and baleen, which could facilitate analysis of any historic samples identified.

10.3 Increase the sample numbers and sample coverage for the eastern North Pacific stock of gray whales

Objectives

While a high proportion of the whales using the Sakhalin feeding ground have been sampled, the proportion of the eastern North Pacific stock that has been sampled is low. In addition, few or no samples have been collected from some parts of the range of eastern North Pacific stock. Such studies are essential to improve comparisons amongst areas, better examine stock structure in the feeding grounds and improve stock structure hypotheses to allow for improved conservation and management via modelling.

Methods
Efforts should be made wherever practical to increase additional sampling and photo-identification efforts in key areas, such as the northern Chukchi, with the goal of evaluating whether additional structure exists on feeding areas used by the ENP stock.

10.4 Improve abundance and trend estimates for the PCFG by identifying and using additional photographic sources (Calambokidis, Darling and Laake)
Objectives
It is important to know the degree to which there was large-scale recruitment into the PCFG during the period prior to around 1998 (which would have to have been from an external source) to evaluate the status of the PCFG. The previous AWMP trials have made assumptions about a pulse increase in recruitment to PCFG. This was because broad-scale collaborative photo-ID sampling of a large portion of the PCFG began in 1998, shortly before the large-scale gray whale mortality event in 1999. Abundance trend models show a sharp increase at the beginning of the sampling that extends through the early 2000s. The addition of some of the partial data available from 1996 and 1997 did not allow for accurate abundance estimates in those years but it did cause the estimates for 1998 to increase somewhat.

Method
It is known that some additional identification photographs from 1996 and 1997 are available from other investigators, naturalists and opportunistic sources. These should be identified and investigated to see if they can inform the trend analysis of the PCFG and thereby improve understanding of recruitment for this population.

10.5 Compare photographs of gray whales from areas of the Okhotsk Sea and elsewhere in Asia with the Sakhalin and Kamchatka catalogues (e.g Weller, Bradford, Tyurneva…)
Objectives
To better understand the stock structure and movements of gray whales on the western side of the North Pacific.

Method
Photographs have been taken of gray whales encountered in other parts of the Okhotsk Sea aside from Sakhalin Island (e.g. Shantar Archipelago, Kuril Islands, Magadan) and have been archived by both the Russia-U.S. western gray whale research program and the Institute of Marine Biology (IBM), Vladivostok. Subsets of these photographs have been compared previously by both teams to individuals photographed off Sakhalin Island (e.g. Weller *et al.* 2002, 2003), but a combined matching effort has not been attempted. The Workshop **recommends** that all available photographs of gray whales outside of Sakhalin in the Okhotsk Sea (and potentially other parts of the western Pacific) be catalogued and matched against the two Sakhalin catalogues.

10.6 Putting bounds on the proportion of Sakhalin whales that migrate to the eastern North Pacific in winter (Cooke)
Objective
In order to further questions of stock structure and whether 'true' western gray whales regularly feed off Sakhalin, it is of great interest to determine what proportion of Sakhalin gray whales migrate to the eastern North Pacific. In statistical terms, the question is what bounds, or confidence limits, can be placed on the proportion that migrates to the eastern North Pacific.

Data sources
The three sources of data are: telemetry, photo-id and genetic. The provisional results obtained so far include:

Data source	Matches	Comparison
Telemetry	3	Sakhalin whales tracked to E. Pacific (out of 3 tagged for whish transmissions lasted sufficiently long)
Photo-identification of individuals	5	Sakhalin whales matched to PNW catalogue
	17	Sakhalin whales matched to Mexican catalogue
	3	Sakhalin whales matched to other ENP catalogues
Genetic identification of individuals	3	Sakhalin whales matched to ENP samples

The interpretation of the genetic and photo-id data requires specifying the sizes of the samples in which the matches were found. Because this varies over the years, the sample sizes by year are needed.

Data required for analysis
For each year of each catalogue (at least the Sakhalin, Mexican and Pacific Northwest):

(1) number of distinct whales photo-identified that year;
(2) number of new whales photo-identified that year; and

(3) for each match between Sakhalin and another catalogue, years for each catalogue in which that whale was photo-identified.

In the case of the Pacific Northwest (PNW) catalogue, whales deemed to belong to PCFG should be omitted. Other catalogues can be included where practicable.

Genetic identification data should be summarized in a similar way to the photo-id data, but the sample sizes are generally lower.

Proposed analysis
The proposed analysis is to apply a capture-recapture model to each source of data to yield a combined likelihood for the proportion p of Sakhalin whales that migrate to the eastern North Pacific in winter. Two models will be considered:

(1) each Sakhalin whale migrates to the eastern North Pacific with a probability p each year

(2) a fraction p of Sakhalin whales migrates to the eastern North Pacific each winter; the rest do not.

Other models can be considered if the data warrant this. The results will be expressed in terms of confidence intervals for p.

10.7 Continued development of the population model for the Sakhalin feeding area
The Workshop **strongly encourages** the continued development and publication of the Cooke approach. It **reiterates** the importance of careful incorporation of all relevant data from Sakhalin and Kamchatka into the model (e.g. see IWC, 2013).

10.8 Continued telemetry studies
The IWC Scientific Committee has several times reiterated the great importance of further telemetry studies, particularly off Sakhalin, Kamchatka and in the northern areas such as Chukotka. This work not only can inform on migration routes and usage but also on determining the likelihood of whales from various areas being taken in hunts, fishing gear or ship strikes. The Workshop **reiterates** this and **recommends** that such work be undertaken.

10.9 Improved estimates of western North Pacific catches 1890-1910 (to come from Brownell and Reeves)
Objective
To determine whether it is possible, and if so to estimate, the likely large catches for the years 1890-1910 in the western North Pacific around the Korean Peninsula.

Method
Carry out a literature/museum/logbook investigation to obtain information on whaling effort (e.g. numbers of vessels, captains, stations) and other aspects (e.g. suspension of effort due to the Sino-Japanese War), by year, that could be used to estimate catches for these years by inference, interpolation or extrapolation using the known catches in 1907 and 1913 as a starting point (see Reeves and Smith, 2010). Such a study will require participation by researchers with appropriate language abilities – i.e. at least Japanese, Russian and Norwegian.

10.10 Improved estimates for future ship strikes and bycatches throughout the whole North Pacific (Scordino and Carreta)
Objective
To develop future removal series to be used in modelling for the entire North Pacific.

Approach
To extend the approach to determine future non-deliberate removals used for the AWMP trials (e.g. see Scordino and Mate, 2011; IWC 2013) and update this for the whole North Pacific. Assumptions on allocations of removals will need to be made for the various stock structure hypotheses.

10.11 Develop plans for a second workshop to review the results of the initial modelling exercise
The Workshop **recommends** that the Scientific Committee begins to plan for a second workshop to review the modelling results recommended from the present workshop as part of the process towards meeting the long term objective of improving conservation and management of this species.

11. ADOPTION OF REPORT

Most of the report text and the recommendations were agreed and adopted on the last day of the Workshop. Additional drafting and editing work was conducted after the Workshop and all participants were given the opportunity to review and comment by e-mail before the report was finalised. This version was completed on 13

May 2014 although some participants had yet to comment. The Chair thanked the participants for their enthusiasm to participate in all aspects of this wide-ranging workshop, whatever their primary disciplines. He noted that this was an important step to understanding the status of gray whales throughout the North Pacific and for determining management and conservation priorities. He also re-iterated thanks for the wonderful facilities provided by the SWFSC. The Workshop participants thanked the Chair for steering them through a long and complex agenda, with good humour and fairness.

