HONORABLE GEORGE J. JORDAN
ADMINISTRATIVE LAW JUDGE

UNITED STATES OF AMERICA
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

In re: **Proposed Waiver and Regulations Governing the Taking of Eastern North Pacific Gray Whales by the Makah Indian Tribe**	Docket No. 19-NMFS-0001 RIN: 0648-BI58 and RIN: 0648-XG584

SECOND DECLARATION OF DR. SHANNON BETTRIDGE

I, Dr. Shannon Bettridge, declare as follows:

1. I am the Chief of the Marine Mammal and Sea Turtle Conservation Division in the Office of Protected Resources (OPR) for the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA). This is the second declaration I have submitted for the above-referenced matter. I incorporate by reference paragraphs one through three of my first declaration, filed April 5, 2019, which explain my qualifications and expertise to testify in this matter.

2. I have reviewed all of the direct testimony submitted to date through declarations by other parties to this proceeding. I have also reviewed the list of "Issues to be Addressed at the Hearing" as stated in the "Announcement of Hearing and Final Agenda Regarding Proposed Waiver and Regulations Governing the Taking of Marine Mammals," 84 Fed. Reg. 30,088 (June 26, 2019), with particular focus on those issues related to the information provided in my first

declaration or otherwise within my areas of expertise. I submit this declaration to respond to certain information provided in the other parties' declarations referenced above and in support of NMFS's proposed waiver and regulations. My testimony is focused on those issues related to my initial direct testimony. I also provide the parties with an update on the publication of the 2018 Stock Assessment Report (SAR), which has published since I submitted my first declaration in this matter.

3. I note that Mr. Schubert states in his declaration that "[i]f there is no [Potential Biological Removal (PBR)] for a stock then that stock, by definition, must be below its [optimum sustainable population (OSP)]." Schubert Decl. ¶ 20. This statement is incorrect. In some cases, NMFS does not calculate a PBR for a stock, for example, if abundance estimates are highly uncertain or outdated or unavailable, or the minimum population estimate (Nmin) is unknown. NMFS Ex. 2-8, at 7 (NMFS 2016). The lack of a PBR calculation for a stock does not mean that PBR for that stock is zero and does not imply a status relative to OSP. *Id.*

4. My first declaration discussed and included as an exhibit the draft 2018 SARs for the ENP and WNP gray whale stocks. Bettridge Decl. ¶¶ 23–24; NMFS Ex. 2-10 (Carretta *et al.* 2018). On June 19, 2019, NMFS published a Notice in the Federal Register announcing the availability of the 2018 Final SARs. 84 Fed. Reg. 28,489. I have attached excerpts from the 2018 SARs addressing both the eastern North Pacific (ENP) and western North Pacific (WNP) gray whale stocks as NMFS Ex. 2-12 (Carretta *et al*. 2019[1]), and full versions of these recently published SARs are also available on NMFS's website:

[1] Carretta, J., and 15 co-authors. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2018. NOAA-TM-NMFS-SWFSC-617.

https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-region.

5. Prior to the 2018 SAR, the ENP gray whale report was most recently revised in the 2014 SAR. NMFS Ex. 2-6 (Carretta *et al*. 2015). The Final 2018 SAR revises the estimate of the ENP stock abundance to be 26,960 whales based on the results of Durban *et al*. (2017) (NMFS Ex. 3-42), and, based on a revised Nmin, calculates a PBR level for ENP gray whales of 801. NMFS Ex. 2-12 (Carretta *et al*. 2019). Human-caused mortality and serious injury for the ENP stock in the final SAR is listed as 139, and continues to be well below the PBR level. This mortality estimate takes into account human-caused mortality and serious injury from fishery entanglement, subsistence/native harvest, and ship-strikes.

6. Contrary to statements raised by some of the parties' declarations regarding the MMPA stock status of the Pacific Coast Feeding Group (PCFG), *see*, *e.g.*, Schubert Decl. ¶¶ 41, 79, the Final 2018 SAR continues to evaluate the Pacific Coast Feeding Group as part of the ENP Stock and notes that "the status of the PCFG as a population stock remains unresolved," meaning we continue to recognize PCFG whales as part of the ENP stock under the MMPA. NMFS Ex. 2-12, at 3 (Carretta *et al.* 2019); *see also* NMFS Ex. 2-11, at 11 (Wieting 2018) (NMFS considers the PCFG as part of the ENP). Nevertheless, because the PCFG appears to be a feeding aggregation and may one day warrant consideration as a stock, the SAR does calculate a separate PBR for the PCFG for informational purposes and to assess whether levels of human-caused mortality are likely to cause local depletion. The final 2018 SAR, citing Calambokidis *et al*. (2017) (NMFS Ex. 3-33), estimated PCFG abundance at 243 whales, identified an Nmin of 227 PCFG whales, and calculated an informational PBR of 3.5 PCFG whales. NMFS Ex. 2-12 (Carretta *et al*. 2019).

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7. The final 2018 SAR, citing Cooke 2017[2] and Cooke *et al*. 2018 (NMFS Exs. 2-13 and 3-89, respectively) identifies the best available abundance estimate for the WNP stock of gray whales as 290 whales, with an Nmin of 271, and estimates a PBR of 0.12 WNP gray whales per year, or approximately one whale every 8 years. NMFS Ex. 2-12, at 13 (Carretta *et al*. 2019). The final 2018 SAR identifies various threats to WNP gray whales, including ship strikes and entanglement in fishing gear, but does not quantify an estimate of human-caused mortality for this stock, nor does it provide a conclusion of the stock's status relative to its optimum sustainable population. It also reports the results of Moore and Weller (2013) regarding the probability of encountering a WNP whale during the proposed Makah gray whale hunt. *Id* at 169. However, it does not discuss or cite Moore and Weller's updated analysis (NMFS Ex. 4-8, Moore and Weller 2018), or the updated analysis presented by Dr. Moore in his Second Declaration (NMFS Ex. 4-14, Moore and Weller 2019), filed concurrently, which we consider to be the best available information regarding estimated risk of encountering WNP gray whales during the proposed hunt.

[2] Cooke, J.G. 2017. Updated assessment of the Sakhalin gray whale population and its relationship to gray whales in other areas. Western Gray Whale Advisory Panel, 18th Meeting. November 15-17, 2017. WGWAP-18/24.

I declare, under penalty of perjury under the laws of the United States, that the foregoing is true and correct to the best of my knowledge, information, and belief.

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Dr. Shannon Bettridge

Dated:________________________

SECOND DECLARATION OF DR. SHANNON BETTRIDGE
EXHIBIT LIST

2-12	Carretta et al. 2019	Carretta, J., and 15 co-authors. 2019. U.S. Pacific Marine Mammal Stock Assessments: 2018. NOAA-TM-NMFS-SWFSC-617.
2-13	Cooke 2017	Cooke, J.G. 2017. Updated assessment of the Sakhalin gray whale population and its relationship to gray whales in other areas. Western Gray Whale Advisory Panel, 18^{th} Meeting. November 15-17, 2017. WGWAP-18/24.

NOAA Technical Memorandum NMFS

JUNE 2019

U.S. PACIFIC MARINE MAMMAL STOCK ASSESSMENTS: 2018

James V. Carretta[1], Karin. A. Forney[3], Erin M. Oleson[2], David W. Weller[1], Aimee R. Lang[9], Jason Baker[2], Marcia M. Muto[4], Brad Hanson[5], Anthony J. Orr[4], Harriet Huber[4], Mark S. Lowry[1], Jay Barlow[1], Jeffrey E. Moore[1], Deanna Lynch[6], Lilian Carswell[7], and Robert L. Brownell Jr.[8]

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[2]NOAA Fisheries, Pacific Islands Fisheries Science Center, 1845 Wasp Blvd., Building 176, Honolulu, HI 96818.

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[8]NOAA Fisheries, Southwest Fisheries Science Center, 34500 Highway 1, Monterey, Ca 93940.

[9]Ocean Associates Inc., under contract to Southwest Fisheries Science Center, 8901 La Jolla Shores Drive, La Jolla, CA 92037.

NOAA-TM-NMFS-SWFSC-617

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

Revised 5/15/2019

GRAY WHALE (*Eschrichtius robustus*): Eastern North Pacific Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Once common throughout the Northern Hemisphere, the gray whale was extinct in the Atlantic by the early 1700s (Fraser 1970; Mead and Mitchell 1984), but recent single sightings in the Mediterranean Sea in 2010 and off Namibia in 2013 are documented (Scheinin *et al.* 2011, Elwen and Gridley 2013). Gray whales are only commonly found in the North Pacific. Genetic comparisons indicate there are distinct "Eastern North Pacific" (ENP) and "Western North Pacific" (WNP) population stocks, with differentiation in both mtDNA haplotype and microsatellite allele frequencies (LeDuc *et al.* 2002; Lang *et al.* 2011a; Weller *et al.* 2013).

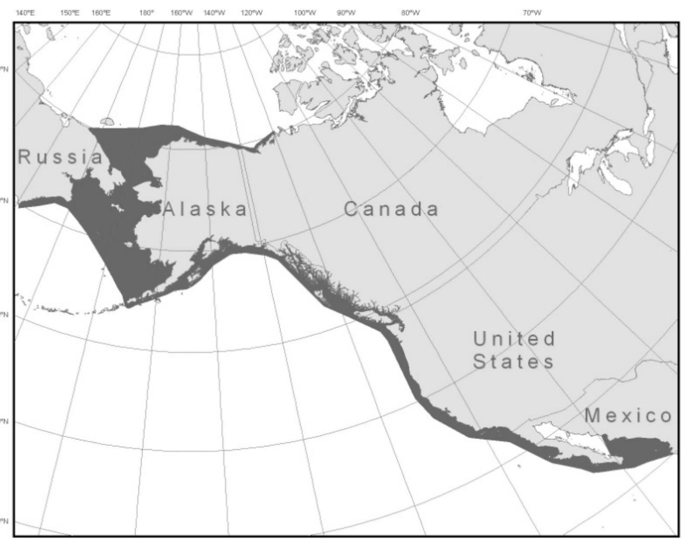

Figure 1. Approximate distribution of the Eastern North Pacific stock of gray whales (shaded area).

During summer and fall, most whales in the ENP population feed in the Chukchi, Beaufort and northwestern Bering Seas (Fig. 1). An exception to this is the relatively small number of whales that summer and feed along the Pacific coast between Kodiak Island, Alaska and northern California (Darling 1984, Gosho *et al.* 2011, Calambokidis *et al.* 2017). Three primary wintering lagoons in Baja California, Mexico are utilized, and some females are known to make repeated returns to specific lagoons (Jones 1990). Genetic substructure on the wintering grounds is indicated by significant differences in mtDNA haplotype frequencies between females (mothers with calves) using two primary calving lagoons and females sampled in other areas (Goerlitz *et al.* 2003). Other research has identified a small, but significant departure from panmixia between two lagoons using nuclear data, although no significant differences were identified using mtDNA (Alter *et al.* 2009).

Tagging, photo-identification and genetic studies show that some whales identified in the WNP off Russia have been observed in the ENP, including coastal waters of Canada, the U.S. and Mexico (Lang 2010; Mate *et al.* 2011; Weller *et al.* 2012; Urbán *et al.* 2013, Mate *et al.* 2015). In combination, these studies have documented approximately 30 gray whales observed in both the WNP and ENP. Despite this geographic overlap, significant mtDNA and nDNA differences are found between whales in the WNP and those summering in the ENP (LeDuc *et al.* 2002; Lang *et al.* 2011a).

