Impacts of Sakhalin II Phase 2 on Western North Pacific Gray Whales and Related Biodiversity

Report of the Independent Scientific Review Panel

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Executive summary

1   BACKGROUND

1.1   The animals and their status

The small population of western gray whales, numbering only about 100 animals, is on the edge of survival. It was reduced to such low numbers by commercial whaling that in the mid 20th century it was thought to be extinct. The population is listed by IUCN – The World Conservation Union as 'critically endangered' and also has been the focus of concern by the International Whaling Commission (IWC) and the 3rd World Conservation Congress. The few surviving animals (possibly including only 23 reproductively active females) face a number of hazards throughout their range. It is particularly unfortunate that the only known foraging grounds for the population lie along the northeastern coast of Sakhalin Island, where existing and planned large-scale offshore oil and gas activities pose potentially catastrophic threats to the population. These include the possibility of direct kills from collisions as well as reduced reproductive success and survival through the degradation of this crucial habitat as a result of physical disturbance, oil contamination of the whales and their prey and the introduction of loud noise. Two major development projects – Sakhalin I and Sakhalin II – occur close to the nearshore and offshore feeding areas and their activities are of great conservation concern.

1.2   The Panel and terms of reference

Under the auspices of IUCN, an independent scientific review panel (hereafter called 'the Panel') was established to evaluate scientific aspects of western gray whale conservation in the context of Phase 2 of Sakhalin II, an integrated oil and gas project being developed by the Sakhalin Energy Investment Company (SEIC) under a production sharing agreement with the Russian Federation and its Sakhalin Oblast. Phase 1 of Sakhalin II has already been in production for six years, producing oil for approximately six months each year during ice-free conditions. Phase 2 is intended to allow production of both oil and gas year-round, with production commencing in November 2007, and it will greatly enhance the project's economic productivity. It is expected to entail construction of two new offshore platforms, offshore and onshore pipelines, and onshore processing and exporting facilities.

The terms of reference for the review were developed and established by IUCN in consultation with SEIC, potential lenders and other stakeholders. The underlying question was whether the risks associated with Sakhalin II Phase 2 are being, or will be, managed in an effective manner that will allow oil and gas development to proceed without further jeopardising the survival and recovery of this critically endangered whale population. The Panel was required *inter alia* to review the plans of SEIC and consider their proposed mitigation measures for minimising the possible impacts of operations on gray whales and 'related key elements of biodiversity' (interpreted by the Panel to mean the benthic communities on which the whales rely for sustenance). Whilst focussing on Sakhalin II Phase 2, the Panel had to consider the cumulative effects of the entire Sakhalin II project, other oil and gas projects (especially Sakhalin I) and other human activities in this region and throughout the population's range. The Panel was not asked to develop prescriptive conclusions, but rather to provide an evidence-based analysis of issues and options.

1.3   The process and documentation

The Panel held four meetings: 6-8 September 2004 in Toronto, Canada; 2-7 October 2004 in Yuzhno, Sakhalin Island, Russian Federation; 6-8 November 2004 in Sausalito, California, USA and 27-31 January 2005 in Seattle, Washington, USA. The Panel received and reviewed a tremendous amount of documentation (most notably the Comparative Environmental Assessment, or CEA) and received considerable assistance from both SEIC and IUCN. It was clear that SEIC have invested substantial sums of money into research on western gray whales, the assessment of risks associated with Sakhalin II and the development of approaches to try to reduce the risks of their project to gray whales.

2   OVERALL CONCLUSIONS

The Panel's report provides a detailed consideration of the risks, the options for mitigation and the need for monitoring if and as oil and gas development proceeds. Despite the considerable documentation provided by SEIC, important information gaps left considerable uncertainty over many aspects of risk evaluation and the efficacy of proposed mitigation measures. Those gaps pertained not only to important scientific information on the whales, their prey resources and their habitat, but also to the SEIC decision-making process. SEIC have applied a conventional risk-reduction standard, whereby risks are to be reduced to levels 'as low as reasonably practicable' (ALARP). The Panel often was unable to determine just what that meant, and how various considerations (e.g. cost-effectiveness,

conservation) were considered and weighed in decision-making. The lack of specificity associated with SEIC's application of the ALARP standard to important decisions, such as location of the proposed PA-B platform, effectively precluded the Panel from completing a reasoned and rigorous evaluation of some of the risks and mitigation strategies associated with Phase 2.

2.1 Examining the cumulative effects of threats on gray whales

The fate of western gray whales will ultimately depend on their ability to cope with the cumulative effects of multiple anthropogenic and natural factors on both the whales themselves and on the prey communities that sustain them. Given the uncertainties and the precarious state of the population, which precludes any possibility of direct experimentation, the only way to examine cumulative effects and risk is through population modelling under various assumptions of threats and their possible effects. Among other things, the results of a limited modelling exercise undertaken by the Panel showed that:

- even with no additional risks to the population beyond those it faces at present, there is some risk that the population will not recover;

- this risk is increased, in some cases substantially so, under the various impact scenarios considered plausible by the Panel (which were not necessarily 'worst case scenarios');

- persistent effects are more serious than acute (short-term) effects of larger magnitude;

- additional whale deaths, regardless of the cause, have the most serious consequences for the population – most importantly, the loss of one additional female per year (over and above the death rates experienced in recent years) would be sufficient to drive the population towards extinction with high probability.

- effects that may be too small to be detected in the short term (such as a 10% reduction in breeding success combined with the loss of one additional female every 3 years) can prevent population recovery if they persist.

Perhaps the most important lesson to be learned from this modelling exercise is that the anticipation and avoidance of potential risks to the population is essential. Waiting for conclusive scientific proof that a particular activity or set of activities is having a population-level effect is not an appropriate approach for ensuring the conservation of this population. Action to prevent or mitigate risk needs to be taken based on the assumption that an impact will occur, until it is shown that it will not. The survival of the population in the context of development impacts cannot be assured until the potential extent of impacts can be better quantified and shown, using a demographic model such as the one employed here, to be within the limits that the population can sustain with high probability.

In this context, annual monitoring of the population through uninterrupted continuation of the collection of photo-identification data, biopsy sampling of new individuals and refinement and updating of the population model, is essential. The loss of a single year of data would limit our understanding of critical population parameters and our attempts to evaluate, detect and predict the cumulative impact of threats to the population.

2.2 Advice

Once completed and fully operational, Phase 2 will considerably reduce certain types of risk to gray whales, specifically those associated with the current procedure of transferring oil from the PA-A platform into tankers for transport to distant markets. However, a number of other risks will increase as Phase 2 construction activity proceeds, and some of those risks will remain throughout the lifetime of the project.

Given the potential effects of the identified risks, as well as the uncertainty surrounding them and the questionable efficacy of proposed mitigation measures, the most precautionary approach would be to suspend present operations and delay further development of the oil and gas reserves in the vicinity of the gray whale feeding grounds off Sakhalin, and especially the critical nearshore feeding ground that is used preferentially by mothers and calves. This would allow much-needed refinement of risk assessment and further development of appropriate, independent mechanisms for monitoring and verification of mitigation practices.

If for some reason this is not deemed possible, risk management needs to be conservative with regard to western gray whales (particularly females with calves in the nearshore foraging area) and their feeding habitat (occupied from June to November). Moreover, substantial monitoring efforts will be required to assess the effects of decisions about risk management on gray whales, with the understanding that subsequent modification of procedures may be required in response to the monitoring results.

SEIC did not provide a comprehensive, quantitative comparison of the three pipeline alternatives under consideration for transportation of oil and gas from the PA-A and PA-B platforms to shore. The 'base case' route poses additional risks because, among other things, it crosses the southern portion of the primary gray whale foraging area and is in close proximity to the mouth of Piltun Lagoon. The two proposed alternatives pass farther south and avoid that problem. Although all three proposed routes eliminate important risks associated with the Phase 1 FSO/tanker-based transportation system, each carries its own array of risks. The Panel identified four pipeline-associated risks: (1) noise and disturbance of whales during construction, (2) ship strikes during construction, (3) physical damage to benthic habitat during construction and (4) potential exposure of gray whales, their prey or ecologically important habitat (e.g. Piltun Lagoon) to oil spills and gas releases. Alternative 1 appears to be the safest with regard to the first three of those risks. It also provides an advantage with regard to the fourth risk in that any oil spills and gas releases would likely occur farther away from the Piltun (nearshore) feeding ground and Piltun Lagoon. A spill occurring in the east-west component of this alternative would: (1) take longer to reach the Piltun Lagoon and foraging area, thereby allowing more time for an effective response; (2) be more dispersed when it reached those areas, and therefore less likely deposit large amounts of oil in sensitive near-shore habitats; and (3) have lost a larger portion of its volatile components and therefore be less toxic to whales and their prey. The only obvious disadvantage of Alternative 1 appears to be that the probability of a leak or rupture would be increased somewhat due to its greater overall length.

The Panel's report provides a detailed review of the individual threats to gray whales and proposed mitigation and monitoring measures, as summarised below.

3   REVIEW OF INDIVIDUAL THREATS AND PROPOSED MEASURES

3.1   Noise
SEIC have invested substantial resources in trying to model the noise fields in the gray whale habitat in the vicinity of oil and gas activities. However, the Panel believes that their efforts have not yet proven successful, and determining to what degree noise will significantly affect western gray whales remains confounded by two major uncertainties: (1) the sound fields that gray whales will actually experience, which will be influenced by the whales' movements, characteristics of the sources, and sound propagation in shallow coastal waters; and (2) the hearing abilities of gray whales and their behavioural and physiological responses to different sound fields. Therefore, a reliable forecasting tool for assessing and managing the impacts of industrial noise on western gray whales is not available.

Noise levels will be greatest and most persistent during the construction phase of the project. Despite the uncertainties, given the almost complete spatial and temporal overlap between ongoing and planned development activities (including those of both Sakhalin I and II) and the feeding habitat used by gray whales off Sakhalin, the Panel concludes that the potentially significant threats from noise associated with Sakhalin II Phase 2 must be taken very seriously. SEIC documents err on the side of optimism in the face of uncertainty and lack specificity in their proposed mitigation measures. Every effort must be made to separate the development activities from the whales in space and time. Real-time monitoring of whale behaviour and habitat use in the presence (and absence) of measured noise levels and other characteristics is required as well as the development and following of strict criteria for the cessation of operations to prevent whales from being subject to high noise levels. The limitations of onboard observers, particularly in poor visibility conditions, also must be recognised.

3.2   Collisions/ship strikes
Ship strikes can and do kill whales. Even if such events are rare, the modelling results show that if, due to any number of factors, only one female is killed per year the probability of extinction of the population is high. Although not quantifiable, the probability that ship strikes will contribute to such mortality will increase with the transition from Sakhalin II Phase 1 to Phase 2 simply because there will be more traffic and vessel activity associated with construction of the proposed PA-B platform and the platform-to-shore pipelines (as well as the traffic associated with Sakhalin I construction and operations). Although traffic in the vicinity of the nearshore feeding area should decrease with the end of construction and once the FSO/tanker-based transportation system has been replaced, a certain amount of vessel support will be required for the two Sakhalin II platforms over the long term. In addition, the risk of ship strikes on migrating gray whales at the southern end of Sakhalin Island will certainly increase as tankers begin moving oil and liquid natural gas from the new terminal at Prigorodnoye in Aniva Bay.

SEIC have described a number of mitigation measures to prevent ship strikes in the Piltun area, including closed areas around feeding habitat, speed limits or guidelines, onboard observers to detect whales and allow necessary speed and course changes, and partial curtailment of vessel activities at night or in inclement weather. The Panel is encouraged that SEIC recognise the potential for collisions and that they have prescribed mitigation measures. However, in the absence of necessary details on implementation and enforcement of these measures, the Panel is unable to judge their effectiveness.

Cautious vessel operation in the presence of whales is essential, but likely not sufficient because collisions often occur before the whale is observed. It is insufficient to rely on onboard observer programmes alone. Even if one assumes the observers are experienced and attentive, the ability to see whales is compromised in poor weather and sea conditions, reduced daylight etc. Clearly, measures that increase the likelihood of spatial separation of whales and ships (e.g. through the use of no-entrance zones, ship traffic lanes) are the most effective means of reducing the risk of ship strikes. Mandatory reductions in speed to specified levels (with even lower levels specified for nighttime and periods of restricted visibility) are also prudent in light of published evidence concerning ship strikes on other whales, including eastern gray whales.

3.3 Oil exposure

The potential effects of oil on gray whales, either through direct exposure or through damage to their prey, are poorly known. Observations of the direct effects of oil on other marine mammals and the well-documented effects of oil on benthic invertebrates indicate that there is reason for serious concern. The consequences for gray whales of oil spills in the Sakhalin marine environment could vary from minor to catastrophic depending on the location, timing and size of the spill, the prevailing conditions and the ability of the benthos to recover. All available information indicates that western gray whales are almost completely dependent on benthic communities for feeding.

The Panel recognises that the oil spill risk from Sakhalin II will be reduced considerably by the transition from Phase 1 to Phase 2. Nevertheless, when viewed over the lifetime of the project, the risks of a spill during Phase 2 are considerable. For example, the probability of at least one blowout occurring at either platform over the 40-year project lifetime is about 3% and the probability of at least one pipeline spill could be as high as 24%, based on data provided in the CEA.

Spill trajectory modelling (in the CEA) revealed a high level of risk to the two gray whale foraging areas off Sakhalin even though the modelling did not consider worst-case scenarios involving platform blowouts and winter spills (under ice). A spill or release of oil in or near Piltun Lagoon also is a major concern because it could alter the ecological processes that maintain the Piltun (nearshore) foraging area where female gray whales nurse and wean their calves. This concern applies to both Sakhalin II and Sakhalin I, which includes plans for a pipeline crossing of the lagoon itself.

Given these concerns, the Panel believes that spill prevention is the key. Although the ability to respond rapidly to an oil spill is important, the overall efficacy of spill response in the face of a major spill is limited because of the conditions in which a large spill is most likely occur (e.g. severe ocean conditions, storms, winter, ice) and the remoteness of the platforms and pipelines from possible response centres.

Although the SEIC documentation on prevention and mitigation measures is extensive, the Panel found that a lack of specificity made it difficult to evaluate. Similarly, it proved difficult to evaluate some of the decisions taken (such as the location of the PA-B platform) in this context. Clearly, from the perspective of gray whale conservation, any reasonable means to reduce platform-associated risks to the feeding grounds, including moving the platform farther away from them, should be taken. Despite the information gaps, the Panel has made a number of general suggestions and comments on how spill risks could be further reduced (e.g. with respect to low-level leakage detection, rules for contractors, the oil spill response plan, the location of platforms and pipelines, the use of double-hulled tankers and the suspension of oil production at the PA-A platform until the pipeline is in place).

3.4 Physical disturbance

As noted above, western gray whales appear to be completely dependent on benthic invertebrates to meet their annual energy requirements. Therefore, it is essential that their foraging areas off the eastern coast of Sakhalin Island remain unspoiled and productive. Physical disturbance of the seabed is unavoidable as part of offshore oil and gas development and therefore this aspect of Sakhalin II Phase 2 deserves close scrutiny. The Panel was disappointed at the relatively superficial consideration given to this issue by SEIC.

Apart from the potentially serious impacts of oil, benthic communities can be disrupted or transformed by physical removal (e.g. a patch of sandy plain becomes an elevated concrete platform), smothering with dredge spoil and other debris or alteration of nearshore current patterns and flows. In the present context, any disruption of exchange mechanisms between Piltun Lagoon and the Piltun (nearshore) foraging area is a special concern. Siting decisions, e.g. for platforms and pipelines, represent the most reliable avenue to mitigation of these effects. Therefore, in deciding where to install the PA-B platform and which pipeline configuration to use, it would have been appropriate to conduct a careful and detailed assessment of the associated risks to the integrity and productivity of the benthic communities on which gray whales depend, with particular attention to the biological and ecological processes that create the Piltun (nearshore) foraging area. This was not done. Instead, the risks of damage to gray whale feeding habitat from development activities were dismissed as insignificant.

4   INFORMATION GAPS AND ESSENTIAL MONITORING

Scientific investigations of the western gray whale population since 1995 have provided a remarkable amount of information regarding the population's abundance and composition (age/sex structure), reproduction, survival, condition, foraging patterns and behaviour on the feeding grounds. The available information provides a strong, albeit preliminary, basis for understanding the biology of these animals in their Sakhalin habitat and their potential vulnerability to oil and gas development. However, much remains to be learned through annual monitoring of the population and its habitat, and through directed studies into the potential effects of Sakhalin II Phase 2.

With regard to the potential effects of noise, collisions, oil and gas spills and habitat destruction, research and monitoring are needed to characterize both the risk factors and the dependent variables (i.e. whale, prey or habitat response). Due to uncertainty regarding potential effects and their detection, monitoring and research efforts will require careful and rigorous design to ensure that there is a high probability of detecting changes in demography that will have a significant effect on the recovery of the population. The Panel's review identified the following general areas for future research, including some that will require annual monitoring and some that will depend on circumstances (e.g. in the event of a spill):

- Continued, uninterrupted annual monitoring of important population parameters including abundance, trends, survival rates, reproductive rates and age (size)/sex structure. Analysis of the resultant time series of data may provide an early warning of problems within the population.
- Annual monitoring of gray whale foraging and habitat use patterns. The resultant time series of data may identify changes in habitat correlated with certain development activities.
- Real-time monitoring of behavioural and (if possible) physiological responses by the whales during periods when levels of underwater noise increase noticeably (e.g. during construction and seismic surveys).
- Recording and monitoring of whale/ship encounters (including strikes, near misses and safe avoidance) to determine if adjustments are needed to vessel traffic based on ship size, location, speed, daylight, or other pertinent variables.
- Surveys at regular intervals during the open-water season along the eastern Sakhalin coast to detect stranded gray whales (or floating carcasses), coupled with a serious effort to investigate cause of death in the event of finding a dead gray whale.
- Investigation of the ocean dynamics (currents, tides, winds) in the vicinity of Sakhalin II, the Piltun (nearshore) and offshore feeding habitats, and the Piltun Lagoon; *inter alia* this will allow for better modelling of the dynamics of oil spills and improved response strategies.
- Investigation of the ecology of Piltun Lagoon and the nearshore foraging area, and the links between them; *inter alia* this will provide a more secure basis for evaluating the likely risks to gray whales and their prey and better inform decisions on siting pipelines and other infrastructure and activities.
- Investigation of the biomass, distribution and ecology of gray whale prey populations and the effects of oil on them.
- If one or more spills occur, investigation of (1) any direct, acute effects of oil and gas on whales and their prey, and (2) the effects of chronic exposure should spilled oil remain present for a prolonged period.
- Periodic monitoring of contaminant levels in the habitats exposed to potential (and actual, should they occur) leaks and spills.

5   THE NEED FOR A COMPREHENSIVE STRATEGY TO SAVE WESTERN GRAY WHALES AND THEIR HABITAT

The Panel's review focused on just one of a number of major oil and gas development initiatives around Sakhalin Island. Importantly, threats to the western gray whale population do not arise solely from oil and gas development, nor are they limited to the Sakhalin region. Further, the threats do not occur in isolation but rather they are cumulative. Most, if not all, western gray whales spend approximately half the year elsewhere in eastern Asia, passing through waters within the EEZs of Japan, the Republic of Korea, the Democratic People's Republic of Korea, and China. Development and use of marine resources throughout the range of these whales, including but not limited to offshore oil and gas, involves a wide array of financial interests and technical support from Russia and other countries in eastern Asia, North America and Europe.

Previous analyses and expressions of concern by major international bodies such as the IWC and the 3rd World Conservation Congress have made it clear that there is serious, widespread interest in the issue of western gray whales and Sakhalin oil and gas development. The Russian stake in western gray whale conservation is clear, given that the entire population apparently derives almost all of its annual sustenance from waters within the Russian EEZ. Nonetheless, a number of other countries will play direct and potentially decisive roles in determining the fate of the population.

A comprehensive, international strategy (including research) is essential for saving this whale population. The Panel recognised the need for a comprehensive strategy that addressed not only oil and gas development, but also other threats to the population. The results of population modelling (Chapter VII) showed that quite small impacts on the animals or their habitat, if they are persistent, could lead to the population's extinction. A piecemeal approach, based on assessment of the impacts of one development project at a time, will not adequately address the western gray whale conservation problem, because the accumulated total of impacts may prevent recovery of the population even if the impact of each project can be limited to apparently acceptable levels. The survival of the population cannot be assured without a protection regime for the nearshore feeding habitat, aimed at limiting the combined impact of all current and future developments (including but not limited to oil and gas developments) on this habitat and the whales feeding there.

Although the subject of a comprehensive strategy was outside the Panel's terms of reference and therefore no attempt was made to develop it, this report may provide at least a partial basis for development and oversight of such a strategy by an independent international organization. In this context, we note and commend the ongoing regular reviews of population status and research needs of western gray whales by the IWC's Scientific Committee, as well as the less regular but important consideration of these matters by the Russian Group for Strategic Planning of Gray Whale Research and the IUCN Species Survival Commission's Cetacean Specialist Group. These bodies may provide the foundation for a comprehensive strategy that includes strong international, independent planning and oversight.

All Panel members acted in their capacities as individual scientists and not as representatives of their agencies, organisations or institutions.

Chapter I: Introduction

1 BACKGROUND

With the discovery of extensive deposits of oil and gas on the Sakhalin Shelf, a small population of gray whales that feeds each summer along the northeastern coast of Sakhalin Island has been placed in jeopardy. In 2000, the population was listed by IUCN – The World Conservation Union as 'critically endangered'. These whales have also been the focus of a number of Resolutions of concern by the International Whaling Commission (IWC) and, most recently, the 3rd World Conservation Congress in November 2004. This group of about 100 whales is one of only two surviving[1] populations of the species *Eschrichtius robustus*, itself the sole living representation of the mammalian family Eschrichtiidae. An eastern North Pacific population (hereafter called eastern gray whales) that migrates annually between Mexico and Alaska now numbers about 20,000, having substantially recovered from severe depletion by commercial whaling in the nineteenth and early twentieth centuries. The initial population size of the western North Pacific population (hereafter called western gray whales) is unknown but probably numbered at least 1,500 at the beginning of the twentieth century and is now smaller by an order of magnitude. With such a small population, the death of just one or two females of reproductive age could mean the difference between recovery and extinction (see Chapter VII). Disappearance of the western population would leave only one surviving population of gray whales in the world.

The only known primary feeding ground of western gray whales lies within a narrow coastal strip of the northeastern Sakhalin Shelf, a region that is also the site of ongoing and planned large-scale oil and gas development. Industrial operations underway, and plans for the immediate future, include seismic exploration, construction of oil and gas platforms, dredging for the placement of sub-benthic pipelines, horizontal drilling from onshore to reach hydrocarbon deposits underneath and offshore of the feeding grounds, and extensive ship and aircraft traffic associated with those activities. Russian and multinational companies involved in oil and gas development around Sakhalin have been aware for more than a decade of the western gray whale population's critically endangered status and its dependence on the Sakhalin Shelf for its primary feeding ground. As a result, they have sponsored a variety of studies of the whale population, ecology of nearshore waters, and potential impacts of development activities on the whale population. To obtain operating licenses and financing, some companies have been required to prepare environmental impact assessments and to develop special protection plans to mitigate some of the potentially damaging effects of their operations on gray whales. All aspects of those assessment and mitigation efforts are compromised by scientific uncertainty.

An independent scientific review panel (hereafter called 'the Panel' – membership is given in Annex A), established under the auspices of IUCN, was established to evaluate scientific aspects of western gray whale conservation in the context of Phase 2 of Sakhalin II, an integrated oil and gas project being developed by the Sakhalin Energy Investment Company (SEIC) under a production-sharing agreement with the Russian Federation and its Sakhalin Oblast (hereafter called 'the Project'). Phase 1 of Sakhalin II has already been in production for six years, producing oil for approximately six months each year during ice-free conditions. Phase 2 is intended to allow production of both oil and gas year-round, with production commencing in 2007. It is expected to entail construction of two additional offshore platforms, offshore and onshore pipelines, and onshore processing and exporting facilities.

2 TERMS OF REFERENCE

The terms of reference for the review (Annex B) were developed and established by the Business and Biodiversity Program of IUCN, in consultation with SEIC, potential lenders and other stakeholders. Essential components of the terms of reference are summarised and paraphrased as follows:

- Identify the major pertinent scientific issues surrounding the ecology and conservation of western gray whales and related key elements of biodiversity.

- Characterise the knowledge base concerning those issues and identify the main gaps in knowledge for assessing potential Project impacts.

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[1] Gray whales inhabited the North Atlantic Ocean in historical times but have been extinct there for several hundred years.

- Analyse the potential impacts (risks) of the Project, including the cumulative impacts in the context of all relevant development in the Sakhalin area, and characterise the range of scientific uncertainty surrounding such analyses.

- Assess the likely effectiveness of proposed control and mitigation measures and evaluate whether they adequately address associated uncertainties.

- Determine whether the relevant studies, assessments and proposed mitigation measures (1) are adequate to ensure that the Project does not have significant negative effects on gray whales and related key elements of biodiversity and (2) take account of the best available scientific knowledge, identify information gaps and treat both existing knowledge and uncertainty in a manner that reflects the precautionary principle.

- Identify and justify project alternatives or additional mitigation measures that should be considered.

- Assess the adequacy of current and proposed monitoring plans and identify alternative or additional monitoring efforts that could provide useful information.

- Determine under what circumstances the results of monitoring could indicate a need for corrective action or a change in the monitoring regime.

