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DISTINCT POPULATION SEGMENT ANALYSIS OF WESTERN NORTH PACIFIC GRAY WHALES (*ESCHRICHTIUS ROBUSTUS*) UNDER THE ENDANGERED SPECIES ACT

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Distinct Population Segment Analysis of Western North Pacific Gray Whales (*Eschrichtius robustus*) Under the Endangered Species Act

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SUMMARY

This report provides an accounting of the work of a Status Review Team (SRT), convened by the National Marine Fisheries Service (NMFS), to determine whether western North Pacific gray whales qualify as a distinct population segment (DPS) under the joint NMFS-U.S. Fish and Wildlife Service policy on identifying Distinct Population Segments ("DPS Policy," 61 FR 4722; February 7, 1996). Following the deliberations and expert elicitation process used by the SRT, it was concluded that three gray whale units meet the DPS Policy criteria for discreteness and significance; these include: (1) Western North Pacific (WNP)-only unit (gray whales that spend their entire life in the WNP), (2) WNP-Eastern North Pacific (ENP) unit (gray whales that feed in the WNP in the summer and fall and migrate to the ENP (including Mexico) in the winter) and (3) WNP-only + WNP-ENP combined as a single unit. The SRT then needed to consider two mutually exclusive options for a recommended DPS listing: (1) a *Separate Option* where the WNP-only and WNP-ENP units are each a DPS or (2) a *Combined Option* where the WNP-only + WNP-ENP are combined into a single DPS. When considering the *Separate Option*, the SRT acknowledged that it is not possible, at this time, to readily assign whales to either the WNP-only or WNP-ENP units in the WNP. Therefore, the ability to evaluate the status of each unit separately (e.g., estimating abundance and trends, survival, evaluating progress toward recovery criteria or in response to management actions) is not scientifically practicable. Therefore, **the SRT recommends the *Combined Option* be used to designate the WNP-only + WNP-ENP units together as a single DPS.** The SRT did not conclude that the WNP-only unit or WNP-ENP unit are not separate DPSs, but rather they agreed that the most practicable means of obtaining positive management outcomes is to combine the units into a single DPS and provide protections throughout the entire range of that DPS.

BACKGROUND

NMFS initiated a 5-year review of the endangered western North Pacific (WNP) gray whale and solicited information from the public on January 29, 2018 (83 FR 4032). The WNP gray whale was listed on January 7, 1993 (58 FR 3121) prior to the adoption of the joint DPS Policy in February 1996.

A 5-year review is a periodic analysis of a species' status that is conducted to ensure the listing classification of a species as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 - 17.12) is accurate. The 5-year review is required by the U.S. Endangered Species Act (ESA) section 4(c)(2) and is prepared pursuant to the joint NMFS-U.S. Fish and Wildlife 5-year Review Guidance and template. The NMFS Office of Protected Resources (OPR) leads the 5-year review process for foreign species and species that range across multiple regions. OPR, in collaboration with the West Coast Region and Southwest Fisheries Science Center, drafted a 5-year review in 2019/2020 for the endangered WNP gray whale DPS, which included a DPS analysis.

During the 5-year review, the review team worked to source, review, and use the best available science to define WNP gray whales. For the purposes of that review, WNP gray whales were defined as:

"…gray whales that spend all or part of their lives in the western North Pacific in the waters of Vietnam, China, Japan, Korea (Republic of Korea and/or Democratic People's Republic of Korea), or the Russian Far East, including southern and southeastern Kamchatka but not necessarily areas north of 55°N in eastern Kamchatka. This definition is consistent with that used in the IUCN/IWC Western Gray Whale Conservation Management Plan as well as with how the western gray whale subpopulation has been evaluated by the IUCN (Cooke et al. 2018). Although not all of the gray whales as defined in this way remain in the western North Pacific year-round, they represent an important conservation unit irrespective of their wintering ground affiliation."

Under this definition, whales that have different wintering ground affiliations would be considered part of the same DPS. That is, gray whales that use the WNP in the summer use two different wintering areas, with some whales staying in the WNP year round while others migrate seasonally between the WNP (summer) to the eastern North Pacific (ENP) in the winter. Given that this definition for evaluating WNP gray whale DPS status differed fundamentally from the 1993 listing language (58 FR 3121; January 7, 1993), it was recommended that a status review team (SRT) be convened to sequentially (1) assess if the description of ENP and WNP gray whale stocks used in the original listing (58 FR 3121; January 7, 1993, and 59 FR 31094; June 16, 1994) remained accurate in light of the best currently available science; (2) then, if a revised DPS definition was necessary following the outcome of point (1), evaluate whether WNP gray whales meet the DPS Policy criteria; and (3) following the outcome of point (2), assess the risk of extinction for a WNP gray whale DPS based on the ESA section 4(a) factors used to determine the listing status.

This report provides an overview of the SRT's work to determine whether WNP gray whales qualify as a DPS following their deliberations and expert elicitation process on points (1) and (2) above, but in advance of undertaking point (3). The work reported herein represents the work of the SRT and was agreed upon by the entire team[1]. The SRT process was completed concurrent

[1] A. Lohe (NMFS, Office of Protected Resources) and A. Lang (NMFS, contractor with SWFSC) capably facilitated the SRT process and greatly contributed to sourcing and providing a comprehensive compilation of the best available science in the lines of evidence document (see Appendix 1 and 2) as well as making significant contributions to SRT discussions. While Lang contributed to the writing of this report and is acknowledged as a co-author, neither Lohe nor Lang were voting members of the SRT.

with finalizing the 5-year review and the conclusions of the SRT report are summarized therein.

REVIEW AND CONCLUSION ON ACCURACY OF EARLIER LISTING

Over the course of four teleconferences between April and August 2020, the SRT discussed the existing definitions of ENP and WNP gray whales provided in the Notice of Determination to Delist the Eastern North Pacific Stock (58 FR 3121; January 7, 1993) and in the Final Rule to Remove the Eastern North Pacific Population of the Gray Whale From the List of Endangered Wildlife (59 FR 31094; June 16, 1994). The 1993 determination (58 FR 3121) describes the western North Pacific population as migrating "between feeding grounds in the Sea of Okhotsk and breeding/calving grounds along the South China Coast," while the eastern North Pacific population "migrates between breeding/calving grounds along the West Coast of Mexico and feeding grounds in the Bering and Chukchi Seas." (Figure 1). This determination also states that eastern and western gray whales "appear to be significantly isolated both geographically and reproductively from each other." (Figure 1). In the 1994 final rule (59 FR 31094), the range of the western North Pacific population is listed as "entire, except eastern North Pacific Ocean: coastal and Bering, Beaufort, and Chukchi Seas."