In 2010, the IWC Standing Working Group on Aboriginal Whaling Management Procedure noted that different names had been used to refer to gray whales feeding along the Pacific coast, and agreed to designate animals that spend the summer and autumn feeding in coastal waters of the Pacific coast of North America from California to southeast Alaska as the "Pacific Coast Feeding Group" or PCFG (IWC 2012). This definition was further refined for purposes of abundance estimation, limiting the geographic range to the area from northern California to northern British Columbia (from 41°N to 52°N), and limiting the temporal range from June 1 to November 30, and counting only those whales seen in more than one year within this geographic and temporal range (IWC 2012). The IWC adopted this definition in 2011, but noted that "not all whales seen within the PCFG area 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." (IWC 2012).

Photo-identification studies between northern California and northern British Columbia provide data on the abundance and population structure of PCFG whales (Calambokidis *et al.* 2017). Gray whales using the study area in summer and autumn include two components: (1) whales that frequently return to the area, display a high degree of intra-seasonal "fidelity" and account for a majority of the sightings between 1 June and 30 November. Despite movement and interchange among sub-regions of the study area, some whales are more likely to return to the same sub-region where they were observed in previous years; (2) **"**visitors" from the northbound migration that are sighted only in one year, tend to be seen for shorter time periods in that year, and are encountered in more limited areas. Photo-identification (Gosho *et al.* 2011; Calambokidis *et al.* 2017) and satellite tagging (Mate *et al.* 2010; Ford *et al.* 2012) studies have documented some PCFG whales off Kodiak Island, the Gulf of Alaska and Barrow, Alaska, well to the north of the pre-defined 41°N to 52°N boundaries used in PCFG abundance estimation analyses. Lagerquist *et al.* (2019) noted that PCFG whales tagged in autumn in northern California and Oregon waters utilized feeding areas from northern California to Icy Bay, Alaska, with one male remaining in the vicinity of the California/Oregon border for almost a year. The highest use areas for these tagged whales were identified as northern California, central Oregon, and southern Washington waters.

Frasier *et al.* (2011) found significant differences in mtDNA haplotype distributions between PCFG and ENP gray whales, in addition to differences in long-term effective population size, and concluded that the PCFG qualifies as a separate management unit under the criteria of Moritz (1994) and Palsbøll *et al.* (2007). The authors noted that PCFG whales probably mate with the rest of the ENP population and that their findings were the result of maternally-directed site fidelity of whales to different feeding grounds.

Lang *et al.* (2011b) assessed stock structure of ENP whales from different feeding grounds using both mtDNA and eight microsatellite markers. Significant mtDNA differentiation was found when samples from individuals (n=71) sighted over two or more years within the seasonal range of the PCFG were compared to samples from whales feeding north of the Aleutians (n=103), and when PCFG samples were compared to samples collected off Chukotka, Russia (n=71). No significant differences were found when the same comparisons were made using microsatellite data. The authors concluded that (1) the significant differences in mtDNA haplotype frequencies between the PCFG and whales sampled in northern areas indicates that use of some feeding areas is being influenced by internal recruitment (e.g., matrilineal fidelity), and (2) the lack of significance in nuclear comparisons suggests that individuals from different feeding grounds may interbreed. The level of mtDNA differentiation identified, while statistically significant, was low and the mtDNA haplotype diversity found within the PCFG was similar to that found in the northern strata. Lang *et al.* (2011b) suggested this could indicate recent colonization of the PCFG but could also be consistent with external recruitment into the PCFG. An additional comparison of whales sampled off Vancouver Island, British Columbia (representing the PCFG) and whales sampled at the calving lagoon at San Ignacio also found no significant differences in microsatellite allele frequencies, providing further support for interbreeding between the PCFG and the rest of the ENP stock (D'Intino *et al.* 2012). Lang and Martien (2012) investigated potential immigration levels into the PCFG using simulations and produced results consistent with the empirical (mtDNA) analyses of Lang *et al.* (2011b). Simulations indicated that immigration of >1 and <10 animals per year into the PCFG was plausible, and that annual immigration of 4 animals/year produced results most consistent with empirical data.

While the PCFG is recognized as a distinct feeding aggregation (Calambokidis *et al.* 2017; Mate *et al.* 2010; Frasier *et al.* 2011; Lang *et al.* 2011b; IWC 2012), the status of the PCFG as a population stock remains unresolved (Weller *et al.* 2013). A NMFS gray whale stock identification workshop held in 2012 included a review of available photo-identification, genetic, and satellite tag data. The report of the workshop states "there remains a substantial level of uncertainty in the strength of the lines of evidence supporting demographic independence of the PCFG." (Weller *et al.* 2013). The NMFS task force, charged with evaluating stock status of the PCFG, noted that "both the photo-identification and genetics data indicate that the levels of internal versus external recruitment are comparable, but these are not quantified well enough to determine if the population dynamics of the PCFG are more a consequence of births and deaths within the group (internal dynamics) rather than related to immigration and/or emigration (external dynamics)." Further, given the lack of significant differences found in nuclear DNA markers between PCFG whales and ENP whales, the task force found no evidence to suggest that PCFG whales breed exclusively or primarily with each other, but interbreed with ENP whales, including potentially other PCFG whales. Additional research to better identify recruitment levels into the PCFG and further assess the stock status of PCFG whales is needed (Weller *et al.* 2013). In contrast, the task force noted that WNP gray whales should be recognized as a population stock under the MMPA, and NMFS prepared a separate report for WNP gray whales in 2014. Because the PCFG appears to be a distinct feeding aggregation and may one day warrant consideration as a distinct stock, separate PBRs are calculated for the PCFG to assess whether levels of human-caused mortality are likely to cause local depletion.

The IWC Scientific Committee has conducted a series of annual (2014-2018) range-wide workshops on the status of North Pacific gray whales. The primary objective was not to determine a single 'best' stock structure hypothesis (unless definitively supported by existing data) but rather to identify plausible hypotheses consistent with the suite of available data. The goal is to create a foundation for developing range-wide conservation advice. The primary hypotheses deemed as most plausible considered two separate 'breeding stocks' or biological populations (western and eastern). These hypotheses include: (a) "Hypothesis 3a" which assumes that while two breeding stocks (western and eastern) may once have existed, the western breeding stock is extirpated. Whales show matrilineal fidelity to feeding grounds, and the eastern breeding stock includes three feeding aggregations: Pacific Coast Feeding Group, Northern Feeding Group, and a Western Feeding Group; and (b) "Hypothesis 5a" which assumes that both breeding stocks are extant and that the western breeding stock feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula. Whales feeding off Sakhalin include both whales that are part of the extant western breeding stock and remain in the western North Pacific year-round, plus whales that are part of the Eastern breeding stock and migrate between Sakhalin and the eastern North Pacific.

POPULATION SIZE

Systematic counts of gray whales migrating south along the central California coast have been conducted by shore-based observers at Granite Canyon most years since 1967 (Fig. 2). The most recent estimate of abundance for the ENP population is from the 2015/2016 southbound survey and is 26,960 (CV=0.05) whales (Durban *et al.* 2017) (Fig. 2).

Photographic mark-recapture abundance estimates for PCFG gray whales between 1998 and 2015, including estimates for a number of smaller geographic areas within the IWC-defined PCFG region (41°N to 52°N), are reported in Calambokidis *et al.* (2017). The 2015 abundance estimate for the defined range of the PCFG between 41°N to 52°N is 243 whales (SE=18.9; CV= 0.08).

Eastern North Pacific gray whales experienced an unusual mortality event (UME) in 1999 and 2000, when large numbers of emaciated animals stranded along the west coast of North America (Moore *et al.*, 2001; Gulland *et al.*, 2005). Over 60% of the dead whales were adults, compared with previous years when calf strandings were more common. Several factors following this UME suggest that the high mortality rate observed was a short-term, acute event: 1) in 2001 and 2002, strandings decreased to levels below UME levels (Gulland *et al.*, 2005); 2) average calf production returned to levels seen before 1999; and 3) in 2001, living whales no longer appeared emaciated. Oceanographic factors that limited food availability for gray whales were identified as likely causes of the UME (LeBouef *et al.* 2000; Moore *et al.* 2001; Minobe 2002; Gulland *et al.* 2005), with resulting declines in survival rates of adults during this period (Punt and Wade 2012). The population has recovered to levels seen prior to the UME of 1999-2000 and the current estimate of abundance is the highest that has been recorded in the 1967-2015 time series (Fig. 2).

Minimum Population Estimate

The minimum population estimate (N_{MIN}) for the ENP stock is calculated from Equation 1 from the PBR Guidelines (Wade and Angliss 1997): $N_{MIN} = N/\exp(0.842\times[\ln(1+[CV(N)]^2)]^{½})$. Using the 2015/2016 abundance estimate of 26,960 and its associated CV of 0.05 (Durban *et al.* 2013), N_{MIN} for this stock is 25,849.

The minimum population estimate for PCFG gray whales is calculated as the lower 20th percentile of the log-normal distribution of the 2015 mark-recapture estimate of 243 (CV=0.08), or 227 animals.

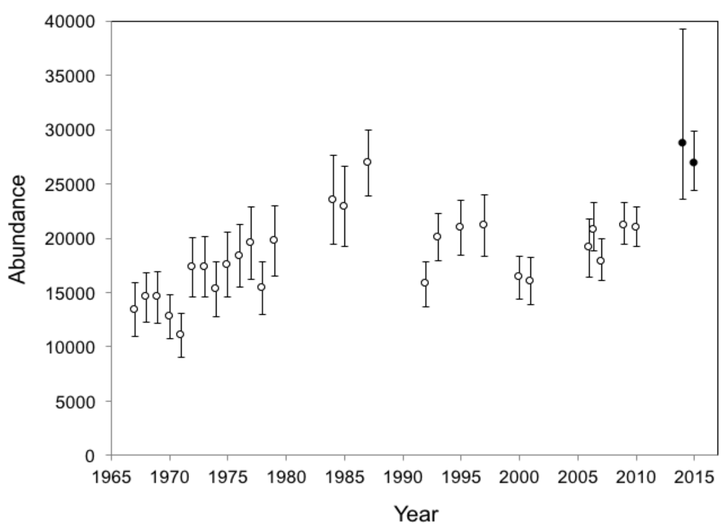

Figure 2. Estimated abundance of Eastern North Pacific gray whales from NMFS counts of migrating whales past Granite Canyon, California. Open circles represent abundance estimates and 95% confidence intervals reported by Laake *et al.* (2012) and Durban *et al.* (2015). Closed circles represent estimates and 95% posterior highest density intervals reported by Durban *et al.* (2017) for the 2014/2015 and 2015/2016 migration seasons.

Current Population Trend

The population size of the ENP gray whale stock has increased over several decades despite an UME in 1999 and 2000 (see Fig. 2). Durban *et al.* (2017) noted that a recent 22% increase in ENP gray whale abundance over 2010/2011 levels is consistent with high observed and estimated calf production (Perryman *et al.* 2017). Recent increases in abundance also support hypotheses that gray whales may experience more favorable feeding conditions in arctic waters due to an increase in ice-free habitat that might result in increased primary productivity in the region (Perryman *et al.* 2002, Moore 2016). Abundance estimates of PCFG whales increased from 1998 through 2004, remained stable for the period 2005-2010, and have steadily increased during the 2011-2015 time period (Calambokidis *et al.* 2017).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Using abundance data through 2006/07, an analysis of the ENP gray whale population led to an estimate of Rmax of 0.062, with a 90% probability the value was between 0.032 and 0.088 (Punt and Wade 2012). This value of Rmax is also applied to PCFG gray whales, as it is currently the best estimate of Rmax available for gray whales in the ENP.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for the ENP stock of gray whales is calculated as the minimum population size (25,849), times one-half of the maximum theoretical net population growth rate (½ x 6.2% = 3.1%), times a recovery factor of 1.0 for a stock above MNPL (Punt and Wade 2012), or 801 animals per year.