As required by its terms of reference, the Panel considered in some detail the concept of 'related key elements of biodiversity' (Annex C). The Panel concluded that, in broad terms, this phrase could be interpreted to mean the entire ecosystem on which the whale population depends. In more practical terms, the review focused on those features of the ecosystem that the Panel judged to be connected, either directly or indirectly, to the energy needs, overall health, and reproductive success of individual gray whales. Prey populations are the most obviously relevant 'related key elements of biodiversity' and therefore the Panel chose to consider the risks to gray whale prey (and indeed the habitat that supports gray whale prey species) on the same level as the direct risks to the whales themselves. Long-term survival of the gray whale population, including its recovery to a substantially greater abundance and wider range in order to reduce extinction risk, was at the centre of the Panel's interest and concern.

The Panel did not analyse the potential risks and impacts of 'demolition, removal or rehabilitation of infra-structure under the Project' (Annex B, Item 3(ii)). Although the subject was mentioned briefly and in generic terms (e.g. flushing of pipelines, consideration for regulatory requirements, socio-economic needs and condition of terrestrial and marine flora and fauna) in the Environment Impact Assessment (EIA) for Sakhalin II Phase 2 (Vol. 5, Ch. 2, pp. 28-29), it was not raised in presentations to the Panel by SEIC, nor was it discussed within the Panel. The Panel's failure to pursue this aspect of its terms of reference is not intended to mean that it regarded the implications of decommissioning as trivial or irrelevant. Indeed, it will be important that 'proposals for decommissioning … be specified towards the end of the life of the project' (EIA, *ibid*.) and that these be independently reviewed at that time.

The Panel was not requested to consider or comment on the strategic, economic, social or security implications of Sakhalin oil and gas development and indeed did not possess the expertise to do so. The Panel was also not asked to develop prescriptive conclusions, but rather to provide an evidence-based analysis of issues and options. Implicit in this approach was the expectation that the Panel would inform decision processes by attempting to answer the questions posed in the terms of reference, offering options, and describing likely consequences of different courses of action.

3   PROCESS FOLLOWED

3.1   Membership
Following establishment of the terms of reference, the Panel membership was determined through an internally organised IUCN selection process. Nominations were solicited from relevant stakeholders (SEIC, the lenders, and interested nongovernmental and intergovernmental organisations), from the IUCN network, and from individual scientists previously involved in assessments of western gray whales. The Business and Biodiversity Program contacted all nominees and invited them to submit a curriculum vitae and statement of interest. A selection committee was established within IUCN to review nominations to chair the panel and Randall Reeves was selected. After this, a second committee was established to select the rest of the Panel. This committee included Reeves, IUCN staff in Gland and two internationally prominent experts on cetacean science and conservation (William Perrin and Giuseppe Notobartolo di Sciara). In making its selections, the committee attempted to balance the needs for topical

expertise and regional representation. Panel members and their affiliations are given in Annex A, and additional biographical information is available at www.iucn.org/business.

IUCN recognised from the outset that, during the course of the review and development of the report, the Panel might need additional expertise for particular tasks or topics. Therefore, they encouraged the Panel to co-opt such expertise as and when needed. David Weller was formally co-opted by the Panel to contribute in particular to Chapters II and VII of the report and to conduct one of two technical reviews of the draft report prior to submission to IUCN. John Harwood was co-opted to conduct the other technical review of the draft report.

3.2   Meetings
The Panel held four meetings: 6-8 September 2004 in Toronto, Canada; 2-7 October 2004 in Yuzhno, Sakhalin Island, Russian Federation; 6-8 November 2004 in Sausalito, California, USA and 27-31 January 2005 in Seattle, Washington, USA.

At its first meeting the Panel (in consultation with IUCN) established rules and working procedures; developed a schedule and process for conducting the review; and discussed field visits, transparency, means of conflict resolution within the Panel and provisions for allowing minority views in the event of a failure to achieve consensus. In addition, the Panel allocated responsibilities among members for covering various topics in the course of the review and considered how to organise the report. Overviews were presented to the Panel by Andy Pearce and Jamie Robinson of SEIC and by David Weller of the Russia-U.S. western gray whale research team. Following discussion with the SEIC representatives, the Panel developed a list of documents needed, outstanding questions to be addressed, and information that would be required to complete the review. That list, with a number of post-meeting additions, was transmitted to SEIC on the Panel's behalf by IUCN.

The Yuzhno meeting included presentations by Dmitri Lisitsyn of Sakhalin Environment Watch (a local environmental non-governmental organisation), by Andrey S. Chibirov of DMNG (a Sakhalin-based seismic survey company) and by SEIC and several contractors involved in the preparation of the company's Comparative Environmental Assessment (led by David Greer, Project Director). Alexey Yablokov, a Panel member, made presentations on the work of the Russia Marine Mammal Council's Working Group for Strategic Research on Western Gray Whales (which he chairs) and on the findings of the Russian State Expertisa that previously reviewed the environmental implications of Sakhalin I and II. A central aspect of this meeting consisted of site visits by panellists to the Piltun Lagoon region, all facilitated by SEIC. With helicopter and other support, Panel members were able to observe the Piltun lighthouse, the existing oil extraction platform (Molikpaq), the Ecoshelf Oil Spill Response base at Nogliki and some of the onshore oil fields at Katangli. The Panel requested that arrangements be made for visits to the Floating Offshore Storage unit ('Okha') and to the SEIC Marine Department but these requests were not met.

The Sausalito meeting focused on internal Panel discussions and report drafting. There were no presentations. Considerable time was devoted to discussion of the Panel's (and IUCN's) response to SEIC's proposed contract modifications to change the terms of report delivery and other aspects of the review (see Timeframes and Deadlines, below).

The Seattle meeting was devoted entirely to drafting, reviewing, editing and compiling the report.

3.3   Documents
As called for in the terms of reference, the Panel conducted an extensive review of relevant literature, including Project documents provided by SEIC, reports and papers provided by the IWC, various documents obtained directly from nongovernmental organisations and scientific colleagues, and the open scientific literature on whale biology and ecology. The information contained in documents was supplemented by presentations given at Panel meetings (see above). To the extent feasible, copies of the presentations (paper, electronic, or both) were secured and archived by IUCN so that they would be available to the Panel for reference.

According to the terms of reference, all relevant project documents were to be supplied to the Panel by SEIC through a process coordinated by IUCN. In practice, some of the key documentation was not completed (and thus made available to the Panel) until late in the review process, as explained in the following section.

3.4   Timeframes and deadlines
The Panel's review was complicated by the fact that a key SEIC document was not available until after the initial review period. The Panel initially had been contracted to conduct its review from early September 2004 through

early November 2004, with the draft report due for submission to IUCN by mid-November 2004. During the course of the review, however, SEIC indicated that they planned to complete their Comparative Environmental Assessment (CEA) by the end of November 2004, essentially coincident with anticipated public release of the Panel's final report. In essence, therefore, the Panel's first three months of deliberations and drafting passed without the benefit of access to information considered by SEIC to be vital for Sakhalin II Phase 2 decision-making and planning. The CEA, representing the culmination of extensive design, survey, monitoring and modelling work begun by SEIC in late 2003 in response to findings of the July 2003 Russian State Environmental Expertisa, was ultimately made available to the panel on 30 November 2004. Thus, it was necessary to extend the Panel members' contracts, initially running from 31 August to 30 November 2004, for an additional 2.5 months, with a final deadline for delivery of the report on 14 February 2005.

Chapter II: Review of knowledge on western gray whales

This section of the report deals with various aspects of the life history, behaviour and ecology of western gray whales and reviews their conservation status. Attention is drawn to the Workshop on the Western Gray Whale held by the IWC Scientific Committee in 2002 (IWC, 2003).

The gray whale (*Eschrichtius robustus* Lilljeborg, 1861) is the sole member of the family Eschrichtiidae and is considered the most primitive living species of baleen whale. It is the only species of baleen whale restricted to the Northern Hemisphere. It was present in the North Atlantic until a few hundred years ago but is now extinct in that ocean (Mead and Mitchell 1984). Today, the gray whale is confined to coastal and shallow shelf waters of the North Pacific, where it occurs in two populations. The western population is observed mainly off Sakhalin Island, Russia, where it feeds in the summer and fall. Late in the fall, the whales migrate south along the coasts of Korea and Japan and then to unknown winter calving grounds, probably in coastal waters of China. The eastern population feeds mainly in the Bering Sea in summer and fall. It migrates along the west coast of North America to and from winter calving grounds in lagoons along the outer coast of Baja California, Mexico.

Very few biological data were collected from western gray whales taken by commercial whaling operations in the early part of the 20th century. The only biologist to examine a series of specimens was R.C. Andrews of the American Museum of Natural History, New York. During January and February 1912, Andrews (1914) examined 23 gray whales killed during their southbound migration off southern Korea and landed at a Japanese-operated shore station in Ulsan. Additional information on the biology of this population is starting to appear as a result of the long-term research project initiated in 1995 by a Russia-U.S. team (Weller *et al.*, 1999). A total of 140 different individual whales were photographically identified on the Sakhalin feeding ground between 1994 and 2004, and biopsies had been collected from 117 of these whales by the end of the 2004 field season (Weller *et al.*, 2004). Not all these whales were alive at the same time, and the current estimated size of the western population is about 100 animals (Wade *et al.*, 2003). In contrast, the eastern population numbers around 20,000 (Rugh *et al.*, 2004).

1   POPULATION IDENTITY

Both mitochondrial and nuclear DNA markers indicate western and eastern gray whales are geographically and genetically distinct (LeDuc *et al*. 2002, Lang *et al*. 2004). Although the two populations share 12 mitochondrial DNA haplotypes, they differ significantly in haplotype frequency (Lang *et al*. 2004).

2   DISTRIBUTION, MIGRATION, MOVEMENT

Most of the western population feeds in coastal waters off northeastern Sakhalin Island. One adult photo-identified off Sakhalin Island was also photographed off Paramushir Island in the northern Kuril Islands and in the southern Shantar Archipelago during the same summer (Weller *et al*., 2002; Fig.1). Another whale photographed off Sakhalin Island was observed off Bering Island in the western Bering Sea (Weller *et al*., 2003). Since 1979, small numbers of gray whales have been found annually off southern Kamchatka, but it is not known whether these animals are from the western or eastern population.

Western gray whales occur off Russia, Japan, Korea and China. Although historic sighting and whaling records indicate that gray whales occurred in the northern Okhotsk Sea, the present day population range appears to be largely confined to the region between the northeastern coast of Sakhalin Island (summer-autumn) and the South China Sea (winter) (see Weller *et al*., 2002).

Known portions of the north-south migratory route include regions off the eastern shore of Sakhalin Island in the Okhotsk Sea and along the eastern shores of mainland Russia near Peter the Great Bay and along the Korean peninsula in the Sea of Japan (Andrews 1914; Brownell and Chun 1977; Berzin, 1975). Prior to the 20th century, two groups of gray whales may have migrated to coastal waters off Japan (Omura 1984). One of these groups was thought to travel along the eastern (Pacific) shore of Honshu during their southbound migration while en route for a supposed calving ground in the Seto Inland Sea (Omura 1984). The other group was suspected to migrate along the eastern shore of Korea, cross the Korean Strait near Ulsan, and ultimately arrive at southwest Honshu and northwest Kyushu (Omura 1984). Although gray whales were once hunted by net fishermen off the eastern shore of Honshu (Omura 1984), present-day sightings of the species off Japan are very rare (Kato and Tokuhiro 1997).

Winter calving and mating areas for this population remain essentially unknown. The idea that western gray whales overwinter off the southern coast of Korea, as suggested by Andrews (1914), was largely speculative (Rice 1998)

and historical records indicate that the calving ground(s) occur as far south as the Yellow Sea, East China Sea and South China Sea (Andrews 1914; Henderson 1972, 1984, 1990; Wang 1978, 1984; Omura 1988; Zhu and Yue 1998; Kato and Kasuya 2002; Uni and Kasuya 2002). Some evidence is available that western gray whales range at least as far south as 20°N off Hainan Island in southeastern China (Wang 1984; Zhu and Yue, 1998; Zhu, 2003; IWC, 2003). In addition, several unverified sighting reports led Omura (1974) to suggest that an alternative or additional calving and mating area was in the Seto Inland Sea (34°-35°N) off southern Japan, but little direct evidence is available to support this idea.

Fig. 1. Map showing the areas mentioned in the text where western gray whales were observed recently other than near Sakhalin Island. A more detailed map of the Sakhalin Island region, showing the two feeding areas and including details of the oil and gas development, is given in Fig.2

3   SAKHALIN HABITAT

Zaliv Pil'tun (referred to as Piltun Lagoon) is on the northeastern shore of Sakhalin Island. The lagoon is approximately 80km long and 15km across at its widest point. A single channel connecting the inner lagoon with the Okhotsk Sea at 52°50'N, 143°20'E has considerable biological influence on the surrounding marine environment. The nearshore marine environment is mostly sandy bottom sloping gradually down a broad continental shelf. Water depths within 5km of shore are mostly less than 20m deep. Despite the physiographic resemblance of Piltun Lagoon to the coastal lagoons used by eastern gray whales off Baja California, Mexico, western gray whales do not enter this lagoon.

The primary (hereafter either 'nearshore' or 'Piltun') feeding habitat of the western gray whale population extends from just south of the mouth of Piltun Lagoon to approximately 70km northward and from the surf zone to about 20m depth seaward (Weller *et al.* 2004). The secondary (offshore) habitat is 30-40km offshore of the middle part of Chayvo Lagoon in waters 30-50m deep. It extends southward about 30-40km north to south and 25-30km west to east (Maminov 2004). Females with calves are only found in the inshore portion of the nearshore feeding habitat. On average they are found about 1.2km from shore in waters 6m deep (Weller *et al.,* 2004). Calves are weaned in this area from July-September (Weller *et al.* 1999) and the majority that survive their first year are likely to return to the area the following summer (see *Survivorship*, below).

4   FEEDING ECOLOGY

Eastern gray whales are known to feed on a wide variety of benthic, epibenthic and planktonic species. Stomach content analyses dating back to 1874 reveal some 70 genera of both benthic and pelagic organisms (Nerini 1984). Information on stomach contents or observations of feeding for western gray whales (outside the recent Sakhalin studies) is rare. Mizue (1951) reported that shrimp, *Nephrops thomsonii* (= *Metanephrops thompsonii*) were found in the stomachs of two gray whales taken in the northern part of the Yellow Sea (probably from Kaiyoto island) in May 1922. Two gray whales were observed feeding in the sandy bottom off Izu-Ohsima Island on the Pacific coast of Japan in April 1993 (Darling 1994). These discrete anecdotal observations are not interpreted to indicate additional feeding grounds.

As described above, the continental shelf off northeastern Sakhalin Island has at least two areas with known prey of gray whales, one near shore (designated the Piltun or nearshore feeding area) and one farther offshore (designated the offshore feeding area) (see Nerini, 1984, Würsig *et al*., 2000, Fadeev, 2003). Benthic surveys of both feeding areas were conducted in 2001 and 2002 (Fadeev, 2003). A variety of potential prey species were found in both locations, including amphipods, isopods, bivalves, cumaceans, decapods, echinoderms, and polychaetes. It is clear that the primary feeding habitat for western gray whales is in the nearshore Piltun area. The whales use this region each year, and it is the only known feeding ground used by females with calves. Apparently the offshore area is a secondary prey base, utilised on a more sporadic basis.

Within the Piltun feeding ground, gray whale feeding is most concentrated in the area approximately 1-3km from shore with depths of 5-15m. A variety of species of amphipods (from genera *Anisogammarus, Anonyx, Pontoporeia, Locustogammarus*) and isopods (of genera *Saduria* and *Synidotea*) were collected from the scat of feeding whales (Würsig *et al.,* 2000). All of these crustaceans are found in the nearshore Piltun region in patchy but dense concentrations (Fadeev, 2003). During benthic surveys, the largest numbers of whales were sighted in the Piltun area's shallow water with maximum benthic biomass (Fadeev, 2003). The most prevalent prey species in scat of gray whales in the Piltun area were brackish-water amphipods (*Pontoporeia* spp.) that occur almost exclusively near shore (Würsig *et al*., 2000). The benthic habitat that supports gray whale prey species is limited beyond the Piltun area. The exception to this is the offshore area described above, with benthic amphipods (*Ampelisca eschrichti*) and cumaceans (*B. bidentata*) that are likely the key prey species in this region (Fadeev, 2003).

A synopsis of benthic communities in the summer feeding range of the western gray whale population is given in Annex D.

Western gray whales show strong site fidelity to the Piltun area and have used it for more than 20 years (Blokhin *et al*., 1985). However, some individuals also use the offshore area and some limited feeding may occur in other areas (Würsig *et al*., 1999, 2000; Weller *et al*., 1999, 2000, 2001, 2002a, 2002d). All of the whales photo-identified in a survey of the offshore area in 2002 were also found in the Piltun area between 1995 and 2003 (Burdin *et al*., 2003, Weller *et al*., 2004). The occurrence of some whales in both areas in a single season has been documented.

5   HEALTH

5.1   Strandings

During the 20th century, only 13 stranded western gray whales have been recorded (IWC, 2004, table 1), some of which died as a result of human actions. Six records are from China, six from Japan and one from Piltun lagoon; no strandings have been reported from Korea. V. A. Vladimirov (*in* Anon. 2004) reported that a carcass of a young gray whale was found in Aniva Bay, Russia, during June 2001. Unfortunately, the species identity of this specimen has

not been confirmed and no samples were collected from it. No information on health status or disease was collected from any of the specimens.

5.2   Disease, parasites etc.

Diseases in baleen whales are poorly documented, mostly due to the difficulty of gaining access to and examining these large animals. The limited data available are mostly from hunted animals, so are predominantly from healthy individuals (Stolk 1950; Cockrill 1960a,b; Roberts *et al*. 1965; Uys and Best 1966). Exposure to various infectious diseases has been investigated by determination of antibody levels in blood samples. Antibodies to Type A influenza were reported from a baleen whale in the Antarctic (Lvov *et al*. 1978), and to *Brucella* spp, (a bacterium that commonly causes reproductive failure in terrestrial mammals) from a minke whale (Clavareau *et al*. 1998). The only virus reported from an eastern gray whale is an unknown type of equine encephalitis observed in the brain of a stranded whale (Moore *et al*. 2001).

Little has been published on ectoparasites and epizoites of western gray whales (Andrews 1914). However, all 140 western gray whales photographically identified as of September 2004 had the barnacle *Cryptolepas rhachianecti* Dall, 1872. These barnacles are found mainly around the host whale's head. Eastern gray whales are known to serve as hosts for three species of whale lice (cyamids): *Cyamus scammoni* Dall, 1872; *C. ceti* Linnaeus, 1758; and *C. kessleri* Brandt, 1872 (Rice and Wolman 1971). *C. scammoni* is the largest of the three and is often found in clusters around the barnacles. This species, or at least the same morphotype, is also seen on western gray whales. None of these ectoparasites or epizoites is thought to be harmful to their hosts although animals in poorer nutritional condition tend to have heavier infestations.

Nothing has been recorded about the occurrence of endoparasites in western gray whales.

5.3   Algal blooms

Harmful algal blooms are well recognised as causes of human and animal morbidity and mortality (Baden *et al*., 1995). Their role in the mortality of marine mammals is often controversial due to the logistical difficulties associated with investigating marine mammal deaths, and the lack of background data on toxic thresholds of marine toxins in these species. The detection of saxitoxin in dead humpback whales (*Megaptera novaeangliae*) off New England (USA) resulted in the first confirmed case of a biotoxin affecting a marine mammal (Geraci *et al*., 1989). In 1998 domoic acid toxicity was determined to be the cause of death of 48 California sea lions (*Zalophus californianus*) that stranded along the California coast during a bloom of the diatom *Pseudonitzschia australis* (Scholin *et al*., 2000). Domoic acid is a relatively recently described marine toxin produced by a number of marine algae species (Baden *et al*., 1995). This neurotoxin was confirmed in the blood and urine of a dead eastern gray whale, at concentrations sufficient to implicate domoic acid toxicity (Moore *et al*., 2001). Domoic acid could have been acquired by feeding on kelp-associated invertebrates or krill swarms, or from the benthos. Recent studies on krill, *Euphausia pacifica* and *Thysanoessa spinifera*, suggest that they readily consume toxic *P. australis*, accumulating domoic acid up to toxic doses (Bargu *et al*., 2002).

There are few published data on the distribution and composition of algal blooms and their toxin production off the eastern coast of Russia, although there are reports of blooms of saxitoxin- and domoic acid-producing species of algae in the Sakhalin region (Orlova *et al*. 2004). A bloom of *Alexandrium tamarense*, accompanied by deaths of cetaceans, fish and birds, was observed in Olyutorsky Bay in July 1986 (Konovalova 1989). The cause of the deaths, however, was not determined. A bloom of *Pseudo-nitzschia pungens* was observed in the coastal waters of Sakhalin Island in August 2000, but the extent of toxin production by this bloom and its impact on marine life were not investigated (Orlova *et al*., 2004).

Under normal conditions, exposure of a population of whales to an algal bloom might not raise serious population-level concerns. However, in this case, a combination of factors needs to be considered. As just noted, algal blooms have been recorded along the Sakhalin coast in recent years. Some of the involved algae are toxic to other marine mammals. Blooms are generally localised events, but in this case the entire population of western gray whales seasonally concentrates in a very small region, i.e. an area that might be covered by a single bloom. Nutrient concentrations in these waters may already be relatively high due to wave-driven mixing and influx from numerous rivers and lagoons. Contamination from oil and gas operations could supplement or add to the nutrients already present, encouraging more production of the same or different algae. Finally, although gray whales are bottom feeders and do not usually feed in the water column where living toxic algae generally occur, algae (or their toxic products) that die and sink to the bottom may become concentrated where the whales feed.

5.4   Poor body condition ('Skinny whales')

During 1999 and 2000, the eastern gray whale population experienced unusually high mortality of immature and adult whales, with annual stranding rates approximately ten times greater than reported during the previous decade (LeBoeuf *et al*., 2000; Brownell *et al*., 2001; Moore *et al*., 2001). Coincident with the high mortality, estimates of calf production in 1999, 2000 and 2001 were the lowest recorded in an 8-year time series (Perryman and Rowlett, 2003). Although the causal mechanism(s) responsible for this increased mortality and lower calf production remain poorly understood, some researchers hypothesised that the biomass of benthic prey of eastern gray whales had been depleted due to the combined influence of increased annual water temperatures in the Bering Sea and 'overgrazing' of the feeding grounds by a gray whale population near (and possibly above) its pre-exploitation level of abundance (LeBoeuf *et al*., 2000; Moore *et al*., 2001).

Western gray whales in poor body condition (referred to as 'skinny' whales) were also observed during this period. The cause of this phenomenon remains unexplained (see Brownell and Weller, 2001) and therefore all of the possibilities mentioned below are speculative to one degree or another. Although the number of such whales observed has declined since the first reports in 1999 (Weller *et al*., 2000, 2001,2002a, 2002d, 2003a, 2003c), the poor body condition of some whales in this population continues to be a serious concern. Possible explanations include natural or human-caused changes in prey availability or habitat quality, physiological changes related to stress, disease or some combination thereof. The most likely proximate cause is nutritional stress but the underlying cause(s) remains unknown (Brownell and Weller, 2001). It seems implausible that the western population, consisting of only about 100 individuals, would have 'overgrazed' its benthic food base or exceeded the carrying capacity of the feeding grounds (Brownell and Weller, 2001) unless the carrying capacity had been severely reduced. The natural interplay among benthic prey communities and environmental parameters such as primary production, ice, water temperature and freshwater flow from coastal lagoon systems (such as Piltun Lagoon) due to snow melt and river/stream runoff may be at least partially responsible. However, it is also possible that the effects of industrial activities near the feeding ground and human activities elsewhere in the range of the western population are contributing to the skinny whale phenomenon. For example, the poor physical condition of some western gray whales beginning in 1999 may have been compounded by the cumulative physiological stress from long-term exposure to anthropogenic stressors such as underwater noise (Würsig *et al*., 1999, 2000; Brownell and Yablokov, 2001; Weller *et al*., 2002) and that the corresponding period of high mortality and low calf production in the eastern population was purely coincidental. Disease and contaminants also could have contributed to the poor physiological condition of skinny whales.

Regardless of the cause or causes, the skinny whale phenomenon reinforces concern about any disruption of normal feeding behaviour, any reduction in the cumulative time spent feeding in a given season, or any change in the feeding locations of gray whales off northeastern Sakhalin. Such concern applies not only to the skinny whales, but especially to adult females with calves as they are subject to exceptionally high energetic demands during lactation (Weller *et al*., 2002d).

5.5   Chemical pollutants

Organochlorines such as polychlorinated biphenyls (PCBs) and 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT) and DDT metabolites are persistent pollutants that biomagnify in the environment and have been measured in tissues of marine mammals world-wide (O'Shea, 1999). Experimental exposure studies have shown effects of these chemicals on the physiology, immune function and reproductive success of pinnipeds (Brouwer *et al*., 1989; Ross *et al*., 1996; reviewed in O'Hara and O'Shea, 2001). Epidemiological investigations have linked high tissue residues of organochlorines to increased prevalence of infection and physiological impairment in other marine mammal species (Hall *et al*., 1992; Jepson *et al*., 1999; Simms *et al*., 2000; Jenssen *et al*., 2003). For example, belugas (*Delphinapterus leucas*) that stranded in the highly polluted St. Lawrence Estuary had a high prevalence of neoplasms and contained high tissue levels of PCBs and DDTs (Martineau *et al*., 1999). These whales also exhibited impaired reproductive and immune function (Beland *et al*., 1993; DeGuise *et al*., 1995). There are no data on the effects of organochlorines on the physiology or reproduction of baleen whales, nor are there data on contaminant levels in western gray whales, but there are data on blubber levels of organochlorine contaminants in eastern gray whales at various stages of their life history (Krahn *et al*. 2001, Tilbury *et al*., 2001). The organochlorine concentrations measured in gray whales are comparable to the levels in other mysticetes from Alaska (O'Hara *et al*., 1999), but are much lower than the concentrations measured in odontocetes from the eastern North Pacific (e.g. Krahn *et al*., 1999; Ross *et al*., 2000). Ruelas *et al*. (2003) analysed tissues of four gray whales that stranded in the Gulf of California during 1999 for total mercury and methylmercury in muscle, kidney and liver, and found lower levels of both than those reported for other marine mammals. These differences are most likely due to dietary

differences, both in trophic level of prey and in feeding locations, between gray whales and odontocetes (toothed cetaceans).