After the SRT considered the best available science (see Appendix 1 and 2), they agreed by unanimous vote that the definitions of ENP and WNP gray whales provided in 58 FR 3121 and 59 FR 31094 do not accurately describe how gray whales utilize and partition their habitat in the North Pacific. While there are several plausible hypotheses about gray whale stock structure in the North Pacific outlined by the International Whaling Commission (2018), none meet the criteria defined in the original 58 FR 3121 and 59 FR 31094 definition of ENP and WNP gray whale stocks. Thus, the SRT unanimously concluded that the original definition of ENP and WNP gray whale stocks used in 58 FR 3121 and 59 FR 31094 is no longer valid based on the best available scientific evidence.

EXPERT ELICITATION

To determine the biological units to be evaluated and, in turn, whether they met the criteria for being recognized as a DPS, the SRT composed a series of dichotomous questions (see below) that related to the specific criteria for discreteness and significance in the DPS Policy. To provide an explicit measure of the certainty of each expert's judgment, the SRT agreed to use an approach whereby each expert was asked to anonymously distribute 100 likelihood points per question across the yes/no options presented to them. Allocation of 100 or zero points to a particular question indicates complete certainty in the response, while splitting the points between yes and no indicates a measure of uncertainty due to limited scientific information and/or differences in how certain lines of evidence were interpreted. For both the discreteness and the significance evaluation, an initial anonymous preliminary point allocation process was conducted and that was followed by open discussion amongst the SRT to ensure that the questions were clear and that the team had a common understanding of the available evidence. This initial discussion was then followed by a final anonymous point allocation process that constitutes the SRT's formal advice.

DPS DISCRETENESS AND SIGNIFICANCE EVALUATION

In advance of evaluating the discreteness criteria, the SRT once again reviewed the best available data/information and spent considerable time in discussion. Following this effort, they then worked together to draft five questions pertinent to evaluating discreteness. Of these five questions, the first (Q1, Table 1) was unique in that it asked not about discreteness directly, *per se,* but rather whether the scientific evidence did or did not support the existence of gray whales that spend their entire life in the WNP (i.e., a WNP-only unit). The remaining 4 questions (Q2-5, Table 1) were intended to evaluate the discreteness of three plausible biological "units" that included: (1) the WNP-only unit, as described above; (2) a WNP-ENP unit (gray whales that feed in the WNP in the summer and fall and migrate to the ENP (including Mexico) in the winter); and (3) a WNP-only + WNP-ENP combined single unit. The first two units were evaluated based on both their discreteness from each other and from the Northern Feeding Group (NFG) unit, which represents the majority of whales that spend all of their lives in the ENP. The third combined unit was evaluated based on its discreteness from the NFG unit. The five questions agreed to by the SRT were:

(1) *Are there gray whales that spend their entire lives in the western North Pacific (WNP)?*

(2) *Assuming there are gray whales that spend their entire lives in the WNP, are they markedly separate from the whales that feed on the Northern Feeding Ground (NFG) and spend their entire lives in the eastern North Pacific (ENP) as a consequence of physical, physiological, ecological, or behavioral factors?*

(3) *Assuming there are gray whales that spend their entire lives in the WNP, are they markedly separate from the whales that feed in the WNP in the summer and fall and migrate to the ENP (including Mexico) in the winter as a consequence of physical, physiological, ecological, or behavioral factors?*

(4) *Are the gray whales that feed in the WNP in the summer and fall and migrate to the ENP (including Mexico) in the winter markedly separate from the whales that feed on the NFG and spend their entire lives in the eastern North Pacific (ENP) as a consequence of physical, physiological, ecological, or behavioral factors?*

(5) *Are whales that spend all or part of their lives in the WNP (the WNP-only whales and the WNP-ENP whales as a combined unit, irrespective of whether they are or are not determined to be discrete from each other) markedly separate from the whales that feed on the NFG and spend their entire lives in the eastern North Pacific (ENP) as a consequence of physical, physiological, ecological, or behavioral factors?*

The SRT found strong support for the existence of a WNP-only unit (Q1, Table 1), with an overall certainty of 91.25%. Evidence supporting the SRT's judgement about the continued year-round existence of gray whales in the WNP included contemporary records of gray whales off Japan and China, including at least two individuals known to use the Sakhalin feeding ground; acoustic recordings from the east China Sea that experts have identified as containing gray whale calls, the timing of which aligns with migration through the area; and results of demographic modeling which indicated that approximately 52% of the gray whales feeding off Sakhalin do not migrate to the ENP. In addition, the historic occurrence of gray whales remaining in the

WNP year-round is confirmed by whaling records, and there is no conclusive evidence to say that these whales were ever extirpated.

Under the DPS Policy, a population segment of a vertebrate species may be considered discrete if it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological or behavioral factors. In considering the evidence of marked separation as a consequence of any of these factors, the SRT found high support for the discreteness of all three of the units evaluated, with all SRT member point allocations reflecting at least 80% certainty that marked separation was present. As mentioned above, the SRT found strong support for the existence of a WNP-only unit (Q1, Table 1), with an overall certainty of 91.25%. The evidence supporting the discreteness of a WNP-only unit (Q2 Table 1) and the combined WNP-only unit + WNP-ENP unit (Q5 Table 1) from the NFG unit (i.e. gray whales that spend their entire lives in the ENP) was considered very strong, with an average of 98.75% of points allocated in support of marked separation, and seven out of eight team members indicating complete certainty (i.e., allocating all 100 likelihood points) that these units were markedly separate as a consequence of at least one of the four discreteness factors. The evidence supporting marked separation between the WNP-only unit and WNP-ENP unit (Q3 Table 1) or between the WNP-ENP unit and the NFG unit (Q4) was slightly less strong, with SRT members allocating on average 91.25% of points in support of marked differences in at least one of the four factors. For both Q3 and Q4 all members of the SRT allocated at least 80% of their likelihood points in support of these units being markedly separate.