The potential biological removal (PBR) level for PCFG gray whales is calculated as the minimum population size (227 animals), times one half the maximum theoretical net population growth rate (½ x 6.2% = 3.1%), times a recovery factor of 0.5 (for a population of unknown status), resulting in a PBR of 3.5 animals per year. Use of the recovery factor of 0.5 for PCFG gray whales, rather than 1.0 used for ENP gray whales, is based on uncertainty regarding stock structure and guidelines for preparing marine mammal stock assessments which state that "Recovery factors of 1.0 for stocks of unknown status should be reserved for cases where there is assurance that N_{min}, R_{max}, and the kill are unbiased and where the stock structure is unequivocal" (NMFS 2005, Weller *et al.* 2013). Given uncertainties in external versus internal recruitment levels of PCFG whales, the equivocal nature of the stock structure, and the small estimated population size of the PCFG, NMFS will continue to use the default recovery factor of 0.5 for PCFG gray whales.

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

The California large-mesh drift gillnet fishery for swordfish and thresher shark includes 4 observed entanglement records of gray whales from 8,845 observed fishing sets over the 27-year period 1990-2016 (Carretta *et al.* 2018a). The estimated bycatch of gray whales in this fishery for the most recent 5-year period is 2.1 (CV=0.76) whales, or 0.4 whales annually (Carretta *et al.* 2018a). By comparison, the more coastal set gillnet fishery for halibut and white seabass has no observations of gray whale entanglements from over 10,000 observed sets for the same time period. This compares with 11 opportunistically documented gillnet entanglements of gray whales in U.S. west coast waters during the most recent 5 year period of 2012-2016, including one self-report from a set gillnet vessel operator (Carretta *et al.* 2018b). The origin of the gillnet gear for the remaining 10 entanglements is unknown. Alaska gillnet fisheries also interact with gray whales, but these fisheries largely lack observer programs. Some gillnet entanglements involving gray whales along the coasts of Washington, Oregon, and California may involve gear set in Alaska and/or Mexican waters and carried south and/or north during the annual migration.

Table 1. Entanglement mortality and serious injury of gray whales, 2012-2016 (Carretta *et al.* 2018a, 2018b). Fractional bycatch estimates in swordfish drift gillnets during 2014-2016 result from a model that incorporates all years of observer data for bycatch prediction, thus bycatch estimates can be positive even when no bycatch is observed. Entanglement in other fisheries is derived from strandings and at-sea sightings of entangled whales and thus represent minimum impacts because they are documented opportunistically (Carretta *et al.* 2018b). Mortality and injury information, where possible, is assigned to either the ENP gray whale stock or PCFG whales. Total ENP mortality and injury also includes records attributable to PCFG gray whales, as PCFG gray whales are included in the abundance estimates for ENP gray whales and thus, the calculated PBR for ENP gray whales also includes PCFG animals.

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed mortality (+ serious injury)	Estimated mortality (CV)	Mean annual takes 2012-2016 (CV)
CA/OR thresher shark/swordfish drift gillnet	2012	observer	19%	0 (0)	0 (n/a)	0.4 (0.76) (ENP stock)
	2013		37%	1 (0)	1 (n/a)	
	2014		24%	0 (0)	0.1 (5.9)	
	2015		20%	0 (0)	0.7 (2.1)	
	2016		18%	0 (0)	0.5 (2.4)	
	2012-2016		23%	ENP 1 (0)	2.1 (0.76)	

Fishery Name	Year(s)	Data Type	Percent Observer Coverage	Observed mortality (+ serious injury)	Estimated mortality (CV)	Mean annual takes 2012-2016 (CV)
CA halibut and white seabass set gillnet	2012-2016	vessel self-report	n/a	ENP 0 (0.75)	n/a	ENP 0.15 (n/a)
CA Dungeness crab pot		strandings + sightings	n/a	ENP 2 (1.75) PCFG 1 (0)	n/a	ENP 0.75 (n/a) PCFG 0.2 (n/a)
OR Dungeness crab pot				ENP 0 (0.75)		ENP 0.15 (n/a)
Cod pot fishery				ENP 0 (0.75)		ENP 0.15 (n/a)
Unidentified pot/trap fishery				ENP 1 (8.75) PCFG 0 (1.5)		ENP 1.9 (n/a) PCFG 0.3 (n/a)
Unidentified gillnet fishery				ENP 3 (5.5)		ENP 1.7 (n/a)
Unidentified fishery interactions				ENP 2 (13) PCFG 0 (1)		ENP 3.0 (n/a) PCFG 0.2 (n/a)
Marine debris entanglement				ENP 1 (0.75)		ENP 0.35 (n/a)
Tribal crab pot gear	2012-2016	self-report	n/a	ENP 0 (0.75) PCFG 0 (0.75)		ENP 0.15 (n/a) PCFG 0.15 (n/a)
Totals				ENP 10 (32.75) PCFG 1 (3.25)		ENP 8.7 (n/a) PCFG 0.85 (n/a)

Entanglement in commercial pot and trap fisheries along the U.S. west coast is another source of gray whale mortality and serious injury (Carretta *et al.* 2018b). Most data on human-caused mortality and serious injury of gray whales are from strandings, including at-sea reports of entangled animals alive or dead (Carretta *et al.* 2018b). Strandings represent only a fraction of actual gray whale deaths (natural or human-caused), as reported by Punt and Wade (2012), who estimated that only 3.9% to 13.0% of gray whales that die in a given year end up stranding and being reported. This estimate of carcass detection, however, also included sparsely-populated coastlines of Baja California, Canada, and Alaska, for which the rate of carcass detection would be expected to be low. Since most U.S. cases of human-caused serious injury and mortality are documented from Washington, Oregon, and California waters, the Punt and Wade (2012) estimate of carcass recovery is not applicable to most documented cases. An appropriate correction factor for undetected anthropogenic mortality and serious injury of gray whales is unavailable.

A summary of human-caused mortality and serious injury from fishery and marine debris sources is given in Table 1 for the most recent 5-year period of 2012 to 2016 (Carretta *et al.* 2018b). Total observed and estimated entanglement-related human-caused mortality and serious injury for ENP gray whales is 8.7 whales annually, which includes PCFG entanglements (Table 1). The mean annual entanglement-related serious injury and mortality level for PCFG gray whales is 0.85 whales, based on one observed death in CA Dungeness crab pot gear and three serious injuries in other fishing gear (Table 1). In addition to the mortality and serious injury totals listed above, there were 5 non-serious entanglement injuries of gray whales (Carretta *et al.* 2018b). Three non-serious injuries involved ENP gray whales, each with one record associated with the following sources: CA Dungeness crab pot fishery, unknown Dungeness crab pot fishery, and unidentified fishery interaction. During the same period, there were two non-serious injuries involving PCFG whales, one in tribal crab pot gear and the other in an unidentified gillnet fishery.

Unidentified whales represent approximately 15% of entanglement cases along the U.S. West Coast, (Carretta 2018). Observed entanglements may lack species IDs due to rough seas, distance from whales, or a lack of cetacean identification expertise. In previous stock assessments, these unidentified entanglements were not assigned to species, which results in underestimation of entanglement risk, especially for commonly-entangled species. To remedy this negative bias, a cross-validated species identification model was developed from known-species entanglements (‘model data’). The model is based on several variables (location + depth + season + gear type + sea surface temperature) collectively found to be statistically-significant predictors of known-species entanglement cases (Carretta 2018). The species model was used to assign species ID probabilities for 21 unidentified whale entanglement cases (‘novel data’) during 2012-2016. The sum of species assignment probabilities for this 5-year period result in an additional 5.8 gray whale entanglements for 2012-2016. Of these 5.8 entanglements, only 0.8 occurred within the geographic range and seasonal limits considered to represent PCFG gray whales, while the remaining 5 are considered to be ENP gray whales. Unidentified whale entanglements typically involve whales seen at-sea with unknown gear configurations that are prorated to represent 0.75 serious injuries per entanglement case. Thus it is estimated that at least 5 x 0.75 = 3.75 additional ENP gray whale and 0.8 x 0.75 = 0.6 PCFG serious injuries are represented from the 21 unidentified whale entanglement cases during 2012-2016. This represents 0.75 ENP gray whales and 0.1 PCFG gray whales annually. The 0.1 PCFG gray whales annually are added to ENP totals as PCFG whales are included in abundance and PBR calculations for the larger ENP stock. Thus, unidentified whale entanglements represent 0.85

ENP gray whales annually. Total serious injury and mortality from Table 1 totals 8.7 whales annually, pluse 0.85 annually from prorated unidentified whale entanglements, or 9.6 ENP whales annually.

Subsistence/Native Harvest Information

Subsistence hunters in Russia and the United States have traditionally harvested whales from the ENP stock in the Bering Sea, although only the Russian hunt has persisted in recent years (Huelsbeck 1988; Reeves 2002). In 2005, the Makah Indian Tribe requested authorization from NOAA/NMFS, under the MMPA and the Whaling Convention Act, to resume limited hunting of gray whales for ceremonial and subsistence purposes in the coastal portion of their usual and accustomed (U&A) fishing grounds off Washington State (NMFS 2015). The spatial overlap of the Makah U&A and the summer distribution of PCFG whales has management implications. The hunt proposal by the Makah Tribe includes time/area restrictions designed to reduce the probability of killing a PCFG whale and to focus the hunt on whales migrating to/from feeding areas to the north. The Makah proposal also includes catch limits for PCFG whales that result in the hunt being terminated if these limits are met. Also, observations of gray whales moving between the WNP and ENP highlight the need to estimate the probability of a gray whale observed in the WNP being taken during a Makah hunt (Moore and Weller 2013). NMFS has prepared a draft environmental impact statement (DEIS) on the proposed hunt (NMFS 2015) and the IWC has evaluated the potential impacts of the proposed hunt and other human-caused mortality sources on PCFG whales. The IWC concluded, with certain qualifications, that the proposed hunt meets the Commission's conservation objectives (IWC 2013). The Scientific Committee has continued to investigate stock structure of north Pacific gray whales and has convened five workshops on the subject between 2014 and 2018. The objective of the workshops has been to develop a series of range-wide stock structure hypotheses, using all available data sources (*e.g.* photo-ID, genetics, tagging), that can be tested within a modelling framework (IWC 2017).

In 2018, the IWC approved a 7-year quota (2019-2025) of 980 gray whales landed, with an annual cap of 140, for Russian and U.S. (Makah Indian Tribe) aboriginals based on the joint request and needs statements submitted by the U.S. and the Russian Federation. The U.S. and the Russian Federation have agreed that the quota will be shared with an average annual harvest of 135 whales by the Russian Chukotka people and 5 whales by the Makah Indian Tribe. Total takes by the Russian hunt during the past five years were: 143 in 2012, 127 in 2013, 124 in 2014, 125 in 2015, and 120 in 2016 (International Whaling Commission). There were no whales taken by the Makah Indian Tribe during that period because their hunt request is still under review. Based on this information, the annual subsistence take averaged 128 whales during the 5-year period from 2012 to 2016. The IWC reports a total of 3,787 gray whales harvested from annual aboriginal subsistence hunts for the 32-year period 1985 to 2016, which includes struck and lost whales. The estimated population size of ENP gray whales has increased during this same period (Fig. 2).