The lack of data on chemical contaminant levels in western gray whales precludes assessment of the likely effects of these compounds on their health. An indirect way of estimating levels for the whale population would be by investigating levels in prey. (Note that the potential impacts of exposure to hydrocarbons are addressed separately in Chapter IV, Section 3, below.)

6   ABUNDANCE AND BIOLOGICAL PARAMETERS

6.1   Historical abundance and catch history

There are no reliable estimates of the initial population size of the western gray whale population, partly because of the incomplete catch history (see review by Weller *et al.,* 2002). Berzin and Yablokov (1978) and Yablokov and Bogoslovskaya (1984) speculated that the original size was between 1,500 and 10,000 animals and Henderson (1984) stated that the western population 'must have been smaller' than the eastern population based on known catches of gray whales from net whaling off Japan and American ('Yankee') whaling in the Okhotsk Sea.

The major commercial hunting operations were those off Japan and Korea in the late 19th and early 20th century although catches by several nations (and some aboriginal subsistence whaling) occurred prior to that (see Weller *et al.,* 2002). Kato and Kasuya (2002) estimated that between 1891 and 1966, the minimum commercial catch of western gray whales was between 1,800 and 2,000 animals, with more than 75% of the total having been taken by the early 1920s. These catches are believed to have seriously depleted the population. Annual catches probably remained low from the 1920s to about 1950 (Kato and Kasuya 2002). At least 67 western gray whales were taken by local whalers in Korean waters and landed at Ulsan between 1948 and 1966, but no catch records are available for the period 1954-1957 (Brownell and Chun 1977).

Recently, historical catch data were used for a 20th century back calculation of the western gray whale population size (Bradford, 2003). Results from this work suggest that the population numbered around 1,000-1,200 individuals in 1900, when intensive modern commercial whaling for gray whales began, and conclude that the population has been highly depleted for over half of the 20th century and is presently, at most, between 8-9% of its original size (Bradford, 2003). However, major catches are missing from the late 1890s to 1910 (Kato and Kasuya, 2002) and this would result in the original population size at the start of commercial whaling in Korea being larger than estimated by Bradford (2003).

6.2   Present abundance

Wade *et al.* (2003) estimated the 2002 population size at 98 animals (95% CI=89-110), based on resightings of photographically identified individuals. This has recently been updated to include the 2003 data (Weller *et al*., 2004), giving an estimate of 99 (SE=5, 95% CI=90-106). The population estimation method used for the projections in Chapter VII of this review (see Annex F) gives a median estimate of the non-calf population in 2004 of 102 animals with 90% confidence limits of 94-110. These represent the best available population abundance estimates. We note that the individuals photo-identified at the Shantar, Paramushir and Bering Islands (see above) have proven to be Sakhalin animals and thus we assume that they are taken into account in the estimates by Wade *et al.* and in Chapter VII. Attention was drawn to an abstract by Vladimirov (2004) stating that population abundance is at least 120 animals; as no information was available on the data collection methods or analysis, however, the Panel was unable to evaluate this statement.

6.3   Reproduction

6.3.1   *Sex ratio*

The sex ratio as of September 2003 in the western gray whale population favoured males: 26 male and 11 female calves and a total of 65 males and 43 females from the sample of 108 whales biopsied between 1995-2003 (Weller *et al.*, 2004; plus data from 2003 supplied to the Panel by D. Weller *pers. comm.*). Mizue (1951) reported a 68:32 male:female ratio among 545 western gray whales killed by commercial whalers in the early 20th century. If these values are representative, the skewed sex ratio in this population would be unusual among mammals. It should be noted, however, that Japanese net fishing (see Omura, 1984) may have reduced the number of females, especially reproductive females that tend to remain very near to the shore, prior to the onset of commercial whaling and therefore the results reported by Mizue (1951) may not have reflected the original sex ratio in the population.

6.3.2   Age at attainment of sexual maturity
There is no information on the present age at attainment of sexual maturity for either male or female western gray whales; no known-age female has yet been photographed with a calf at Sakhalin Island. Based on information from USA catches in the 1960s, eastern females reach sexual maturity between 6-12 years with a median of 9 whilst the equivalent for males was 5-9 years with a median of 6 years (see IWC, 1993).

6.3.3   Reproductive cycle
Weller *et al.* (2004) report that the recent calving intervals (*n*=14) for western gray whales range between 2-4 years (median 3 years). The calving interval in eastern gray whales is around 2 years (e.g. IWC, 1993). The longer values for western gray whales may reflect inherent differences but may also reflect recent nutritional stress.

The gestation period for eastern gray whales is approximately 13 months (Rice 1983).

6.3.4   Pregnancy
As of the end of summer 2004, at least 23 photo-identified females in the western population were known to have been reproductively active (i.e., to have given birth). Nine of these (39.1%) had multiple offspring during between 1995 and 2003 (Weller *et al.*, 2004). The number of calves recorded has varied annually, ranging from 2 – 11 with estimates of GARR (gross annual reproductive rate) ranging from 4.3 – 14.8% (Weller *et al,* 2004). For the period 2001-2003 the mean number of calves was 8 and the mean GARR was 10.7%.

6.3.5   Other
The estimated mean birth date for eastern gray whales is in mid-January (Rice and Wolman 1971). Based on the limited data available, the western population probably has a similar mean birth date. The total body length at birth in the eastern population averages around 4.9 m (Rice and Wolman 1971), and it is probably about the same for western population.

6.4   Survival

6.4.1   Adult survival
Annual survival rate for non-calves in this population isestimated at 0.951 (Bradford, 2003). The median estimate for non-calf survival from the model used in Chapter VII is 0.97.

6.4.2   Juvenile survival
Calf survival from 0.5 to 1.5 years in western gray whales is estimated at 0.70 (Bradford, 2003). The median estimate from the model used in Chapter VII is 0.73. Naïve estimates of calf survival may be negatively biased if young animals do not return to the Sakhalin feeding ground each year, as has been documented for some individuals in some years, but the estimate obtained in Chapter VII allows for this possibility.

6.4.3   Predation
Killer whales (*Orcinus orca*) are the only known predators of gray whales (Scammon, 1874). Numerous observations have been made of killer whales attacking eastern gray whales over the past 50 years (Gilmore, 1961; Goley and Straley 1994). Andrews (1914) found killer whale tooth rakes on the flukes and flippers of most of the gray whales killed off Korea, and he noted numerous accounts of attacks on both living gray whales and carcasses of whales killed by commercial whalers.

Although killer whales are somewhat common off the Sakhalin Island gray whale feeding grounds, no aggressive interactions between the two species have been documented in the scientific literature (Weller *et al.*, 2000). However, of 69 gray whales photographically identified there between 1997 and 1998, more than 33% had tooth rakes from killer whales on their flukes, flippers or bodies (Weller *et al*., 1999). This suggests that killer whales are at least threatening, and perhaps killing, western gray whales somewhere in their range.

6.5   Status

6.5.1   Sources of mortality (direct and indirect)
This issue is covered thoroughly in Chapters IV and V. In summary, in addition to the potential mortality as a result of the actual and proposed oil and gas developments, other potential sources of mortality include direct illegal killing, incidental capture in fishing gear, vessel strikes, disease, toxic algal blooms, exposure to chemical pollutants and predation by killer whales.

6.5.2   Current status
As noted in Chapter 1, serious concern over the present status of this population has been expressed by *inter alia* the IWC Scientific Committee, the IUCN Cetacean Specialist Group and the 3rd World Conservation Congress. These concerns centre on the population's extremely small size (*ca* 100 individual), low number of reproductive females (*ca* 23), low juvenile survival, and apparently male-biased sex ratio, the dependence of mother-calf pairs on specific habitat, the dependence of the whole population on a limited feeding area, and the nutritional stress suggested by observations of skinny whales starting in 1999.

7   INFORMATION NEEDS
The following topics have been identified as needing additional research:

7.1   Distribution
Wintering regions

Migration routes

Historic distribution and habitats use.

 Tendencies of modern dispersion (e.g. Kamchatka and Commandor Islands observations)

7.2   Ecosystems
Critical ecosystem dynamics and variation thereof, especially for wintering, breeding and feeding areas

Food preferences by seasons, areas, years

Anthropogenic impacts on critical ecosystem properties

Killer whale predation and other dangers outside Sakhalin shelf area

7.3   Population properties
Paternities and relatedness of individuals

Breeding system (social structure)

Growth rate and variation under different conditions

7.4   'Skinny' whale phenomenon
Causes

Recovery and survival of skinny whales

Impact of skinny whale phenomenon on population reproduction and survival rates

7.5   Behaviour
Communication system (infrasound, chemoreception) and alarm signals

7.6   Contamination
Exposure to and tissue levels of contaminants (e.g., persistent organic pollutants, heavy metals, hydrocarbon and pesticide residuals)

Possible impacts on demography

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Chapter III: General description of present and proposed oil and gas activities in the Sakhalin region

1   OVERVIEW

Oil extraction began from onshore areas of northern Sakhalin Island in the early part of the 20th century. Onshore production continues on a year-round basis, although production is declining with the gradual depletion of the onshore oil reserves. Oil exploration and production in the offshore regions around Sakhalin Island is, in contrast, a relatively recent phenomenon. Although offshore oil and gas reserves had been located in the northeastern shelf of the island by the 1970s, and some exploratory wells were drilled over the next decade, development of these fields did not begin in earnest until the 1990s and production did not begin until 1999.

Development of oil and gas resources around Sakhalin Island is proceeding through collaborative arrangements between the Russian Federation and national and international oil and gas companies and conglomerates. Sahkalin's offshore area has been divided into nine different projects (see Fig. 3 below), three of which are currently underway (I, II and V). The vast majority of the oil and gas reserves identified to date are off the northeastern shore, where these three projects are sited. The underlying concern to be addressed in this report is that the operations, and particularly those undertaken under Sakhalin II, are in close proximity to the only two identified foraging areas of the critically endangered western population of gray whales.

2   PRESENT AND PROPOSED OFFSHORE ACTIVITIES

2.1   Sakhalin II

This review pertains principally to Sakhalin II and, more explicitly, Phase 2 of Sakhalin II. Sakhalin II oil and gas development and operations are being undertaken by the Sakhalin Energy Investment Company (SEIC). SEIC is comprised of a partnership of Shell (55%), Mitsubishi (25%) and Mitsui (20%). The Sakhalin II project, as presently planned (and as described in more detail in the CEA), is the phased development of integrated oil and gas resources in two offshore fields: Piltun-Astokhskoye (PA) and Lunskoye (Fig. 2). The PA Field contains primarily oil and natural gas and is directly offshore of the nearshore gray whale feeding area.

The PA Field is being developed in two phases. Phase 1 consisted of the 'Molikpaq' (hereafter referred to as the PA-A platform), which was completed and began drilling and extraction in late 1998 and early 1999. Oil recovered from the PA-A platform is transferred through a subsea pipeline to a Floating Storage and Offloading tanker (FSO) moored at a single-anchor leg mooring (SALM). Oil is then transferred to tankers for distribution around the world. Under best conditions the PA-A platform is capable of extracting 90,000 barrels per day of liquid and 74 million cubic feet per day of gas. Under its present configuration, however, this platform and associated transportation system are unable to operate during approximately half the year when the sea is covered with ice. Phase 2 involves replacing the FSO/tanker-based oil transportation system with sea-to-shore pipelines to allow year-round operation, plus the construction and operation of two additional platforms. One, hereafter referred to as the PA-B platform, will be located about 12km offshore, 24km north of the PA-A platform and about 7km east of the nearshore gray whale foraging habitat. The PA-B platform also will extract both oil and gas, and is scheduled for construction during the summer seasons of 2005 and 2006. Details of the PA-B structure, site preparation and installation are given in the CEA.

The second platform to be constructed in Phase 2 will be in the Lunskoye Field to the south. This platform will primarily extract natural gas. It is not in close proximity to any known gray whale feeding area, although whales may move past the platform (and associated pipeline) during their migration to and from the two known feeding areas.

To transport the oil and gas from these fields, Phase 2 will also involve construction of:

- six platform-to-shore pipelines (two each for oil and gas from the PA platforms and two from the planned Lunskoye platform; three alternative pipeline configurations are under consideration for moving oil from the PA-A and PA-B platforms to shore – see below);

- an onshore processing facility;

- an onshore pipeline system to transport oil and gas from the onshore processing facility to Prigorodnoye;
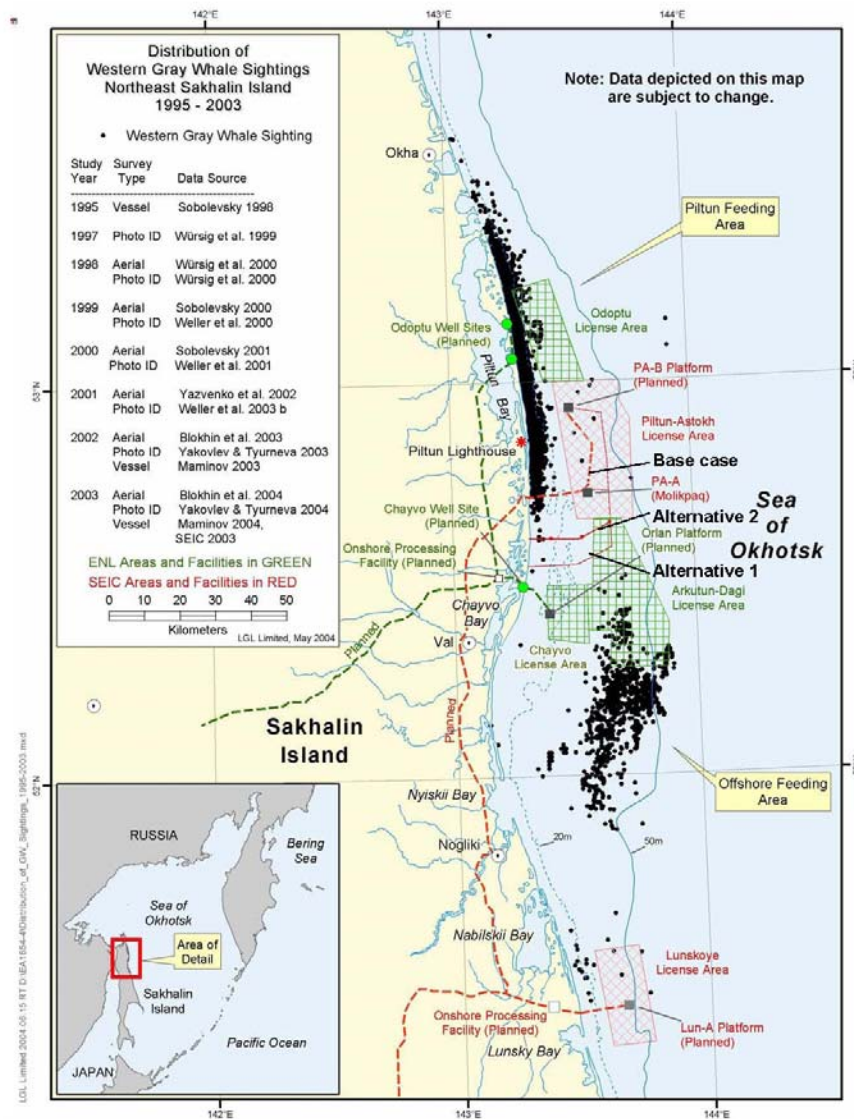
Fig. 2: Map of the Sakhalin area showing main components of Sakhalin II, including the locations of platforms and alternative pipeline routes for the Project, and the gray whale feeding areas and sighting positions (provided by SEIC)

- a liquified natural gas (LNG) processing plant at Prigorodnoye; and

- an export terminal at Prigorodnoye for loading oil and LNG into tankers for worldwide distribution. The export terminal is expected to load an LNG tanker every two days and an oil tanker every four days, based on expected platform production.

The three alternative pipeline routes are referred to as the 'base case' – the route initially proposed – and Alternatives 1 and 2 (Fig. 2). The base-case route (total length about 59.5km) would start at the planned PA-B platform and run southeast to about midway between PA-B and PA-A, then due south to the PA-A platform. From there, the route would run almost due west to shore, with landfall about 15km south of the mouth of Piltun Lagoon. Maximum water depth for this route would be about 30m. Alternatives 1 and 2 would leave the PA-B platform heading due east and then turn southward, passing about 5km east of the PA-A platform (where pipelines from the PA-B and PA-A platforms would be joined). Alternative 2 would continue an additional 8km south before turning west-southwest and finally due west to reach land about 12km south of the base-case landfall and 27km south of the mouth of Piltun Lagoon. Alternative 1 would continue an additional 7km (i.e. to 15km south of the PA-A platform) before turning west-southwest and finally due west to reach land about 20km south of the base-case landfall, and about 35km south of the mouth of Piltun Lagoon. The total lengths of Alternatives 1 and 2 would be about 117km and 98km, respectively. Maximum depths along these routes would be about 43m and 40.5m, respectively. The CEA indicates

that pipelines in waters deeper than 30m do not require burial to protect from ice scour. The CEA (project description) provides a more detailed description of the alternative pipeline routes.

2.2   Sakhalin 1

In response to requests to Exxon officials by IUCN (on the Panel's behalf), some limited information on this major project was made available. However, most of what is presented here came from SEIC or from the Sakhalin I website (www.sakhalin1.com) .

The Sakhalin I project is an oil and gas development on the northeastern Sakhalin Shelf. It includes three offshore fields: Chayvo, Odoptu and Arkutun Dagi. It is operated by Exxon Neftegas Limited (ENL) for the multinational Sakhalin-I Consortium, of which ExxonMobil holds 30% interest. Co-venturers include the Japanese consortium SODECO (30%); two affiliates of the Russian state-owned oil company Rosneft – RN-Astra (8.5%) and Sakhalinmorneftegas-Shelf (11.5 %); and the Indian state-owned oil company ONGC Videsh Ltd. (20%). Potential recoverable resources from Sakhalin I include 2.3 billion barrels of oil and 17.1 trillion cubic feet of gas (i.e. 307 million tons of oil and 485 billion cubic meters of gas). Like Sakhalin II, Sakhalin I also will be developed in phases. The initial phase involves development of the Chayvo Field with production expected to start in the second half of 2005. The Odoptu and Arkutun Dagi Fields will be developed in subsequent phases to maintain the target level of production.

The Chayvo Field (oil and gas) is located 6-10km offshore of Chayvo Lagoon, south of the primary (nearshore) gray whale feeding ground but overlapping the outer edge of the migratory corridor and adjacent to the offshore feeding area. This field will be developed using both offshore and onshore facilities. Construction of the Chayvo Yastreb land rig was completed in June 2002. This rig was engineered exclusively for Sakhalin I and is designed to drill 8-10km extended-reach wells to offshore targets from locations on land. This approach should reduce offshore environmental impact. In June 2003, ENL initiated the shore-based extended-reach drilling program to install wells under the seabed at distances up to 11km offshore to tap the northwestern flank of the main Chayvo oil zone. The onshore drilling site is located on the elevated portion of the shoreline along the eastern (seaside) shore of the Chayvo Lagoon barrier spit.

Chayvo will also produce oil from an offshore platform, called the 'Orlan', to be placed 8.6km from shore in 14m of water. This platform will be used to develop the southwestern flank of the main Chayvo zone. A single drilling rig will be operated on the 'Orlan' year-round. Offshore processing facilities will be minimal, with the oil transported via pipeline to the Chayvo Onshore Processing Facility for further processing. An additional east-west pipeline will be built from Chayvo to the DeKastri export terminal on the Russian mainland. The DeKastri terminal will provide storage and tanker loading facilities and year-round shipping is contemplated using conventional tankers and icebreaking support vessels. The 'Orlan' was towed from Alaska to the Russian Far East in 2001 and installation is scheduled for 2005. The Odoptu Field (oil and gas) is located 6-10km offshore of the central portion of Piltun Lagoon. As part of the development of this field, two onshore drilling facilities will be constructed on the eastern side of the Piltun Lagoon barrier spit, which separates the lagoon from the Okhotsk Sea. Construction of these facilities will begin in 2005 or 2006. Construction will require frequent beach landings of barges, supplies and equipment in the northern part of the nearshore gray whale feeding ground during the ice-free period. In addition, a pipeline crossing from the northern and southern sites will be constructed across or under the central portion of Piltun Lagoon and then run southward along the interior of the island.

2.3   Sakhalin V

British Petroleum (BP; 49%) and Rosneft (51%) have been working under a joint operational agreement in the Sakhalin V lease area since 1998. Their operations are exploratory at present, with production not expected for at least three to six years. Sakhalin V operations by BP (the operating partner) will include development of the Kaigansko Vasyukansky Field off the northeastern tip of Sakhalin. It also may include development in the region north of Exxon's Odoptu Field, where BP conducted exploratory drilling in 2004. Although this site is north of the Piltun feeding ground, vessels involved in its development may arrive from the south and travel along the offshore perimeter of the feeding ground, increasing the risks of disturbance and ship strikes. Exploratory wells drilled in 2004 resulted in the discovery of oil and gas reserves in the Kaigansko Vasyukansky Field. The development of drilling operations in this field will pose additional risks to gray whales and their habitat, including those from oil spills, noise, and vessel strikes.

2.4 Sakhalin III – IV, VI – IX
Planning efforts are in their early stages for Sakhalin III – IV and VI – IX. The information available to the Panel was not sufficient to describe with confidence how development of oil and gas operations in these regions will proceed, or how they might affect western gray whales and their habitat.
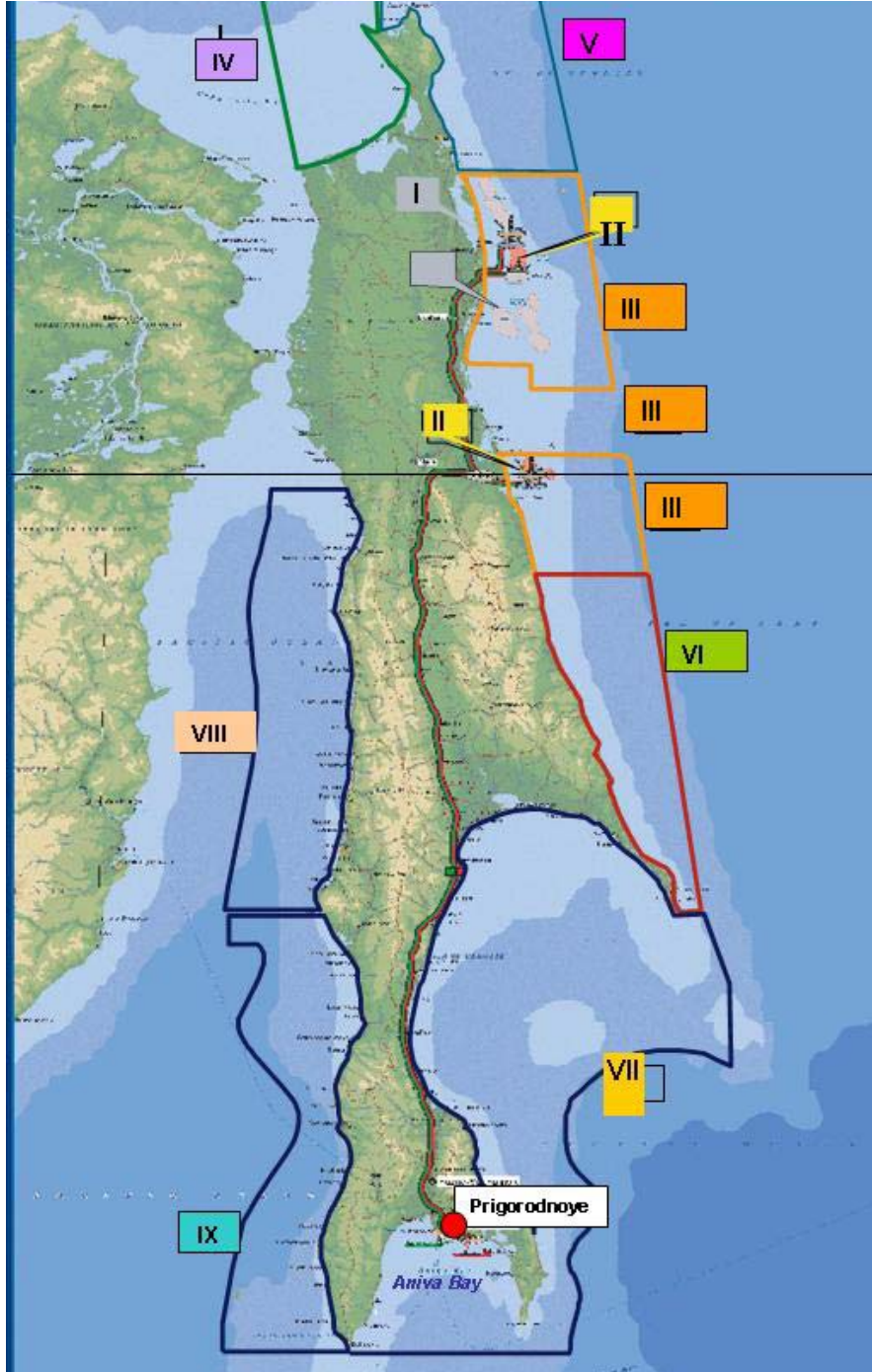

Fig. 3. Map of the Sakhalin region showing the nine project areas (provided by SEIC)

Chapter IV: Discussion of actual and potential threats to western gray whales from proposed oil and gas activities

1 NOISE

Underwater noise associated with the construction and production phases of Sakhalin II Phase 2 is one of the major concerns with regard to the health and conservation of western gray whales. In a recent review of potential biologically significant effects of noise on marine mammals, the U.S. National Research Council (2005) recognized that noise-induced disrupton of feeding in preferred areas could have serious impacts on this whale population.