The support for each of these units being considered discrete was largely driven by marked differences in behavioral and ecological factors. For all three units, the SRT concluded that the use of different migratory routes, and the associated differences in metabolic costs and predation risks, supported marked separation, even given that the WNP-ENP unit and the NFG unit overlap on part of their migration. The strong matrilineal fidelity exhibited by the whales feeding off Sakhalin Island, which includes whales of both the WNP-only unit and the WNP-ENP unit, was also regarded as strong evidence of behavioral separation of these two units from the NFG unit. In addition, each unit differs in the biogeographic realms used for at least part of their life cycle, with whales of the WNP-only unit overwintering in a different realm than all other gray whales, and both the WNP-only unit and the WNP-ENP unit feeding in a region that they share but that differs from that used by the NFG unit. There is also direct and/or indirect evidence that whales from each unit likely breed primarily with each other. For the WNP-only unit, which represents only a portion of the whales feeding off Sakhalin (where distinction between WNP-only individuals and WNP-ENP individuals is not possible), this evidence comes not from genetic analyses but is based on what is known about the timing of reproduction and migration in gray whales (Rice and Wolman 1971). This evidence is also considered as supporting a lack of substantial interbreeding between the WNP-ENP unit and the NFG unit. However, for the WNP-ENP unit and for the WNP-only + WNP-ENP combined unit, the nuclear genetic differentiation identified between the NFG unit and the whales sampled off Sakhalin, even when represented by only the subset of whales known to be part of the WNP-ENP unit, combined with the estimated small effective population size of the whales feeding off Sakhalin provide further support for a lack of substantial interbreeding with the NFG unit.

The uncertainty expressed by some SRT members when evaluating the discreteness of the WNP-ENP unit from the NFG unit was a reflection of the fact that these two groups do share a common ecology and behavior during some parts of their life cycle (e.g., while on wintering grounds and during part of the migration). Some uncertainty in the discreteness of the WNP-ENP unit from the WNP-only unit was based on whether, at least in years when the Sakhalin feeding ground remains ice-free into late November and December when breeding is thought to commence, whales from these two units may have the opportunity to interbreed. This possibility also increased the certainty of some SRT members that the WNP-only + WNP-ENP combined unit was discrete. In addition, support for the WNP-only + WNP-ENP combined unit was derived from the results of demographic modeling that suggest gray whales in the WNP during the summer are demographically self-contained (Cooke et al. 2018).

Having determined that all three of the units under consideration met the criteria for being discrete, the SRT was then tasked with evaluating the significance of those units to the taxon as a whole. The DPS Policy is a set of sequential criteria designed to both capture the importance of populations below the subspecies level but also to do so 'sparingly'. As such, it is plausible that units can meet the discreteness criteria but not meet the significance criteria.

Prior to initiating the evaluation of significance, the SRT agreed that they needed to have a common understanding of how to interpret the significance and importance of each discrete unit or segment to the taxon as a whole. The DPS Policy puts the significance conditions in the context of factors that affect the overall welfare of the taxon. Wherein, welfare was agreed by the SRT to mean the persistence of the taxon as a whole, where persistence is defined as the taxon's ability to respond to challenges, both biological and physical, that the taxon has endured throughout its historical range in the past and/or is currently facing or could face in the future.

The SRT rephrased the conditions provided in the DPS Policy as questions and assigned 100 likelihood points to possible answers of "yes" or "no" for each of the following:

(1) *Does the Unit persist in an ecological setting unusual or unique for the taxon such that persistence in this setting is important to the taxon?*

Where 'unique or unusual ecological setting' was agreed by the SRT to refer to habitats with distinctive ecological features that would likely result in the segment developing adaptations to its environment. Consideration of whether the adaptation to its environment is exclusive to the Unit was given when allocating likelihood points.

(2) *Would the loss of the Unit result in a significant gap in the range of the taxon such that maintaining this area as part of the range is important to the taxon?*

Where 'significant gap in the range' was agreed by the SRT to imply that the loss of the segment from this area would result in the loss of resiliency (ability to sustain itself while facing demographic and environmental stochasticity), redundancy (ability to withstand unforeseen catastrophes), and/or representation (ability to adapt over time to long-term changes in the environment) of the taxon as a whole, and where the importance of the range to the taxon considers its historical and future range.

(3) *Does the Unit differ markedly from other populations of the same species in its genetic characteristics, such that these genetic characteristics are important to the taxon?*

Where 'differ markedly' in genetic characteristics is understood by the SRT to mean that the segment contains components of genetic diversity that may be associated with adaptation to its environment and that are unlikely to be present in high frequencies in other population segments. Direct evidence for adaptation to their environment is rare for cetaceans, but genetic evidence of the segment being isolated from the rest of its taxon for a lengthy period of time can be used to infer that localized adaptation is plausible. One example, amongst others, of such indirect evidence could be a large magnitude of differentiation in both mitochondrial and nuclear genetic markers. Statistically significant differences between groups alone are not necessarily sufficient evidence of marked genetic differences.

(4) *Is the Unit significant to the species because of other biological or ecological factors that are important to the taxon?*

Where other factors that could be important to the taxon were agreed by the SRT to include behavioral or cultural diversity, in which culture refers to knowledge passed through learning from one generation to the next. For instance, learned migratory behavior, bioenergetics, and differences in predation pressure could be considered under this question.

For clarity in the discussion that follows, these questions are referred to as: (1) ecological setting, (2) significant range gap, (3) marked genetic differences and (4) behavioral differences. The SRT considered several different ways of interpreting the likelihood point allocation results. Given that the DPS policy specifies that consideration of significance may include one or more of the criteria referenced in the questions, the SRT favored an approach that used the highest likelihood points allocated by each expert to any one of the four questions in the final consideration (Table 2). Using this approach, all three discrete units had high support for significance, with the WNP-only unit and the WNP-only + WNP-ENP combined unit receiving an average of 80 or more of 100 likelihood points and the WNP-ENP unit receiving 67 out of 100 points. Examining which questions were considered most important to the welfare of the taxon, there was strong support (i.e., the highest average likelihood point allocations across units) for both the significant range gap (Q2, Table 2) and the behavioral differences (Q4, Table 2), with less support for the ecological setting question (Q1, Table 2). Scores for the genetic differences question (Q3, Table 2) indicated a high degree of uncertainty due primarily to what the SRT felt was a lack of applicable data.

Therefore, the SRT concluded that all three gray whale units meet both the ‘discreteness’ and the ‘significance’ criteria of the DPS Policy criteria. Given this outcome, the SRT agreed that there are two mutually exclusive options for recommending a DPS listing that include: (1) a *Separate Option* where the WNP-only unit and the WNP-ENP unit are separate DPSs, or (2) a *Combined Option* where the WNP-only unit and WNP-ENP unit are combined into a single unit (i.e., WNP-only + WNP-ENP unit) and considered one DPS. The SRT considered the biological and practical merits of these options.