Other Mortality

Ship strikes are a source of mortality and serious injury for gray whales. During the most recent five-year period, 2012-2016, serious injury and mortality of ENP gray whales attributed to ship strikes totaled 4 animals (including 4 deaths and 2 non-serious injuries) or 0.8 whales annually (Carretta *et al.* 2018b). Total ship strike serious injury and mortality of gray whales observed in the PCFG range and season was 2 animals, or 0.4 whales per year (Carretta *et al.* 2018b). Ship strikes attributed to PCFG whales are also included in ENP totals. Additional mortality from ship strikes probably goes unreported because the whales either do not strand, are undetected, or lack obvious signs of trauma.

HABITAT CONCERNS

Nearshore industrialization and shipping congestion throughout gray whale migratory corridors represent risks due to increased likelihood of exposure to pollutants and ship strikes, as well as a general habitat degradation.

Evidence indicates that the Arctic climate is changing significantly, resulting in a reductions in sea ice cover that are likely to affect gray whale populations (Johannessen *et al.* 2004, Comiso *et al.* 2008). For example, the summer range of gray whales has greatly expanded in the past decade (Rugh *et al.* 2001). Bluhm and Gradinger (2008) examined the availability of pelagic and benthic prey in the Arctic and concluded that pelagic prey is likely to increase while benthic prey is likely to decrease in response to climate change. They noted that marine mammal species that exhibit trophic plasticity (such as gray whales which feed on both benthic and pelagic prey) will adapt better than trophic specialists.

Global climate change is also likely to increase human activity in the Arctic as sea ice decreases, including oil and gas exploration and shipping (Hovelsrud *et al.* 2008). Such activity will increase the chance of oil spills and ship strikes in this region. Gray whales have demonstrated avoidance behavior to anthropogenic sounds associated with oil and gas exploration (Malme *et al.* 1983, 1984) and low-frequency active sonar during acoustic playback experiments (Buck and Tyack 2000, Tyack 2009). Ocean acidification could reduce the abundance of shell-forming organisms (Fabry *et al.* 2008, Hall-Spencer *et al.* 2008), many of which are important in the gray whales' diet (Nerini 1984).

STATUS OF STOCK

In 1994, the ENP stock of gray whales was removed from the List of Endangered and Threatened Wildlife (the List), as it was no longer considered endangered or threatened under the Endangered Species Act (NMFS 1994). Punt and Wade (2012) estimated the ENP population was at 85% of carrying capacity (K) and at 129% of the maximum net productivity level (MNPL), with a probability of 0.884 that the population is above MNPL and therefore within the range of its optimum sustainable population (OSP).

Even though the stock is within OSP, abundance will fluctuate as the population adjusts to natural and human-caused factors affecting carrying capacity (Punt and Wade 2012). It is expected that a population close to or at carrying capacity will be more susceptible to environmental fluctuations (Moore *et al.* 2001). The correlation between gray whale calf production and environmental conditions in the Bering Sea may reflect this (Perryman *et al.* 2002; Perryman and Weller 2012). Overall, the population nearly doubled in size over the first 20 years of monitoring, and has fluctuated for the last 30 years, with a recent increase to over 26,000 whales. Carrying capacity for this stock was estimated at 25,808 whales in 2009 (Punt and Wade 2012), however the authors noted that carrying capacity was likely to vary with environmental conditions.

Based on 2012-2016 data, the estimated annual level of human-caused mortality and serious injury for ENP gray whales includes Russian harvest (128), mortality and serious injury from commercial fisheries (9.6), marine debris (0.35), ship strikes (0.8) totals 139 whales per year, which does not exceed the PBR (801). Therefore, the ENP stock of gray whales is not classified as a strategic stock.

The IWC completed an implementation review for ENP gray whales (including the PCFG) in 2012 (IWC 2013) and concluded that harvest levels (including the proposed Makah hunt) and other human caused mortality are sustainable, given the population abundance (Laake *et al.* 2012, Punt and Wade 2012).

PCFG gray whales do not currently have a formal status under the MMPA. Abundance estimates of PCFG whales increased from 1998 through 2004, remained stable during 2005-2010, and have steadily increased from 2011-2015 (Calambokidis *et al.* 2017). Total annual human-caused mortality of PCFG gray whales during the period 2012 to 2016 includes mortality and serious injuries due to commercial fisheries (0.7/yr), tribal fisheries (0.15/yr), ship strikes (0.4/yr), plus unidentified whale entanglements assigned as PCFG gray whales (0.1), or 1.35 whales annually. This does not exceed the calculated PBR level of 3.5 whales for this population. Levels of human-caused mortality and serious injury resulting from commercial fisheries and ship strikes for both ENP and PCFG whales represent minimum estimates as recorded by stranding networks or at-sea sightings because not all cases are detected or documented.

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GRAY WHALE (*Eschrichtius robustus*): Western North Pacific Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Gray whales occur along the eastern and western margins of the North Pacific. In the western North Pacific (WNP), gray whales feed during summer and fall in the Okhotsk Sea off northeast Sakhalin Island, Russia, and off southeastern Kamchatka in the Bering Sea (Weller *et al.* 1999, 2002; Vertyankin *et al.* 2004; Tyurneva *et al.* 2010; Burdin *et al.* 2017; Figure 1). Historical evidence indicates that the coastal waters of eastern Russia, the Korean Peninsula and Japan were once part of the migratory route in the WNP and that areas in the South China Sea may have been used as wintering grounds (Weller *et al.* 2002; Weller *et al.* 2013a). Present day records of gray whales off Japan (Nambu *et al.* 2010; Nakamura *et al.* 2017a; Nakamura *et al.* 2017b) and China are infrequent (Wang 1984; Zhu 2002; Wang *et al.* 2015) and the last known record from Korea was in 1977 (Park 1995; Kim *et al.* 2013). While recent observations of gray whales off the coast of Asia remain sporadic, observations off Japan, mostly from the Pacific coast, appear to be increasing in the past two decades (Nakamura *et al.* 2017b).

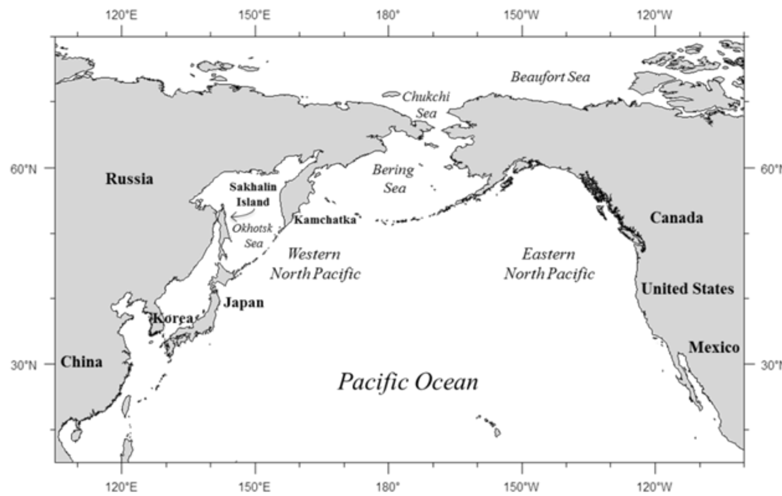

Figure 1. Range map of the Western North Pacific Stock of gray whales, including summering areas off Russia and wintering areas in the western and eastern Pacific.

Information from tagging, photo-identification and genetic studies show that some whales identified in the WNP off Russia have been observed in the eastern North Pacific (ENP), including coastal waters of Canada, the U.S. and Mexico (Lang 2010; Weller *et al.* 2012; Urbán *et al.* 2013, Mate *et al.* 2015). In combination, these studies have recorded about 30 gray whales observed in both the WNP and ENP. Some whales that feed off Sakhalin Island in summer migrate east across the Pacific to the west coast of North America in winter, while others migrate south to waters off Japan and China (Weller *et al.* 2016). Cooke (2015) estimated that 37-100% of the whales feeding off Sakhalin Island could potentially migrate to the coast of North America or, in other words, at most 63% could migrate solely within the WNP. Despite these estimates of cross-basin movements, analysis of photo-identification data, including data on mother-calf pairs and paternity assessments, suggest that gray whales summering in the WNP may constitute a demographically self-contained subpopulation where mating occurs at least preferentially and possibly exclusively within the subpopulation (Cooke *et al.* 2017, IUCN 2018). Despite the observed movements of some gray whales between the WNP and ENP, significant differences in their mitochondrial and nuclear DNA exist (LeDuc *et al.* 2002; Lang *et al.* 2011). Taken together, these observations indicate that not all gray whales in the WNP share a common wintering ground. Brüniche-Olsen *et al.* (2018) reassessed the genetic differentiation of gray whales feeding off Sakhalin and ENP whales from the Mexican breeding lagoons using nuclear Single Nucleotide Polymorphisms (SNPs). The degree of differentiation between these two regions was small but significant despite the existence of some admixed individuals. In conclusion, these authors suggested that gray whale population structure is not currently determined by simple geography and may be in flux as a result of emerging migratory dynamics.

In 2012, the National Marine Fisheries Service convened a scientific task force to appraise the currently recognized and emerging stock structure of gray whales in the North Pacific (Weller *et al.* 2013b). The charge of the task force was to evaluate gray whale stock structure as defined under the Marine Mammal Protection Act (MMPA) and implemented through the National Marine Fisheries Service's Guidelines for Assessing Marine Mammal Stocks (GAMMS; NMFS 2005). Significant differences in both mitochondrial and nuclear DNA between whales sampled off Sakhalin Island (WNP) and whales sampled in the ENP provided convincing evidence that resulted in the task force advising that WNP gray whales should be recognized as a population stock under the MMPA and GAMMS guidelines. Given the interchange of some whales between the WNP and ENP, including seasonal occurrence of WNP whales in U.S. waters, the task force agreed that a stand-alone WNP gray whale population stock assessment report was warranted.

The IWC Scientific Committee has conducted a series of annual (2014-2018) range-wide workshops on the status of North Pacific gray whales. The primary objective of these meetings was not to determine a single 'best' stock structure hypothesis (unless definitively supported by existing data) but rather to identify plausible hypotheses consistent with the suite of data available. The goal is to create a foundation for developing range-wide conservation advice. The primary hypotheses deemed as most plausible considered two separate 'breeding stocks' or biological populations (western and eastern). These hypotheses include: (a) Hypothesis 3a which assumes that while two breeding stocks (western and eastern) may once have existed, the western breeding stock is extirpated. Whales show matrilineal fidelity to feeding grounds, and the eastern breeding stock includes three feeding aggregations: Pacific Coast Feeding Group, Northern Feeding Group, and a Western Feeding Group; and (b) Hypothesis 5a which assumes that both breeding stocks are extant and that the western breeding stock feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula. Whales feeding off Sakhalin include both whales that are part of the extant western breeding stock and remain in the western North Pacific year-round, and whales that are part of the Eastern breeding stock and migrate between Sakhalin and the eastern North Pacific.