The ability of gray whales to hear frequencies below roughly 2kHz has been demonstrated in playback studies (Dahlheim 1987; Dahlheim and Ljungblad 1990) and in their responsiveness to underwater noise associated with oil and gas activities (e.g. Malme *et al*. 1986). In addition, the structure of the gray whale ear is evolved for low-frequency hearing (Ketten 1992; see also Cross *et al*., 2003: Section 4.4.2). The potential impacts of noise on gray whales are acknowledged repeatedly in the Project's Environmental Impact Assessment, or EIA (e.g. Section 2.4.3) prepared for SEIC by LGL Limited (Cross *et al*., 2003). However, only two paragraphs are devoted to the cumulative impacts of multiple noise sources (Section 9.3.2).

1.1 Noise Sources

Many sources of very loud noise are associated with the construction phase of the Sakhalin II project, summarised in Table 2-4 of the EIA (Cross *et al*. 2003: 22), as drawn from Richardson *et al*. (1995: Table 6.9). The loudest underwater noise radiates from *transient* sources, including seismic airguns (to 210dB @ 50Hz) and the bow thrusters of supply boats (to 184dB @ 50Hz), with source levels of 159dB associated with both piledriving (@ 1500m @ 250Hz) and helicopter overflights (@ 22Hz). Loud *continuous* noise sources include large tankers and supply ships (to 174-177dB @ 100-400Hz) and tug and barge operations (to 162dB @ 630Hz). These transient and continuous sources often operate simultaneously during construction. Measurements of the combined noise field, if they have been made, remain unreported.

The largest acoustic impact on gray whales is anticipated during the pipeline construction phase of Sakhalin II Phase 2 because of the protracted and intensive work required. During pipeline construction, the major sources of noise can be classified into four groups by type of operation (two types of dredging, pipe-laying and surveying), with maximum source levels of a single ship reaching 208.4dB (Table 1). Within each group, several ships usually operate simultaneously. Also, more than one of the types of operation may be concurrent. Underwater noise measurements of individual construction-related sources in the Lunskoye region of the Sakhalin II project were made in summer/autumn 2004 (Hannay *et al*., 2004). Issues surrounding the adequacy of the source level (SL) measurements are considered in Section 1.3.6.

Table 1

Sample broadband SL measurements (10Hz – 10kHz) from vessels involved in pipeline construction and surveying. These source levels are representative of only some of the activities of these vessels, which may not be the loudest ones. Full details of the source levels by 1/3 octaves can be found in Hannay *et al*. (2004). Unless otherwise noted, SL was measured with a 10Hz high-pass filter - *indicates SL measured with 15Hz high-pass filter, **indicates SL measured with 20Hz high-pass filter; ***indicates SL measured with 30Hz high-pass filter. Note the difference in levels for vessel *DN43* measured with 20 vs. 30Hz high-pass fiter; this 6dB difference represents a *doubling* of power.

Operation	SL dB re: 1μPa @ 1m	Operation	SL dB re: 1μPa @ 1m
Pipelay		**Dredging - CSD**	188.9***
Semac One	179.3	*JFJ de Nul*	184.0***
Castoro 2	180.1**	*Pompei*	191.5***
Britoil	203.1	*Fujisan Maru*	
Katun	190.3**		
Setouchi Surveyor	190.8*		
Surveying		**Dredging - THSD**	202.3
Professor Gagarinsk	208.4	*Gerardus Mercator*	190.2
Oparin	192.5	*Cristoforo Columbo*	
DN43	174.1*** 180.2**		

Less underwater noise will be generated during the operation phase of Sakhalin II Phase 2, although some of the same sources (i.e. helicopter over-flights, supply vessels) will continue to operate at some level.

With regard to operation of the PA-B platform and the potential for ongoing noise disturbance, Section 4.6.5.1 of the CEA notes that noise level measurements have not been acquired from a similar platform structure, although concrete gravity-base structures (CGBS) are 'predicted to be quieter'. In the absence of details on how these predictions were made, the Panel was unable to evaluate this comment.

During construction and over the 40-year life of the Sakhalin II project, the combined noise from ships, dredging, pile driving, seismic surveys, helicopter over-flights and other offshore activities will enter shallow-water habitats off Sakhalin Island. The EIA reviews potential impacts of individual noise sources during the Construction and Exploration phase (Section 5.3.4) and the Operations phase (Section 5.4.3) (Cross *et al*., 2003), but see also Chapter 6 of Richardson *et al*. (1995) for a review of man-made noise sources. This is discussed further under Item 1.3.5.1.

1.2   Effects of noise on gray whales

Gray whale reactions to offshore human activities have been relatively well studied compared to those of other mysticetes (Moore and Clarke, 2002). Studies of short-term behavioural responses to underwater noise associated with aircraft, ships and seismic survey operations indicate that there is a probability of 0.5 that whales will respond to continuous broadband noise when received sound levels (RL) exceed *ca* 120dB and to intermittent noise when levels exceed *ca* 170dB. Humans are similarly more sensitive to continuous than to pulsed noise (Fidell *et al*., 1970). Further, Dahlheim (1987) found that gray whales moved away from drillship sounds and reduced their calling rates. The whales also altered their call characteristics when exposed to playbacks of other noise sources; Dahlheim (1987) interpreted this as an effort to overcome masking. While most research on gray whale responses to anthropogenic noise has taken place in wintering and migratory areas, Malme *et al.* (1986, 1988) documented the responses of eastern gray whales to airgun shots on the feeding grounds. They reported avoidance responses by 10% and 50% of whales to received levels of 163dB and 173dB, respectively.

A study examining the influence of seismic surveys on western gray whales off the Sakhalin Island nearshore feeding ground was conducted in 1997 (Würsig *et al*., 1999). During that time, acoustic recordings collected in gray whale foraging locations had sound levels from seismic pulses of approximately 153dB re 1 µPa, zero-to-peak; 159dB re 1 µPa, peak-to-peak; and 139dB re 1 µPa, averaged over one second while the survey vessel was 30-35km from shore. These recordings indicated that even at relatively long distances, seismic noise was detectable in the nearshore feeding area. Behavioural reactions included changes in whale swim speeds and orientations, respiration patterns and offshore distribution. Such behavioural changes were hypothesised to indicate short-term disturbance to feeding behaviour (Würsig *et al*., 1999).

Richardson *et al.* (1995) cited the abandonment of Guerrero Negro Lagoon in Baja California, Mexico, during shipping and construction activities associated with an evaporative saltworks (Gard, 1974) as 'the best documented case' of long-term displacement of baleen whales due to human disturbance. Bryant *et al.* (1984) documented the return of gray whales to the lagoon after vessel and saltwork activities had diminished, suggesting that the displacement was in fact due to the industrial activities. Unfortunately, no direct measurements were reported of the noise associated with the industrial activities in Guerrero Negro Lagoon.

The current state of modelling to estimate zones of impact on marine mammals from anthropogenic noise is rudimentary and focused almost solely on received levels, RL (e.g. Erbe and Farmer, 2000). Recent evidence indicates, however, that other characteristics of a signal, e.g. frequency content and structure, are also important to how the animal perceives and responds to it (Miller et al., 2000; Nowacek et al., 2004). In a set of controlled exposure experiments, Nowacek *et al.* (2004) showed that the response of North Atlantic right whales (*Eubalaena glacialis*) to a sound did not depend on the RL but on the content of the signal. In that case, right whales were exposed to several different stimuli in a playback experiment while wearing a tag that recorded the acoustic environment as well as the whale's movements, postures and fluke stroke rates. The stimuli included their own social sounds, sounds of an approaching vessel, a silent control and finally a synthesised alert/alarm signal designed to pique their auditory system and give them cues as to the location of the source. The design of this signal followed the same process that is used to design warning signals in hospitals, i.e. to alert nearby listeners but not to scare them. The whales responded strongly to the alert/alarm signal but showed virtually no response to the other stimuli despite the fact that the levels received by the tag, and therefore the whale, were similar to those from the alarm signal. These results suggest that simply considering RL may be insufficient for predicting a response.

When predicting RL, for example, the CEA reports only a broadband RL from the results of the noise transmission model used by JASCO (see later). As the noise spectra show, however, the sound produced by the various vessels is not uniform across the spectrum, i.e. some frequency bands are significantly louder than others. This is not surprising given the nature of the source but, as we have discussed, the characteristics of the signal can be even more important to the whale than the broadband RL. Additionally, research carried out with humans has shown that at the same source level (SL): (a) broadband 'white' noise is perceived to be louder than pure tone and (b) within limits, tones added to broadband noise increased the perceived annoyance more than simply increasing the loudness (Hellman and Aylward 1980, Hellman 1982). The noise spectra of multiple construction-related sources include combinations of tonal components and broadband noise. Therefore, behavioural reactions of western gray whales (or lack thereof) exposed to acoustic stimuli may be more related to perceived annoyance than to loudness or RL, the sole metric used by SEIC to estimate disturbance. For these reasons (saliency, perception and total energy), a simple estimate of broadband RL is unlikely to represent the disturbance level to western gray whales.

1.3   Actual and potential threats from existing and proposed activities

Threats to western gray whales associated with noise exposure include: (a) masking and hearing loss, (b) abandonment of feeding areas (complete displacement), (c) behavioural modification (partial displacement) and (d) stress. Any of these become biologically significant if they affect reproduction or survivorship. Each factor is discussed briefly below.

1.3.1   Masking

Although no hearing threshold audiograms are available, ear structure and behavioural responses to industrial noise strongly suggest that gray whales hear well in the low frequencies (<2kHz) of noise generated by ships and construction activities. Underwater noise from industrial activities can mask communication signals among whales, or other important signals that whales may obtain through listening (passively) to their environment.

1.3.2   Hearing loss

Like masking, hearing loss can affect fitness by impairing an animal's ability to navigate, communicate and detect predators or prey (Richardson *et al.,* 1995; Erbe and Farmer, 2000). Chronic exposure to noise can decrease auditory sensitivity, causing shifts in hearing thresholds that may be temporary (TTS – temporary threshold shift) or permanent (PTS – permanent threshold shift). The degree and nature of threshold shifts depend on the spectral characteristics (frequency and amplitude) of the noise, the amount of energy per unit of time, the duration of noise exposure and the duty cycle, i.e. recovery time between exposures. Most of the underwater noise associated with the construction phase of the Sakhalin II project is anticipated to be low-frequency, high-amplitude and almost continuous – a combination which could lead to masking and possibly hearing loss (e.g. TTS or PTS) in gray whales.

1.3.3   Abandonment of feeding areas

Prolonged displacement from or abandonment of a particular area as a result of exposure to a particular stimulus (e.g. underwater noise) indicates either that the animal was truly disturbed or that once displaced, it found another area that met its needs. Conversely, if an animal remains in or returns to an area where it experienced (or continues to experience) such a stimulus, this does not necessarily confirm that the stimulus is no longer aversive or threatening. The area may be so important to the animal that it remains there and tolerates a potentially harmful stimulus (see 1.3.4 below). Recent studies of situations in which harbour porpoises (*Phocoena phocoena*) avoided acoustic pingers (Culik *et al.,* 2001; Kastelein *et al.,* 2005) may be informative in this regard.

The abandonment of Guerrero Negro Lagoon described above provides a troubling example that gray whales can be displaced from important habitat by anthropogenic activities and related noise. The 2003 Western Gray Whale Environmental Impact Assessment (WGW EIA) states that during construction of the Sakhalin II Phase 2 project, underwater noise will be generated from at least seven types of activity: (1) pipe/cable installation, (2) GBS and topsides installation, (3) construction of a landing pier and approach channel, (4) construction of a jetty, (5) TLU installation, (6) multiple supply vessels needed to support construction and (7) multiple aircraft to support construction. Although the lack of noise measurements associated with the activities at Guerrero Negro Lagoon precludes a direct comparison, it is possible that the combined or aggregate underwater noise from Sakhalin I and Sakhalin II would be sufficient to cause similar displacement from the Sakhalin feeding grounds.

1.3.4   Behavioural modification

Noise associated with the Sakhalin II project may displace western gray whales temporarily, causing them to alter their distribution in order to avoid the areas of loudest activities, even if it does not displace them permanently (see 1.3.3 above). Short-term studies of gray whale responses to ships and continuous noise from oil and gas operations

generally show that the whales change course, or are deflected, from such activities when received noise levels are higher than about 120dB (e.g. Moore and Clarke, 2002).

For Sakhalin II Phase 2, the radius of noise influence will overlap the gray whale feeding grounds. Whales seeking to avoid noise may thus be forced to reduce their foraging time in prime habitats. This may lead to reduced energy intake and reduced fat reserves. This latter condition has been associated with lower reproductive rates in several mammalian species (Schneider, 2004). Quantifying the relationship between nutritional condition and reproduction in whales is extremely difficult (e.g. Lockyer, 1987), particularly as existing methods provide only proxies for physiological body condition (e.g. Perryman and Lynn, 2002; Pettis *et al*., 2004).

Some temporary displacement of western gray whales from prime feeding areas is a probable effect of Sakhalin II Phase 2, given the almost complete temporal and spatial overlap of anticipated construction activities with the whales' foraging distribution. Such overlap is cause for special concern according to Richardson *et al.* (1995). Although it is difficult to quantify and measure the consequences of lost foraging time in prime habitat, such loss may be great enough to reduce individual fitness significantly. This may apply especially to breeding females in light of their high energy requirements. The observations of 'skinny' whales off Sakhalin in 1999, 2000 and 2001 (see Chapter II) suggest that at least some whales in this population were unable to secure adequate food in those years (Weller *et al*., 2002a).

1.3.5   Stress
Chronic exposure to noxious or threatening stimuli can result in elevated stress levels, although stress resulting from noise exposure has not been assessed directly in any marine mammal (and is indeed difficult to measure). The only physiological response to noise that has been measured in marine mammals is change in heart rate (Andrews *et al*., 1997; Fletcher *et al.*, 1996, Miksis *et al.*, 2001). Not only does increased heart rate (tachycardia) represent an increase in metabolic rate, but it has also been linked to the release of the stress hormone cortisol in some mammals (Harlow *et al*., 1987). Laboratory studies with terrestrial mammals have explored many aspects of noise-induced stress, and they indicate that chronic and/or periodic exposure to noise can have behavioural and/or physiological consequences (e.g., Smiley and Wilbanks, 1982; Sackler *et al.,* 1959; Krebs *et al.,* 1996, 1997; Fride and Weinstock, 1984; Fride *et al*., 1985).

1.3.6   Review of assessment of effects given by SEIC
1.3.6.1   MODELLING TRANSMISSION LOSS AND COMBINED NOISE FIELDS
Modelling transmission loss (TL) of low-frequency (i.e. long wavelength) sound in shallow water is a complex undertaking (Urick 1983; Kuperman and Lynch 2004) but is central to the approach SEIC have used to assess the potential effects of noise on gray whales and to develop mitigation and monitoring strategies. It is relevant to both feeding areas off Sakhalin (the nearshore area is <20m deep while the offshore area is <50m deep). Several factors, including sound speed profile in the water and sediment and the bathymetry, result in frequency- and time-dependent complexity in the propagation of sound through these environments. Annex E provides a detailed critique of the process SEIC used to predict noise TL through gray whale feeding areas off Sakhalin. In summary, four problems were identified: (1) the limited accuracy (for a variety of reasons) of SL measurements used in model development, (2) deficiencies in the model with respect to taking into account the properties of the 'elastic bottom', (3) lack of data on bottom characteristics in the Piltun area and (4) lack of calibrated ground truth measurements to test the model predictions.

The framework most commonly used to address the potential impacts of noise on marine mammals is one whereby zones (or radii) of audibility, responsiveness, masking, hearing loss and injury (i.e. Zones of Influence, or ZOI) are estimated (Richardson *et al*., 1995: Chapter 10; Richardson and Würsig 1997: Fig. 1; Erbe and Farmer 2000). Noise from single sources is most often considered, although most experts agree that the combined noise from multiple sources may increase the severity of impact. Further, while the ZOI approach is useful to bound the problem of potential noise impacts, it does not estimate noise exposure at the level of populations. That is, while the proportion of the population exposed to noise from one particular source may be small, the proportion exposed to at least one noise source may be much larger (Richardson e*t al.*, 1995). An alternative approach, recently suggested by Zacharias and Gregr (2005), is to identify 'vulnerable ecological features' (VEFs) by overlaying species-specific habitat models with acoustic stress surfaces calculated for various anthropogenic activities such as vessel traffic and offshore hydrocarbon production. In their example exercise, Zacharias and Gregr (2005) found (not surprisingly) that an inshore or nearshore species (in this case the humpback whale, *Megaptera novaeangliae*) was most sensitive to on-shelf, coastal activities such as hydrocarbon production, ferry traffic and small-boat traffic. Using their schema for identifying VEFs, the feeding areas used by western gray whales off Sakahlin clearly fall into 'code CE10',

identified by 'biological structures used by a significant component of the population' where ecological effects causing behavioural changes can lead to siginificant changes in population distribution.

The combined noise field experienced by gray whales from multiple sources is going to be modelled by JASCO Ltd., but model results were not available for the Panel's review (CEA: Section 4.3.2.4 – Step 4 is incomplete and Step 5 is described as being in progress). However, given the difficulties noted above (and in Annex E) with respect to modelling shallow-water TL, the results will be of questionable accuracy. Indeed, three TL model runs are illustrated in the CEA (PTL2A, PTL5A and PTL 11A), and they reveal considerable differences between model predictions and actual measurements, especially at low frequencies. In JASCO's own words, 'Model predictions for the nine tracks included in this report [the CEA] were found to be in *reasonable agreement* [italics added] with measurements'. Additionally, the variability in JASCO's own measurements are indicative of the variability of sound propagation in such an environment. Indeed, JASCO describe the variability to be 'generally less than *about* 10 dB' (italics added). Because decibels are a logarithmic scale, this represents an order of magnitude of variability.

While JASCO are to be commended for completing a very ambitious field program and formulating a prototype model in a short period, the model in its present stage of development cannot predict RL with the accuracy needed to properly assess noise exposure in shallow-water environments.

1.3.6.2 ESTIMATE OF THE NUMBER OF WHALES POTENTIALLY 'IMPACTED'

The CEA calculation of the number of whales potentially 'impacted' (Section 4.5.2.1) appears to be based largely (or possibly entirely) on the 'executive summary' of a report on the effects of seismic activities in 2001 (Johnson 2002). According to the CEA, Johnson (2002) found that only 4-5 whales were 'impacted' by the activities. This contrasts with the actual wording of the Johnson (2002) document, 'the multiple regression analysis indicated that on average 3-4 [not 4-5 as stated in the CEA] were displaced from the area immediately adjacent to the Odoptu seismic block ….' The sentence preceding that one (see Johnson 2002) states that a statistically significant (P<0.05) southward shift (10-20km) occurred 'in the mean latitudes of observed gray whales during the seismic period'. Although it would be difficult to confirm without reference to the full report of the Johnson (2002) study (i.e. without more than just the 'executive summary'), their results, in combination, appear generally consistent with those of Weller *et al.* (2002b) who found that a significant number of whales in the Piltun feeding area were displaced by the 3D seismic surveys conducted during summer 2001. To test the hypothesis that the distribution of gray whales on the feeding ground would shift away from nearby seismic surveying, Weller *et al.* (2002b) examined the number of whales and number of pods (dependent variables) sighted during systematic scans in relation to three treatments (i.e. pre-seismic, seismic, post-seismic). Results showed the main effect of condition was highly significant (P<0.001), with both the number of whales and the number of pods during pre- and post-seismic conditions significantly differing from the seismic condition. These findings indicated that significantly more whales and more pods were in the scan area during the seismic condition than during the pre- and post-seismic periods. These results suggested that whales shifted their distribution into the scan area (i.e. from the north to the south) and away from the northern region where the seismic surveys were being conducted. Once the seismic surveys had ceased, overall whale and pod numbers in the scan area returned to pre-seismic levels, suggesting that whales had reoccupied, within a matter of days, the region from which they had been displaced.

With regard to the temporal definition of the feeding area and duration of impact (Section 4.3.2.3), the CEA estimated a 150-day feeding season as the basis for calculating acceptable vs. unacceptable displacement duration. The data upon which this was based show that whale densities in June and October are significantly lower than in July-September. However, the subsequent analysis did not assign lower weight to June and October, and therefore underestimated the percentage of the season 'impacted'. This is important because the percentage of season 'impacted' is one of the three criteria used in the CEA to determine whether particular site choices and activity configurations were or were not acceptable.

Another assumption made in the CEA (Section 4.5.2) is that the use of avoidance criteria for feeding gray whales that are based on responses to noise by gray whales migrating along the California coast is a 'conservative' approach. This assumption is countered by observations summarised by Richardson and Würsig (1997) who state that 'cetaceans are often less responsive when feeding, socializing or mating than when resting'. Indeed, avoiding a disturbing sound during migration carries a smaller cost (swimming deflection) than moving away from the sound source when feeding (disruption of caloric intake). Gray whales feeding near Sakhalin may not have the option to move to another feeding area, so may endure exposure to high noise levels in order to continue to feed. A feeding whale that remains in the vicinity of a disturbing sound source may become stressed (see Item 1.3.5) and suffer more subtle but chronic effects of exposure to noise.

Finally, in calculating the number of whales affected, the CEA (Table 4.6) divides the construction activities into periods involving particular arrays of noise sources. These then appear to have been used in the noise model (see discussion under 1.3.5.1 above) to estimate the respective zones of impact for those periods. If the model results indicated that the 120dB threshold would be exceeded at all within the feeding area, the authors estimated the durations of the various operations and used this information to estimate the numbers of whales potentially affected. However, the partitioning approach as implemented in the CEA will result in an underestimate of the number of whales affected (and ignores cumulative effects). For example, 'Periods A2-3 to A2-5' are all in July and entail the use of the same equipment with only minor differences in activity. It would seem more appropriate to estimate numbers for the total period rather than attributing them to the different periods and restarting the counting for each period.

In summary, the analysis presented in the CEA does not sufficiently take into account the uncertainty surrounding the assumptions it makes; notably it errs on the side of underestimating the potential effects of noise and relies on an as yet underdeveloped and untested transmission loss model.

1.4   Review of proposed mitigation measures

Although the Western Gray Whale Protection Plan (WGW PP) lists four measures to 'mitigate specifically against noise impacts', both it and the CEA lack specific information on how and when mitigation will be employed to reduce the impacts of noise, especially those likely to occur during construction operations (i.e. the real-time adaptive management capability). The measures themselves are not well specified. For example, although it is stated that potentially disturbing operations 'should' be conducted in 'good visibility conditions', the WGW PP goes on to say that if 'poor' conditions are 'unavoidable', additional precautions such as increased bridge watch or use of spotlights will be employed. The WGW PP, however, does not define such terms as 'good', 'poor' or 'unavoidable', nor does it provide an assessment of the efficacy of such measures. Similarly, whilst it states that when operating in shallow waters where gray whales aggregate to feed, 'extreme care will be taken to avoid activities that may have negative impacts on whales', it does not specify what constitutes 'extreme care'. Moreover, criteria for determining if and when an effect has occurred, and therefore mitigation action is warranted, are qualitative and vague (see Kurianov, 2004, for discussion).

In fact, the only specific parameters given in the WGW PP are a 1,000m 'buffer' and a 250m 'safety' zone for baleen whales[2], which apply only for small-scale (10-20 cubic inch airguns) seismic operations, pingers and boomers. The rationale for this limitation is unclear since no information is provided on the received levels anticipated from these sources.

Some of the shortcomings of the WGW PP as proposed for offshore pipe-laying activities were outlined in a letter from A. Vedenev (Russian Grey Whale Research Strategic Planning Group) to Stephen McVeigh (SEIC) in April 2004. Among other things, the letter noted that the 'cumulative source level' of noise anticipated from the pipeline construction fleet would likely exceed 200dB and that received levels in coastal habitats used by gray whales would be on the order of 140dB, thereby exceeding the 120dB threshold that SEIC had set for itself. SEIC subsequently decided to postpone pipe-laying activities so that a comprehensive series of underwater sound measurements could be obtained and analysed from similar activities in the Lunskoye Field in the summer and autumn of 2004. As indicated in Table 1 above, recent measurements have confirmed that some source levels were above 200dB. If transmission loss is not more than 60dB @ 400Hz at a distance of *ca* 10km from the source (Vedenev 2004a), then levels well in excess of the 120dB threshold can be expected in the nearshore feeding area. Hence, the concern expressed in the Vedenev letter appears to have been warranted.