The *Separate Option* recognizes the importance of both the WNP-only unit and ENP-WNP unit. Both feed in the western North Pacific and thereby occupy an area significant to the welfare of the species and both have unique migratory routes. Further, the WNP-only unit occupies a unique wintering area also considered significant to the welfare of the species. It is unknown whether there is interbreeding between the WNP-only unit and WNP-ENP unit in the early winter months, but complete reproductive isolation is not required as prerequisite to recognizing a DPS.

When measured as the average proportion of points allocated toward the supporting arguments (i.e., “yes” answers), the *Combined Option* (WNP-only unit + WNP-ENP unit) had the strongest support for significance. Thus, the SRT recognized that the loss of this unit would result in a significant gap in the range of the taxon and, in turn, be detrimental to the persistence of the species. Unlike other large baleen whales, gray whales do not occupy other ocean basins. The majority of gray whales depend on the high North Pacific Arctic to feed, which is an area predicted to change dramatically in the coming decades due to climate change. Thus, gray whales in the western North Pacific may be important to the resiliency of the species given the uncertainty of how summer feeding areas might change in suitability and how gray whales may respond to these changes. The high certainty expressed by the SRT in the significance of the WNP-only + WNP-ENP combined unit was with this idea in mind - to ensure that gray whales are maintained in the western North Pacific and that having both units (WNP-only and WNP-ENP) provides the greatest chance of ensuring this objective.

SRT CONCLUSION AND RECOMMENDATION

In summary, the SRT concluded that three gray whale units met the DPS Policy criteria for discreetness and significance, these included: (1) WNP-only unit, (2) WNP-ENP unit and (3) WNP-only + WNP-ENP combined as a single unit. Given this outcome, the SRT then considered two mutually exclusive options for a recommended DPS listing: (1) a *Separate Option* where the WNP-only and WNP-ENP units are separate DPSs or (2) a *Combined Option* where the WNP-only + WNP-ENP are combined into a single DPS. When considering the *Separate Option*, the SRT acknowledged that it is not possible, at this time, to readily assign whales to either the WNP-only or WNP-ENP units in the WNP. Therefore, the ability to evaluate the status of each unit separately (e.g., estimating abundance and trends, survival, evaluating progress toward recovery criteria or in response to management actions) is not scientifically practicable. Therefore, **the SRT recommends the *Combined Option* be used to designate the WNP-only + WNP-ENP units together as a single combined DPS.**

It is important to state that the SRT did not conclude that the WNP-only unit or WNP-ENP unit are not separate DPS, but rather that they agreed that the most practicable means of obtaining positive management outcomes is to combine the units into a single DPS and provide protections throughout the entire range of the DPS. Should future information provide a means to distinguish between individuals of the WNP-only unit and WNP-ENP unit that will allow separate monitoring and management of them, it may be necessary to reevaluate this conclusion.

Figure 1. Map showing the approximate locations of key areas mentioned in the report.

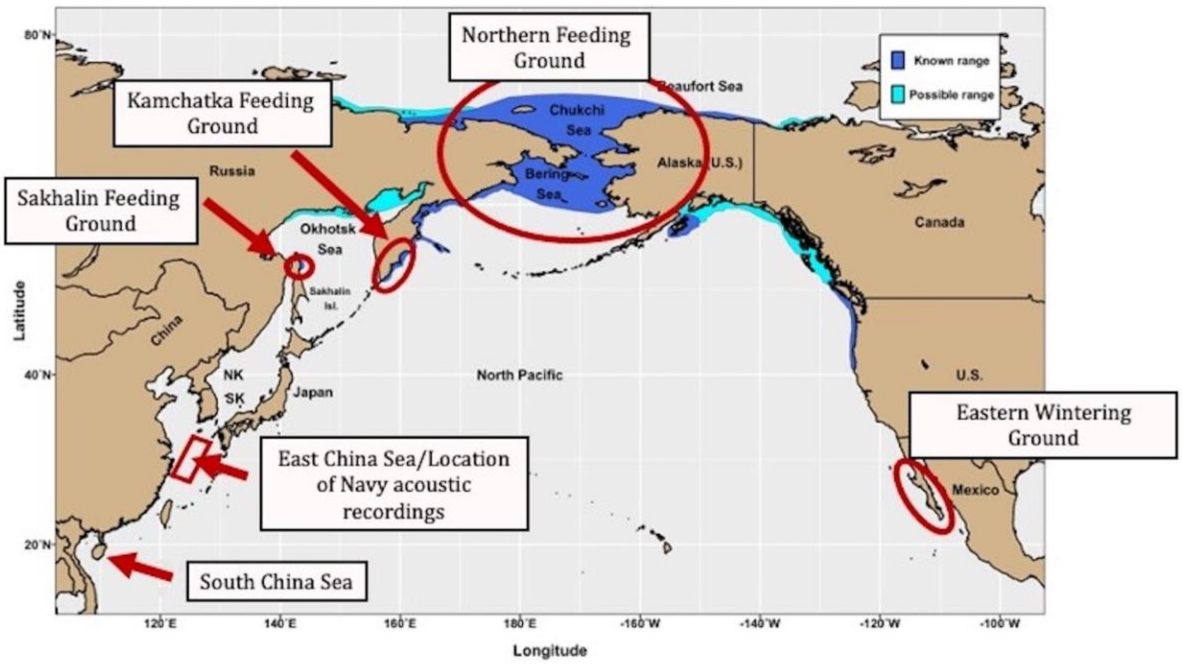

Table 1. Final point allocations assigned by each SRT member on the five questions pertaining to the discreteness of each unit under consideration. Refer to the "DPS DISCRETENESS AND SIGNIFICANCE EVALUATION" section above for the full text of questions 1 through 5.

Expert	WNP-only	WNP-only vs NFG	WNP-only vs WNP-ENP	WNP-ENP vs NFG	WNP-only + WNP-ENP vs NFG
	Q1 (% Yes)	Q2 (% Yes)	Q3 (% Yes)	Q4 (% Yes)	Q5 (% Yes)
Expert A	95	100	100	100	100
Expert B	90	90	85	85	90
Expert C	90	100	100	100	100
Expert D	85	100	95	85	100
Expert E	100	100	80	80	100
Expert F	80	100	85	90	100
Expert G	100	100	100	100	100
Expert H	90	100	85	90	100
Average	91.25	98.75	91.25	91.25	98.75
Number of experts assigning >50% points	8	8	8	8	8
Percentage of experts assigning >50% points:	100%	100%	100%	100%	100%

Table 2. Final point allocations assigned by each SRT member on the four questions used to evaluate whether each unit meets the criteria for being considered significant. The final set of columns represents the highest number of points each expert allocated toward the supporting arguments across all four questions for each unit. The average percentage of points allocated toward the supporting arguments for each question and the number and proportion of team members allocating more than 50 points in support of each question are shown in the rows below the team member allocations. Refer to the "DPS DISCRETENESS AND SIGNIFICANCE EVALUATION" section above for the full text of questions 1 through 4.