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Annex A

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Annex B
Agenda

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

1.2 Election of Chair

1.3 Appointment of rapporteurs

1.4 Adoption of Agenda

1.5 Documents and data available

2. SUMMARY OF POPULATION MODELLING APPROACHES THAT HAVE BEEN OR MAY BE RELEVANT FOR NORTH PACIFIC GRAY WHALES

2.1 AWMP (including Pacific Coast Feeding Group)

2.2 Western North Pacific (Cooke model)

3. STOCK STRUCTURE AND MOVEMENTS

3.1 Summary of existing hypotheses

3.2 Review of available data and analyses

- 3.2.1 Genetic data on population structure
- 3.2.2 Osteological data comparing populations
- 3.2.3 Individual identification data (photo and genetic)
- 3.2.4 Telemetry data
- 3.2.5 Removals data
- 3.2.6 Sightings data
- 3.2.7 Biological data
- 3.2.8 Ecology and behaviour
- 3.2.9 Other

3.3 Discussion of possible population structure hypotheses

3.4 Recommendations for hypotheses for inclusion in the modelling framework

3.5 Recommendations for future data collection and/or analyses

4. REMOVAL DATA

4.1 Commercial catches [post 1850]

- 4.1.1 Western North Pacific
- 4.1.2 Eastern North Pacific
- 4.1.3 Future

4.2 Aboriginal subsistence catches

- 4.2.1 Past
- 4.2.2 Future

4.3 Incidental catches in fishing gear

- 4.2.1 Past
- 4.2.2 Future

4.4 Ship strikes

- 4.3.1 Past
- 4.3.2 Future

4.5 Recommended time series for use in modelling framework

5. ABUNDANCE AND TRENDS

5.1 Review of available data and analyses

- 5.1.1 Western North Pacific
  - 5.1.1.1 Individual identification (photo and genetic)
  - 5.1.1.2 Sightings
  - 5.1.1.3 Previous analyses, models and assumptions (including historical catch series)
- 5.1.3 Eastern North Pacific
  - 5.1.3.1 Individual identification (photo and genetic)
  - 5.1.3.2 Sightings
  - 5.1.3.3 Previous analyses, models and assumptions (including historical catch series)
- 5.1.4 Consideration of integrated approach taking into account discussions under Item 2

6. POPULATION PARAMETERS

6.1 Review of available data and analyses

6.2 Consideration of integrated approach taking into account discussions under Item 2

7. HUMAN ACTIVITIES (OTHER THAN DIRECT REMOVALS) THAT MAY (OR MAY IN THE FUTURE) AFFECT STATUS

7.1 Habitat degradation and modification e.g. by climate change

7.2 Industrial activities

7.3 Other

7.4 Consideration of how these may be incorporated into a modelling framework

8. DEVELOP MODELLING APPROACH/SCENARIOS

9. WORKPLAN UP TO 2014 IWC ANNUAL MEETING AND BEYOND

9.1 Prior to SC65b

9.2 During SC65b

9.3 After SC65b

10. RECOMMENDATIONS

11. ADOPTION OF REPORT

Annex C

List of Documents

SC/A14/NPGW01. Bickham, J., Dupont, J., Broker, K. Status of the western North Pacific gray whale: review of stock structure hypotheses and genetic approaches. 17pp.

SC/A14/NPGW02. Bickham, W. J. The challenge of identifying management units in large, vagile marine animals: meta-analysis reveals why conservation geneticists should think smart not big. 34pp.

SC/A14/NPGW03. Calambokidis, J., Laake, J., and Perez, A. Updated analysis of abundance and population structure of seasonal gray whales in the Pacific Northwest, 1996-2012. 76pp.

Annex D

Summary of genetic data and analyses

Table 1
Available samples by study

					Month																
Region	Reference	Samples*	Time Period	Type of samples	1	2	3	4	5	6	7	8	9	10	11	12	Utilized mtDNA?	mtDNA bps sequenced	Utilized microsatellites?	# of microsatellite loci	Comments
Baja Mexico, all three lagoons	Urban in process	450	2013-2014	Biopsies		x	x										Y (In progress)		N		Approximately 50% of samples processed
Baja Mexico, Bahia Balenas	Goerlitz et al. 2003	2	1996	Biopsies			x										Y	302	N		Urban confirmed that this is a different sample set from Alter et al. 2009
Baja Mexico, Bahia Magdalena lagoon	Alter et al. 2009	32	2001-02, 2005-2006	Biopsies		x	x										Y	442	Y	9	
Baja Mexico, Offshore, San Jose del Cabo	Goerlitz et al. 2009	1	1996	Biopsies			x										Y	302			Urban confirmed that this is a different sample set from Alter et al. 2009
Baja Mexico, Ojo de Liebre lagoon	Alter et l. 2009	24	2001-02, 2005-2006	Biopsies		x	x										Y	442	Y	9	
Baja Mexico, Ojo de Liebre lagoon	Goerlitz et al. 2009	14	1997	Biopsies		x	x										Y	302	N		Urban confirmed that this is a different sample set from Alter et al. 2009
Baja Mexico, San Ignacio lagoon	Alter et al. 2009	56	2001-02, 2005-2006	Biopsies		x	x										Y	442	Y	9	
Baja Mexico, San Ignacio lagoon	Goerlitz et al. 2009	66	1996, 1997	Most biopsies, 4 strandings		x	x										Y	302	N		Urban confirmed that this is a different sample set from Alter et al. 2009
ENP (not specified)	Alter et al. 2007	42															N		N		Incl. sequences from mtDNA cyt B, seven nuclear introns, and one X-linked region.
Migratory, CA/OR/WA (89), AK (9), Chukotka (5)	LeDuc et al. 2002	104	1979-2000	Strandings (91), harvest (6), bycatch (2), biopsies (21)	x	x	x	x	x	x	x	x	x	x	x	x	Y	523	N		Analysis also included n=16 Steeves et al samples, grouped with ENP stratum
Pacific Northwest, 41-52 (not ided as PCFG)	Lang et al. 2011, Pers. Comm.	33	1996-2012	Biopsies					x	x	x	x	x	x	x		Y	523	Y	12	
Pacific Northwest, 41-52	Alter et al. 2012	16	150-2690 ybp	Bones from middens													Y	383	N		