POPULATION SIZE

Estimated population size from photo-ID data for Sakhalin and Kamchatka in 2016 was estimated at 290 whales (90% percentile intervals = 271 – 311) (Cooke 2017, Cooke *et al.* 2018). Of these, 175-192 whales are estimated to be predominantly part of a Sakhalin feeding aggregation. These estimates represent animals in the 1-year plus age category. Cooke (2017) notes that not all of these animals belong to the Western North Pacific stock of gray whales and proposes an upper limit of approximately 100 whales from Sakhalin that could belong to the Western North Pacific breeding population.

Minimum Population Estimate

The minimum population size estimate is taken as the lower 5^{th} percentile of the estimate from Cooke (2017), or 271 animals. This is a more conservative estimate of minimum population size than using the lower 20^{th} percentile of a population estimate, however, Cooke (2017) did not provide such an estimate in his analysis.

Current Population Trend

The combined Sakhalin Island and Kamchatka populations were estimated to be increasing from 2005 through 2016 at an average rate between 2-5% annually (Cooke 2017).

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

An analysis of the ENP gray whale population provided an estimate of R_{max} of 0.062, with a 90% probability the value was between 0.032 and 0.088 (Punt and Wade 2012). This value of R_{max} is also applied to WNP gray whales, as it is currently the best estimate of R_{max} available for any gray whale population.

POTENTIAL BIOLOGICAL REMOVAL

The potential biological removal (PBR) level for this stock is calculated as the minimum population size (271) times one-half the estimated maximum annual growth rate for a gray whale population (½ of 6.2% for the Eastern North Pacific Stock, Punt and Wade 2012), times a recovery factor of 0.1 (for an endangered stock with N_{min} < 1,500, Taylor *et al.* 2003), and also multiplied by estimates for the proportion of the stock that uses U.S. EEZ waters (0.575), and the proportion of the year that those animals are in the U.S. EEZ (3 months, or 0.25 years) (Moore and Weller 2013), resulting in a PBR of 0.12 WNP gray whales per year, or approximately 1 whale every 8 years (if abundance and other parameters in the PBR equation remained constant over that time period).

HUMAN-CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

The decline of gray whales in the WNP is attributable to commercial hunting off Korea and Japan between the 1890s and 1960s. The pre-exploitation abundance of WNP gray whales is unknown, but has been estimated to be between 1,500 and 10,000 individuals (Yablokov and Bogoslovskaya 1984). By 1910, after some commercial exploitation had already occurred, it is estimated that only 1,000 to 1,500 gray whales remained in the WNP population

(Berzin and Vladimirov 1981). The basis for how these two estimates were derived, however, is not apparent (Weller *et al.* 2002). By the 1930s, gray whales in the WNP were considered by many to be extinct (Mizue 1951; Bowen 1974).

A significant threat to gray whales in the WNP are incidental catches in coastal net fisheries (Weller *et al.* 2002; Nakamura *et al.* 2017b; Weller *et al.* 2008; Weller *et al.* 2013a; Lowry *et al.* 2018). Between 2005 and 2007, four female gray whales (including one mother-calf pair and one yearling) died in fishing nets on the Pacific coast of Japan. In addition, one adult female gray whale died as a result of a fisheries interaction in November 2011 off Pingtan County, China (Wang *et al.* 2015). An analysis of anthropogenic scarring of gray whales photographed off Sakhalin Island found that at least 18.7% (n=28) of 150 individuals identified between 1994 and 2005 had evidence of previous entanglements in fishing gear but where the scars were acquired is unknown (Bradford *et al.* 2009). Trap nets for Pacific salmon have been deployed in the feeding area off northeastern Sakhalin Island since 2013, resulting in two known entanglements and one probable entanglement mortality (Lowry *et al.* 2018).

Given that some WNP gray whales occur in U.S. waters, there is some probability of WNP gray whales being killed or injured by ship strikes or entangled in fishing gear within U.S. waters.

Subsistence/Native Harvest Information

In 2005, the Makah Indian Tribe requested authorization from NOAA/NMFS, under the Marine Mammal Protection Act of 1972 (MMPA) and the Whaling Convention Act, to resume limited hunting of gray whales for ceremonial and subsistence purposes in the coastal portion of their usual and accustomed (U&A) fishing grounds off Washington State (NOAA 2015). Observations of gray whales moving between the WNP and ENP highlight the need to estimate the probability of a gray whale observed in the WNP being taken during a hunt by the Makah Tribe (Moore and Weller 2013). Given conservation concerns for the WNP population, the Scientific Committee of the International Whaling Commission (IWC) emphasized the need to estimate the probability of a WNP gray whale being struck during aboriginal gray whale hunts (IWC 2012). Additionally, NOAA is required by the National Environmental Policy Act (NEPA) to prepare an Environmental Impact Statement (EIS) pertaining to the Makah's request. The EIS needs to address the likelihood of a WNP whale being taken during the proposed Makah gray whale hunt.

To estimate the probability that a WNP whale might be taken during the proposed Makah gray whale hunt, four alternative models were evaluated. These models made different assumptions about the proportion of WNP whales that would be available for the hunt or utilized different types of data to inform the probability of a WNP whale being taken (Moore and Weller 2013). Based on the preferred model, the probability of striking at least one WNP whale in a single year was estimated to range from 0.006 – 0.012 across different scenarios for the annual number of total gray whales that might be struck. This corresponds to an expectation of ≥ 1 WNP whale strike in one of every 83 to 167 years. This analysis was based on a 2012 abundance estimate of 155 (95% CI 142-165) which is smaller than the 2016 abundance estimate of 290 (90% CI 271-311) whales reported by Cooke (2017).

HABITAT ISSUES

Near shore industrialization and shipping congestion throughout the migratory corridors of the WNP gray whale stock represent risks by increasing the likelihood of exposure to pollutants and ship strikes as well as a general degradation of the habitat. In addition, 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 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, increased shipping traffic, habitat modification, and risks associated with oil spills (Weller *et al.* 2002). During the past decade, a Western Gray Whale Advisory Panel, convened by the International Union for Conservation of Nature (IUCN), has been providing scientific advice on the matter of anthropogenic threats to gray whales in the WNP. Ocean acidification could reduce the abundance of shell-forming organisms (Fabry *et al.* 2008, Hall-Spencer *et al.* 2008), many of which are important in the gray whales' diet (Nerini 1984).

STATUS OF STOCK

The WNP stock is listed as "Endangered" under the U.S. Endangered Species Act of 1973 (ESA) and is therefore also considered "strategic" and "depleted" under the MMPA. At the time the ENP stock was delisted, the WNP stock was thought to be geographically isolated from the ENP stock. Documentation of some whales moving between the WNP and ENP indicates otherwise (Lang 2010; Mate *et al.* 2011; Weller *et al.* 2012; Urbán *et al.* 2013). Other research findings, however, provide continued support for identifying two separate stocks of North Pacific gray whales, including: (1) significant mitochondrial and nuclear genetic differences between whales that feed in the WNP and those that feed in the ENP (LeDuc *et al.* 2002; Lang *et al.* 2011), (2) recruitment into the WNP stock is almost exclusively internal (Cooke *et al.* 2013), (3) a single nucleotide polymorphism (SNP) study that indicates the gray whale gene pool is differentiated into two populations (Brüniche-Olsen *et al.* 2018) and (4) the abundance of the WNP stock remains low while the abundance of the ENP stock grew steadily following the end of commercial whaling (Cooke *et al.*2017). As long as the WNP stock remains listed as endangered under the ESA, it will continue to be considered as depleted under the MMPA.

The IWC Scientific Committee has conducted a series of annual (2014-2018) range-wide workshops on the status of North Pacific gray whales. The objective of the workshops has been to develop a series of range-wide stock structure hypotheses, using all available data sources (*e.g.* photo-id, genetics, tagging), that can be tested within a modelling framework (IWC 2017). Cooke *et al.* (2017) conducted an updated assessment of gray whales in the WNP using an individually-based stage-structured population model with modified stock definitions that allows for the possibility of multiple feeding/breeding groups. Cooke *et al.* (2017) noted that "there is preferential, but not exclusive, mating within the Sakhalin feeding aggregation. The hypothesis of mating exclusively within the Sakhalin feeding population is just rejected ($p < 0.05$). We conclude that the Sakhalin feeding aggregation is probably not genetically closed but that the Sakhalin and Kamchatka feeding aggregations, taken together, may be genetically closed. However, genetic data from Kamchatka would be required to confirm this." In this scenario, whales identified feeding off Sakhalin represent about 2/3 of the combined Sakhalin Island-Kamchatka subpopulation. Further substructure within the subpopulation was not excluded by Cooke *et al.* (2017), including the possibility of less than 50 mature whales that breed only in the WNP. The IWC analysis is ongoing and the results of Cooke *et al.* (2017) are considered provisional pending further exploration of additional gray whale stock structure hypotheses.

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WGWAP-18/24

Updated assessment of the Sakhalin gray whale population and its relationship to gray whales in other areas

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ABSTRACT

The population assessment of gray whales *Eschrichtius robustus* feeding off Sakhalin and Kamchatka is updated, using photo-id data collected up to and including the 2016 season. These data are supplemented by sex-determinations from biopsies, long-range movements from satellite-tracked tags, and photo-id matches with gray whales in Baja California, Mexico. An individually-based population model that allows for multiple feeding and breeding areas is fit to the different datasets simultaneously. For the stock structure hypotheses that were considered, the the Sakhalin population, or the combined Sakhalin and Kamchatka feeding populations combined, are estimated to have been increasing at 2-5% p.a. over the 10 years to 2016, but with significant variation in reproductive success over the last 20 years. Using all available data, the combined non-calf population is estimated at 271- 311 whales in 2016, of which 175-192 whales are predominantly Sakhalin-feeding whales. If there still exists a western breeding population, then the requirement for consistency with the long-range tracking and photo-id matching with the eastern North Pacific places an upper limit of about 100 whales on the number of Sakhalin whales that could belong to a western breeding population. These results should be considered provisional pending exploration of further stock structure hypotheses. The cross-matching of photo-id catalogues compiled under the different research projects should preferably be updated.

1. INTRODUCTION

Gray whales (*Eschrichtius robustus*) have been regularly reported during the summer months (June to October) off northeastern Sakhalin Island since the early 1980's (Brownell *et al*. 1997) and have been intensively studied there every year since 1995 (Burdin *et al*. 2015). Initially the Sakhalin gray whales were assumed to be a remnant of the western gray whale population formerly hunted in Korean and southern Japanese waters until the 1960s. The timing of gray whales catches in the Korean grounds was suggestive of a migration to a wintering ground in Asian waters (Kato and Kasuya 2002). However, tagging results and photo-id and genetic matches have shown that at least some of the Sakhalin gray whales migrate to breeding grounds in Mexican waters along with the bulk of the eastern North Pacific gray whale population (Mate *et al*. 2015; Weller *et al*. 2012). Many individuals observed off SE Kamchatka during 2006-11 have been matched with those off Sakhalin (Yakovlev *et al*. 2013, 2014) and some have been matched with whales seen in Mexico (Urbán *et al*. 2013).

In an analysis of the data on movement between Sakhalin and the eastern North Pacific, including data from satellite tagging of individuals and photo-id matches between Sakhalin and Mexico, Cooke (2016) concluded that 30-100% of Sakhalin whales migrate in winter to the eastern North Pacific. Thus, those data alone could not confirm or exclude the possibility of a western breeding migration. However, repeated sightings of Sakhalin-matched gray whale of the Pacific coast of Japan in spring are suggestive of the possibility that at least some of the gray whales seen off Sakhalin undertake a western North Pacific migration that may lead to a western North pacific breeding area whose location is unknown (Weller *et al*. 2016).