Expert	Q1 (% Yes)			Q2 (% Yes)			Q3 (% Yes)			Q4 (% Yes)			Highest score per expert across questions		
	WNP-only	WNP-ENP	Combined	WNP-only	WNP-ENP	Combined	WNP-only	WNP-ENP	Combined	WNP-only	WNP-ENP	Combined	WNP-only	WNP-ENP	Combined
Expert A	90	10	15	90	10	15	5	5	5	90	10	15	90	10	15
Expert B	80	60	80	80	90	100	60	50	50	90	90	90	90	90	100
Expert C	10	10	100	10	10	100	10	50	80	30	50	85	30	50	100
Expert D	100	75	100	100	75	100	50	50	50	80	40	80	100	75	100
Expert E	65	55	65	85	70	100	50	60	55	70	70	70	85	70	100
Expert F	80	60	80	80	65	100	50	80	80	80	70	80	80	80	100
Expert G	40	30	40	85	90	100	40	20	20	80	80	80	85	90	100
Expert H	35	25	30	80	20	90	50	35	35	70	70	70	80	70	90
Average	62.5	40.625	63.75	76.25	53.75	88.125	39.375	43.75	46.875	73.75	60	71.25	80	66.875	88.125
Number of experts assigning >50% points	5	4	5	7	5	7	1	2	3	7	5	7	7	6	7
Percentage of experts assigning >50% points:	62.50%	50.00%	62.50%	87.50%	62.50%	87.50%	12.50%	25.00%	37.50%	87.50%	62.50%	87.50%	87.50%	75.00%	87.50%

APPENDIX I

LINES OF EVIDENCE USED BY THE SRT

1. Movements (photo-id, satellite tagging, genetic matches)

1.1 Strong matrilineally-driven fidelity to the Sakhalin feeding ground (Burdin *et al.* 2020, Weller *et al.* 1999, Bröker *et al.* 2020):

- Bröker et al. (2020):
  - Between 2002-2014, n=243 whales identified (including n=94 whales first identified as calves)
  - Most newly identified individuals on the Sakhalin foraging grounds after 2005 were a result of calf production (72.0%) as opposed to new non-calf individuals (28.0%)
  - After 2005, ≥80% of whales sighted per year were resights
- Burdin et al. (2020)
  - Between 1994-2019, n=302 whales identified (n=165 first identified as calves)
  - After the first three years of study, the number of new non-calves identified each year has remained low (0-7/yr) and most whales (≥80%, except in 2018) have been seen in previous years

1.2 What is known about fidelity to wintering grounds and migratory routes:

- Some whales documented to return to the same Mexican wintering lagoons in multiple years (Jones 1990, Urban R. et al. 2003, Martínez A. et al. 2016, Urban R. et al. 2019).
- One of the whales that was first observed off Sakhalin as a calf with its mother was subsequently recorded off the coast of Japan as a yearling in March-April (months in which the northbound migration occurs in the ENP), then photographed off Sakhalin the following summer, and then again off Japan in January-February (months in which the southbound migration occurs in the ENP) of the next year (Weller *et al.* 2016b). This provides some evidence of fidelity to migratory routes.
- Two of the Japan whales from which samples were obtained had the same mtDNA control region haplotype (Kanda *et al.* 2010). The haplotype has not been found among whales sampled off Sakhalin but has been found in one whale sampled off Kamchatka and two sampled on the NFG. Microsatellite profiles indicate that these two whales do not share a mother-offspring relationship (but whether they share a more distant familial relationship has not been tested).
- Some humpback whales known to use multiple wintering grounds (e.g., Darling & Cerchio 1993, Salden *et al.* 1999, Forestell & Urbán 2007, Pomilla & Rosenbaum 2005, Félix *et al.* 2020, Stevick *et al.* 2013, Stevick *et al.* 2016, Stevick *et al.* 2011).

1.3 Interchange between Sakhalin and Kamchatka (Tyurneva *et al.* 2010, Yakovlev *et al.* 2013, Burdin *et al.* 2011, Burdin *et al.* 2019):

- Approximately 50% of the whales sighted off Kamchatka have also been identified off Sakhalin
- Some intra-seasonal movements between Kamchatka and Sakhalin occur
- Many of the Sakhalin whales sighted on the Kamchatka feeding area are known to be juveniles

1.4 Interchange between Sakhalin and the ENP (Urbán R. *et al.* 2019, Weller *et al.* 2012, Mate *et al.* 2015, Lang 2010)

- N=53 whales identified in both WNP (Sakhalin and Kamchatka) and ENP
  - N=42 in Mexico (13M, 21F, 8U)
  - N=11 ENP migratory route (6M, 1F, 4U)

1.5 Evidence for external recruitment into the Pacific Coast Feeding Group (Calambokidis *et al.* 2019):

- The number of "new" (previously unidentified within the area) whales identified within the Pacific Coast Feeding Group (PCFG) range in the years following the 1999-2000 gray whale Unusual Mortality Event was higher than that seen in subsequent years. However, PCFG photo-identification efforts increased in 1998 (when compared to previous years), making it difficult to compare the number of new animals in the post-UME years with those prior to it.

2. Genetics

2.1 Genetic diversity

- Reduced mtDNA haplotype diversity among Sakhalin whales (n=156, h=0.760) when compared to NFG whales (n=103, h=0.952) (Lang *et al.* 2020)
- Reduced mitogenome haplotype diversity among Sakhalin whales (n=38 whales, 9 haplotypes, h = 0.723) versus whales sampled off Mexico (n=36, 25 haplotypes, h= 0.975) (Brüniche-Olsen *et al.* 2020)
- Nuclear diversity (n=12 microsatellite loci) similar but slightly lower in Sakhalin whales (n=156) versus NFG whales (n=103) (Lang et al. 2020)

2.2 Shared haplotypes/alleles

- 20 of 22 mtDNA control region haplotypes found in Sakhalin whales are also found among NFG whales (Lang et al. 2020)
    - 11 of the 22 haplotypes are found in only a single male
- Six mitogenome haplotypes found only in WNP (Brüniche-Olsen et al. 2020)
- Microsatellites (n=12 loci): 7 alleles found only among Sakhalin samples versus 13 alleles found only among NFG samples (Lang et al. 2020)

2.3 Phylogeographic signal:

- No phylogeographic pattern is apparent in the haplotype network for either the mtDNA control region (Lang et al. 2020) or the mitogenome (Brüniche-Olsen et al. 2020), although one group/branch is very divergent.