Region	Reference	Samples*	Time Period	Type of samples	Month												Utilized mtDNA?	mtDNA bps sequenced	Utilized microsatellites?	# of microsatellite loci	Comments
					1	2	3	4	5	6	7	8	9	10	11	12					
Pacific Northwest, 41-52	Ramakrishnan et al. 2001	45		Biopsies													Y	523	N		Includes Steeves et al. samples from Pacific Northwest; not all samples correlated with photoid (i.e. may not be PCFG)
Pacific Northwest, 41-52, PCFG	Lang et al. 2014, Lang pers comm.	134	1996-2012	Biopsies	x	x		x	x	x	x	x	x	x	x	x	Y	523	Y	23	
Pacific Northwest, 41-52, PCFG	D'Intino et al. 2012	82		Biopsies							x	x	x	x	x		N		Y	15	Likely overlap with Frasier et al., which provides mtDNA data.
Pacific Northwest, 41-52, PCFG	Frasier et al. 2011	40	1995-2006	Biopsies							x	x	x	x	x		Y	345	N		
Pacific Northwest, 41-52, PCFG	Steeves et al. 2001	16	1995-1996	Biopsies						x	x	x	x	x	x		Y	311	N		These samples likely used in Frasier et al. and D'Intino et al.
Alaska, Kodiak	Lang pers com	6	2001, 2005	Biopsies							x	x					Y	523	N		
Alaska, Barrow	Lang et al. 2014, Lang pers comm.	23	1997-1998, 2000, 2002, 2010-2011	Biopsies, Tagging, Strandings							x	x	x				Y	523	Y	12	Only Lang et al. 2014 samples processed for 12 loci.
Russia, Chukotka	Kanda et al. 2010	7	2008	Harvest						x	x	x	x	x			Y	486	N		
Russia, Chukotka	Meschersky et al. 2012	84		Harvest													Y	555	N		Also 1137 bp of cyt B sequence
Russia, Chukotka	Ilyashenko pers comm.	~150		Harvest													N		N		
Russia, Chukotka	Lang et al. 2014	75	1994, 2001, 2003-2005	Harvest							x	x	x	x	x		Y	523	Y	12	
Russia, Koryak coast	Meschersky et al. 2012	16	2010-2011	Biopsies													Y	555	N		Also 1137 bp of cyt B sequence
Russia, Koryak coast	Lang et al. 2014	17	2010	Biopsies						x							Y	523	Y	12	Likely same samples as Meschersky et al. 2011
Russia, Sakhalin Island	Meschersky et al. 2012	14	2010-2011	Biopsies													Y	555	N		Also 1137 bp of cyt B sequence
Russia, Sakhalin Island	Lang reported	155	1995-2007, 2010-2011	Biopsies							x	x	x				Y	523	Y	23	
Russia, Sakhalin Island	LeDuc et al. 2002	45	1995-1999	Biopsies						x	x	x	x	x			Y	523	N		These samples also included in Lang et al. studies
Russia, Sakhalin Island	Bickham et al. 2013	6	2011	Biopsies						x	x	x	x	x			Y		N		Cytochrome B sequences also generated; these individuals also sampled as part of LeDuc et al. 2002 and Lang et al. studies

Region	Reference	Samples*	Time Period	Type of samples	Month 1	2	3	4	5	6	7	8	9	10	11	12	Utilized mtDNA?	mtDNA bps sequenced	Utilized microsatellites?	# of microsatellite loci	Comments
Russia, SE Kamchatka	Meschersky et al. 2012	17	2010-2011	Biopsies													Y	555	N		Also 1137 bp of cyt B sequence
Russia, SE Kamchatka	Lang pers comm.	16	2004, 2010-2011	Biopsies						x	x	x					Y	523	Y	12-23	
Japan, Pacific coast	Kanda et al. 2010	5	1995-2007	Strandings, Bycatch	x			x	x		x	x					Y	486	N		
Japan, Sea of Japan coast	Kanda et al. 2010	1	1996	Strandings Bycatch					x								Y	486	N		
China	Lang Pers. Comm.	2*	1996, 2011	Strandings, Bycatch											x	x	Y*	523	Y*	23	The 1996 sample failed to produce useable DNA when extracted.

Table 2

Summary of genetic analyses, including regions compared, sample sizes (n), number of mtDNA haplotypes (Nb haps), mtDNA haplotype diversity (h), number of mtDNA haplotypes shared between areas (Nb shared), and results of comparisons between strata for both mtDNA (p-values in parentheses for F_{ST} and Φ_{ST}) and microsatellites (p-values in parentheses for F_{ST}).

Reference	Stratum 1				Stratum 2				mtDNA				Microsatellites	
	Region	n	Nb haps	h	Region	n	Nb haps	h	Nb shared	F_{ST}	Φ_{ST}	Exact Test	F_{ST}	Exact Test/Chi-square
Mexico (within lagoons)														
Goerlitz et al. 2003	Laguna San Ignacio (LSI) cows	42			LSI single females	11				0.027 (p=0.044)	0.088 (p=0.034)			
Mexico (lagoons v. outside lagoons)														
Goerlitz et al. 2003	LSI cows	42			non-lagoon females	25				0.064 (p<0.01)	0.041 (p=0.043)			
Goerlitz et al. 2003	LSI single females	11			non-lagoon females	25				0.07 (p<0.01)	0.003 (p=0.34)			
Goerlitz et al. 2003	LSI males	13			non-lagoon males	28				0.08 (p<0.01)	-0.03 (p=0.8)			
Goerlitz et al. 2003	Ojo de Liebre (OdL) cows	10			non-lagoon females	25				0.074 (p<0.01)	-0.03 (p=0.82)			
Mexico (between lagoons)														
Goerlitz et al. 2003	LSI cows	42			OdL cows	10				0.03 (p=0.08)	0.013 (p=0.27)			
Alter et al. 2009	Ojo de Liebre	24	13	0.942	Laguna San Ignacio	56	20	0.948		0.0174 (p=0.89)			0.0168 (p=0.99)	p=0.806
Alter et al. 2009	Laguna San Ignacio	56	20	0.948	Bahia Magdalena	32	20	0.9587		0.0150 (p=0.92)			0.0057 (p=0.025)	p<0.0001
Alter et al. 2009	Ojo de Liebre	24	13	0.942	Bahia Magdalena	32	20	0.9587		0.0177 (p=0.77)			0.0217 (p=0.99)	p=0.163
North Pacific														
Alter et al. 2007														
Sakhalin v. CA & NBS (CA->WA)														
LeDuc et al. 2002	Sakhalin	45	10	0.7	ENP	120	33	0.95	7	0.087 (p<0.001)	0.117 (p<0.001)	p<0.001		
PCFG: Pacific Northwest, 41-52 (ancient) v. WNP														
Alter et al. 2012	South* - middens	16	9	0.933	WNP	45	10	0.7	2	0.2794 (p<0.001)				
PCFG: Pacific Northwest, 41-52 (ancient) v. ENP														

Alter et al. 2012	South* - middens	16	9	0.933		ENP		120	33	0.95		6		0.1004 (p<0.001)					
														PCFG: SOUTH					
Ramakrishnan et al. 2001	South*	45	20	0.93															
PCFG v. NBS & N. Chukchi																			
Lang et al. 2014	PCFG	71	23	0.945		Northern Feeding		106	32	0.952		19		0.012 (p<0.0045)	0.012 (p=0.0740)	0.0067		0.000 (p=0.5269)	0.3491
PCFG v. NBS																			
Lang et al. 2014	PCFG	71	23	0.945		Chukotka		71	23	0.953		18		0.010 (p=0.0349)	0.020 (p = 0.0386)	0.0254		0.001 (p=0.2539)	0.3503
PCFG v. Mexico																			
D'Intino et al. 2012	PCFG	82				Mex lagoons		51										0.001 p = 0.489	
PCFG v. CA (CA->AK)																			
Frasier et al. 2011	PCFG	40	18	0.928		ENP		105	28	0.95		18		0.0125 (p = 0.0303)	0.0311 (p = 0.0259)				
Steeves et al. 2001	PCFG	16	11			ENP		41	19			5			-0.007 (p<0.51)				
Sakhalin																			
Bickham et al. 2013	Sakhalin	6	4/3*																
Lang et al. 2010	Sakhalin	142	22	0.77															
Sakhalin v. NBS & N. Chukchi																			
Lang et al. 2011	Sakhalin	142	22	0.77		Northern Feeding		106	32	0.952		20		0.086 (p<0.0001)	0.152 (p<0.0001)	p<0.000		0.01 (p=0.001)	p=0.001
Sakhalin v. CA (CA->AK)																			
Lang 2010	Sakhalin	142	22	0.77		ENP (CA - AK)		122	34	0.956		20		0.065 (p<0.001)	0.100 (p=0.001)	p<0.000		0.008 (p=0.001)	p=0.001
Sea of Japan & Pacific coast of Japan																			
Kanda et al. 2010	Japan	6	5																

* "South" refers to samples collected within the season (June – November) and range (41-52° N) of the PCFG but not necessarily linked to a whale photographically identified as being part of the PCFG.