This analysis updates previous assessments of the Sakhalin gray whale population using all available data collected up to and including the 2016 season. Because of the substantial overlap between individuals observed off Sakhalin and Kamchatka, esitmates are also obtained for a combined Sakhalin and Kamchatka population.

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2. MATERIAL AND METHODS

2.1. Data

2.1.1 Photoidentification and sex-determination data

Photo-identification data from the Russian Gray Whale Project (RGWP) were available for each summer season (June to September) from the Piltun area of north-eastern Sakhalin from 1997 to 2016, with some data also collected in 1994 and 1995. A total of 261 distinct individual whales had been catalogued as of 2016. The catalogue has been published and annually updated since 2006 (Weller *et al*. 2006). A total of 140 individuals were identified as calves using the criteria specified by Bradford et al (2010), of which 123 were accompanied by identified mothers.

Photo-identification data collected by the IBM programme each season from 2002 to 2016 are tabulated by Yakovlev *et al*. (2017). A total of 272 distinct individuals were catalogued as of 2016, excluding "temporary whales" for which images of both sides are lacking. A total of 120 individuals were identified as calves, including 70 with identified mothers.

Yakovlev *et al*. (2013) list a total of 155 distinct whales identified off SE Kamchatka during 2004-12, of which 85 were matched with whales seen off Sakhalin. Sixteen (16) individuals were identified as calves, including 13 with identified mothers.

The distinction between calves as non-calves is assumed to be reliable for the RGWAP data for all years, and for the IBM and Kamchatka data from the 2006 season, following adoption of scoring criteria for calves, except that one mother-calf pair recorded in Kamchatka was discounted because the mother was herself only recorded as a calf only three years previously.

The 2011 versions of the IBM and RGWP Sakhalin catalogues (i.e. those containing whales sighted in seasons up to and including the 2011 season) were cross-matched and the results made available through IUCN (IUCN 2013). For the whales first sighted in 2011 or earlier, the entire sighting history through 2016 from all datasets combined can be used. For the new whales first sighted in 2012 or later, it is necessary to choose just one dataset as the primary dataset and include only the new whales from this dataset, because an unknown subset of these will represent individuals that are also included in the other dataset.

2.1.2 Sex determination

Genetic sex determinations from biopsy were obtained for 155 whales (89 males and 66 females) in conjunction with the RGWP and for 23 whales (12 males and 11 females) in conjunction with the IBM programme (Bickham *et al*. 2015). One sex determination that disagreed between the two data sets was discounted.

2.1.3 Tracking and long-range matching data

Three whales that were successfully satellite-tracked from Sakhalin to the eastern North Pacific (Mate *et al*. 2015). In addition, 17 matches between the Sakhalin catalogues and the San Ignacio lagoon catalogue for the years 2006-12 were found (Urbán *et al*. 2013). Of these, 15 were known to be alive as of 2011, of which 13 were known to be born in 2000 or earlier. Because of the low rate of matching of other whales, only whales satisfying these age and survival criteria (born before 2000 and alive in 2011) were treated as candidates for matching with Mexico.

2.1.4 Known deaths

A total of three identified whales were found dead: one in each of the years 2007 (in Japan), 2010 and 2016 (in Sakhalin).

2.2. Model structure

2.2.1 Basic (single-stock) population model

The core population model is as used by Cooke *et al*. (2016). It is an individually-based stage-structured population model, working in discreet time with a time step of one year.

The reproductive females are divided into three stages: pregnant, lactating, and resting. Females are assumed not to be simultaneously pregnant and lactating. A female can become pregnant immediately following lactation, resulting in a 2-year calving interval (the minimum observed). Optionally, a female can enter the resting phase for one or more years, resulting in a 3-year or longer calving interval. The minimum age at first successful pregnancy is 7 years; thereafter, the probability of becoming pregnant is assumed to increase as a logistic function of age, reaching a plateau at age 12. The "calving rate" rate in the model refers to the annual probability that a female starts a "successful" pregnancy, that is, a pregnancy that results in a live calf that survives the migration to the feeding ground.

The basic version of the model contains a total of 24 living stages: calves (2 stages: male and female); immature and maturing males (11 stages); adult males (1 stage); immature and maturing females (11 stages); and adult females (3 stages). In addition, there is an unborn stage, a "freshly dead" stage (where a carcass might be found and identified), and a "dead and buried" stage (no further possibility of being found), making a total of 27 stages in the core set.

The calving rate and the calf mortality rate are optionally allowed to vary with time. The pregnancy rate is also allowed to differ between stages: maturing, resting and lactating whales may start a successful pregnancy with different probabilities.

The possibility of density-dependent limitation of the population was explored by allowing the calving rate to decline linearly with adult population size such that the average net population growth rate becomes zero at a pre-specific carrying capacity.

2.2.2 Multiple feeding and breeding stocks

Two breeding populations are assumed: western North Pacific (WNP) and an eastern North Pacific (ENP). The Sakhalin feeding area is assumed to contain a mix of ENP and WNP whales, while the Kamchatka feeding area is assumed to contain only ENP whales. The population is divided into are three feeding/breeding subpopulations: (1) WNP breeding population, feeding off Sakhalin; (2) ENP breeders that feed predominantly off Sakhalin; and (3) ENP breeders that feed predominantly off Kamchatka. In each year, whales in each of the three subpopulations can be in any of the above 27 stages, which results in 81 possible states for each whale. The relative abundance of ENP and WNP whales, and of Sakhalin and Kamchatka feeders, are parameters of the model.

The meaning of "predominantly" is not fixed in advance. The sampling probabilities of whales in each group in each area are parameters of the model, as are the relative numbers of whales in each group. Individuals are not assigned definitively to either group, but the posterior likelihood of each whale belonging to each group depends in its sampling history, and is estimated together with all the parameters of the model.

The possibility that some Kamchatka-feeding whales belong to the WNP breeding population was not considered in this analysis, although in principle this would be possible.

2.2.3 Sampling model

2.2.3.1 Photo-id sampling

An animal is 'sampled' in a given year when it is photographed in that year, and the photographs have been processed and assigned to an existing known whale in the catalogue, or to a new whale which is added to the catalogue. A lactating (or post-lactation) female may be sampled alone or with its calf; likewise, a calf may be sample alone or with its mother. The probability that a mother-calf pair has separated before it is recorded is a parameter of the model, and may differ between the three data photo-id sets.

An animal may be sampled off Sakhalin, off Kamchatka or off Mexico. The sampling probabilities off Sakhalin and Kamchatka are parameters of the model allowed to vary by year, location, stage and individual. Individual (as opposed to stage-related) heterogeneity in sampling probability is modelled by assigning each individual with equal probability to one of a number of availability strata. The sampling probability may also depend on various interactions between the above factors, as determined by the model-selection process.

The required number of strata is determined by the model-selection process (see below). When there are *m* strata, each whale can be in a total of 81*m* different states.

The sampling probability for Mexico was estimated externally by Cooke (2016). The sampling probability of an "adult" whale (i.e. one meeting the age criteria defined above) in the Mexican breeding grounds was estimated at 0.054 per year, or 0.32 in total for the years 2006-12 combined. There may be scope for refining this estimate.

2.2.3.2 Satellite tracking

We assume that the tracking success probability is independent of breeding location. That is, we assume that if the three whales tracked from Sakhalin to the eastern North Pacific had instead migrated south in the western North Pacific, they would have been tracked there too. With this assumption, we condition on the actual number and identity of whales successfully tracked, and do not need to model the tracking probability.

This approach implies a qualitative difference in the evidentiary value of satellite-tracked animals versus long-range photo-id matches: for photo-id, the relevant sampling probability must be known or estimated, but this is not necessary for tracked animals.

2.3. Likelihood, model fitting and model selection

Table 1 lists the factors/terms included in each of the alternative models fitted. Each model was first fitted by maximum likelihood (REML) to produce estimates of model parameters and of the population trajectory. The factors/terms to include in the model were selected using the AIC criterion, to identify a preferred model. The Bayesian posterior distribution of the population trajectory was sampled for the preferred model. Full details of the model and fitting procedure are given by Cooke *et al*. (2016).

In summary, each individual has a range of potential biographies, each of which consist of a time series of its putative true state in each year. Some aspects of the state are assumed to remain constant over its lifetime, such as sex and membership of a feeding and/or breeding group. Other aspects, such as age, reproductive status, live vs. dead, change from year to year according to the transition probabilities.

In addition, each individual has an observed history. The observed history may be null for some individuals (i.e. individuals that exist but have not yet been sampled). The likelihood is calculated by comparing each putative biography with the observed history. Some aspects of the comparison are probabilistic. For example, whether an individual is sampled in a given area in a given year: the likelihood depends on the relevant sampling probabilities. Other aspects, such as sex or membership of a breeding stock, are of an either/or nature. For example, if a whale is tracked to the eastern North Pacific, all its potential biographies that involve it being a western breeder get assigned a zero likelihood. Likewise, if a whale is determined through genetic sampling to be male, all the potential biographies that involve it being female get assigned a zero likelihood.

3. RESULTS

3.1. Using RGWP photo-id and biopsy data only

Table 1 shows the result of fitting various models to the RGWP data only. These data were collected in Sakhalin only, thus the model involves a single feeding population. Case A represents the minimal reasonable model, because the sampling probability is a function of the research effort expended each year. The inclusion of a stage-specific sampling probability (case B) improves the fit (as measured using the AIC criterion), and inclusion of annual variation in the relative stage-specific sampling probability (case C) improves the fit further. The inclusion of individual heterogeneity in the sampling probability (case D) improves the fit yet further, as does the inclusion of annual variation in the calf mortality rate (case E) and the calving rate (case F).

Including density-dependence in the calving rate with a carrying capacity (K) of 300, 200 or 100 adult animals progressively worsens the fit (case G through I).

We conclude that there is annual variation in the calving rate and the calf mortality rate, but, as yet, no evidence of density-dependence in the reproductive rate.

Table 2 lists estimates of key parameters from best-fitting model (case F). The non-calf population size in 2016 is estimated at 168 (median) with 90% confidence limits 155-183. The number of reproductive (pregnant, lactating and resting) females is estimated at 37 (31-43) whales. The population growth rate during the last 10 years (2006-2016) is estimated at 2.8% p.a. with confidence limits 2.0-3.6% p.a.

Fig. 1. Sakhalin gray whales
Effective reproductive rate 1995-2014

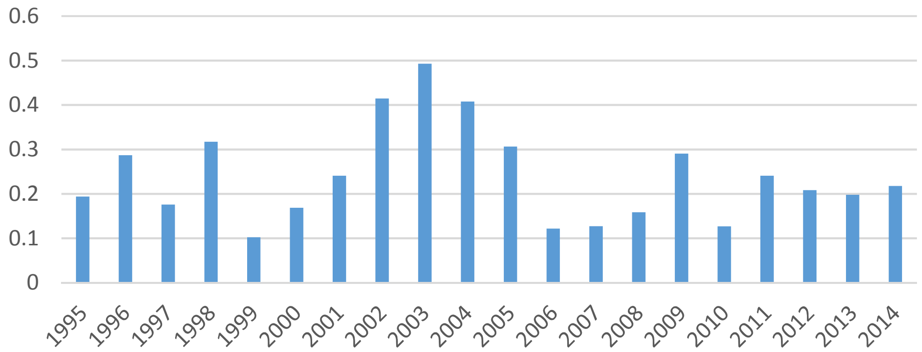

Fig. 1 shows the variation over time net reproductive success (calving rate multiplied by calf survival rate) . While it is not simple to characterize the uncertainty in the annual rates, the model-fitting exercise (Table 1) shows that the variation is significantly greater than would be expected by chance. The factors that drive the variation in reproductive success are not known at this time.