2.4 Hardy-Weinberg Equilibrium:

- No loci out of Hardy Weinberg Equilibrium (HWE) among Sakhalin samples (this is a weak test but in general if you have a mixed stock group you would expect to find loci out of HWE).

2.5 Linkage disequilibrium:

- 13 of 66 locus pairs in linkage disequilibrium among Sakhalin whales (could be generated by mixture, admixture or colonization by a small number of individuals)

2.6 Inbreeding based on analysis of whole genomes (Brüniche-Olsen *et al.* 2018b):

- N=2 genomes from Sakhalin whales and 1 genome from an ENP whale
- Analyzed number and length of runs of homozygosity (ROHs). Comparison between the Sakhalin whales and the ENP whale suggested recent elevated level of inbreeding among Sakhalin whales, consistent with small population size or bottleneck among the Sakhalin whales that persisted for multiple generations.
- The two Sakhalin whales were more closely related to each other than to the one ENP whale.

2.7 Genetic differentiation:

- MtDNA:
    - Control region: Sakhalin (n=156) v. NFG (n=103), F_{ST} = 0.093 (p<0.001) (Lang *et al.* 2020)
    - Mitotypes (control region + cytochrome B + ND2 genes): Sakhalin (n=21) v. Chukotka/NFG (n= 85), F_{ST} = 0.124, p<0.0001 (Meschersky *et al.* 2015)
- Nuclear:
    - Microsatellites (Lang et al. 2020)
        - n=12 loci
        - Sakhalin v. NFG F_{ST} = 0.016 (p<0.001)
        - Whales known to migrate between Sakhalin and the ENP v. NFG: F_{ST} = 0.008 (p=0.004)
    - SNPs (Brüniche-Olsen *et al.* 2018a)
        - N=84 loci genotyped in 55 Sakhalin whales and 111 ENP-Mexico whales
        - F_{ST}=0.039, p<0.001

- Whole genomes (Brüniche-Olsen et al. 2018b):
    - Although some of results were consistent with the presence of population structure (described above), the hypothesis that all individuals belonged to same random mating population could not be rejected.

2.8 Clustering analyses (Lang et al. 2020, Brüniche-Olsen et al. 2018a)

- Generally consistent patterns found among microsatellite and SNP analyses
- Both analyses supported the presence of two genetic clusters among the sampled whales. One cluster was comprised primarily of whales sampled off Sakhalin. The other cluster was comprised of most of the whales sampled in the ENP and some whales sampled off Sakhalin.
- STRUCTURE barplots showed evidence of admixture (interbreeding) between these two genetic clusters
- Individuals known to travel to the ENP are present in both clusters
- Caveat: power of STRUCTURE-like analyses depends on the amount of genetic differentiation between groups and how evenly each stock is represented in the sample set.

2.9 Paternity assessment (Lang *et al.* 2010)

- Analysis of 57 mother-calf pairs and 42 candidate males using 13 microsatellite loci
- Putative fathers were identified for 46-53% of calves sampled off Sakhalin between 1995-2007
- 18 putative fathers identified among sampled males; analysis of relatedness patterns among calves that weren't assigned fathers suggested that an additional 15 males may be contributing to reproduction in the population.

2.10 Genetic effective size (basically represents the number of breeding whales over last few generations, Lang et al. 2020):

- N_e = 80 (61.9-107.7)
- Generally consistent with a census size of ~200-300 whales (based on parameters used to estimate N_c in other whale populations)

2.11 Relationship with Kamchatka:

- Limited number of samples from Kamchatka
- MtDNA control region haplotype diversity for Kamchatka is intermediate between Sakhalin and NFG; nuclear diversity similar between Kamchatka and Sakhalin, with both slightly lower than NFG
- Genetic differentiation:
    - Meschersky et al. (2015): significant mtDNA differences (CR + CytB + ND2 combined sequences, F_{ST}=0.165, p<0.0001) observed between Sakhalin (n=21) and Kamchatka (n=19)
    - Lang et al. (2020): No significant differences between Sakhalin (n=156) and Kamchatka (n=16) in either mtDNA control region (F_{ST} = 0.001, p=0.355) or microsatellites (F_{ST} = 0.001, p=0.348)
- Assignment tests based on microsatellites assign some Kamchatka individuals to Sakhalin cluster and others to NFG cluster (Lang et al. 2020)

3. Demographic modelling

3.1 Recruitment:

- Little to no external recruitment is occurring (Cooke *et al.* 2016)

3.2 Growth rate:

- Growing at 4.5% for past 20 years (Cooke 2020)

3.3 Proportion of whales using Mexican wintering ground:

- Estimated 48% (SE=10%) of Sakhalin whales use Mexican wintering grounds, thus an estimated 52% migrate elsewhere (Cooke 2020)
    - The number of matches of Sakhalin whales with the Mexican catalogues is less than would be expected if all Sakhalin whales migrate to the ENP in winter.

  - Catalogue comparison based on whales identified off Sakhalin by the Russian Gray Whale Project (1994-2019) and by the Joint Programme Sakhalin Photo-Id project run by the Scientific Centre of Marine Biology (2002-2019) in Vladivostok with those identified in the Mexican wintering lagoons (1998-2018/19 winter season)

3.4 Genetic closure:

- A test of the model output against the results of paternity analysis (see above) rejects the hypothesis of genetic closure of the Sakhalin feeding ground but does not reject the hypothesis of genetic closure of the combined Sakhalin and Kamchatka feeding population (Cooke *et al.* 2017)

4. Records of gray whales in the WNP outside of Sakhalin

4.1 Okhotsk Sea and western Bering Sea (Weller *et al.* 2002a, Weller & Brownell 2012, Weller *et al.* 2003)

- Paramushir Island, Kuril Islands (Okhotsk Sea) July 2000 – match to Sakhalin.
- Shantar Island (Okhotsk Sea) September 2000 –match to Sakhalin (same whale as above record)
- Bering Island (Bering Sea) June 2000 –match to Sakhalin
- Kamchatka (see #1 above)

4.2 Japan (Nakamura *et al.* 2020)

- 30 records off Japan since 1990; most (n=21) during months of March through May
- Increased frequency of records in recent years
- One known mother-calf pair
- At least two of the records are whales known to have been first brought to Sakhalin as calves by their mothers (Weller *et al.* 2008, Weller et al. 2016b)
  - One entangled and killed as yearling
  - Second was sighted initially off Sakhalin as a calf (summer 2014), then off Japan as a yearling (March-April 2015), back on Sakhalin (summer 2015), then again off Japan (Jan – Feb 2016)
- MtDNA haplotype information available for n=6 animals recorded off Japan
  - N=2 carry haplotypes common off Sakhalin and in the NFG;
  - N=1 carries a haplotype found in a single animal off Sakhalin and two animals from the NFG;
  - For one whale, the sequence was too short to discriminate between two closely related haplotypes, one of which is found in both Sakhalin and the NFG and the other which is found only among the NFG
  - n=2 carry a haplotype that has not been found off Sakhalin, has been found in a single Kamchatka whale, and is found in two NFG whales. Microsatellite profiles are available for these two whales – they are not genetic matches for any sampled Sakhalin whales. Their profiles are not consistent with being a parent offspring pair but we have not evaluated whether they could be more distantly related.