Annex E

Summary of catch data for the western North Pacific

Minimum numbers and details of western gray whales caught during the 20th century (from Bradford, 2003). Years are displayed continuously until 1966, the reported end of modern whaling for western gray whales. Highlighted rows represent total yearly minimum catches.

Year	Month	Location	Water Body	Country	Whalers	Method	Catch	Source
1900	?	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	23	Kato and Kasuya (2002) from Park (1987)
1900	?	Kawajiri, Yamaguchi	Sea of Japan	Japan	Japanese	?	2	Omura (1984) from Tada (1978)
1900							25	
1901							?	Kato and Kasuya (2002) from Park (1987)
1902	?	Jangjeon	Sea of Japan	Korea	Russian	Modern	9	Kato and Kasuya (2002) from Park (1987)
1902	?	Unknown	Unknown	Unknown	Unknown	Modern	5	Kato and Kasuya (2002) from Park (1987)
1902							14	
1903							?	Kato and Kasuya (2002)
1904							?	Kato and Kasuya (2002)
1905							?	Kato and Kasuya (2002)
1906	Nov-Mar	Ulsan	Sea of Japan	Korea	Japanese?	Modern	59	Kato and Kasuya (2002) from Park (1987)
1906	?	Unknown	Unknown	Unknown	Unknown	Modern	11	Kato and Kasuya (2002) from Park (1987)
1906							70	
1907	Nov-Mar	Ulsan	Sea of Japan	Korea	Japanese?	Modern	125	Kato and Kasuya (2002) from Park (1987)
1907							125	
1908	Nov-Mar	Ulsan	Sea of Japan	Korea	Japanese?	Modern	26	Kato and Kasuya (2002) from Park (1987)
1908							26	
1909	Dec	Ulsan	Sea of Japan	Korea	Japanese	Modern	65	Andrews (1914)
1909	Dec	Chan Chien Dogo	Sea of Japan	Korea	Japanese	Modern	18	Andrews (1914)
1909	Dec	Hidokatsu	Sea of Japan?	Korea?	Japanese	Modern	1	Andrews (1914)
1909							84	
1910	Jan	Ulsan	Sea of Japan	Korea	Japanese	Modern	32	Andrews (1914)
1910	Feb	Ulsan	Sea of Japan	Korea	Japanese	Modern	3	Andrews (1914)
1910	Mar	Ulsan	Sea of Japan	Korea	Japanese	Modern	1	Andrews (1914)
1910	Feb	Oshima, Nagasaki	Tsushima Strait	Japan	Japanese	Modern	1	Andrews (1914)
1910	Mar	Chan Chien Dogo	Sea of Japan	Korea	Japanese	Modern	1	Andrews (1914)
1910							38	
1911	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	106	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1911	Nov-Apr	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	13	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1911	?	North Kyushu	Korea Strait?	Japan	Unknown	Modern	2	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1911							121	
1912	Mar	Chan Chien Dogo	Sea of Japan	Korea	Capt. Melsom	Modern	2	Andrews (1914), Mizue (1951)
1912	Jan	Ulsan	Sea of Japan	Korea	Japanese	Modern	23	Andrews (1914)
1912	?	Unknown	Unknown	Unknown	Unknown	Modern	193	Kato and Kasuya (2002), Omura (1988) from Kasahara (1950)
1912							218	
1913	?	Unknown	Unknown	Unknown	Unknown	Modern	131	Kato and Kasuya (2002), Omura (1988) from Kasahara (1950)
1913							131	
1914	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	109	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1914	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	30	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1914	Oct?	Ayukawa, Miyagi	Pacific	Japan	Japanese?	Modern	3	Mizue (1951), Brownell and Chun (1977)
1914	Jul?	Nemuro, Hokkaido	Pacific	Japan	Japanese?	Modern	1	Kasahara (1950), Mizue (1951), Brownell and Chun (1977), Kato and Kasuya (2002)
1914	?	North Kyushu	Korea Strait?	Japan	Unknown	Modern	15	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1914							158	

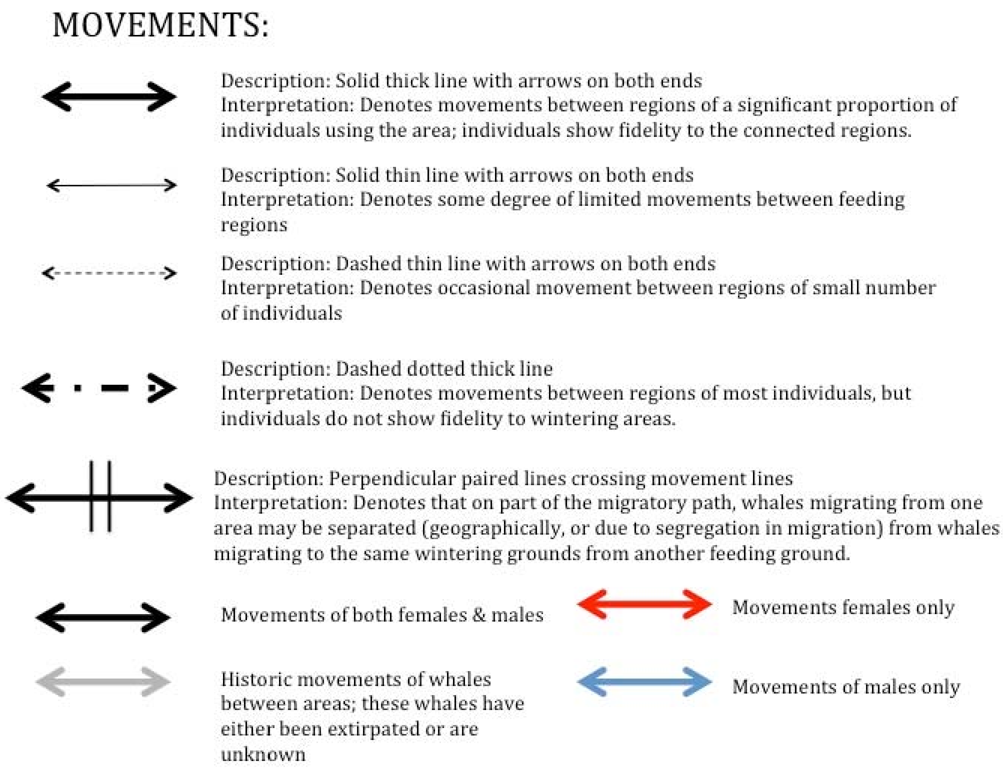
Year	Month	Location	Water Body	Country	Whalers	Method	Catch	Source
1915	?	Area XII-XIV	Unknown	Unknown	Japanese?	Modern	130	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1915	?	North Kyushu	Korea Strait?	Japan	Unknown	Modern	9	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1915							139	
1916	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	36	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1916	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	41	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1916	?	Area II, III, or IV	Unknown	Japan	Unknown	Modern	1	Kasahara (1950)
1916							78	
1917	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	53	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1917	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	13	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1917	?	Area XIV	Yellow Sea	Korea?	Japanese?	Modern	2	Kasahara (1950), Wang (1984), Omura (1988), Kato and Kasuya (2002)
1917							68	
1918	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	91	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1918	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	10	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1918	?	Area XIV	Yellow Sea	Korea?	Japanese?	Modern	2	Kasahara (1950), Wang (1984), Omura (1988), Kato and Kasuya (2002)
1918	?	"Other"	Unknown	Unknown	Unknown	Modern	1	Kato and Kasuya (2002) from Kasahara (1950)
1918							104	
1919	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	35	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1919	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	11	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1919							46	
1920	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	51	Kasahara (1950), Kato and Kasuya (2002)
1920	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	14	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1920	?	North Kyushu	Korea Strait?	Japan	Unknown	Modern	10	Kasahara (1950), Kato and Kasuya (2002)
1920							75	
1921	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	23	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1921	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	53	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1921	?	North Kyushu	Korea Strait?	Japan	Unknown	Modern	2	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1921							78	
1922	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	19	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1922	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	19	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1922	May?	Area XIV	Yellow Sea	Korea?	Japanese?	Modern	2	Kasahara (1950), Mizue (1951), Wang (1984), Omura (1988), Kato and Kasuya (2002)
1922							40	
1923	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	4	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1923	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	23	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1923							27	
1924	?	Ulsan	Sea of Japan	Korea	Japanese?	Modern	1	Kato and Kasuya (2002) from Emoto Log
1924	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	13	Kasahara (1950), Omura (1988), Kato and Kasuya (2002)
1924	?	Unknown	Unknown	Unknown	Unknown	Modern	4	Kato and Kasuya (2002) from Kasahara (1950)
1924							18	
1925	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	10	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1925							10	
1926	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	9	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1926	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	1	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1926	May?	Sakhalin	Sea of Okhotsk	Russia	Unknown	Modern	1	Kasahara (1950), Mizue (1951), Kato and Kasuya (in press)
1926							11	
1927	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	6	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1927	Nov-May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	3	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)