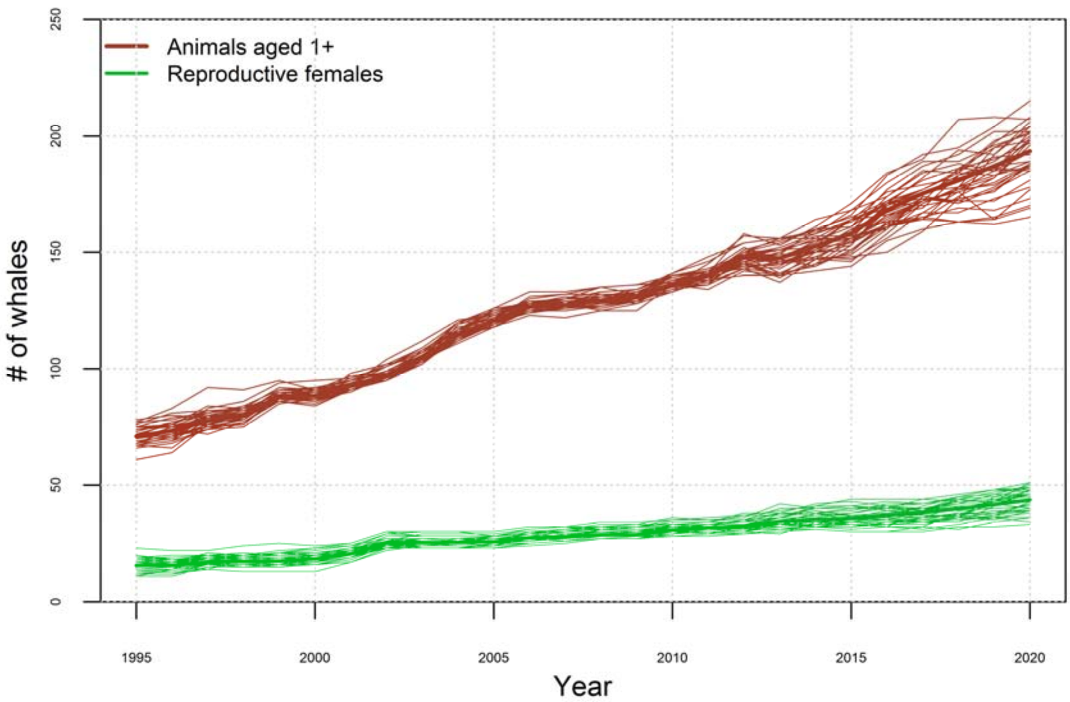

Fig. 2. Sample of population trajectories for Sakhalin gray whales from the posterior distribution from the fit to the RGWP data only, for the best-fitting model (ENP and WNP breeding populations combined).

Fig. 2. Shows the maximum likelihood population trajectories for the aged 1+ (non-calf) and reproductive female population sizes, along with a random sample of 50 population trajectories drawn randomly from the Bayesian posterior distribution of population estimates. The population is seen to have been growing over this period but at a variable rate.

Fig. 3. Shows a posterior distribution of population trajectories for both the total population and for the subset of Sakhalin whales that may be Western North Pacific breeders. No point estimate of the Western North Pacific breeding population is available, but the results show that if this population still exists, it numbers at most about 100 whales.

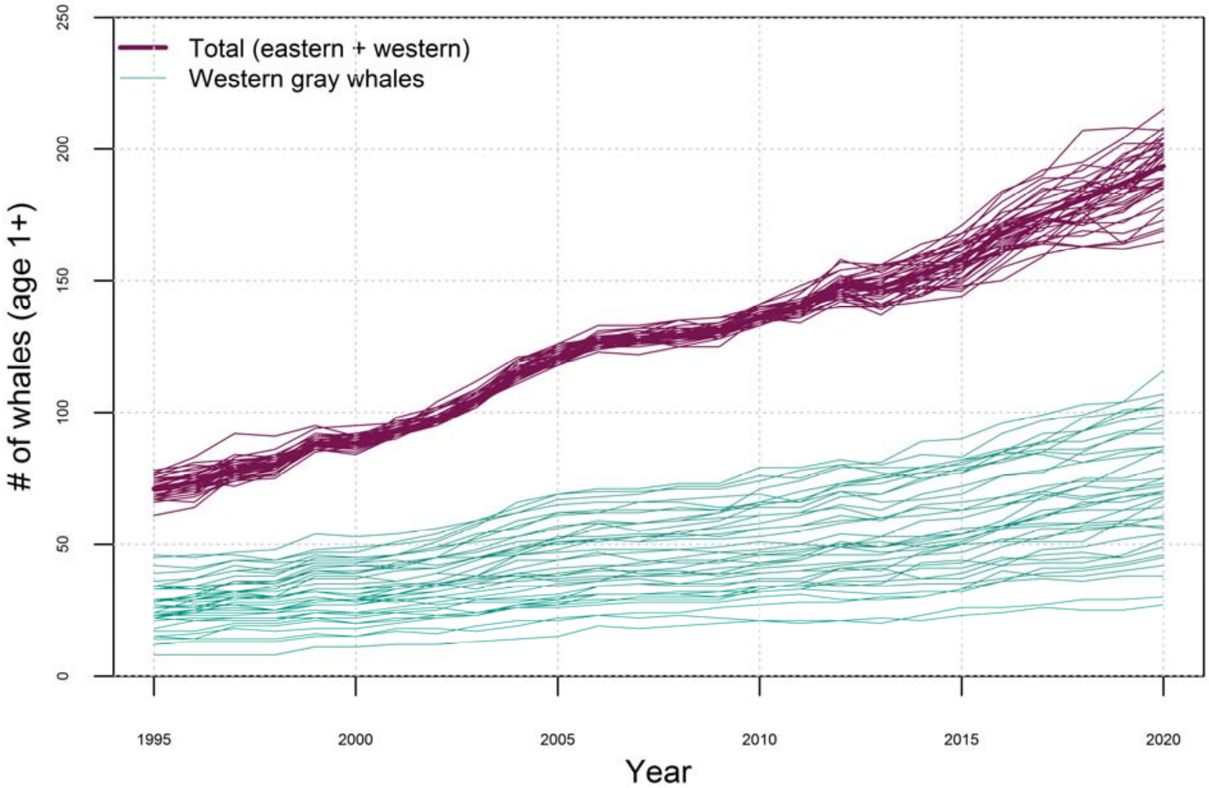

Fig. 3. Sample of population trajectories for Sakhalin gray whales from the posterior distribution from the fit to the RGWP data only, for the best-fitting model, showing the putative western (WNP) breeding population as a subset of the total.

3.2. Using all Sakhalin and Kamchatka photo-id data

The model was fit combining all the photo-id data, using the RGWP data as the primary data set for the period 2012 onwards for which matching was not available. The model includes two feeding populations ("stocks"): Sakhalin and Kamchatka, with some overlap between them.

Table 3 shows the result of fitting various models. Case A represents the minimal reasonable model, because the sampling probability is a function of the research effort expended in each location (Sakhalin or Kamchatka) by year and the two feeding stocks are differentially present in the two areas. The inclusion of a stage-specific sampling probability (case B) improves the fit, and allowing the relative stage-specific availability to vary by location (case C) improves the fit further. The inclusion of individual heterogeneity in the sampling probability (case D) improves the fit yet further, as does the inclusion of annual variation in the calf mortality rate (case E) and the calving rate (case F).

As expected, excluding the feeding stock/location interaction (case G) substantially worsens the fit. This confirms the impression that the Sakhalin and Kamchatka whales are not distributed randomly between the two areas, but that some whales are more likely to feed in Sakhalin than others. Using the estimates from best-fitting model (case F), Fig. 4 shows the average annual sampling probability of the whales from the Sakhalin and Kamchatkan feeding stocks in the two areas. We see that the two groups are roughly equally well represented in Kamchatkan samples, but that whales in the Kamchatkan group only rarely visit Sakhalin.

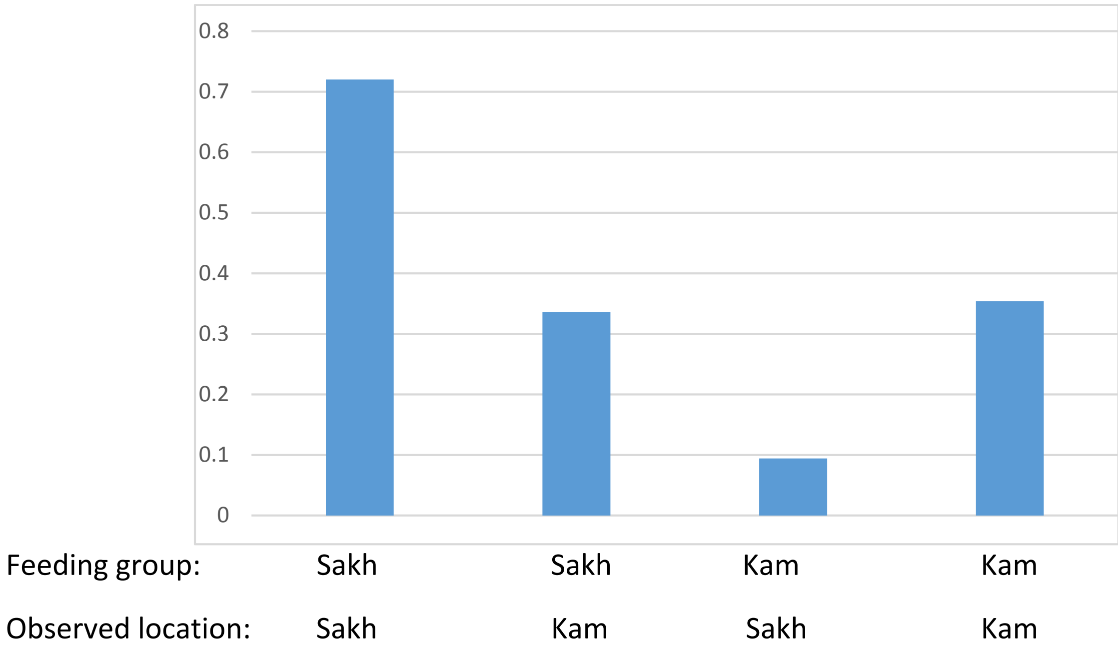

Fig. 4. Average annual sampling probability for the whales of the Kamchatka and Sakhalin feeding populations, in the two areas.

Table 4 lists estimates of key parameters from best-fitting model (case F). The non-calf population size in 2016 is estimated at 183 whales (median) with 90% confidence limits 175-192 whales for the Sakhalin feeding group and 290 (271-311) whales for the Sakhalin and Kamchatka feeding groups combined. The number of reproductive (pregnant, lactating and resting) females is estimated at 37 (33-42) whales for Sakhalin or 61 (51-72) for Sakhalin and Kamchatka combined. The population growth rate during the last 10 years (2006-2016) is estimated at 3.4% (3.0-3.9) p.a. for Sakhalin or 4.1(3.4-4.8) for Sakhalin and Kamchatka combined.