4.3 China (summarized in Weller & Brownell 2012)

- Fossil specimens (n=2 juveniles) recovered from sea floor between Taiwan and Penghu Islands (Tsai et al. 2014); partial skeleton recovered from Quanzhou coast, Fujian Province, in 1958 (Li et al. 1997)
- N=24 sightings, strandings, or capture records since 1933, including two mother-calf pairs
- On 5 November 2011, an adult female became entangled in a set gillnet in Taiwan Strait. This whale carried haplotype 18 (not found off Sakhalin) and was not photographically matched to Sakhalin, Kamchatka, or ENP (Wang *et al.* 2015)
- 11.5 m female stranded live at Zhuanghe (Bohai Sea ca. 39˚N) in December 1996 (Zhao 1997)
- 1869 logbooks of two New Bedford whaling ship described ‘Chinese whale grounds’, gray whales sighted in February at same general location as 2011 entangled whale (Reeves et al. 2008)

4.4 Korea (summarized in Weller & Brownell 2012)):

- Historically hunted off coast of South Korea and off Yushin (ca. 40°N 129°E), North Korea (Kato & Kasuya 2002)

- Last reported commercial catches were in 1966 off Ulsan, South Korea (Kato & Kasuya 2002, Brownell & Chun 1977)
- No gray whales sighted during systematic annual sighting surveys conducted 2003 - 2011 during May and June when gray whales would be expected to be present off South Korea (Kim *et al.* 2013)
- Female with calf sighted in 1968; last confirmed sighting two whales off Ulsan 3 Jan 1977
- No reports of strandings or bycatch since 1996 when national reporting system initiated (Kim et al. 2013)
- Possible sighting of gray whale off Korea (~37°N) on 28 Feb 2015; video too poor resolution to confirm (Kim *et al.* 2018)

4.5 Acoustic recordings by Navy in East China Sea

- Gagnon (U.S. Navy, 2016) reports on recorded calls that were identified by experts as being made by gray whales (pres. Comm. B. Southall)
  - Up to 11 individuals heard in a two-hour period
  - Movement pattern generally south in fall and north in spring

5. Historic catch data:

- Peak annual catch of 100-200 whales in the 1910s, rapid decline in the 1920s and 1930s and a continued low-level catches (perhaps 10-20 whales/year) through the l960s. Sporadic sightings in Okhotsk Sea in late 1960s and 1970s
- Contrasts with ENP, where the abundance was estimated to be near 20,000 by the end of the 1970s

6. Reproduction

6.1 Timing of ovulation:

- All southbound adult females not carrying near-term fetuses (n=56) had recently ovulated (n=28) (based on whales collected off central CA 1959-1969, Rice & Wolman 1971)

6.2 Estimated mean conception date:

- Based on fetal growth curve the estimated mean conception date = 5 December (27 November – 13 December except one on 22 Dec and one on 5 January) (based on whales collected off central CA 1959-1969, Rice & Wolman 1971)

6.3 Median (peak) sighting dates for southbound migration in the ENP:

- Estimated to be 12 December for Unimak Pass, Alaska, in 1998/1999 (Rugh *et al.* 2001), suggesting that many animals that feed on the NFG are north of the Aleutians during the first mating period.

6.4 Timing of movements of tagged whales:

- Of the three Sakhalin whales that were tagged before they began migrating east, one remained off Sakhalin until 10 December and the other two remained there until 24 November (Mate et al. 2015).

6.5 Observations of mating behavior:

- Mating behavior has been observed on the wintering grounds, migration route, and feeding grounds used by gray whales. In the case of some of the groups of gray whales involved in mating behavior off Sakhalin, all individuals identified in the group were known to be males (pers. comm. Weller)

7. Bioenergetics (based on a model developed for reproductive females, Villegas-Amtmann *et al.* 2015, Villegas-Amtmann *et al.* 2017):

7.1 Mean total energy requirements for migration:

- Mean total energy requirements were 11 and 15% greater for whales that feed off Sakhalin and travel to Mexico and to the South China Sea, respectively, compared to eastern gray whales migrating between the NFG and Mexico.
- These differences were attributable to a longer migration distance (~25%) for the Sakhalin-Mexico whales and higher metabolic rates for whales overwintering in the WNP (based on the assumption that given the

shorter migration length these females would remain on the wintering grounds longer in years they had calves)

7.2 Predicted impacts of differences in bioenergetic costs:

- On average, WGW breeding in Mexico and the South China Sea, respectively, needed 9 and 17% more energy for survival than ENP whales.
- Based on the model, energy losses could result in increased mortality and lower reproductive rates.

8. Habitat characteristics (including biogeographic provinces, Spalding *et al.* 2007) and use:
8.1 Feeding ground characteristics:

- The feeding grounds used include the Arctic realm and province (NFG) and the Temperate North Pacific realm, Cold Temperate Northeast Pacific province (PCFG)
- The feeding grounds located in the WNP are part of the Temperate North Pacific realm, Cold Temperate Northwest Pacific province.

8.2 Wintering ground characteristics:

- The ENP wintering grounds (used by the NFG, the PCFG, and the Sakhalin whales that overwinter in Mexico) are part of the Temperate North Pacific realm and the Warm Temperate Northeast Pacific province.
- The presumed location of the wintering grounds in the WNP are part of the Central Indo-Pacific Realm and the South China Sea province, and may extend into the Temperate Northern Pacific realm and the Warm Temperate Northwest Pacific province.
- Along the WNP migratory routes and wintering ground, the bottom topography is characterized by a broad continental shelf. In contrast, the ENP migratory route and wintering ground are characterized by a narrow continental shelf with deep water found near to shore.