Year	Month	Location	Water Body	Country	Whalers	Method	Catch	Source
1927	?	Area III	Sea of Okhotsk	Unknown	Unknown	Modern	1	Kasahara (1950), Kato and Kasuya (in press)
1927							10	
1928	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	9	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1928							9	
1929	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	11	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1929	?	Area XIV	Yellow Sea	Unknown	Japanese?	Modern	1	Kasahara (1950), Wang (1984), Omura (1988), Kato and Kasuya (in press)
1929							12	
1930	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	30	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1930							30	
1931	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	10	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1931							10	
1932	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	Modern	7	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1932							7	
1933	Nov-Apr	Ulsan	Sea of Japan	Korea	Japanese?	modern	1	Kasahara (1950), Omura (1988), Kato and Kasuya (in press)
1933							1	
1934							?	Kato and Kasuya (in press) from Kasahara (1950)
1935							?	Kato and Kasuya (in press) from Kasahara (1950)
1936							?	Kato and Kasuya (in press) from Kasahara (1950)
1937							?	Kato and Kasuya (in press) from Kasahara (1950)
1938							?	Kato and Kasuya (in press) from Kasahara (1950)
1939							?	Kato and Kasuya (in press) from Kasahara (1950)
1940							?	Kato and Kasuya (in press) from Kasahara (1950)
1941							?	Kato and Kasuya (in press) from Kasahara (1950)
1942	?	Ulsan	Sea of Japan	Korea	Japanese?	Modern	1	Kato and Kasuya (in press) from Emoto Log
1942	?	Otomae, Kurils	Unknown	Russia	Japanese?	Modern	1	Kasahara (1950), Mizue (1951), Brownell and Chun (1977), Kato and Kasuya (in press)
1942							2	
1943	?	Ulsan	Sea of Japan	Korea	Japanese?	Modern	1	Kato and Kasuya (in press) from Emoto Log
1943							1	Kato and Kasuya (in press) from Emoto Log
1944							?	Kasahara (1950) and Kato and Kasuya
1945	Jan	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	3	Kato and Kasuya (in press) from Emoto Log
1945	May	Jangjeon	Sea of Japan	Korea	Japanese?	Modern	2	Kato and Kasuya (in press) from Emoto Log
1945							5	
1946							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1947							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1948	Jan?	Ulsan	Sea of Japan	Korea	Korean?	Modern	9	Brownell and Chun (1977), Kato and Kasuya (in press) from Park (1987)
1948							9	
1949	?	Ulsan	Sea of Japan	Korea	Korean?	Modern	4	Brownell and Chun (1977), Kato and Kasuya (in press)
1949	Sep	Area XIV	Yellow Sea	China?	Chinese	Modern	1	Kato and Kasuya (in press) from Wang (1978)
1949							5	
1950							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1951	?	Ulsan	Sea of Japan	Korea	Korean?	Modern	7	Brownell and Chun (1977), Kato and Kasuya (in press)
1951							7	
1952	?	Ulsan	Sea of Japan	Korea	Korean?	Modern	1	Brownell and Chun (1977), Kato and Kasuya (in press)
1952							1	
1953	?	Ulsan	Sea of Japan	Korea	Korean?	Modern	7	Brownell and Chun (1977), Kato and Kasuya (in press)
1953	Mar-Jun	Wailuo Harbor, Lui Zhou Peninsula	South China Sea?	China	Chinese?	?	4	Wang (1984)
1953							11	

Year	Month	Location	Water Body	Country	Whalers	Method	Catch	Source
1954							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1955							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1956							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1957							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1958	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	7	Brownell and Chun (1977), Kato and Kasuya (in press)
1958	Jun	Yantai, Shandong	Yellow Sea	China	Chinese	Modern	1	Kato and Kasuya (in press) from Wang (1978)
1958							8	
1959	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	7	Brownell and Chun (1977), Kato and Kasuya (in press)
1959	Jun	Southeast Honshu	Pacific	Japan	Japanese	Modern	1	Nishiwaki and Kasuya (1970), Brownell and Chun (1977)
1959							8	
1960	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	8	Brownell and Chun (1977), Kato and Kasuya (in press)
1960	Apr	Area XIV	Yellow Sea	China?	Chinese	Modern	1	Kato and Kasuya (in press) from Wang (1978)
1960							9	
1961	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	3	Brownell and Chun (1977), Kato and Kasuya (in press)
1961							3	Brownell and Chun (1977), Kato and Kasuya (in press)
1962							?	Brownell and Chun (1977), Kato and Kasuya (in press)
1963	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	2	Brownell and Chun (1977), Kato and Kasuya (in press)
1963							2	Brownell and Chun (1977), Kato and Kasuya (in press)
1964	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	3	Brownell and Chun (1977), Kato and Kasuya (in press)
1964							3	Brownell and Chun (1977), Kato and Kasuya (in press)
1965	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	4	Brownell and Chun (1977), Kato and Kasuya (in press)
1965							4	Brownell and Chun (1977), Kato and Kasuya (in press)
1966	Dec-May	Ulsan	Sea of Japan	Korea	Korean?	Modern	5	Brownell and Chun (1977), Kato and Kasuya (in press)
1966							5	Brownell and Chun (1977), Kato and Kasuya (in press)
1968	Feb	Shingu, Wakayama	Seto Inland Sea?	Japan	Japanese	?	1	Nishiwaki and Kasuya (1970), Omura (1984), Brownell and Chun (1977), Kato and Kasuya (in press)
1996	May	Suttu, Hokkaido	Sea of Japan	Japan	Japanese	Hand Harpoon	1	Brownell and Kasuya (1999), Kato and Kasuya (in press)

Annex F

Stock structure hypotheses



AREAS:

Wintering Regions:

(1) MEX: wintering area(s) in the Mexican lagoons and offshore waters of Baja California

(2) ?AS: wintering area(s) in the western North Pacific; the location is unknown but suspected to be near the South China Sea

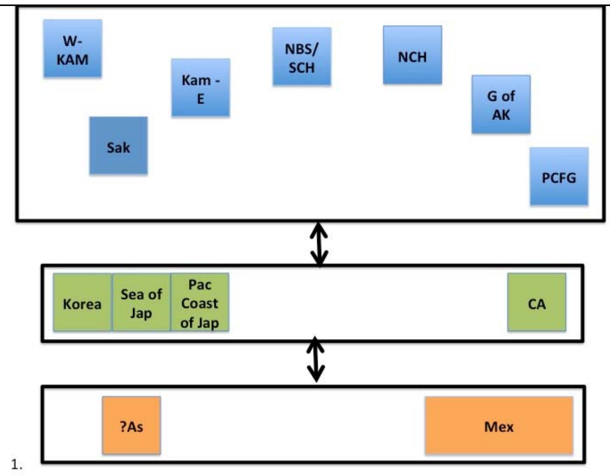
Migratory Routes:

- CA: the migratory route that extends from the feeding area north of the Aleutians to the Mexican wintering area(s). This route is also refered to as the ENP migratory route. Of note, this migratory route passes through the PCFG feeding region, although it is not depicted as such in the schematic to avoid confusion about where whales are feeding versus migrating.
- KOREA, SEA OF JAP, PAC COAST OF JAP: These are potential migratory routes in the WNP. Although it is possible that all three of these routes (mainland coast of Korea, Sea of Japan coast of Japan, and the Pacific coast of Japan) were utilized in the past, it is not possible to identify which routes connected with specific feeding regions; therefore these routes are grouped together in most schematics.
- NCP: this region was designated to identify an area to the west of the CA route that might be used by whales largely by whales migrating from Sakhalin. This region was removed from the schematics following the discussion.

Feeding regions:

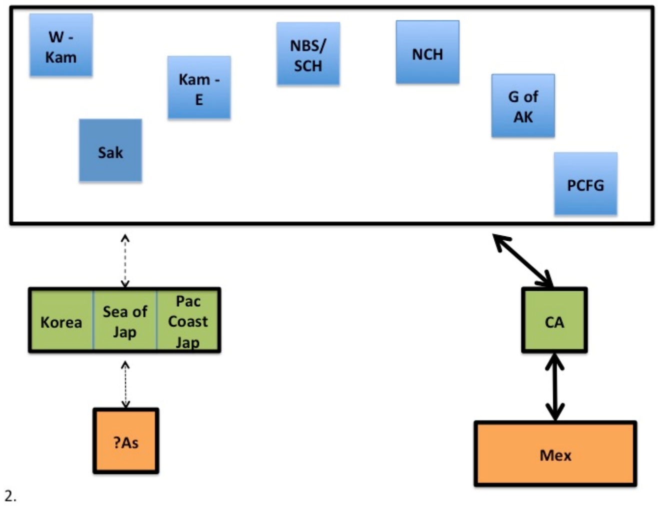
- PCFG: feeding range used by the Pacific Coast Feeding Group. This area extends from the coast of northern CA (41° N) to western Vancouver Island (52° N).
- G of AK: the Gulf of Alaska region
- NCH: the northern portion of the Chukchi Sea, including Wrangel Island in the west to Barrow, AK in the east.
- NBS/SCH: the northern Bering and southern Chukchi Seas, including the Chukotka Peninsula and St. Lawrence Island
- KAM-E: includes the coastal regions of southeastern Kamchatka, Russia, including Vestnik Bay and Olga Bay
- KAM-W: includes waters to the west of Kamchatka in the Sea of Okhotsk, incorporating Shelikov Gulf, Taui Bay (Magadan area), and the Shantar Islands region. Excludes the northeastern coast of Sakhalin Island, which is considered separately.
- SAK: waters off the northeastern coast of Sakhalin Island.

HYPOTHESES CONSIDERED



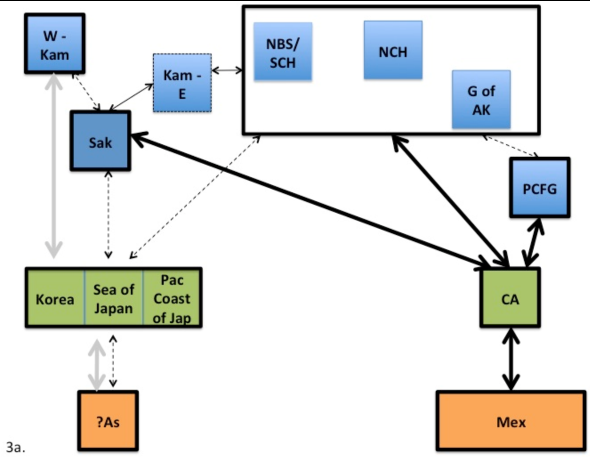
1. Panmixia with no matrilineal fidelity to feeding grounds – persistent

All gray whales in the North Pacific (both currently and historically) are part of a single breeding stock, and whales choose feeding regions randomly.



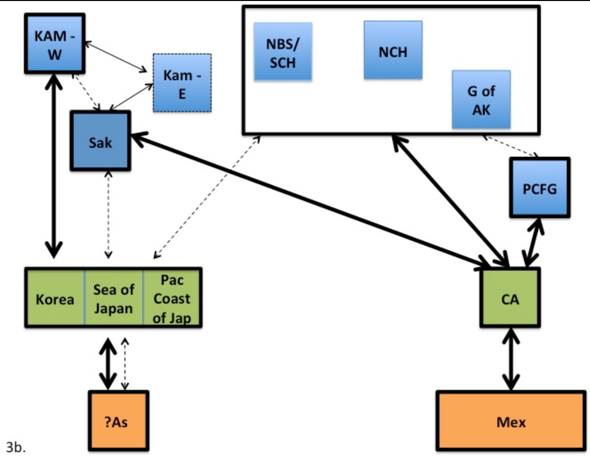
2. Panmixia with no matrilineal fidelity to feeding grounds – post-exploitaiton

Two breeding stocks (Asia and Mexico) may have existed in the past. The Asian stock may have been extirpated by commercial whaling, or, if extant, it includes whales that utilize unidentified areas in the WNP. Currently all known feeding regions for gray whales in the North Pacific are utilized by a single breeding stock (Mexico), and whales choose feeding regions randomly.