The monitoring and mitigation component of the CEA (Section 4.6.6) mentions 'establishment of "shut-down" criteria in the event that the real-time noise monitoring program indicates noise levels and impacts on the whales near the Piltun feeding area that are higher than predicted, and considered unacceptable'. However, unacceptability remains undefined. Throughout the document there is a lack of measurable criteria for action. It is thus extremely difficult to evaluate the efficacy of the monitoring and mitigation measures proposed.

That said, certain of the proposed alternatives in CEA Section 4.6 (Noise Assessment Results) show promise for significant mitigation. For example, Section 4.6.4.5 states that if the 'base case' pipeline routing and configuration are pursued, the majority of the loudest dredging activities would occur during the winter when no gray whales are present, although the Panel's current understanding is that only the THSD dredging and backfilling can be done in

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[2] Reduced to 250m and 100m, respectively, for all other marine mammals.

winter and then only with icebreaker support (CEA Section 4.6.4.2). Although not completely effective, it will certainly reduce the exposure of gray whales to potentially harmful noise (and see 1.4.3.1 below). Also there are benefits of additional mitigation measures including flexibility in routing the pipeline to the farthest offshore route (i.e. Alternative 1 will keep the noisiest activities farthest away from the whales) and the modification of operational procedures to separate, in timing, the installation of PA-B topside and the dredging and laying of the pipeline.

1.4.1 Ramp-up procedures
The use of 'ramp-up' (also known as 'soft-start') procedures is mentioned as a potential mitigation strategy, specifically for seismic survey operations (e.g. air guns). Although this is the industry-standard mitigation measure (JNCC 2004), there is ongoing discussion about its effectiveness and the level of safety that it provides for marine mammals (www.jncc.gov.uk; www.mmc.gov; Barlow and Gisiner, 2004, note that its effectiveness has not been properly evaluated). The total energy in a particular 'shot' from an air gun can be extremely high, so many protocols call for starting operations with low levels, usually adding air guns over the ramp-up period and thereby allowing animals to vacate the area as noise levels become uncomfortable. However, there are two potential problems with this strategy: (1) If an animal is exposed to a signal that is not initially annoying or harmful, but that slowly becomes harmful, the animal may not move away because it may not perceive the incremental increase in level. (2) If the goal is to warn an animal that it is soon to be exposed to an unpleasant or harmful signal, that signal itself at some lower level probably is not the most appropriate to use as the warning sound.

1.4.2 Effectiveness of 'bubble screens'
Bubble screens (or curtains) have been considered as means of mitigating against noise by a number of authors. The mechanism of sound propagation through bubble screens, however, is not fully understood (Druzhinin *et al.*, 1996; Ostrovsky *et al.*, 1998; Khismatullin and Akhatov 2001; Karpov *et al.*, 2003). In recent years, attention has been focussed on whether bubble screens may simply shift the energy to another frequency band instead of dissipating it. Nonetheless, bubble screens may have some utility around stationary activities. For example, Würsig *et al.* (2000) showed that a bubble curtain could reduce broadband acoustic signals by 3-5dB (i.e., by a factor of 1.8). The experiment was carried out over two days in waters 8m deep near Hong Kong and the bubble curtain was developed by blowing air through a perforated rubber tube. Rapid-onset acoustic signals were produced by pile driving at various distances (250 – 1000m) and noise levels were measured in the broad band from 100Hz to 25.6kHz. The largest (5dB) decrease was observed in the range of 400 – 6400Hz within 1km of the source. Simultaneous observations of marine mammals showed that Indo-Pacific hump-backed dolphins (*Sousa chinensis*) occurred in the immediate area of the industrial activity before and during pile driving, but with a lower abundance immediately after it. While the dolphins generally showed no overt behavioural changes with and without pile driving, their speeds of travel increased during pile driving, suggesting that bubble screening did not eliminate all behavioural responses to the loud noise.

To date, an important limitation of the available data is that measurements of noise associated with the Sakhalin II project have been conducted independent of observations of whale behaviour and distribution (Vedenev 2004b). It would be appropriate for gray whale monitoring during the construction phase of Sakhalin II Phase 2 to take advantage of recent technological advances and incorporate simultaneous acoustic and behavioural measurements to provide real-time evaluation and feedback on the impact of noise on the animals. Such an approach could integrate biological and acoustic research and monitoring.

1.4.3 Alternative/additional mitigation measures
Methods to partially mitigate the effects of noise on marine mammals include: (1) avoidance of critical habitat, (2) scheduling activities to avoid co-occurrence with animal aggregations, (3) removal or quieting of equipment, (4) flexibility in routing and positioning of activities and (5) modification of operational procedures (Barlow and Gisiner 2004; Richardson *et al.*, 1995: Section 11.10). Sakhalin II Phase 2 is already well into its construction phase (~ 40% complete) so avoidance of habitat critical to gray whales (item 1, above) and (to some extent) positioning of activities (item 4) are no longer viable mitigation options. However, some combination of the remaining measures could provide significant protection to gray whales, as outlined below.

1.4.3.1 ACTIVITY SCHEDULES
Scheduling activities to avoid co-occurrence with feeding gray whales and mother-calf pairs would reduce noise impacts. Whales typically arrive off northern Sakhalin Island by late May and some remain through early November, with peak numbers present from July through September (Weller *et al.*, 2002a). If construction and other operations were to occur before or after the peak season, this would obviously reduce the cumulative noise exposure. The statement in the CEA that some operations (at least THSD dredging) can now be conducted in the winter is encouraging; until recently this was considered infeasible. Clearly, undertaking as much of the noise-generating

work as possible outside the July – September period would be a highly effective strategy for reducing exposure of gray whales to potentially harmful noise.

1.4.3.2 EQUIPMENT

Noise control engineers are employed routinely to reduce the noise emitted by military and passenger vessels. It should be possible, through the application of technical expertise and the careful selection of materiel (e.g. shock mounting of machinery), to further reduce the noise emitted by vessels and equipment involved in Sakhalin II construction and operational activities. Even without further development, it is desirable that the quietest available equipment be used for the construction and operational phases of Sakhalin II. SEIC have suggested that with equipment modifications, the 'base case' pipeline option becomes 'acceptable', and these reductions in noise output are technically feasible. Such changes, however, can be time-consuming and there is reason to refer again to the problems with the initial source level measurements for the vessels involved and to question the operators' ability to reduce their noise output to what SEIC have defined as acceptable levels.

1.4.3.3 EXXON OPERATIONS

Finally, despite requests made on the Panel's behalf by IUCN, little information was received concerning the operations to be undertaken by Exxon as part of Sakhalin I. The relevant measures discussed here in the context of SEIC's Sakhalin II Phase 2 operations will also be appropriate for any similar operations undertaken by Exxon under Sakhalin I. Co-ordination of the two companies' operations (e.g. avoiding temporal overlap of noisy activities) could make a major contribution towards reducing exposure of gray whales to noise.

1.5 Review of proposed monitoring and compliance measures

Given the potentially important effects of noise disturbance on gray whales in their feeding grounds, it is important (1) that appropriate quantified guidelines are established to determine when (and what) action should occur and then (2) to monitor both received sound levels and whales to ensure that appropriate mitigation measures are quickly implemented when necessary. Such monitoring would require dedicated visual surveys integrated with acoustic observations using bottom recorders that transmit noise level data in real-time, via radio or satellite communication systems during the pipe installation operations. Commendably, this appears to be the intention expressed in Section 4.66 *Acoustic Monitoring* of the CEA (p. 36). However, the CEA does not specify how this will be achieved in the detail needed for rigorous review, particularly with respect to recorder placement and the need for simultaneous visual tracking of whales.

The CEA implies that only the 'perimeter' of the nearshore feeding area will be monitored for received levels (RL) of noise during construction activities. Two issues arise out of this. The first is the location of the perimeter of the feeding area. The SEIC contractors (JASCO) have assumed that the spatial boundaries of the feeding area are rigid, i.e. that no whales feed at or just outside the edges of the defined area. In several of their 'final figures', JASCO found the boundary of their estimated 120dB RL threshold (via modelling – see Annex E) to be just outside the feeding area. However, it seems unlikely that the boundaries of the feeding area are completely static and indeed whales are sighted routinely outside it (Weller *et al*., 2002b; Johnson 2002). It would be appropriate for some kind of buffer area to be established between the whale feeding ground and the estimated 120dB RL zone. The second issue arises from evidence (Kuperman and Lynch, 2004) that there is extreme variability in sound transmission loss in shallow water. In addition, the dependence of transmission loss on ambient conditions, as shown in Figs 4.2 and 4.3 of the CEA, means that RL cannot be modelled confidently in the shallow gray whale feeding areas.

Given the uncertainty in the modelling approach, particularly for shallow waters, it is important for measurements to be taken within the 'perimeter' of the proposed feeding grounds, ideally near feeding whales and in association with observations of responses by the whales. A real-time adaptive management programme would dictate that if the RL near a whale exceeds the 120dB threshold or observational data suggest a disruption of normal whale behaviour, work is suspended until the whales have moved outside the ensonified area.

As stated earlier, if SEIC were to schedule noisy operations such as dredging for winter months or at least for periods of anticipated low density of gray whales in the nearshore feeding area (i.e. March-April and September-October), and were to slow down the construction work, this could reduce substantially the exposure of gray whales to potentially harmful noise.

Finally, in the Conclusion section of the CEA, several references are made to 'monitoring' and 'mitigation' measures. For example, section 4.6.6.2 states that the focal points for a proposed 2005-2006 monitoring program would include 'monitoring the predicted potential impacts of introduced noise….' Another stated focus would be to evaluate 'effectiveness of the mitigation measures in order to adapt them if deemed necessary'. In neither case,

however, is there clear guidance on the 'predicted potential impacts' or the 'mitigation measures' that are to be evaluated.

In summary, there is a lack of specificity throughout the document in both the monitoring methods to be used and the criteria for transferring the monitoring results into mitigation action. Effective monitoring would require dedicated visual surveys integrated with acoustic observations using bottom recorders that transmit noise level data in real-time, via radio or satellite communication systems, during the pipeline installation operations. Moreover, for mitigation of this kind to be effective, there needs to be a mechanism for independent monitoring of compliance. Such independent monitoring programmes have been prescribed by regulatory agencies in other parts of the world (e.g. Minerals Management Service in the United States, Joint Nature Conservation Committee in the UK). Without further details on SEIC's plans, the Panel is unable to evaluate the efficacy of the monitoring and mitigation measures proposed.

1.6   Information needs
Key requirements for an improved appraisal of the effects of noise on western gray whales off Sakhalin include obtaining better (quantitative where possible) information on:

- transmission of noise through western gray whales habitats;

- noise fields experienced by western gray whales from multiple noise sources;

- behavioural and physiological responses of western gray whales to noise;

- gray whale hearing abilities.

1.6.1   Gray whale hearing
Although it is clear that gray whales can hear underwater noise associated with construction and operation activities, a number of important gaps in knowledge remain. These include: (1) gray whale hearing sensitivity – to date no attempt to produce an audiogram of a mysticete whale has proved successful; (2) whether gray whales rely on passive listening to environmental cues for orientation and food finding; (3) the potential for underwater noise to mask environmental sounds or the calls of con-specifics; (4) zones (radii) from noise sources within which gray whales may hear, respond or be injured by noise; (5) the aspect of noise (e.g. frequency content, modulation, loudness) that may elicit a response from a gray whale.

1.6.2   Response of gray whales to noise
1.6.2.1   RELEVANCE OF SIGNAL
As noted elsewhere, further work is needed on the response of gray whales in the field to noise, in particular with respect to a wider variety of characteristics of sound than simply the broadband RL.

1.6.2.2   PHYSIOLOGICAL RESPONSE OF GRAY WHALES TO NOISE
Based on studies of terrestrial animals (see section 1.2.4), it is plausible that noise from the proposed and existing sources associated with Sakhalin II could cause significant physiological stress in western gray whales. This requires further study.

1.6.3   Modelling noise TL and noise fields from multiple sources
As noted under Item 1.3.5.1, the modelling of transmission loss, particularly in shallow water, is complex and the models developed to date produce results of debatable accuracy and low precision. The same is true for the related exercise of modelling noise fields from multiple sources. Development of such models will benefit greatly from *inter alia* reliable SL measurements and observed geoacoustic bottom parameters in the Piltun area (see Annex E). Further investigation is also needed of methods to incorporate signal content, not simply loudness, into predictive models of noise response.

In summary, there are two critical scientific information gaps related to the noise field that western gray whales experience from multiple sources: (1) inability to accurately model and predict received levels from multiple (or single) noise sources in shallow-water environments; and (2) uncertainty regarding what aspects of the noise signal (e.g. the saliency of the signal) would be disturbing to a gray whale.

1.7   Summary and conclusions
The EIA and WGW PP focus solely on prediction of received noise levels, from single and multiple sources, with regard to noise mitigation. There are two important problems with this approach. The first concerns the inadequacy of the predictive modelling, especially in the shallow water characteristic of the feeding grounds. The uncertainty

associated with the acoustic model, especially in shallow water, makes it an unreliable forecasting tool for noise-control planning in western gray whale feeding habitat. Quantitative estimates of the uncertainty associated with received levels estimated by the model, if they were available, could be incorporated by using the lower confidence limits. Such estimates of uncertainty appear to be unavailable at this time and would represent a novel (untested) approach in any case. The second problem is that while received level is an important variable, especially near critical levels, recent evidence suggests that signal type and saliency are also important.

The SEIC documents rightly acknowledge the importance of noise impacts. However, they consistently interpret uncertain data optimistically and thus may seriously underestimate the nature of the threats posed by the operations and hence the requisite mitigation measures. In addition, there is a lack of specificity concerning the proposed mitigation measures and how and when they will be enforced.

The *Principal Conclusions* section of the CEA refers to 'criteria developed for measuring impacts from anthropogenic noise' that are considered 'state of the art'; yet 'determination of impact' based on the *Noise Impact Criteria* is to be 'based on *available information* and *professional judgement* [our emphasis]'. Such statements are not metrics that can be rigorously applied to make judgments that are potentially decisive in ensuring the conservation of western gray whales.

In conclusion, there are significant threats to western gray whales from noise associated with the Sakhalin II project. Although the uncertainty surrounding the quantification of these threats and their impacts is high, the Panel takes these threats very seriously given the implications for the population. Our concern about the effects of noise on western gray whales is especially acute due to the nearly complete spatial and temporal overlap between ongoing and planned development activities (including those of both Sakhalin I and II) and the use of Sakhalin feeding habitat by gray whales.

More specifically, noise from the Sakhalin II project may:

(1) cause hearing loss (TTS or PTS) in, or mask sounds important to, gray whales;

(2) cause temporary or permanent displacement of gray whales from their prime feeding habitat off Sakhalin Island.

(3) cause stress to gray whales that remain in a noisy habitat in order to feed.

The cumulative noise from activities associated with the Sakhalin II project may be sufficient to displace western gray whales from their primary feeding habitat. Even temporary displacement may have significant negative effects, especially for breeding females and calves. Although the effects of stress on gray whales are unknown, there is sufficient evidence from other mammal species to warrant concern that it could negatively affect reproduction in western gray whales.

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2   COLLISIONS

2.1   Introduction - vulnerability of gray whales to vessel strikes

Collisions between vessels (of several types) and whales occur throughout the world, killing or injuring the whales (e.g. Laist *et al.,* 2001). Between 1970-1999, 35% of 45 North Atlantic right whale deaths for which the cause could be determined were from collisions (Knowlton and Kraus, 2001). Eastern gray whales are among the most frequently struck large whales (Sumich and Harvey, 1986; Laist *et al.*, 2001). Although no vessel strikes on western gray whales are reported in the CEA, EIA, WGW PP or the broader scientific literature, at least one whale photo-identified off northeastern Sakhalin Island by the Russia-U.S. research team has scars that appear to be from an injury caused by a vessel (D. Weller, pers. comm.).

The coastal distribution and migratory behaviour of western gray whales may be generally similar to those of North Atlantic right whales, for which ship strikes are a major threat. Compared to right whales, gray whales may spend a higher proportion of their time near shore. In fact, except when they are crossing deep straits or port approaches, eastern gray whales tend to remain well inshore of shipping lanes (where these exist). Gray whales are more manoeuvrable and forage primarily on the bottom, and on their feeding grounds they may be slightly less at risk from ship strikes than right whales, which often feed in the water column and sometimes at the surface. The relative collision risks to gray whales off northeastern Sakhalin, where whales and large vessels are in close proximity, is hard to gauge from existing knowledge.

Right whales die from vessel collisions even though they apparently are able to hear approaching ships (Ketten 1998; Richardson *et al*. 1995). Why they do not move out of the path of oncoming ships is not known (Laist *et al*. 2001; Terhune and Verboom 1999). Anecdotal observations suggest that they only begin to respond when vessels approach to within a very close range. Right whales off the eastern coast of North America are exposed to frequent vessel traffic, and they may have habituated to the sounds of approaching vessels at greater distances (Laist *et al*. 2001; Richardson *et al*. 1995; Terhune and Verboom 1999). Such habituation could occur with western gray whales as they are exposed to sounds from many types of vessels during their annual migration. However, whales are also struck and killed in areas with less vessel traffic (Alzueta *et al*., 2001; Greig *et al*., 2001), and alternative explanations need to be considered. One such alternative hypothesis is that whales become confused if noise is distorted or attenuated at or near the surface. Also, hydrodynamic models indicate that animals on the surface within ~1 beam width or submerged within a critical distance of the hull of a moving ship are at risk of being entrained in the low-pressure area around the ship and then dragged back towards the propeller (Knowlton *et al*., 1995, 1998). The 'safe' distances in such scenarios depend on hull type, ship speed and vessel draft, but all travelling ships create a certain amount of low pressure around the hull that can entrain nearby objects.

Extensive efforts at ship strike reduction have been developed to locate whales, to notify ships of whale locations, and even to redirect vessel traffic. Vessels in certain areas off the northeastern and southe astern coasts of the United States are required to report when they enter one of these areas and are then notified of the locations of recent whale sightings. The extent of these measures, their rationales, and documents describing methods to reduce the likelihood of collisions (e.g., suggestions for mariners) are available at http://www.nero.noaa.gov/whaletrp/. The website also includes the U.S. National Marine Fisheries Service's Proposed Strategy to Reduce Ship Strikes of North Atlantic Right Whales, which explores strategies for minimizing the risks of collisions.

Feeding western gray whales may be at elevated risk of vessel collision for at least two reasons. Firstly, as they move between the nearshore and offshore feeding areas (a relatively common occurrence – Burdin *et al*., 2002; Weller *et al*., 2002), they cross the most direct corridor for vessels travelling from the south to the Piltun-Astokhskoye area, therefore increasing the likelihood of an encounter. The distance between the two feeding areas is about 60-65km and the whales would likely transit between them in less than a day (assuming they travel at a rate similar to that of most southbound-migrating gray whales along the California coast – 115-144km/day; Swartz, 1986; Rugh *et al*., 1999). Whales travelling between the feeding areas could be: (1) difficult to detect because of infrequent and widely spaced surfacings and (2) more vulnerable to collisions because they (presumably) travel near the surface most of the time. This concern also applies to occasional west to east (nearshore to offshore) movements of some whales. Secondly, actively feeding whales may be less aware of approaching vessels and thus be more susceptible to collisions with ships on the feeding grounds than they are in other portions of their range.

The proposed mitigation measures are unlikely to be adequate to prevent collisions entirely. For that reason, and because any mortality in addition to that already experienced by this population would jeopardise recovery (see Chapter VII), a precautionary approach to risk assessment and mitigation is appropriate.

2.2   Assessment of actual and potential threats from proposed activities

2.2.1   Traffic on or near the Piltun (nearshore) and offshore feeding areas
Vessels may be most likely to strike gray whales during periods of construction on or near their feeding grounds. The PA-A platform was towed to the production site and installed in 1998 and oil production started in 1999. Shore observers from the Russia-U.S. team recorded up to 15 vessels in the vicinity of the nearshore (Piltun) feeding ground at any one time during the installation (Würsig *et al.*, 2000). Similarly, a large number of vessels will be needed to support the installation of the PA-B platform in 2005 and 2006 (and possibly 2007) and the installation of PA-A modifications in 2006 (CEA, Chapter 4). The installation will occur in two phases: the concrete gravity-base structure will be towed to the site in 2005 and the topside facility will be towed to the site in 2006. The proposed new platform site is approximately 12km offshore and 12km northeast of the channel opening of Piltun Lagoon in a water depth of about 30m. It is about 24km north of the PA-A platform and 7km east of the eastern edge of the nearshore feeding area. Whales have been seen within several kilometres of the proposed PA-B location itself. The close proximity of PA-B to the nearshore feeding area means that vessel traffic associated with platform installation will be near whales. This situation will increase the risk of whale-vessel interactions and is therefore of far greater concern than was the case for the installation of the PA-A platform and the Lunskoye platform and pipeline.

The probability of collisions is also heightened on and near the offshore feeding area. The occurrence, density and distribution of gray whales in this region are poorly known and appear to vary both within and between feeding seasons. Between-year differences may be extreme, as noted in 2004 (Weller *et al.,* 2004a). Collisions are more likely whenever visibility is poor (e.g. during vessel transits at night or during inclement weather or ocean conditions), which is common in this region.

During installation of the PA-B platform and the undersea pipelines (i.e. until November 2007), tankers will continue to load oil near the PA-A platform at a rate of approximately two tankers per 10-day period. During 2004, SEIC's Vityaz Complex completed its regular production season in December. At the end of each production season when a small number of whales may be present, a vessel delivers fuel to the Vityaz Complex for its winter operations.

2.3   Traffic on the migration route along the eastern coast of Sakahlin Island
Although the exact route used by migrating gray whales along the eastern coast of Sakhalin Island is not known, they presumably travel close to shore, as do gray whales in the eastern North Pacific. Therefore, migrating gray whales off Sakhalin Island are most likely to encounter vessel traffic near the onshore processing facility in Lunsky Bay, off the Nyiskii Bay port of Nogliki (near the Sakhalin I 'Orlan' platform in Chayvo) and northwards to the feeding ground. Any installation or transport vessel that transits 65km or farther offshore would be unlikely to encounter gray whales in the offshore feeding area or elsewhere.

2.4   Oil and LNG tankers in La Perouse (Soya) Strait and Aniva Bay
Beginning in March 2005, vessel traffic in Aniva Bay will increase as vessels begin delivering supplies and equipment to Korsakov for construction of the oil and LNG terminal at Prigorodnoye. After November 2007, when shipments of oil and gas are scheduled to commence, the number of large vessels (more than 80m in length) will increase in both Aniva Bay and La Perouse Strait. Such vessels were identified by Laist *et al.* (2001) as causing the most severe injuries to whales. At Prigorodnoye, one LNG tanker will load every two days (i.e. about 180/yr) and one oil tanker (80,000-90,000 DWT) will load every four days (i.e. about 90/yr). It is uncertain whether tugs will be used to dock the vessels at the Prigorodnoye facilities. After departure from port, the vessels will transit either to the west through La Perouse Strait into the Sea of Japan or to the east and around the eastern end of Hokkaido and through the narrow Nemuro and Notuke straits in the southernmost Kuril Islands. With the increase in traffic, the probability of vessel collisions with gray whales will increase during both the northbound and southbound whale migration.

The collision risk to gray whales posed by this new traffic was not addressed with any degree of rigour in the documents received from SEIC. Therefore, the Panel made its own assessment, using an estimate of approximately 270 oil and LNG tankers going into and out of Aniva Bay (i.e. to and from Prigorodnoye port) annually, on a more or less regular schedule. It was assumed that migrating gray whales would be present in La Perouse Strait and along the southern coast of Sakhalin for 1.5 months during the northbound migration (May to early June) and for 1.5 months during the southbound migration (late November and December) for a total of three months per year. Thus, we suggest that about 25%, or 67, of the 270 tankers carrying oil or gas from Aniva Bay would have some chance, albeit small, of striking a gray whale each year. This number is an overestimate because some proportion of the vessels will transit to the east and not pass through La Perouse Strait, and so have a much lower chance of encountering gray

whales. The tankers going east will pass through a narrow (*ca* 20km) strait between Hokkaido and Kunishara Island and through Notuke Strait (*ca* 5km), areas where gray whales have not been reported in recent years (a few may still use this route, however).

2.5   Review of proposed mitigation measures

The CEA states that since no collisions with gray whales have been reported off Sakhalin thus far, existing mitigation measures have been effective and adequate, and with continued use of those measures, 'ship-whale collisions will not represent a significant risk for continuing operations' (CEA, Section 6.7). These statements are unfounded (although it may be true that no collisions have been documented thus far). The fact that no gray whale deaths from ship strikes have been reported along the eastern coast of Sakhalin to date does not mean that the probability of collisions is zero. Whatever that probability actually is, it is bound to increase between 2005 and 2007 for three reasons. Firstly, the vessels associated with construction of the new platform and with dredging and pipe-laying will need to be closer to the nearshore feeding ground than the large-vessel traffic associated with any previous oil and gas operations in the region has been. Secondly, the number of vessels will be much larger than was the case during previous construction periods in this area, e.g. during construction of the PA-A platform. Thirdly, Exxon are expected to have an unspecified number of vessels and barges transiting on or near the offshore feeding ground to support their onshore work at two Sakhalin I sites about 10km apart and bordering the nearshore feeding ground. The amount of ship and barge traffic in and near the coastal feeding distribution of western gray whales will undoubtedly increase as the Sakhalin I and Sakhalin II projects proceed and as the other Sakhalin oil and gas projects, especially Sakhalin V, are developed. Furthermore, large vessel traffic will increase off southern Sakhalin starting in March 2005 as supplies and equipment are delivered to Korsakov for the oil and gas terminal at Prigorodnoye.