Fig. 5 Shows the maximum likelihood population trajectories for the aged 1+ (non-calf) and reproductive female population sizes, along with a random sample of 50 population trajectories drawn randomly from the Bayesian posterior distribution of population estimates, for each of the two breeding groups.

For comparison, the best-fitting model (case F) was also fit using the IBM dataset as the primary dataset for whales first sighted in 2012 or later (i.e. those which have not been matched across photo-id catalogues). Fig. 6. compares the maximum-likelihood population estimates for the two choices of primary dataset. While the results are virtually identical for the two choices, it would still be desirable to update the cross-catalogue matching and so eliminate this source of uncertainty.

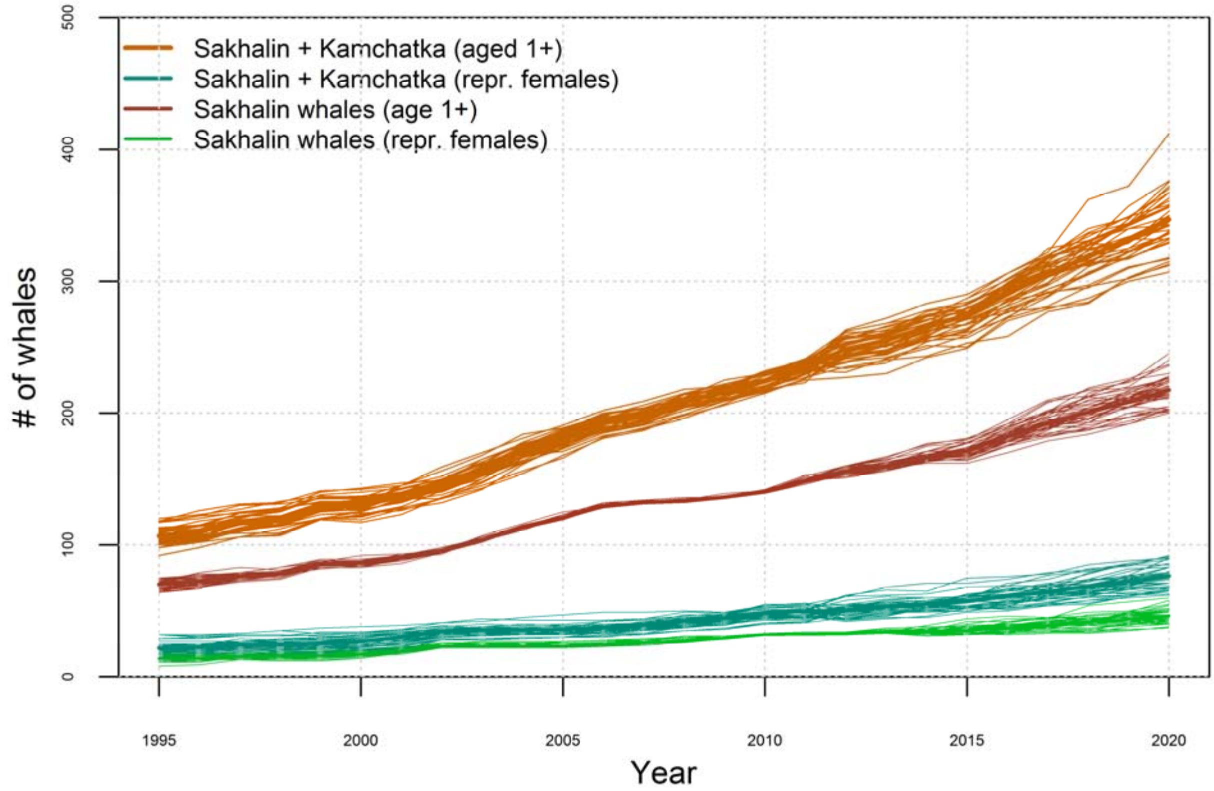

Fig. 5. Population trajectories for a. Sakhalin whales and b. Sakhalin and Kamchatka whales combined, for i) the aged 1+ and ii) reproductive female population components. Random sample of 50 trajectories from the posterior distribution.

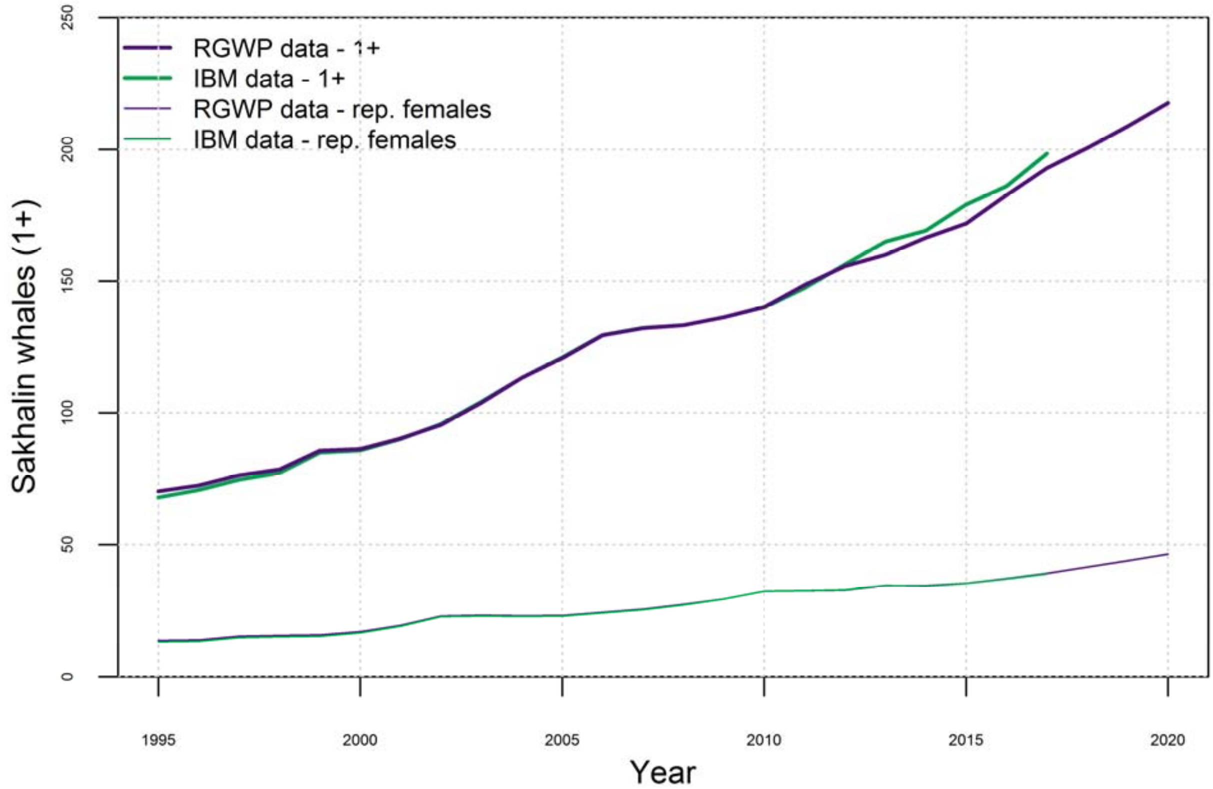

Fig. 6. Comparison of maximum likelihood population tractories using (i) RGWP and (ii) IBM data sets as primary datasets.

4. DISCUSSION

The results show that both the Sakhalin or the Sakhalin and Kamchatka combined feeding populations have been increasing over the past 20 years. There is some separation but also considerable overlap among the groups of gray whales that utilize the Sakhalin and SE Kamchatka freeing areas, such that, depending on the specific conservation or management question at hand, it may be appropriate to treat the groups separately or together for conservation or management purposes. The Sakhalin whales represent about 2/3 of the combined Sakhalin and SE Kamchatkan feeding populations.

If a Western North Pacific breeding population still exists, the data indicate that at most about 100 of the Sakhalin whales can belong to this population.

The population ("stock") structure of gray whales in the North Pacific is still under ongoing investigation by the International Whaling Commission Scientific Committee (IWC 2017). The feeding and breeding stock structure hypotheses considered in this paper represent only one example from the range of possibilities. Pending further progress on the stock structure question, the results presented in this paper should be considered provisional.

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Table 1. Model selection fits - RGWAP data

Case	Sampling probability model	Calf mortality	Calving rate	Carrying capacity	log like-lihood	df	AIC	
A	Year	const	Stage	∞	-1741.6	27.5	3538.2	
B	Year + 'Stage	const	Stage	∞	-1723.0	31.5	3509.0	
C	Year + Stage + 'Stage x Year	const	Stage	∞	-1658.5	71.4	3459.7	
D	Year + Stage + Stage x Year + Individual	const	Stage	∞	-1595.9	71.5	3334.9	
E	Year + Stage + Stage x Year + Individual	const	Stage + Year	∞	-1581.9	79.9	3323.7	
F	Year + Stage + Stage x Year + Individual	Year	Stage + Year	∞	-1571.0	87.8	3317.5	**
G	Year + Stage + Stage x Year + Individual	Year	Stage + Year	300	-1567.6	96.0	3327.2	
H	Year + Stage + Stage x Year + Individual	Year	Stage + Year	200	-1567.0	100.5	3335.0	
I	Year + Stage + Stage x Year + Individual	Year	Stage + Year	100	-1577.9	94.8	3345.3	
**	Selected model							

Table 2. Estimates of key parameters from preferred model (RGWP data)

	5%-ile	median	95%-ile
Population size in 2016 (aged 1+)	155	168	183
Population size in 2016 (reproductive females)	31	37	43
Mean annual trend in population size (%p.a.) 2006-16	2.0	2.8	3.6

	Estimate	SE
Mean calf survival rate (6-18 mo)	0.69	0.06
Mean annual adult survival rate	0.978	0.004

Table 3. Model selection fits - combined data

Case	Sampling probability model	Calf mortality	Calving rate	log like-lihood	df	AIC	
A	Year + Location.Stock	const	Stage	-3796.3	53.4	7699.3	
B	Year + Location.Stock + Stage	const	Stage	-3677.7	64.8	7485.0	
C	Year + Location.Stock + Stage + 'Stage x Year	const	Stage	-3757.1	57.7	7629.7	
D	Year + Location.Stock + Stage + Stage x Year + Individual	const	Stage	-3578.5	66.6	7290.1	
E	Year + Location.Stock + Stage + Stage x Year + Individual	const	Stage + Year	-3562.5	77.3	7279.6	
F	Year + Location.Stock + Stage + Stage x Year + Individual	Year	Stage + Year	-3555.2	83.6	7277.5	**
G	Year + Location + Stage + Stage x Year + Individual	Year	Stage + Year	-3876.1	84.0	7920.3	
**	Selected model						

Table 4. Estimates of key parameters from preferred model (combined data)

	"Sakhalin whales"			Sakhalin + Kamchatka		
	5%-ile	median	95%-ile	5%-ile	median	95%-ile
Population size in 2016 (aged 1+)	175	183	192	271	290	311
Population size in 2016 (reproductive females)	33	37	42	51	61	72
Mean annual trend in population size (%p.a.) 2006-16	3.0	3.4	3.9	3.4	4.1	4.8

	Estimate	SE
Mean calf survival rate (6-18 mo)	0.74	0.05
Mean annual adult survival rate	0.990	0.002