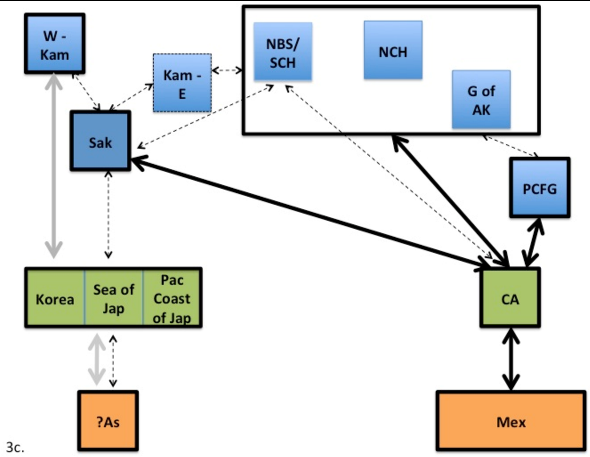


3. Maternal feeding ground fidelity, one migratory route/wintering region used by Sakhalin whales, random mating

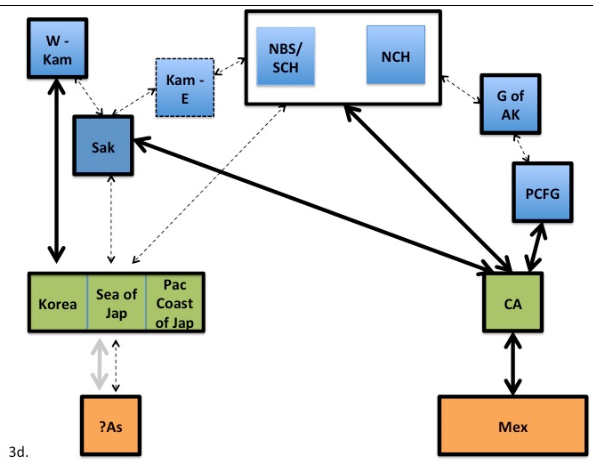
(3a) Two breeding stocks (Asia and Mexico) may exist, although the Asian stock, which included whales that feed west of the Kamchatka Peninsula in the Okhotsk Sea and utilized migratory routes and wintering grounds in the WNP, may have been extirpated. The Mexico stock includes three feeding sub-stocks: PCFG, NBS/SCH-NCH-G of AK [hereafter, Northern], and Sakhalin. The whales that feed off eastern Kamchatka are a mixed-stock aggregation including whales from both the Sakhalin and Northern feeding sub-stocks. Occasional movements of whales occur between 1) Sakhalin and the feeding region (W-Kam), migratory routes, and wintering grounds of the potentially extirpated Asian stock, 2) the Northern feeding area and the Asian migratory routes and wintering grounds, and 3) the PCFG and the Northern feeding region.



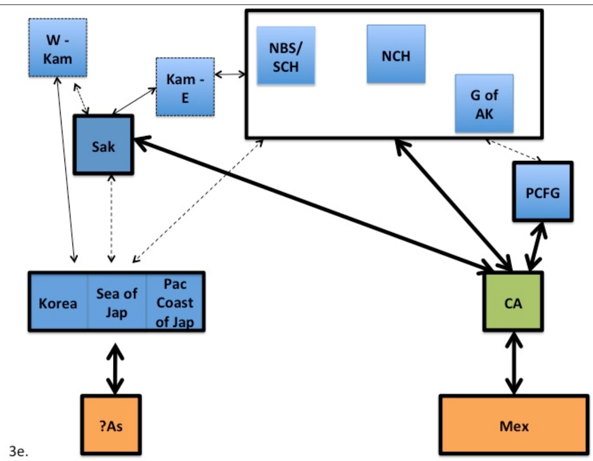
(3b) Identical to 3a, except that the Asian stock is considered to be extant and to feed in the Okhotsk Sea west of the Kamchatka Peninsula as well as off the coast of eastern Kamchatka. Thus the eastern coast of Kamchatka is used by a mixed-stock aggregation of the Sakhalin feeding sub-stock (part of the Mexican breeding stock) and the W-Kam feeding stock (of the Asian breeding stock).



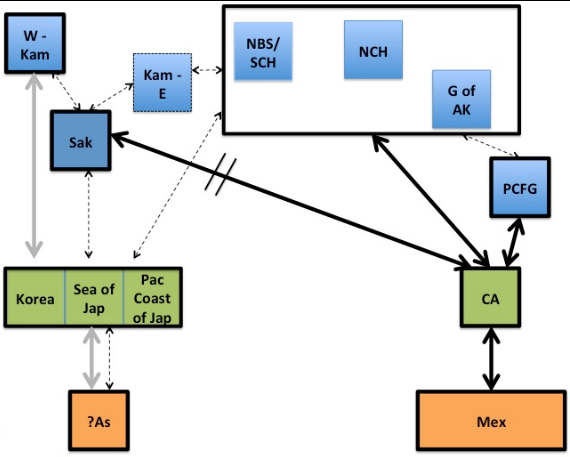
(3c) Identical to 3a except that on occasion whales migrating between the Sakhalin feeding region and Mexico travel through the NBS/SCHK region.



(3d) Identical to 3a except that the Gulf of Alaska region is considered a separate feeding sub-stock of the Mexico breeding stock.



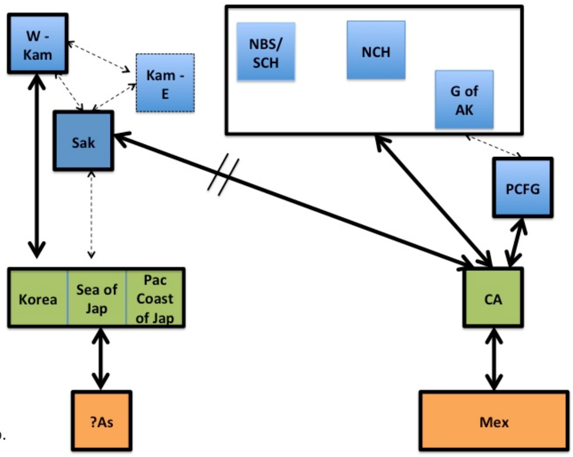
(3e) Identical to 3a except that the Asian breeding stock is extant and feeds off both coasts of Japan, Korea, and in the northern Okhotsk Sea west of the Kamchatka Peninsula. This scenario is also similar to 3b, with two exceptions: 1) that the coast of Korea and both coasts of Japan are used as feeding areas rather than migratory routes, and 2) that the KAM-E region is not used by whales that are part of the Asian stock.



4a

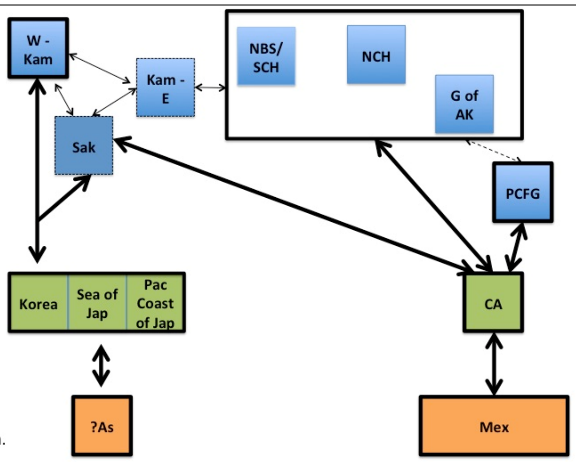
4. Maternal feeding ground fidelity, one migratory route/wintering ground used by Sakhalin whales, non-random mating

(4a) Identical to 3a except that the whales that travel from Sakhalin to Mexico are still in the western portion of their migration during the late November to mid-December period that Rice & Wolman (1971) identified as the first breeding period.



4b.

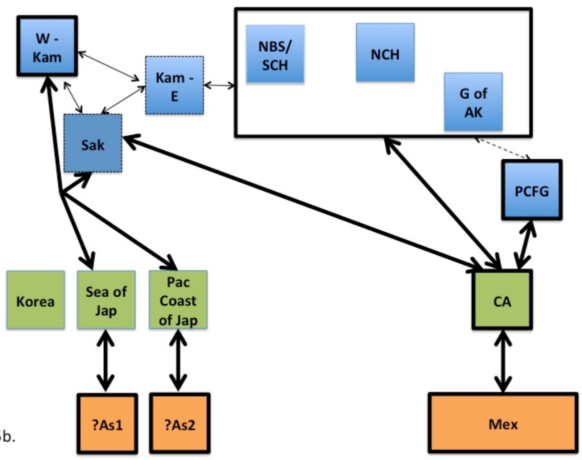
(4b) Identical to 3b except that the whales that travel from Sakhalin to Mexico are still in the western portion of their migration during the late November to mid-December period that Rice & Wolman (1971) identified as the first breeding period.