Section 6.6 of the CEA notes, 'the likelihood of a ship-whale collision is low in the vicinity of both platforms, the pipeline route, and along the designated shipping routes' and that 'mitigation measures will be used to reduce the likelihood of ship-whale collisions in all phases of SEIC operations'. However, the WGW EIA states that 'impacts from collisions … may range from low to high magnitude and can occur over the medium to long-term, at a regional geographic scale, [and] thus are *major*'. Both documents outline similar mitigation measures:

- limiting the number of vessels in the area;

- controlling vessel routes by use of sensitivity zones;

- limiting vessel speeds; and

- using marine mammal observers to allow maintenance of pre-defined vessel-whale separation distances.

2.5.1   *Limits on number of vessels*

The number of vessels in an area is presumably dictated by the operational needs of the proposed SEIC activities. At the same time, it stands to reason that unnecessary vessels already have been and will continue to be excluded from areas where they may strike whales. Continuation of this policy seems essential. If unnecessary vessels are transiting closed areas when whales are present, then appropriate sanctions presumably will be brought into force.

2.5.2   *Controlling vessel access to sensitive areas*

In spite of SEIC's description of vessel-access restrictions, it is difficult to see how vessels will not cross the offshore feeding ground (i.e. the area between Chayvo Bay and Nyiskii Bay) or closely approach the nearshore feeding area during pipeline construction. The CEA (Section 6.6) discusses the establishment of 'specific shipping lanes/corridors for transferring [transiting] vessels' and the EIA states that 'vessels will not traverse the nearshore Piltun or offshore Chayvo feeding areas unless essential for safety or specifically required and authorized'. The corridors mentioned in the CEA (Section 6.7) are not specified, nor are special procedures proposed for circumstances when vessels need to be on the feeding grounds. Several measures to ensure the highest degree of mitigation might be to (1) restrict all vessels from entering the 'Zone 1' feeding areas during night and periods of poor weather, (2) require vessels en route to or from the PA-A and PA-B sites or those assisting with pipeline construction to maintain a minimum distance of 65km from shore (i.e. the outer boundary of the offshore feeding area) between Lunsky Bay in the south and Okha in the north, and (3) require vessels to use east to west routes when approaching or leaving the PA-A, PA-B or LUN-A platform.

The zones of sensitivity outlined in the WGW PP are mentioned but not defined in the CEA (Section 6.2.2) so the status of this proposed mitigation measure is uncertain. That said, the concept of identifying the feeding areas as exclusion zones with buffers around them is logical and of value for mitigation. In light of recent findings by Burdin

et al. (2002) and Weller *et al.* (2004b) showing that in some seasons whales travel frequently between the nearshore and offshore feeding areas, a controlled area linking the two feeding grounds would be an appropriate addition to the existing exclusion zones.

2.5.3 Controlling vessel speeds

SEIC proposes to limit vessel speeds in the nearshore and offshore feeding grounds to 5 knots at night and during periods of reduced visibility, and to 7 knots during daylight with good visibility conditions. However, it is not clear how visibility is to be judged. Even on 'clear' days the visibility of whales can be almost nil if winds are high and seas rough.

Outside the feeding areas the SEIC proposal for vessel speeds is 17 knots within shipping corridors. However, as of this writing, these corridors apparently have not been defined and presumably are still being assessed. Outside the shipping corridors and during daylight with good visibility, the vessel speed limit is 10 knots. At night outside the shipping lanes the speed limit is set at 7 knots.

Reduced vessel speed appears to lower the chance of collisions considerably (Laist *et al.* 2001). However, ship strikes can occur even at slow speeds, as demonstrated by a recent event in Morro Bay, California, described below. Therefore, extreme caution, including but not limited to reduced speed, is needed when a vessel of any kind is in an area where western gray whales may occur.

2.5.4 Onboard observer programme

The use of trained onboard observers is a common strategy that has been used in a variety of contexts to mitigate risks to whales, including the risks of collisions. In theory, the observers watch for whales in the path of the ship, and if a whale is detected the vessel operator can be alerted so that a collision can be avoided. However, for large vessels, even when whales are detected, it is often too late to take corrective action and avoid collisions (Russell *et al.* 2001). Furthermore, observers may fail to see whales in time for such action, even under good conditions. This is well illustrated by a recent event (9 January 2001) in Morro Bay, California, where the propeller of a dredging vessel cut the flukes off a young gray whale. Despite the fact that trained observers were on board and the vessel was stationary with the variable-speed propeller presumably rotating slowly, the whale was not sighted prior to the accident. The fate of this whale is unknown but it is believed to have died due to the severity of the injury (James Harvey, pers. comm. to F. Gulland, January 2005). Any onboard observer programme depends on having highly trained and motivated observers, who are responsible only for searching for whales, and success in detecting whales is highly dependent on weather and sea conditions, e.g. fog, sea state and time of day or year (i.e. lighting conditions).

Observer programmes such as those proposed by SEIC to prevent collisions with western gray whales have another important limitation, unless those observers are truly independent. Any observer working for a company that stands to lose large amounts of work time (and money) when whales are sighted (requiring expensive mitigation procedures such as shutdown or diversion) is subject to a clear conflict of interest. Assuming that an observer in such circumstances will be able to maintain appropriate vigilance and judgement is more an act of faith than reason. Whether true or not, the observer may anticipate that full and accurate reporting would place his/her livelihood at risk. Thus, observer programmes require independent oversight or verification of compliance to ensure their effectiveness.

2.5.5 Pipeline alternatives

Section 6.7 of the CEA acknowledges that 'installation of the Base Case pipeline route will result in more whales being encountered and thus a greater risk of collision, than under either of the other two alternatives'. Taggart and Vanderlaan (2003) quantitatively analysed whale density and vessel traffic data to define shipping lanes that minimised the probability of an encounter between right whales and ships in eastern Canada. The unsurprising conclusion was that the risk of collision was minimised by routing ships around whale- dense areas, and this simple strategy can be interpreted as an endorsement of the Alternative 1 pipeline route. However, although the risk of collisions is likely reduced with construction of either southerly alternative (particularly Alternative 1), it is not eliminated entirely.

2.6 Additional/alternative mitigation measures

In our review of proposed mitigation measures above, we offer some suggestions on ways to specify and improve SEIC's general guidelines for restricting vessel activity on and near the gray whale foraging grounds. These include greater specificity of the terms under which vessels would be allowed to enter 'sensitivity zones', and specific routing instructions for transiting vessels associated with platform and pipeline activities.

Spatial separation of vessel traffic from areas where whales are likely to occur during migration and feeding represents the most promising and effective way of reducing collision risk. As just noted, routes that minimise spatial and temporal overlap of whales and vessel traffic will minimise risk (c.f. Taggart and Vanderlaan 2003). A possible means to minimise risk of collision for ships departing Prigorodnoye would be to route them immediately offshore from the southwestern tip of Sakhalin Island and then plot the lane through La Perouse Strait equidistant from each coast to minimise the amount of time spent transiting close to shore. While this route may add a small amount of time to the total transit, it could be applied only seasonally when the whales migrate through the area.

Similar use of lanes may reduce the risk of ship strikes off northeastern Sakhalin. Furthermore, if ships can be restricted to specific travel lanes, mitigation measures can be more effective as they can target relatively small areas. For example, a real-time update system could be employed to alert ships of the presence of whales. Based on sightings from devoted observational vessels (ships or planes), ships entering or crossing the lanes would call in and get an update of any whale sightings before entering the area. At times of high vessel traffic, the observation effort could be intensified to 'patrol' the lanes. Such an effort would introduce additional vessel(s) into the area, but smaller vessels could be used, as well as aerial surveys, to ameliorate this risk. Restricting tankers to lanes simplifies the problem because only those areas need to be kept clear.

2.7   Monitoring

A programme to detect and investigate stranded whales (as well as floating carcasses) along the east coast of Sakhalin Island would provide valuable information of particular relevance to the issue of ship strikes but also of relevance to other threat factors discussed in this report and in the risk assessment documents provided by SEIC. The utility and importance of such a programme have been demonstrated in many other contexts, but perhaps none so notable as that of North Atlantic right whales along the North American east coast (Kraus 1990; Knowlton and Kraus 2001). Such a programme would seem to be especially desirable during the next three construction seasons (2005-2007). Ideally, aerial surveys would be conducted at 10-day intervals and cover the coastline from Ohka to at least 100km south of Lunsky Bay. If any dead whale is discovered, it will be necessary to examine it on the beach to determine the species. This identification needs to be supported with photographs and a genetic sample and baleen plate. If the stranded animal is a gray whale, it would be important to conduct a necropsy to determine the cause of death.

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3   OIL AND GAS SPILLS AND ACCIDENTS

The purpose of this section is to review and evaluate the available SEIC information on: (1) the nature and potential severity of direct and indirect effects of oil spills and accidents on western gray whales and their habitat, (2) the likelihood of such effects and (3) the measures taken by SEIC to prevent and respond to circumstances that would lead to such effects.

A discussion of potential direct and indirect effects of gas releases and consequences thereof was not found in the documents provided for review. Natural gas poses a risk of platform or pipeline explosion that could disrupt production and transportation operations and have potential direct and indirect effects on the whales and their habitat. The apparent lack of attention to gas-associated risks is a serious shortcoming of plans for Sakhalin II Phase 2.

3.1   Effects of oil and gas spills and accidents on gray whales – what is known/suspected

3.1.1   Direct effects
Information on the direct effects of oil on cetaceans, particularly whales, is sparse (e.g. Geraci 1990; Loughlin 1994). This reflects the great difficulties in undertaking appropriate studies and interpreting the results. Direct effects include death or a reduction in reproductive fitness. Determining the effect of oil on the reproduction and survival of western gray whales would require *inter alia* measurement of levels of oil products in tissues and their metabolites in bile and urine, and studies to relate these to observed effects, as well as physical and histological examination of tissues to detect lesions.

Migrating eastern gray whales have been associated with several major oil spills. Dead gray whales were found associated spatially and temporally with spills in Santa Barbara, California, USA (*Union Oil* in 1969) and Alaska (*Exxon Valdez* in 1989). Three dead gray whales were found during the northward migration of gray whales after the 1969 spill (Brownell, 1971) while 26 were found between Kayak Island and Cape Sarichef after the 1989 spill (Loughlin, 1994). Although oil was present on these carcasses, the animals had been dead for weeks to months and the carcasses were too decomposed to determine either cause of death or health of organs prior to mortality. The few (*n*=3) measurements of hydrocarbon levels in either blubber or liver were insufficient to reach conclusions as to whether they had been implicated in the deaths of the animals (see Loughlin, 1994). The number of strandings after the 1989 spill (*n*=26) was considerably higher than the total number of carcasses (*n*=6) reported for the area from 1975-1987 (Zimmerman 1989) although the interpretation of this information is confounded by the fact that these areas are remote and search effort for carcasses greatly increased after the spills.

Although the direct effects of oil cannot be determined from known exposures of gray whales, they can be inferred from oil exposure in other species.

3.1.1.1   INHALATION
Inhalation of oil and petroleum products is a well-documented cause of mortality in other marine mammals that are easier to examine due to their small size. Lipscomb *et al.* (1993) reported that the most common lesion in sea otters (*Enhydra lutris*) that died during the *Exxon Valdez* spill was interstitial pulmonary emphysema (accumulation of air bubbles within the supportive connective tissue of the lung) which was observed in 73% of the heavily contaminated otters, 45% of the moderately contaminated otters and 15% of the lightly contaminated otters (n=51). Volatile petroleum compounds have been shown to cause respiratory failure, abnormal nervous system function and death in laboratory rodents (Engelhardt 1977; Cornish 1980) and neurological lesions common in harbour seals (*Phoca vitulina*) collected after the *Exxon Valdez* spill were attributed to exposure to volatile hydrocarbons (Spraker *et al.* 1994).

3.1.1.2   INGESTION
Ingested petroleum hydrocarbons have been shown to be toxic to all mammals investigated to date. Experimental exposure studies reveal that petroleum products damage gastrointestinal, pulmonary, liver, kidney, nervous and haemopoietic tissues, resulting in a range of effects from sublethal to lethal depending upon the dose ingested (ATSDR 1995 a and b). Reproductive failure and cancer are other sublethal effects observed in experimental studies of laboratory rodents and mink (ATSDR 1995b; Mazet *et al.* 2001). Accidental ingestion of oil by pinnipeds, river otters and sea otters after accidental oil spills has resulted in similar lesions including gastric ulceration, pulmonary emphysema, kidney damage, anaemia and neuronal damage (Baker *et al.*, 1981; Lipscomb *et al.*, 1993; Spraker *et al.*, 1994). Thus some adverse effects on gray whales after ingestion of oil are likely, the effects depending upon the dose and type of oil ingested. As gray whales consume large volumes of prey, contamination of a significant proportion of the feeding grounds could result in considerable ingestion of oil. For example, if oil comprised 10% of

1600kg of food consumed by a 40-ton whale, the total ingested oil would be 160kg per day, which, depending on the duration of the exposure, could be lethal (Geraci 1990; ATSDR 1995a and b).

3.1.1.3   DIRECT CONTACT

Contact with oil results in irritation of the eyes and skin of marine mammals (Geraci, 1990). Irritation occurs because cutaneous lipids are soluble in the oil and removed by contact, leading to an inflammatory response and necrosis if contact is prolonged (Walsh *et al*., 1974). Species differ in their response to short-term exposure of skin to oil. For example, ringed seals immersed in oil had ocular and cutaneous lesions and died (Geraci and Smith, 1976), whereas odontocetes that had discrete areas of skin sponged with gasoline healed within one week of exposure lasting 75 minutes (Geraci, 1990). The effects of oil on baleen whale eyes and skin are unknown but would depend on the composition of the oil (e.g. percent toxic components), the duration and extent of exposure of skin or eyes to oil, and the condition and age of the animal.

The potential effects of oil coating baleen plates are better understood. Laboratory studies using bowhead whale (*Balaena mysticetus*) baleen showed that filtering efficiency is reduced by approximately 10% when coated with Prudhoe Bay crude oil and by up to 85% when coated with oil of higher wax content (Braithwaite, 1981). Geraci and St Aubin (1985) reported similar studies for fin and gray whale baleen, finding a temporary inhibition of water flow despite minimal change in baleen structure. This inhibition by light- to medium-weight oil was eliminated rapidly when flushed with seawater, although oil residues persisted for many hours. The adhesion of oil to baleen may also promote ingestion of oil.

3.1.1.4   AVOIDANCE BEHAVIOUR

The likelihood and severity of oil spills having a negative effect on gray whales will depend upon the extent to which the whales avoid the oil. Gray whales were observed swimming in oil in March 1989 near Montague Island after the *Exxon Valdez* spill (Loughlin 1994) and in 1969 off Santa Barbara, California (Easton 1972). The fate of those animals was not determined but their movements did not appear to be altered by presence of oil on the water surface. However, Evans (1982) reported that migrating gray whales spent less time at the surface and made fewer blows when entering oiled waters adjacent to natural oil seeps along the California coast compared to when they were in non-oiled water. It should be noted that these limited studies on avoidance of oil by gray whales have been conducted on migrating animals. Feeding, non-migrating whales may respond differently than migrating whales to stimuli such as oils spills, and potentially be less likely to leave an area of plentiful prey than are migrating whales to alter their swimming course due to a similar stimulus. Other studies on reactions to oil by captive dolphins (Geraci *et al*. 1983) are not likely pertinent to the avoidance behaviour of gray whales due to the considerable physiological, anatomical and behavioural differences between baleen whales and small odontocetes. If gray whales do not avoid oil slicks, they will be vulnerable to inhalation and ingestion of oil, as well as fouling of the baleen, eyes and skin.

Given the overall uncertainty about effects on whales, the statements given in the Lunskoye 2004 Gray Whale Protection Plan that 'whales are normally not affected by oil carpets' and 'will avoid polluted areas' and that the potential effects of oil will be of 'short duration (<1 month)' and 'moderate severity' are not supported by the available data. Further, statements in the CEA (Chapter 7) that 'ingestion is considered unlikely as most marine mammals do not drink large amounts of sea water' and that 'to feed in the vicinity of a substantial spill for a prolonged period of time, something that would be [sic] appear unlikely' are unfounded. Whales could ingest oil with prey and after its adhesion to baleen, and in this way they could ingest considerable amounts of oil if the feeding grounds were contaminated. Other statements in the CEA (Chapter 7) – e.g. that 'inhalation of volatile hydrocarbons could potentially result in inflammation of the mucous membranes, lung congestion, pneumonia, neurological disorders and liver damage' and 'oil is a systemically harmful substance and ingestion may result in gastrointestinal irritation, vomiting, pneumonia and even death' – are plausible. These latter statements indicate that if the 'precautionary approach is used throughout this assessment', as stated in the CEA (Section 7.5.1.1), then effects on whales would be assumed to be similar to those documented in other mammals and likely to result in decreased survivorship and reproduction. Although the CEA (Chapter 7) does not come to a conclusion on the direct effects of oil on western gray whales, the WGW EIA concludes that 'the impact from a major oil spill could be significant to the whale population'. A spill near the feeding grounds could result in deaths due to direct contact of whales with oil.

3.1.2   *Indirect effects*
3.1.2.1   INTRODUCTION

Gray whales forage primarily on crustaceans associated with benthic habitats although they consume other marine invertebrates as well. Oil spills are toxic to marine invertebrates in certain circumstances and habitat types.

Spilled oil can result in surface 'slicks' of various physicochemical configurations, hydrocarbon vapours in the air immediately above the sea surface, dissolved hydrocarbons in the water column, suspended oil globules in the water column, oil adsorbed to small particles of suspended sediments in the water column, layers or patches of oil on the sea bottom, and interstitial concentrations of oil within benthic sediments or among biogenic benthic structures such as amphipod tube mats. In all such forms spilled oil can kill or injure marine invertebrates. Benthic accumulations of spilled oil can be long-lasting if oil becomes incorporated interstitially into bottom sediments or biogenic structures such as amphipod tube mats. Structural integration may shelter the oil from physical weathering such as sand abrasion and reduces the rate of dissolution into the water because of reduced surface area exposed to the water. The likely result is greater temporal persistence and increased risk of chronic damage to prey.

The literature is sparse regarding impacts of oil spills on the benthic invertebrates of sandy sub-littoral habitats along fully exposed open shores such as those of Sakhalin Island. Some conceptual models suggest that recovery of ecological communities from oil spill effects is more rapid on highly exposed shores than in physically protected locations such as bays or estuaries. We were unable to find published literature explicitly describing known or potential effects of oil spills on prey populations of gray whales near Sakhalin Island. Limited data are available on effects of the *Tsesis* oil spill of October 1977 on benthic communities of the Baltic Sea (and see Annex D). We summarise those data below (Section 3.1.2.3) because (a) benthic communities in the Baltic region bear striking structural similarities to those of the northeastern Sakhalin shelf, (b) we are aware of no other well-documented oil spill event in a location with benthic communities more similar to those of northeastern Sakhalin and (3) the technical literature on benthic community ecology in the Baltic region is detailed and excellent. We also summarise known benthic ecological effects of the *Nakhodka* oil spill of 1997 in the Sea of Japan. Although affected habitats are substantially different from those of northeastern Sakhalin, the *Nakhodka* spill occurred relatively near the Sakhalin region and its ecological effects were documented in some detail.

Epibenthic habitats are extraordinarily important to the nutritional health of the western gray whale population (see Annex D and Fadeev 2003). The great majority of abundant benthic species in the feeding areas, including those known to occur in the gray whales' diet, rely heavily on ecological processes on the sediment surface and within 1-2cm of the surface for nutrition, shelter from predators and habitat. The key sources of primary production for the benthic communities are microalgae attached to the sediment surface, phytoplankton in the epibenthic water column, phytodetritus accumulating on the sediment surface from the water column, and detritus and associated microbiota advected from other locations to sediment surfaces in the feeding areas. Many of the known or potential prey species live on or within a few centimetres of the sediment surface, are herbivorous or detritivorous, and have vertical distributions clearly linked to the location of the benthic food base. Effects of oil spills on gray whale prey populations depend fundamentally on the extent to which spilled oil, in its various forms and products, reaches the sediment surface. The dependence of whales on food produced or aggregated on a dynamic sediment layer of 1-2cm thickness may be a highly fragile circumstance that could be disrupted either temporarily or permanently by disturbances resulting from the Project.

3.1.2.2   FACTORS INFLUENCING THE PROBABILITY OF CONTACT OF SPILLED OIL WITH PREY POPULATIONS
The significance of direct contact of spilled oil with western gray whale prey will depend on:

(a) the probability that spilled oil will reach important aggregations of prey, which will vary by volume, season and spill location;

(b) condition of the oil at the time it reaches prey aggregations;

(c) prey aggregations (benthic, midwater or sea surface) of greatest importance to the whales at the time;

(d) vulnerability of prey to the oil (e.g. fouling of feeding apparatus, acute mortality, reproductive impairment);

(e) effects of dispersant, if applied, on the above considerations.

Factors a, b, c, and e are considered in this section, with factor d covered in section 3.1.2.3.

Resolution of key questions regarding oil spill effects on prey requires modelling of spilled oil behaviour, collection of data on prey populations in the area and empirical study of the effects of spilled oil of various kinds on those populations. As noted in section 3.1.3, the Project CEA considers potential spill sizes for different Project components and characterises likely trajectories for floating oil. As noted below, trajectory modelling studies in the CEA are based on single projected oil spill sizes and do not address the full range of possible oil spill sizes or trajectories that could result from the Project.

Determination of excursion envelopes for Project-associated oil spills could have been followed with quantitative calculations of the proportion of the two known whale feeding areas included in excursion envelopes for each oil spill scenario reviewed in Chapter 7 of the CEA. It is surprising that these calculations were not done, given the obvious relevance of such information to the general question of oil spill effects on gray whales. In the absence of any calculations in the CEA, the Panel had to rely on qualitative estimates of inclusion of feeding areas in excursion envelopes, based on simple visual inspection of figures shown in the CEA. Our estimates are given in Table 2.

Table 2

Qualitative estimates of proportion of gray whale feeding areas included in 48-hr excursion envelopes as presented in the CEA (Chapter 7, Figs 7.7 – 11)

Spill source structure	Season	Proportion of gray whale feeding area	
		Nearshore area	Offshore area
FSO at Vityaz	Spring	*Ca* 50%	*Ca* 95%
Pipeline at PA-A platform	Summer	*Ca* 90%	100%
Pipeline at PA-B platform	Summer	100%	*Ca* 50%
Base-case pipeline, 1km offshore	Summer	*Ca* 85%	*Ca* 25%
Base-case pipeline, 10km offshore	Summer	*Ca* 95%	*Ca* 95%
Pipeline Alternative 1, 1km offshore	Summer	*Ca* 60%	*Ca* 70%
Pipeline Alternative 1, 10km offshore	Summer	*Ca* 75%	*Ca* 95%
Pipeline Alternative 2, 1km offshore	Summer	*Ca* 85%	*Ca* 80%
Pipeline Alternative 2, 10km offshore	Summer	*Ca* 80%	100%

Patterns of dispersal of spilled oil off the northeastern Sakhalin coast will be influenced by wind speed and direction and by the current field. Currents in and near the Project area have been evaluated by Dobrynin *et al.* (2004), a document that is not mentioned in the CEA but is highly relevant to the issue of oil spill risk. The current field is influenced fundamentally by aperiodic large-scale flow determined by the three-dimensional density field, by nearshore eddies, jets and other forms of mesoscale turbulence generated by interactions of large-scale flow with coastal geomorphological features, and by periodic flows generated by tidal forces. Tidal flows at lagoon entrances and freshwater input from Sakhalin Island watersheds to the coastal zone, either through lagoon entrances or directly across the coastline, will have additional significant local effects on the current field. Modelling of the current field in the Project area for purposes of oil spill trajectory analyses is of extraordinary importance and is extremely challenging technically. Descriptions of analytical methods for trajectory analyses in the CEA are inadequate. As noted above, the CEA does not present model results for risks and trajectories for a broad range of spill volumes, and presents only cursory analytical results. This circumstance hinders the task of evaluating potential effects of the Project on western gray whales.

The excursion envelopes presented in the CEA describe a spatial field within which spilled oil may reasonably occur at the specified time after a spill. The envelopes do not represent the estimated size of a surface slick of spilled oil. Nevertheless, a precautionary interpretation of the envelopes indicates that spills of 'maximum credible volumes' assumed in the CEA are quite likely to move through significant portions of the nearshore and offshore feeding areas.

The CEA describes the crude oil that has been extracted from the PA-A platform as relatively light, indicating low specific gravity and high concentration of volatile components. Spilled light crude oils are likely to weather more quickly than heavy crude oils, but are generally more toxic to marine life due to their volatile components. The CEA projects likely persistence times for spilled Vityaz crude oil. However, it does not define 'persistence' precisely, and thereby confounds any effort to link changes in oil condition over time and potential effects on benthic invertebrates. Persistence time is estimated to be 120hr or more for summer conditions with sea surface temperature at 15ºC and mean surface winds of 5 knots or less, and 18hr or less for summer conditions with sea surface temperature at 15ºC and mean surface winds of 15-25 knots. These estimates indicate that sea surface temperature and wind speed are important determinants of persistence time, but the CEA does not give the year-round information on regional sea surface temperature and wind speed needed to predict their actual influence on persistence times of spilled oil. Since the waters in this region are covered with ice for about six months, it is reasonable to assume that sea surface temperature is well below 15ºC for most of the year. Indeed, unpublished measurements taken during research on the Piltun feeding ground indicate that temperatures are well below 15ºC even in the summer. Mean (minimum, maximum) sea surface temperatures from 1999 to 2003 were 9ºC (1.6ºC, 16.1ºC), 10.4ºC (5.1ºC, 15.1ºC), 8.3ºC (3ºC, 11ºC), 9.2ºC (3ºC, 12.5ºC), 2.6ºC (-1.5ºC, 6.5ºC), respectively (Weller *et al.* 2000, 2001, 2003a, 2003b, 2004).