8.3 Historic usage

- Pyenson and Lindquist (2011) reconstructed gray whale carrying capacity fluctuations over the past 120,000 years by quantifying available feeding habitat using bathymetric data.
- They estimated that historically the region that includes Japan, the Kurils, and the southern half of Sakhalin Island, Russia, could have supported >65,000 individuals, which comprised approximately 40% of the whales that were estimated to be in the North Pacific historically.

9. Predation:
9.1 Evidence of predation:

- Scarring patterns (e.g. rake marks) associated with killer whale attacks have been documented on 43% of the gray whales photographically identified off Sakhalin Island; this is the highest reported prevalence of killer whale-associated scars in a baleen whale population (Weller *et al.* 2018a).
- Andrews (1914) found killer whale scars on the majority of gray whales killed by whalers off Korea in 1909-1910 and documented numerous accounts of killer whales attacking both live and dead gray whales during whaling operations in Korean waters.
- Rice and Wolman (1971) indicated that 18% of the gray whales examined at a California whaling station showed evidence of having been attacked by killer whales.

9.2 Areas of known attacks or transient killer whale presence:

- Killer whales are known to hunt gray whales off Monterey Bay, CA (largely during spring when mothers and calves are traveling north, Goley & Straley 1994)), and Unimak Pass, AK (as whales are migrating onto the northern feeding grounds, Barrett-Lennard *et al.* 2011).
- Bering, Chukchi and Beaufort Seas: Transient killer whales have been documented using the waters surrounding the Chukotka Peninsula (in the Bering and Chukchi Seas, Melnikov & Zagrebin 2005, Filatova *et al.* 2019), and evidence suggests they are using the waters that comprise the gray whale NFG more frequently. Passive acoustic monitoring between 2009-2016 in the southern Chukchi Sea indicates that

transient killer whales are spending more time in the Chukchi Sea as seasonal sea ice decreases (Stafford 2019). The proportion of Bering-Chukchi-Beaufort Sea bowhead whales that bear evidence of killer whale attacks has also increased in recent years (George *et al.* 2017), which may also reflect increased presence of transient killer whales within their range. Imagery and sighting data from bowhead whale carcasses in the eastern Chukchi Sea and western Beaufort Sea further confirm the presence of transient killer whales within this area (Willoughby *et al.* 2020).

- WNP feeding areas: Transient killer whales are known to use the coastal waters of the Sea of Okhotsk and eastern Kamchatka (Filatova et al. 2019).

10. Foraging flexibility:

10.1 Diet:

- Within the NFG, gray whales are thought to feed primarily on benthic amphipods (Brower *et al.* 2017).
- Within the PCFG range, gray whales have been observed feeding in epibenthic and pelagic waters and on a greater diversity of prey, including mysids, crab larvae, herring eggs/larvae, and ghost shrimp (Dunham & Duffus 2001, Dunham & Duffus 2002, Nelson *et al.* 2008, Newell & Cowles 2006, Feyrer & Duffus 2011, Oliver *et al.* 1984, Nerini 1984).

10.2 Shifts in feeding ground distribution:

- In the 1980s the Chirikov Basin in the Bering Sea was considered a primary gray whale feeding area. However, surveys in 2002 revealed a restricted distribution and a 3-17-fold decline in gray whale sighting rates (Moore *et al.* 2003), coincident with a precipitous decline in amphipod productivity within this area (Coyle *et al.* 2007).
- Prior to 2002, PCFG gray whales consistently foraged in Ahous Bay, Clayoquot Sound, British Columbia, presumably on infaunal amphipods, which are the only known gray whale prey within this bay. Amphipod abundance declined in this area in the early 1990s. In 2002 and subsequent years, gray whales have not been seen foraging in Ahous Bay, and appear to have moved to other areas within Clayoquot Sound to forage on mysids and, opportunistically, on pelagic crab larvae (Burnham & Duffus 2016).

11 Fossil history:

- Based on the lack of Pliocene gray whale fossils in the eastern North Pacific, Tsai and Boessenecker (2015) hypothesize that the extant gray whale lineage may have originated in the western North Pacific and then later invaded the eastern North Pacific.

12. Localized threats

12.1 Vessel strikes

- Scordino *et al.* (2020) compiled records of gray whale deaths and serious injuries between 1924 – 2018.
    - Within U.S. waters, 19.1% were attributed to vessel strikes, with an average of ~2 vessel strikes/year between 2013-2018
- Silber *et al.* (2021) compared patterns of whale distribution with the density of vessel traffic seasonally throughout the North Pacific in 2019 to qualitatively assess the risks posed to gray whales throughout their range.
    - Gray whales are exposed to the threat of vessel strikes throughout their range and in all seasons, but the relative degree of risk varied spatially and temporally
    - Areas of apparently high risk were in the Russian Far East (Kamchatka peninsula and Okhotsk Sea), Bering Sea (including the Aleutian Islands), Gulf of Alaska, and along the entire west coast of North America

12.2 Fisheries entanglements and entrapments

- Scordino et al. (2020) compiled records of gray whale deaths and serious injuries, including those due to entanglement and entrapment in fishing gear, between 1924 – 2018.
- Saez *et al.* (2013) compared commercial fixed-gear fisheries effort and seasonal gray whale densities along the coasts of CA, OR and Washington

    - Within this area, gray whales were determined to be at greatest risk while on migratory routes between December and June
    - The Dungeness crab fishery was judged to be the fishery posing the highest risk to gray whales.
- Between 2005 and 2007, four gray whales were known to have died in set nets along the Pacific coast of Honshu, Japan (Weller et al. 2008)
- Lowry *et al.* (2018) identified and characterized, by region, specific fisheries within the Russian Far East that may entangle or entrap whales. They identified the coastal salmon net fishery near Piltun Lagoon (operating within the Sakhalin nearshore feeding area) as being of high risk of entangling/entrapping gray whales (see also Weller *et al.* 2014)

12.3 Oil and gas development

- Anthropogenic activities related to oil and gas exploration and development have been increasing over the past two decades off northeastern Sakhalin Island, Russia, just offshore of the nearshore Sakhalin feeding area that is used for feeding by mothers and calves.
- Some studies have documented changes in the distribution and behavior of gray whales during seismic surveys off Sakhalin Island (Weller *et al.* 2002b, Gailey *et al.* 2007, Yazvenko *et al.* 2007a), while others have failed to do so (Yazvenko *et al.* 2007b, Bröker *et al.* 2015, Gailey *et al.* 2016).

APPENDIX 2

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