5a.

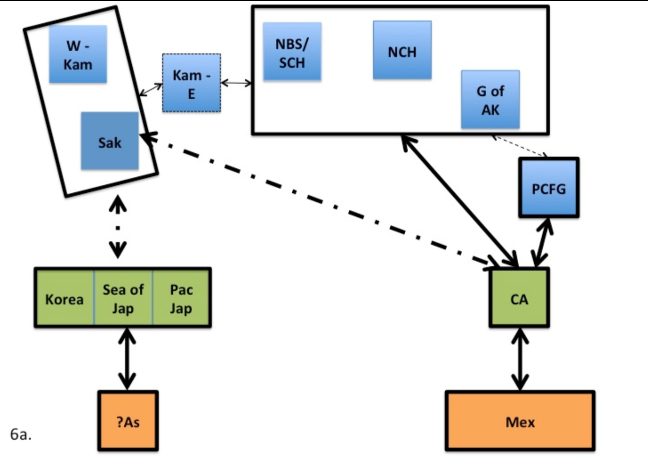
5. Maternal feeding ground fidelity, two migratory routes/wintering grounds used by Sakhalin whales, random mating

(5a) There are two breeding stocks (Asia and Mexico). The Mexico stock includes three feeding sub-stocks: PCFG, Northern, and Sakhalin feeding sub-stocks. All of the whales that are part of the Asian stock feed off Sakhalin, the eastern coast of Kamchatka, and the Sea of Okhotsk west of the Kamchatka Peninsula. Thus Sakhalin is utilized by a mixed-stock aggregation of the Sakhalin feeding sub-stock of the Mexico breeding stock and by whales that are part of the Asian breeding stock. KAM-E is also used by mixed-stock aggregation of the Northern feeding sub-stock of the Mexican breeding stock and by the whales that are part of the Asian stock.



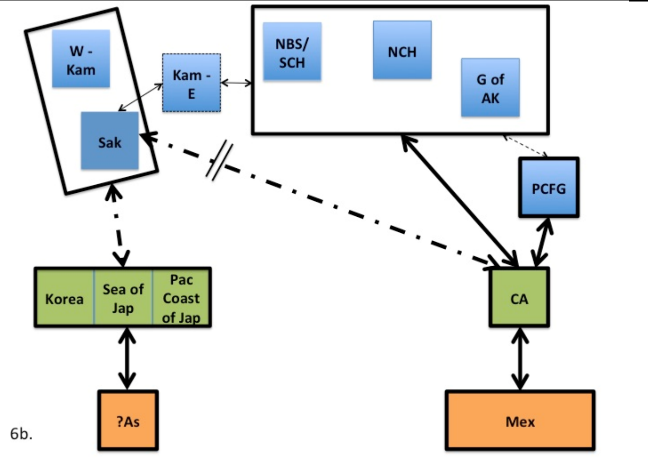
5b.

(5b) Identical to 5a except that the whales that remain in the WNP year-round show fidelity to two different migratory routes/wintering grounds. Thus there are two breeding sub-stocks of the Asian stock. Of note, although the arrows indicate the Sea of Japan coast of Japan and the Pacific coast of Japan as the two migratory routes, this schematic could apply to any two of the three possible routes.

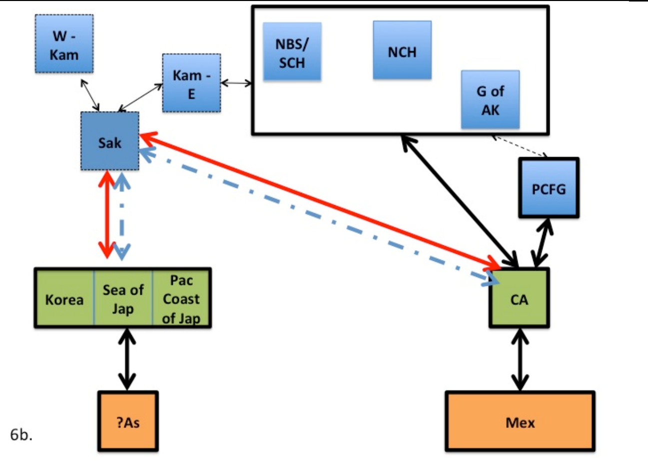


6. Maternal feeding ground fidelity, Sakhalin whales use two migratory routes/wintering grounds but show no fidelity to them, random mating

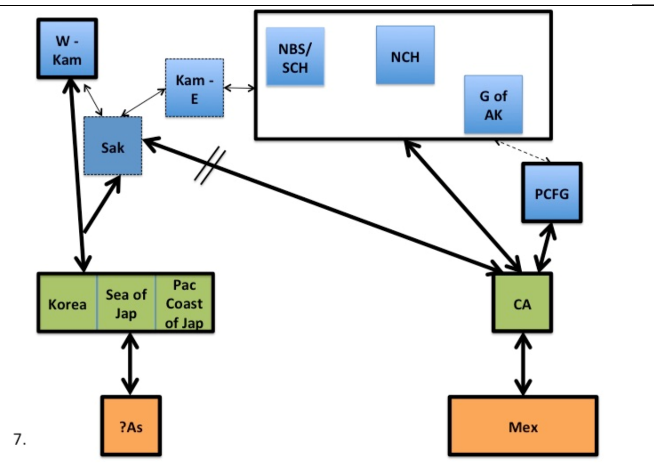
(6a) One breeding stock exists in the North Pacific, as all whales utilize migratory routes and wintering grounds in the ENP in at least some years. Three feeding sub-stocks exist: Sakhalin-WKam, Northern, and PCFG. Eastern Kamchatka is utilized by two feeding sub-stocks (Sak-WKam and Northern).



(6b) Identical to 6a, except that when Sakhalin whales choose to migrate to the ENP they breed largely with each other. This results in two breeding stocks – one includes whales from the PCFG and Northern feeding sub-stocks that migrate to Mexico and largely breed with each other, and the other includes all whales that feed off Sakhalin and breed largely with each other whether on the ENP or WNP migratory routes/wintering grounds [This hypothesis was originally referred to as 7a during the workshop].



(6c) Identical to 6a except that females that feed off Sakhalin exhibit fidelity to two migratory routes/wintering grounds, while males use both migratory routes/wintering grounds. This would result in two breeding sub-stocks (???): one includes the Sakhalin females that always migrate and overwinter in the WNP and Sakhalin males (which provide their only mating opportunities), and the second includes the same Sakhalin males as well as the whales belonging to the PCFG and Northern feeding sub-stocks [this hypothesis was originally labelled hypothesis 8 by the intersessional email group].



7. Maternal fidelity to feeding grounds, Sakhalin whales show fidelity to two migratory routes/wintering grounds, non-random mating

Two breeding sub-stocks utilize the Mexican wintering grounds – one breeding sub-stock that feeds off Sakhalin (e.g. contains one feeding sub-stock) and one breeding sub-stock that feeds in the Northern and PCFG regions (i.e. comprises two feeding sub-stocks). An additional Asian breeding stock exists; these whales feed off Sakhalin and in the Okhotsk Sea west of the Kamchatka Peninsula. Thus Sakhalin and Kamchatka-East are used by mixed-stock aggregations [This schematic was originally referred to as 7b during the workshop].