Thus, the available information is not sufficient to determine persistence patterns or rule out persistence times that are sufficiently long to expose the feeding areas, whales and prey populations to oil and at least some portion of its more toxic components.

A second caveat to estimation of persistence time involves physicochemical changes in spilled oil (i.e. weathering). In conditions of heavy weather and seas, spilled oil is often mixed with surface seawater at a sufficient level of energy to create water-in-oil emulsions, often termed 'chocolate mousse'. Emulsions of this type are characterised by extended persistence times (often measured in weeks) and greatly reduced rates of chemical weathering over time. The CEA does not explicitly consider effects of possible emulsification processes on persistence time, and as a result may be underestimating the persistence of oil spills at sea. Underestimation of persistence time contributes to important biases in estimating both trajectories and excursion envelopes for spilled oil. As a consequence, sizes of excursion envelopes presented in the CEA are very likely biased downwards.

Chemical dispersants are applied to emulsify floating spilled oil into small droplets that are more readily dispersed from the sea surface and result in greater dissolution into the water column. The premise behind use of dispersants is that they reduce the risk of environmental damage. Their use certainly reduces the visibility of spilled oil and may give the impression that environmental risks have been lessened. However, oil droplets dispersed into the water column are more likely to reach benthic habitats and bind to sediment particles or to the tubes or other biogenic structures of benthic organisms, as compared to untreated oil slicks on the sea surface. Thus, they may actually increase the likelihood of damage to benthic communities, with consequent negative effects from both the oil and the dispersant itself.

3.1.2.3   KNOWN EFFECTS OF THE *TSESIS* AND *NAKHODKA* OIL SPILLS, WITH IMPLICATIONS FOR BENTHIC COMMUNITIES IN FEEDING AREAS OF WESTERN GRAY WHALES.

The *Tsesis* spilled ~1,100 m^3 of medium-grade fuel oil in the Baltic Sea in October 1977. Within 16 days of the spill, populations of the benthic amphipod *Pontopoteira affinis* Lindstroem and the benthic polychaete *Harmothoe sarsi* Kinberg had declined to 5% of pre-spill biomass densities at the most heavily affected station (Elmgren *et al*. 1983). Other macrofaunal species showed minimal mortality but substantial contamination of tissues. The densities of meiofaunal species, including ostracods, harpacticoid copepods, kinorhynchs and turbellarian flatworms were significantly reduced. During winter months following the spill, eggs of gravid female *Pontoporeira affinis* had significantly increased rates of malformation and failed development. Oil residue was transferred through the food web from benthic invertebrates to benthic fishes. Affected components of benthic communities in the spill area had not recovered five years after the spill (Elmgren *et al*. 1983). *Pontoporeira affinis* is one of the most abundant benthic invertebrates in feeding areas of western gray whales (see Annex D) and is likely a significant prey for them.

The *Nakhodka* spilled ~6,200 m^3 of heavy fuel oil in January 1997 near Mikuni-cho shore in the Sea of Japan. Rocky intertidal fauna from the affected area showed varying levels of contamination (indexed by concentrations of polycyclic aromatic hydrocarbons [PAH]) within the first month after the spill; Koyama *et al*. 2004). Tissues of the gastropod mollusk *Turbo cornutus* initially contained high PAH concentrations but PAH levels dropped rapidly in the following month. The data of Koyama *et al*. (2004) suggest relatively complete recovery of Mikuni-cho intertidal invertebrates three years after the *Nakhodka* spill.

Studies following the *Tsesis* spill provide unequivocal cause for concern regarding possible oil spill effects on benthic communities used by western gray whales for food. A precautionary interpretation of those studies suggests that oil spills directly affecting preferred feeding areas could reduce food availability to feeding whales over an extended time period, with unknown but potentially serious consequences for fitness and population growth in the whale population. Application of *Nadhodka* data to the Project area is of limited predictive value because post-spill studies focused on rocky intertidal habitats, which are uncommon on the northeastern Sakhalin shelf and probably have little significance to the ecology or productivity of gray whale feeding areas.

3.1.2.4   KEY SCIENTIFIC INFORMATION AND GAPS:

Prediction of oil spill effects will be enhanced by several types of information currently not available, including:

- direct acute toxicity of spilled oil to prey, by prey species;

- pattern of change over time in acute toxicity of oil to prey, by prey species, due to natural weathering of spilled oil;

- plteration of acute toxicity patterns for spilled oil resulting from application of dispersants;

- chronic effects of spilled oil on prey health and life history, including age-specific survival rates, age-specific fecundity rates, feeding efficiency and population-level resilience to additional disturbances, both natural and anthropogenic (e.g. a second spill);

- acute and chronic effects of spilled oil on prey food supply;

- potential for spill-derived contaminants to concentrate through the food chain and become detrimental to gray whale health and population parameters;

- potential patterns of acute and chronic toxicity and health impairment of gray whale prey in the event of spillage of drilling muds, domestic sewage or other toxic pollutants from offshore drilling platforms or other categories of project infrastructure.

The lack of such information does not rule out the potential for ecologically significant effects on western gray whale prey.

3.1.2.5 POTENTIAL RISKS AND IMPACTS

Given the existing lack of critical information, reliable quantitative predictions of oil spill risks to gray whale prey cannot be made. At best, we can identify plausible consequences of a significant spill within the Piltun foraging area.

A plausible scenario is that spilled oil will cause either a temporary or permanent reduction of prey available to foraging gray whales. In such a scenario, whales may respond in several ways. If they continue foraging in traditional habitat they must either accept lower rates of intake of preferred prey, or shift their foraging effort to less frequently used, and presumably less nutritionally rewarding, prey types. In either case, net nutritional gain may be diminished, with consequent reductions in vital demographic rates. If whales move to new foraging locations as a result of prey contamination or loss in traditional foraging habitat, a number of questions arise, including the following:

- Where will they relocate and what will be the associated costs (e.g. energetic) or risks (e.g. predation)?

- What food is available at alternative sites and is it sufficient in terms of biomass?

- How will whales respond if available biomass is not sufficient at the new sites? Will their condition and survival be affected? Will they continue to search until good alternative feeding areas are found? What are the spatial and temporal limits to a search for new foraging habitats before demographic consequences become significant?

The possibility that spilled oil could enter Piltun Lagoon raises considerable concern. Circumstantial evidence suggests that organic detrital effluent from Piltun Lagoon is an important source of food for benthic communities outside the lagoon. This possibility may explain the fidelity of gray whales to the Piltun foraging area. Should spilled oil alter the lagoon such that detrital effluent is curtailed, the consequences for the gray whale population could be catastrophic. In concept, such a scenario could be investigated using appropriate field research methods. Without such studies, the effects of this and other plausible scenarios about indirect effects cannot be evaluated.

Ultimately, determination of possible oil spill effects on gray whales requires assessment of the loss of prey biomass to the whales and their ability to compensate for those losses

Information needed to predict cumulative impacts of other Sakhalin oil and gas projects, both onshore and offshore, suffer the same limitations noted above.

3.2 Assessment of threats from proposed activities - likelihood of occurrence and potential impact at population level

Any assessment of the threats to western gray whales of oil and gas spills as a result of Sakhalin II Phase 2 requires quantitative risk assessment and spill trajectory modelling. If undertaken correctly, this will inform decision-makers on:

- areas of potential failure associated with oil and gas extraction, storage, and transportation (including distribution of pollutants by local sea currents);

- vulnerable species and habitat that may require special protection.

It will also provide them with information to guide:

- construction and operational plans to reduce the probability of failure (e.g. location of platforms and pipelines);

- prevention strategies to avoid potential spills/accidents; and

- response strategies to minimise the effects of potential spill/accident effects.

This section reviews the results of SEIC's quantitative risk assessment and spill trajectory modelling, as well as the potential consequences of oil and gas spills on the western gray whale population. It is important to stress that given the time schedule for review and the level of information provided, the Panel had no choice but to assume that the risk assessment techniques and models used by SEIC were appropriate and that the information and data presented in the CEA were accurate. The following review therefore qualitatively examines the risk assessment/modelling exercise and considers whether the conclusions reached by SEIC appear justified by the results presented.

3.2.1 Quantitative risk assessment
Sakhalin II Phase 2 involves the following elements:

- replacement of the Phase I FSO-Tanker oil transportation system with oil and gas pipelines from the existing PA-A platform to shore.

- extension of PA-A platform operations to a year-round schedule.

- construction of the PA-B platform followed by year-round operation.

- construction of additional pipelines from Platform PA-B to the PA-A pipeline and then on to shore.

- construction of the Lunskoye platform and associated pipeline to shore.

- construction and operation of 800km of pipeline to southern Sakahlin and Prigorodnoye export terminal and associated tanker transport from the terminal.

The Panel considered the following issues in its review of SEIC's quantitative risk analysis of Phase 2:

- replacement of the Sakhalin II Phase I FSO-Tanker transportation system and associated risks to western gray whales.

- the additional probability of a spill/blowout from construction and year-round operation of a second platform (PA-B) and associated pipeline.

- the probability of a spill from each of the three pipeline alternatives and associated risks to western gray whales.

- the overall probability of a Sakhalin II Phase 2 oil spill/accident that significantly affects western gray whales.

To address these questions, the Panel reviewed the CEA for evidence that the analyses by SEIC adequately identified the key operations; characterised the nature of potential hazards associated with each operation; reasonably estimated the probability of occurrence of each hazard; accurately and fully characterised the potential consequences of each hazard; and provided a reasoned, comprehensive, and understandable explanation of the resulting risks associated with Sakhalin II Phase 2.

The review below is based on or derived from the probabilities of spills, accidents, or blowouts ('releases') reported in the CEA. As noted above, without more detailed information on the methods and data used by SEIC to calculate spill probabilities for the different components of Phase 1 and Phase 2 operations, we have been required to assume that they are accurate. We also assume that the lifetime of Phase 1 in its current configuration is 3 years, and the lifetime of Phase 2 in its proposed configuration is 30 to 40 years. If that is the case, then the probabilities of interest are those in Table 3, which is an expansion of Table 7.1 in the CEA. It is noteworthy that the probabilities are expressed in the CEA as precise values rather than ranges; we would expect ranges to provide a more realistic expression of probabilities. It is also worth reiterating that the numbers provided indicate the probability of these events, but do not address consequences. Furthermore, correctly characterizing the probability of unlikely events is inherently difficult and the probabilities reported below should be recognised as rough estimates based on data that we have not been able to verify; thus, they are of uncertain reliability.

Table 3

Probabilities of 'releases' occurring during the lifetime of Phases 1 and 2, based on values given in the CEA.

Source	Release probability per year	Expected lifetime (years)	Probability of at least one release per expected lifetime
FSO/shuttle tanker	0.076	3	0.21
PA-A SALM and pipeline	0.0014	3	0.0042
PA-A pipeline base case	0.0018	30-40	0.053 - 0.070
PA-A pipeline alt. 1	0.0029	30-40	0.083 - 0.11
PA-A pipeline alt. 2	0.0025	30-40	0.072 - 0.095
PA-B pipeline base case	0.0027	30-40	0.078 - 0.10
PA-B pipeline alt. 1	0.0038	30-40	0.11 - 0.14
PA-B pipeline alt. 2	0.0035	30-40	0.10 - 0.13
PA-A blowout	0.00032	30-40	0.010 - 0.013
PA-B blowout	0.000467	30-40	0.014 - 0.019

3.2.1.1   REPLACEMENT OF THE SAKHALIN II PHASE I FSO-TANKER TRANSPORTATION SYSTEM WITH A PIPELINE SYSTEM AND ASSOCIATED RISKS TO WESTERN GRAY WHALES.

From a western gray whale perspective, the main proposed changes can be divided into those that reduce risk and those that increase risk. The former include discontinued use of

- the sub-sea pipeline from PA-A to the SALM and removal of the SALM,

- the FSO including loading from the pipeline and offloading to tankers, and

- tanker-based transport of oil-laden tankers along the east coast of Sakhalin Island.

The latter include:

- installation and use of a pipeline from PA-A to shore,

- increased operation of the PA-A platform from a seasonal to full-year schedule, and

- construction of an export terminal at Prigorodnoye and associated tanker traffic.

The CEA (Figure 7.1, p 7-5) indicates that the net change in the probability of a release associated with the transition from Phase 1 to Phase 2 (including the PA-B platform and associated pipeline) will be a reduction from 7-8 percent per year to about 1 percent. The reduction appears to result primarily from the change from a tanker-based system to a pipeline-based system for transporting oil and gas from the PA-A platform.

Although these estimates of release probability are informative, they are not comprehensive. First, they do not include the potential for platform blowouts. On an annual basis, the potential for a blowout will increase by a factor of about two for the PA-A platform as it changes to year-round operation (assuming the risk of a blowout is similar in winter and summer months). Second, they do not indicate the probability of a failure over the expected lifetime of the project.

Clearly, the primary probability of concern is not the probability of a failure on an annual basis, but rather the overall probability over the lifetime of the project. Although related, a false impression of the actual risks may be given if only annual probabilities are provided. For example, if Phase 1 were to continue in its current configuration for an additional 40 years, then the estimated probability of at least one spill or blowout during that period would be about 0.96, with the largest portion of that due to the probability of a spill associated with the FSO or shuttle tankers. In contrast, replacing the SALM/FSO/shuttle transportation system with a pipeline (the assumed 'base case' is the preferred option of SEIC) and switching the PA-A platform to year-round operation results in an estimated probability of 0.081 that at least one spill or blowout will occur over the next 40 years. Thus, changing the oil transportation system associated with PA-A results in a marked reduction in the probability of at least one spill or blowout off northeastern Sakhalin Island. The question remains as to whether a 0.081 chance of a spill or blowout comprises an acceptable level of risk.

In addition, although the CEA indicates that the level of risk associated with Phase 2 is an order of magnitude lower than for Phase 1, an alternative but still valid interpretation of this comparison is that continued operation of Phase 1 during the transition period may pose an unacceptable level of risk.

Finally, these probabilities do not take into account risks associated with the construction and operation of the Prigorodnoye export terminal and associated LNG and oil tankers. This terminal and associated tankers are a

significant component of Phase II. Although gray whales do not feed in this region, they do migrate through it in both spring and fall, placing them at risk of oil exposure in the event of a spill. As tanker-based transportation is known to constitute a significant risk of a spill, specific information was requested on all tankers that have loaded at the Vityaz Marine Terminal and those that will be used to carry oil from the Prigorodnoye export terminal. All that was provided was a list of names, ages and hull configurations for tankers that have loaded to date. Thus, a credible characterization of the fleet with regard to spill risk was not possible. The increasing use of double-hulled tankers will significantly reduce spill risk. Nonetheless, a full analysis of risk associated with tanker operations is essential for a comprehensive understanding of risks associated with Sakhalin II Phase 2.

3.2.1.2 THE ADDITIONAL PROBABILITY OF A SPILL/BLOWOUT FROM CONSTRUCTION AND OPERATION OF A SECOND PLATFORM (PA-B) AND ASSOCIATED PIPELINE

The added probability of a spill or blowout from construction of platform PA-B and associated pipeline can be calculated from Table 3, assuming that all the potential sources of an accident are included in the numbers provided in the CEA. Over a 40-year lifetime, the probability of at least one blowout at PA-B would be $1-[(1-0.000467)^{40}] = 0.019$, and the probability of a pipeline spill (assuming the base case) would be $1-[(1-0.0027)^{40}] = 0.10$. The probability that at least one spill or blowout would occur would be 0.12. When the annual probability of a blowout from platform PA-B is added to the increased probability of a blowout from year-round operation of platform PA-A, the annual risk of a blowout increases about five-fold with the transition to Phase 2, and the 40-year lifetime probability of at least one blowout increases from 0.0064 to 0.031.

3.2.1.3 THE PROBABILITY OF A SPILL FROM EACH OF THE THREE PIPELINE ALTERNATIVES AND ASSOCIATED RISKS TO WESTERN GRAY WHALES

The CEA provides estimates of the annual spill probability associated with the different pipeline alternatives from each of the platforms separately. It does not combine those estimates to provide the total risk for each alternative per year or over the lifetime of Phase 2. Assuming a lifetime of 40 years, the probabilities of a spill from the various options are given in Table 4.

Table 4

Probabilities of a spill occurring for the various pipeline alternatives based on values given in the CEA

Alternative	Annual probability of a spill for alternative	Probability of at least one spill over a 40-year lifetime
Base case	0.0045	0.16
Alternative 1	0.0067	0.24
Alternative 2	0.0060	0.21

Based on these values, the base-case route appears to have the lowest probability of a spill, Alternative 1 the highest probability, and Alternative 2 an intermediate probability. Presumably, the different spill probabilities for the pipeline alternatives are related simply to their different lengths. However, to evaluate fully the risks associated with these alternative routes, one must also consider the consequences of pipeline construction as well as the consequences of a pipeline spill. For example, construction of the base-case pipeline would result in the most disturbance to the nearshore foraging habitat and spilled oil from the base-case pipeline would be most likely to have significant effects on the nearshore foraging habitat, assuming all other things are equal. The CEA did not discuss in any detail the relative consequences of spills associated with the alternatives, but they could be important and are considered in more detail below in section 1.3.1.1 (selection of platform location and pipeline alternative).

3.2.1.4 THE OVERALL PROBABILITY OF A SAKHALIN II PHASE 2 OIL SPILL/ACCIDENT THAT SIGNIFICANTLY AFFECTS WESTERN GRAY WHALES.

Based on the information provided in the CEA, the overall lifetime probability of a Phase 2 oil spill or platform blowout can be estimated as 0.19 (based on pipeline base case) to 0.26 (based on pipeline alternative 1). Because the probability and consequences of a pipeline spill versus a platform blowout may be markedly different, it may be more appropriate to assess these risks separately. As indicated above, the lifetime probability of at least one pipeline spill ranges from 0.16 (base case) to 0.24 (alternative 1) and the lifetime probability of at least one platform blowout appears to be about 0.031.

As noted earlier, the probability estimates reported here should be viewed with some caution because they are based on numbers provided in the CEA and have not been verified by the Panel. To the extent that the estimates were based on past performance in the oil industry, they may be biased either positively or negatively depending, in part, on whether the measures of past performance pertain to situations or conditions similar to those characteristic of Sakhalin II Phase 2. For example, it is not clear that the industry measures reflect the type of winter conditions expected off Sakhalin Island or the high level of seismic activity in this region. It is also not clear if the industry measures accounted for spills or accidents related to gas production and transportation. Finally and importantly, the numbers suggest the probability of a spill or blowout event, but do not indicate the nature of the consequences. That will depend on, among other things, what happens to the spilled oil when an accident occurs. Thus, spill or blowout trajectory modelling is necessary to understand the potential consequences of such events.

3.2.2   *Spill trajectory modelling*

The purpose of spill trajectory modelling is to predict the movement and fate of oil or gas when released during plausible spill or accident scenarios. Combined with estimates of the likelihood of each of those scenarios, the resulting information provides a basis for assessing the risks to sensitive species/populations (e.g., gray whales) and habitat. As was the case with estimating spill probabilities (above), our review of spill trajectory modelling was limited by both the time available and the amount of information provided in the CEA, which prevented verification of modelling methods and results.

The following conclusions are based on results reported in the CEA and in published literature:

- Oil spills of the size modelled are reasonably likely to affect both the nearshore and offshore foraging areas and may do so within a matter of hours to a few days, as noted in section 3.1.2.2.

- Physical processes, including currents, winds, and tides, would influence the movements and fate of spilled oil. A description of the ocean currents in this region (Dobrynin *et al*. 2004) indicates complex current patterns, and it is not clear that these patterns were incorporated into the spill trajectory modeling exercises.

- The feeding areas appear be at risk from spills originating from all three pipeline alternatives despite the statement in the CEA (p. 28) that 'only the base case pipeline route could result in direct oil impact on the sediments within the identified WGW feeding area.' However, the risks to the nearshore foraging area appear to decrease with the more southerly alternatives. The effect of this apparent reduction in risk on the choice of pipeline alternative is not quantified in the CEA.

- As noted in section 3.1.2.3, available published information, particularly studies of the *Tsesis* oil spill in the Baltic Sea in 1977, indicates substantial vulnerability of known or potential gray whale prey species. Further, as noted in section 3.1.2.2, the nutritional base for known or potential prey populations in the Project area is linked strongly to production processes in a thin layer that includes the sediment surface and the top few centimetres of the sediment column. It follows that ecosystem integrity likely is vulnerable to any event causing contamination of the sediment surface, and any potential incursion of spilled oil onto the feeding areas, as indicated by trajectory probability analyses, is likely to have major indirect effects on the western gray whale population.

- The potential indirect effects of spilled oil may decrease with increasing ocean depth. From that perspective, the nearshore foraging area may be more vulnerable to the effects of a spill than the secondary (offshore) area. In this regard, the CEA notes (p. 30) that oil from the *Exxon Valdez* was not discernable below 40m in most of Prince William Sound and effectively absent below 100m. However, the nearshore foraging area of gray whales off Sakhalin Island is in waters generally less than 20m deep and even the secondary area is in waters less than 50m deep.

- The CEA estimates 'maximum credible' volumes from pipeline spills by assuming that the leak detection system will work effectively. This system is expected to detect a spill of 1% or more of the volume transported. If oil transport from a platform is on the order of 70,000-90,000 barrels per day (CEA, pp. 8, 12), then leaks of up to 700-900 barrels per day (110-140m^3) could go undetected. If such leaks persisted for several days, they could exceed the maximum credible amounts modeled. With regard to the pipeline leak detection system, the oil spill quantitative risk assessment (Risktec 2004) itself recommended (and the Panel concurs) that 'an assessment of the system reliability and availability should be conducted during commissioning to ensure that the system performance criteria can achieve the levels assumed….'

- In the event of spills below the leak detection threshold or failure of the leak detection system, visual observation appears to be the only means of detection. The efficacy of visual detection of leaks will vary considerably with conditions (e.g. sea state, presence of ice, amount of daylight) and it can be considered neither a reliable backup system nor a primary system for detecting such leaks. Without adequate detection, chronic or repeated leaks pose a cumulative risk to gray whales and their habitat.

- The CEA did not model the worst-case scenario, i.e. that of a platform blowout, but such modelling is essential for a thorough and unbiased assessment of risk. The risks associated with such a low-probability event may exceed considerably those from the spills that were modelled. A blowout could result from the influence of natural factors (e.g. storms, extreme seas, earthquakes, tsunamis, ice build-up or scour) or human-related factors (e.g. equipment or control system failure, error in human judgement; Steiner, 1999; Phase I EIA) or even terrorist attack. Well blowouts (e.g. as a result of over-pressurisation), platform explosions and/or fires could release significant quantities of oil and/or gas into the marine environment. For example, Sakhalin NIPImorneft estimated that a (winter) well blowout could result in as much as 230,000 barrels (~36,600 m^3) being released into the environment over a 20-30 day period (Phase I EIA); this is comparable to estimates of the oil spilled by the *Exxon Valdez*.

- The CEA did not model spills occurring during winter months when weather conditions may be more severe than those modelled (10-year averages for spring, summer and autumn) and when the sea may be covered with ice. Again, such modelling is essential for a thorough and unbiased assessment of risk. The behavioural dynamics of spilled oil and the factors that influence them (e.g. wind) may be considerably different during winter months when the sea is covered with ice. Spills during the winter may not have immediate direct consequences for gray whales but are likely to have significant consequences for gray whale habitat and prey. These then could have serious, albeit delayed, direct and indirect consequences for the whales when they return to the feeding grounds.

- Seismic activity in the Sakhalin region poses an unknown but potentially significant risk to the platforms and pipelines. With respect to seismic activity, the Expert Commission (State Expertisa) stated that 'Sakhalin Oblast and surrounding offshore parts of the Sea of Okhotsk and Tartar Strait are characterised by a very high degree of seismic hazard with the northern part of the island and the adjacent waters to the east being in a zone of seismicity 10'. They note that 'the probability of seismotectonic dislocations, especially along active faults, is very high'. Although they were referring specifically to the potential for pipeline failure, some risk to platforms is indicated as well. SEIC maps indicate that the proposed location of the PA-B platform is directly over a system of shallow faults, and that pipelines will either cross or run in close proximity to these faults. The proximity of these faults to the planned platform and pipelines raises serious concerns regarding seismic risk, particularly from large destructive earthquakes. Two major earthquakes occurred in the northeastern region of Sakhalin in the recent past, one at Nogliki in 1964 and one at Neftegorsk in 1995.

- The CEA did not model the effects of spills and accidents on gray whales and their habitat as a result of an accumulation of leaks, spills and accidents over the lifetime of Phase 2. Such an exercise is essential to a thorough and balanced assessment.

3.3   Mitigation – prevention, response and monitoring

The effectiveness of oil spill mitigation measures will be determined by the extent to which spilled oil is kept physically and trophically separate from prey populations and underlying ecological mechanisms that sustain the western gray whale population. Experience with other major oil spills (e.g. *Exxon Valdez* oil spill of 1989) indicates two mitigation strategies may be most effective. The first is a focus on prevention, recognizing that reduction of impacts resulting from response to an oil spill is trivial compared to the magnitude of impacts avoided altogether by effective spill prevention. The second is a focus on preparation, given the likelihood that prevention will be imperfect. Response measures that are adequately funded, of appropriate scale and scope, fully supplied and equipped, and operational *prior* to spill events are certain to be significantly more effective than any measure developed and implemented after a spill occurs.

SEIC documents often refer to prevention measures based on 'best practice' or 'internationally accepted standards'. However, they do not define those standards in the context of activities associated with Sakhalin II Phase 2. This lack of specificity with regard to standards precludes a proper evaluation of many of the planning and conservation decisions made by SEIC with respect to gray whales. Similarly, it precludes interested parties, including the public,

from developing a clear understanding of the actual risks involved and the value judgements that were brought to bear in decision-making. Many of the resources that are put at risk by oil and gas development are of interest to the public. For that reason, forthrightness and transparency are required to identify and appreciate the nature and extent of risk involved. Such openness seems particularly relevant in circumstances such as these, where the public may need to respond to oil spills and gas releases (as described below). In fact, their ability to respond effectively will depend, in part, on the extent to which they are adequately informed. Because other parties, including the public-at-large, have expertise that will contribute to overall mitigation efforts, some mechanism for involving them in decision-making or oversight not only seems prudent, but also may enhance overall prevention and response efforts. Public involvement has proven effective elsewhere in reducing and managing risks from large-scale oil and gas development activities (e.g. in Alaska and Scotland; see Steiner 1999, 2003; Lawn *et al.* 1999).

3.3.1   Prevention
SEIC documents provide considerable discussion regarding prevention and mitigation efforts for Sakhalin II Phase 2 (see, for example, table 7.7 of the CEA and chapter 7 of the WGW EIA). Whether and to what extent prevention efforts will be effective is extremely difficult to predict. With this caveat in mind, the Panel offers the following general comments on prevention efforts.

3.3.1.1   SELECTION OF PLATFORM SITE AND PIPELINE ROUTE
Prevention should begin in the planning stage of any potentially high-risk endeavor. In this instance, site selection for the PA-B platform and determination of pipeline routing are significant elements of the overall effort to prevent the potentially severe effects of a significant spill or accident. Different platform and pipeline locations represent different levels and types of risks in terms of spills or accidents that could affect gray whales and their foraging areas – particularly the nearshore foraging area.

With regard to the location of the PA-B platform, the WGW EIA states that a location was investigated a few kilometres farther offshore – that is, farther from the gray whale feeding habitat. The EIA then states that this option was 'declined as a technically feasible option'. The underlying question with regard to location of this platform is whether and to what extent risks (e.g. spills, noise, vessel strikes) would be reduced by placement of the platform farther offshore and away from the nearshore foraging habitat. To evaluate such risks the Panel requested detailed information on how the PA-B platform site was selected. Specific information was not provided.

The general rationale used to determine the best possible site for the PA-B platform is discussed in section 2.4.2 of the CEA, where Fig. 2.4 provides a 3D depiction of the platform's location relative to the oil field. The CEA lists the factors that were taken into account in selecting a location (i.e. distribution of hydrocarbon reserves, feasible drilling reach and total well length, avoidance of shallow gas hazards, avoidance of shallow faulting, competence of the seabed, avoidance of palaeo-channels filled with soft shale, distance to the gray whale feeding area at Piltun) but not their relative importance in reaching a conclusion. The CEA does not specify why this particular site was selected or whether additional geological, technological, ecological and economic constraints were taken into account.

The CEA does not describe the implications of trajectory modelling results for site selection. Based on the timing of site selection and the subsequent trajectory modelling, it appears that the site was chosen prior to analysis of spill trajectories. If so, then risks to key areas such as the nearshore foraging habitat for gray whales were not fully understood and considered in the site selection process unless it was assumed that the whales' nearshore foraging habitat is exposed to the same level of risk regardless of the platform site. This assumption does not seem reasonable and is not supported by the trajectory modelling results reported in the CEA.

With regard to the pipeline route from the PA-A and PA-B platforms, a more comprehensive, quantitative analysis of the alternatives is needed. All three proposed routes eliminate important risks associated with the Phase 1 FSO/tanker-based transportation system. However, they still pose non-negligible risks: (1) noise and disturbance of whales during construction, (2) ship strikes during construction, (3) physical damage to benthic habitat during construction and (4) potential exposure of gray whales, their prey or ecologically important habitat (e.g. Piltun Lagoon) to oil spills and gas releases. Alternative 1 appears to be the safest based on the first three of those risks. Alternative 1 also provides an advantage with regard to the fourth risk in that any oil spills and gas releases would likely occur farther away from the Piltun feeding ground and Piltun Lagoon. A spill occurring in the east-west component of this alternative would: (1) take longer to reach the Piltun Lagoon and foraging area, thereby allowing more time for effective response; (2) be more dispersed when it reached those areas, and therefore less likely deposit large amounts of oil in sensitive nearshore habitats; and (3) have lost a larger portion of its volatile components and therefore be less toxic to whales and their prey. The only obvious disadvantage of Alternative 1 appears to be that the probability of a leak or rupture would be increased somewhat due to its greater overall length.

3.3.1.2   HAZARDS

Phase 2 may be subject to a number of hazards ranging from severe weather to equipment failure and even terrorist attack. Identification of hazards is a key element of prevention. At least two general (not mutually exclusive) approaches can be used to identify and mitigate hazards. The first involves an analytical assessment of oil and gas drilling, extraction and transportation in a stepwise manner. Each step in the process is systematically described, the hazards associated with those steps are identified and the prevention measures incorporated to address the hazards are explained. This last phase will describe the nature of both the prevention measures themselves and the rationale for assuming that they will be effective. Such an approach simplifies the description and evaluation of prevention strategies considerably.

A second approach for identifying potential hazards is to work on the premise that past performance is the best predictor of future risks. This approach would evaluate the past records of the involved oil and gas companies and contractors in relation to activities similar to those proposed as part of Sakhalin II Phase 2. As over 90% of the proposed work is to be carried out by contractors (WGW EIA, p. 9), the track records of those contractors are particularly relevant, as well as the records of the SEIC partners themselves. SEIC documents did not include information on the past performance of the responsible oil companies or their contractors. Performance information would be particularly useful with regard to risks associated with the platforms, pipelines, floating storage and offloading facility, associated tankers, support vessels, and construction vessels and equipment. It is noteworthy that in late September 2004, an oil spill response barge itself ran aground on Sakhalin during efforts to respond to the grounded dredger *Christopher Columbus*. The dredger had been involved in construction of the Lunskoye pipeline. In early September it broke loose from its mooring in a storm and spilled 70-100 tons of diesel fuel and heavy oil.

With regard to platforms, useful information would include: the number of platforms constructed and operated by the involved oil companies and contractors (particularly under the conditions characteristic of the Sakhalin region); the types of accidents they have experienced; the severity of those accidents; the response performance of the various operators; and the new measures put in place to address the underlying causal mechanisms.

With regard to the pipeline alternatives under consideration, useful information would include: the number of pipeline systems constructed and used under similar conditions; the nature and severity of any spills or leaks that occurred; and the steps taken to correct them. The past efficacy of leak detection systems and associated backup systems also would be informative, particularly with regard to the efficacy of visual detection systems in regions with atmospheric and oceanic conditions similar to those around Sakhalin Island. As noted earlier, the leak detection system proposed by SEIC is capable of detecting leaks equal to 1% of the daily amount of oil transported. However, a more effective leak detection (0.4%) has been reported for the TransAlaska Pipeline System (U.S. Bureau of Land Management 2003). This system employs a combination of deviation alarms for pressure and flow rate, line volume balance leak detection, and transient volume balance leak detection systems. This might be considered as 'best practice' but the CEA does not explain why such a system (with a corresponding level of detection) is not proposed for use in Sakhalin II Phase 2.

3.3.1.3   HUMAN ERROR

A recent report suggests that 80% of maritime accidents involve human error (National Research Council 1994). Whether this is true for oil and gas exploration and drilling in the marine environment is not clear, but human error can be reasonably viewed as a significant hazard with regard to the Sakhalin II Phase 2 operations. SEIC documentation indicates a considerable effort to document and impose standard operating procedures, maintenance schedules, and other mechanisms for prevention of spills and accidents. It is not clear whether these will be sufficient to avoid human error, particularly if they are not applied to the contractors who will be responsible for 90% of the work to be accomplished. It is unclear whether the contractors will be required to comply with SEIC's own standards or simply 'requested and encouraged' to do so (cf. WGW EIA, p. 96 with respect to contractors and noise impacts). It seems logical and essential that contractors would be required to comply with standards to minimise the possibility of human error (e.g. provide needed training, ensure appropriate supervision, require backup systems for dealing with all recognised potential hazards, and impose pre-determined management actions in uncertain circumstances where safety and conservation are at risk).

3.3.2   Response

If, despite preventative measures, a Phase 2 spill or accident occurs, then the overriding concern from the standpoint of gray whale conservation would be whether an effective response could be mounted to protect the whales and their habitat. SEIC states (Phase I EIA) that response techniques for spills under ice-free conditions are 'well established and … generally recognised as effective worldwide'. The basis for this statement is not clear and, in any event, interpretation will depend to some extent on the standard used to define 'effective'.

Historical records show that spill and accident responses have had minimal success based on recovery of oil. For example, despite a US$2 billion response effort, only about 7% of the oil spilled by the *Exxon Valdez* was recovered. In 1990, when the *American Trader* broke loose from its offshore mooring near Huntington Beach, California, only about 25% of the oil spilled was recovered even though conditions were ideal with calm seas and extensive response equipment and personnel on hand. Given the winter operations of Phase 2, designing effective spill responses poses an even greater challenge to the responders and, therefore, an even greater threat to the potentially affected environment.

To the extent that an effective response to a major spill can be mounted, it will require adequately trained personnel in the right locations; sufficient equipment and resources in the right locations; ongoing assessment of spill characteristics; an adequate communication system; and an effective planning and decision-making system. The response system must be able to cope with the temporal and spatial characteristics of the spill or accident under the potentially severe conditions (e.g. winter storm) that can occur in the Sakhalin region. The trajectory modelling results indicate that to be effective, spill responses – particularly for large spills – must be employed within hours in regions that are not readily accessible. Developing a robust response system that will be effective for all plausible Phase 2 spill scenarios will be both difficult and expensive. The resources to respond must be in place, funded, staffed and known to be operational prior to the occurrence of a spill, and the state of readiness must be maintained on a continuing basis for the life of the project.

3.3.2.1   THE PILTUN-ASTOKHSKOYE OIL SPILL RESPONSE PLAN

SEIC's Piltun-Astokhskoye Oil Spill Response Plan does not single out gray whales to any extent. Its stated objectives – to 'minimise environmental damage through ... cleaning of oil impacted areas, [and] ensuring that an overall net benefit to the environment is achieved' (p. 1-1) – understate the adverse effects of a spill and overstate the efficacy of response measures. Given the critical status of western gray whales, this objective may be too limited; it is essential that the response plan prevent, to the extent possible, exposure of the whales and their habitat to oil. A clean-up operation alone, although important, cannot be expected to provide the needed level of protection.

The response plan is based on three tiers of response, distinguished in part by the amount and type of hydrocarbon spilled and the predicted time before it reaches the shoreline (table 3.3, p. 3-5) and in part by a judgement as to whether the spill (a) can be contained by the involved company (Tier 1), (b) requires regional response (Tier 2) or (c) requires federal or international response (Tier 3). Response to Tier 2 and 3 spills, in particular, will require considerable planning, communication and organisation because of the number of persons, agencies, organisations and (potentially) nations involved. In all cases, any reasonable preparation that can be completed beforehand will help to minimise the time required for effective response. To that end, the response plan describes a number of documents that are necessary to guide decision-making but have not yet been completed. For example, page 1-6 of the plan refers to an appendix B, which 'summarises the potential sizes of oil spills that could occur at the Vityaz complex and worst case scenarios.…' However, appendix B was not included in the documentation provided to the Panel. Similarly, the CEA (Chapter 7, page 7) indicates that 'for each platform the design QRA [Quantitative Risk Assessment] leads to the development of a platform HSE [Health, Safety and Environment] Case, in which hazards and mitigation of risks are described in detail and demonstrated to be ALARP. For the PA-B platform at the current stage, the HSE case has not yet been completed.' Until this document is completed, it is not feasible to evaluate the likely effectiveness of the proposed system or to accept assurances regarding prevention and response strategies.

Tier 1 – Tier 1 responses appear to be based primarily, at least initially, on the onsite oil spill response vessel and contractor. Having a vessel on site provides an opportunity for immediate response to spills originating on the platforms and, to some degree, to leaks or spills from the pipelines. The capacities of the vessels were not described in sufficient detail to evaluate the expected efficacy of their response, but the efficacy will depend on the spill source and volume; the onboard personnel, equipment and supplies; competing demands (e.g. safety of platform personnel); and the environmental conditions under which the spill occurs. Although an effective response may be mounted to spills of limited volume in open waters and good weather conditions, it is not clear that a vessel stationed beside the platform will be able to operate effectively in winter conditions when sea ice may reach or exceed a thickness of several metres. Similarly, if vessel-based and onsite personnel and equipment are insufficient to address a spill, resources will be required from other locations (e.g. Nogliki). Even in the open-water season, it is not clear that those resources can be effectively mobilised in the short time it could take for the spilled oil to reach the nearshore environment during periods of open water. Response time in winter is likely to be even slower, if it is feasible to respond at all.

Tier 2 - Tier 2 situations will require expansion of response efforts to include regional authorities and resources. Although elevation to Tier 2 certainly expands the potential for response, it also adds multiple parties with similar

goals but potentially competing objectives or methods for achieving them. The proposed response plan describes an elaborate organisational system with multiple lines of authority and extensive lines of communication in addition to extensive lists of equipment and supplies that may be used in a response. However the plan is less clear as to how efficiently these additional resources can be mobilised, transported to the spill site and used in a coordinated, effective manner to prevent exposure of western gray whales and their habitat to the spilled oil.

Tier 3 - Tier 3 situations require further expansion of response efforts to include federal and international authorities, resources and response organisations. Although the resources that are brought to bear may again increase considerably, the overriding challenge would be to implement a Tier 3 response in a timely manner. The reservations expressed above for the effective deployment and coordination of Tier 2 apply equally here. In particular, it is not clear that, even with the additional resources, a response would be possible within the timeframe indicated as crucial by spill trajectory modelling. Although resources from different parts of the world (e.g. United Kingdom, Singapore) might be flown in by aircraft, some might require transport by vessel. The delay in response to a major spill would probably mean that the focus would shift from preventing exposure of wildlife (including whales) and habitat to clean-up and remediation of exposure effects. The response plan does not specify how international efforts would be coordinated (including consideration of what to do if a major spill were to threaten the coast of Japan) and does not discuss the possible implications of an international response for western gray whales and their habitat.

There are no known effective strategies or tools for protecting individual gray whales in the event of a spill or for treating individuals that have been exposed to oil. Several methods to deter them from areas where they may contact oil might be attempted, including harassing the whales and using nets or other obstructions. However, these methods may be ineffective, or worse, pose additional risks to the animals.

None of the response strategies assigns sufficient priority to nearshore gray whale feeding habitat. Although the WGW EIA (p. 42) indicates that in the event of oil approaching a coastal zone, 'a priority would be placed on those inlets or other locations, such as seal haulouts, identified as 'Areas of Special Value'... in the OSRP' (SEIC 2002). Whilst 'Rare sea mammal species population areas' are included in the list of such areas, the feeding grounds of western gray whales are not explicitly identified. The implication of the statement with regard to priorities is not clear. The response plan itself (Chapter 8) indicates the bays that would be protected, including Piltun Bay, by the setting of booms. However, such booms would give limited protection to only a small portion of the nearshore foraging habitat. What protection the nearshore foraging area would receive is therefore unclear; it is possible that a considerable portion of it would receive no protection in the event of a moderate to large spill. The response plan also states that in the event of a spill, a 'Marine Mammal Emergency Response Procedure' will be followed. Without additional information on this procedure and its utility with respect to gray whales, it is not possible to evaluate its potential efficacy.

Finally, the strategies envisioned in each of the tiers may themselves pose threats to gray whales and their habitat. For example, while dispersants or other chemicals may facilitate effective responses in some circumstances, they also may have significant adverse effects (e.g. toxic effects on the whales or their food resources). Ensuring that dispersants are used only when appropriate and are then used carefully requires that they be readily available but dispensed only under clear and informed guidance. Vessels, aircraft and equipment could disturb whales to the point where they abandon nearshore foraging habitat or, in the case of nursing mothers, abandon their calves.

3.4 Monitoring the effects of oil (and physical disturbance) on western gray whale prey
Monitoring is essential for determining the ecological effects of oil- and gas-related activities on the abundance, distribution, demography and productivity of gray whale prey and their associated habitats. Such effects can result from oil spills as well as physical disturbance (as discussed in the following section on the ecological effects of physical changes to habitat).

3.4.1   General requirements for monitoring gray whale prey communities and their physical, chemical and biological environment
Monitoring will be most effective when based on an array of permanent stations in the whales' foraging habitat. Station arrays will be most informative when stratified by habitat characteristics such as depth, exposure to waves, exposure to ice scour, sediment characteristics and proximity to project infrastructure. Stations should be distributed randomly within strata. Statistical power analyses must be performed for each variable of interest in order to determine the minimum necessary number of sampled stations, by stratum and variable, for detecting predetermined levels of change by variable. The most effective way to support required power analyses is to collect preliminary

data for variables of interest, by stratum. Such data are most useful when collected and analysed prior to implementation of the monitoring program, such that results can be used to guide program design.

3.4.2 *Monitoring of physical habitat variables important to gray whale prey*
The following variables, measured over time, will provide information on ecologically significant trends in physical habitat characteristics for prey populations: sediment grain size distribution, sea surface temperature and salinity, and rate and pattern of ice disturbance to benthic habitats.

3.4.3 *Monitoring of chemical habitat variables important to gray whale prey*
The following variables, measured over time, will provide information on trends in chemical habitat characteristics for prey populations: concentrations of total organic carbon and total organic nitrogen (as a proportion of total sediment by weight); depth within sediment of the oxidation-reduction discontinuity layer; concentrations of petroleum hydrocarbons (total PHC) in sediments and in gray whale prey species; concentrations of chemical components of Vityaz crude oil, such as polycyclic aromatic hydrocarbons (PAH), known to have the capacity for deleterious effects on marine organisms, including known or potential gray whale prey species.

Monitoring of total PHC and PAH levels will be most informative when supported by detailed records of product spillage anywhere in the region (volume, chemical characteristics, time and date, location and infrastructural source), and by use of chemical signature analyses to allow tracing of any detected PHC or PAH residues in habitat or prey to source.

3.4.4 *Monitoring of biological variables associated with gray whale prey*
The following variables, measured over time, will provide information on trends in prey populations: density and size distribution, by species, of gray whale prey; biological structure of benthic prey communities (species number, evenness and consequent indices of diversity).

3.5 Conclusions and information needs
In general, the direct and indirect effects of oil on gray whales are not well understood. Based on observed adverse effects on other mammal species, it must be assumed that large oil spills from Sakhalin II Phase 2 could pose significant risks to the western gray whale population. Spills or accidents may result from structural or operational failures during drilling and extraction (e.g. blowouts, fires, explosions), transportation (e.g. loading and transport on tankers, pipeline failure) or associated activities (e.g. platform support operations, construction, dredging).

Although some of the work by SEIC with respect to prevention and response strategies is commendable, better documentation and evaluation is needed and significant improvement can be made. Among the deficiencies that deserve to be highlighted are those related to: (a) the leak detection system; (b) minimizing the possibility of human error, including specifications and requirements for contractors; (c) choice of platform site(s) and pipeline routes; (d) specification of more scenarios (especially winter) for response plans; (e) documentation of the decision criteria for Tier 2 and Tier 3 responses; i.e. those at regional and international levels.

Specific conclusions are as follows:

- the risks associated with Phase 1 were estimated in the CEA to be an order of magnitude greater than predicted for Phase 2 in the PA area due largely to removal of the FSO and associated tanker traffic.

- increasing use of double-hulled tankers in Phase 1 is definitely a step in the right direction, and a policy to use only double-hulled tankers would reduce risks associated with oil transportation during the remainder of Phase 1 and the lifetime of Phase 2.

Information is needed on the following topics for a comprehensive analysis of risks associated with Phase 2:

- risks related to construction and operation of the Prigorodnoye Oil and Gas Export Terminal;

- description and analysis of risks associated with gas releases;

- a more explicit rationale for the location of the PA-B platform, in view of the apparent reduction of risk achieved with regard to noise reduction, vessel traffic reduction and increased distance from potential platform oil spills;

- a more thorough analysis of pipeline spill risk to compare the base case and the southernmost pipeline alternative (Alternative 1) based on the likelihood of a spill due to pipeline length, noise disturbance associated

with construction and other relevant factors (e.g. bottom type) versus the chance that a spill would reach the nearshore gray whale foraging habitat;

- amore explicit rationale for the proposed leak detection system with a purported efficacy of 1% of throughput when greater efficacy (0.4%) has been achieved in other pipeline systems;

- spill responses plans, particularly with respect to winter scenarios, training and 'practice' exercises, coordination of Tiers 2 and 3 and measures to protect gray whales and their habitat;

- independent engineering assessment of existing and planned Phase 2 platforms to identify and verify additional risk-reduction opportunities;

- independent analysis of seismicity to assess the implied risks of earthquakes to Phase 2 operations, given the known high seismicity of the Sakhalin region;

- data on performance records of SEIC partners and contractors; and

- data to allow quantitative review (and expansion) of the spill trajectory modelling for a number of additional Phase 2 scenarios (e.g. blowouts, winter spills), including the pipeline options (this could be done relatively quickly as the data exist and are held by or are available to SEIC).

3.6 References

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4   ECOLOGICAL EFFECTS OF PHYSICAL CHANGES TO HABITAT

As noted in Chapter II, the nearshore and offshore feeding grounds in the Sakhalin area appear to be the only major feeding grounds for western gray whales. Physical changes to the habitat caused by development activities could adversely affect the health of prey communities on the feeding grounds and thus the health and productivity of the whales themselves. There are two major mechanisms whereby this could occur:

(1) habitat alteration leading to shifts in species abundance, diversity, distribution and biological interactions with consequent changes in ecosystem function;

(2) alteration of the temporal and spatial scales of natural ecological disturbance to the prey communities with ecological consequences for the quality and quantity of prey species.

Concern about mechanism (1) relates to the specificity of habitat and the complex biological interactions, as reported in the literature, of species common in the benthic communities of the project area (Annex D). It is very likely that benthic communities are sensitive to a number of significant coevolved biological interactions (e.g., competition, predation and the complex of behaviour that influences or responds to such interactions) both obvious and subtle. With respect to mechanism (2), amphipod-dominated benthic communities can be represented as a spatial-temporal mosaic of disturbance and recovery, with disturbances facilitating community productivity as long as they are of appropriate scale.

It is important to emphasise that the extent to which ecological effects can be predicted and recognised is restricted due to the complexity and natural variability of the system and to our limited understanding of it. Because the northeastern Sakhalin ecosystem is influenced by a variety of physical and biological processes at local, regional and at least to some extent global scales, it is likely that only overt changes in immediate timeframes will be traceable to, or convincingly linked with, oil and gas development activities. The sensitivity of detection of oil spill effects on benthic communities will be influenced by the scope and statistical power of monitoring efforts as described in section 3.4 of this chapter.

4.1   System overview
The gray whale feeding habitat in the Piltun area is the result of complex interactions between natural physical and biological processes.

At the local level, relevant features and processes (apparently) include the transport of suspended matter from Piltun Lagoon, inshore eddy systems, sediment deposition, inshore flow of offshore upwelled water, seasonal ice cover, and the geographic location of the lagoon entrance in relation to prevailing winds (Dobrynin *et al.,* 2004). According to the CEA, broader scale influences may include runoff from the large Amur River on the Russian mainland to the north and west of Sakhalin (however the Panel was unable to find any evidence to support this), tidal streams that flood and ebb north and south along the coast at speeds of up to 1.45m/sec, and waves as high as 6m or more (CEA – Food Resources, p. 1). The interaction of physical forces creates a specific inshore zone, dominated by fine sands (0.1-0.25mm grain size), that largely coincides with the main feeding area of gray whales (Fadeev, 2002; 2003). This inshore zone is a limited, distinct habitat. Farther offshore and to the north, coarser sediments are deposited, whereas to the south near Chayvo, an abrupt narrowing of the zone of fine sand indicates the presence of an abrasive bottom current (Dobrynin *et al.,* 2004).

Dobrynin *et al.* (2004) speculated on the processes that form the broad Piltun zone of fine sand and the high productivity of the area. They suggested that the export of terrigenous material from Piltun Lagoon, specifically in spring when wave activity in the surrounding sea is limited by remaining sea ice, is one key factor. The nearshore eddies developing in the area apparently capture the particles and concentrate, redistribute and deposit them over an area to the east and north of Piltun Lagoon. The same processes may determine the export and retention of particulate organic matter that settles in that region. Upwelled water, sometimes expressed as a flow towards the coast between the entrance of Piltun Lagoon and the northern part of the spit (Odoptu area), further enriches the area with nutrients, while a sub-latitudinal salinity front (Fadeev, 2002) may contribute to the regular formation of areas with a stable water column, leading to increased phytoplankton productivity.

The physical structure of the offshore feeding habitat has not been investigated to the same degree as the Piltun feeding habitat. Dobrynin *et al.* (2004) noted that the location of the offshore feeding area generally coincides with an area of eddy formation and the outreach of the zone of fine sands (Fadeev, 2003). They suggested that, as with the Piltun area, hydrodynamics and sedimentation are important in forming this habitat and sustaining its productivity.

The importance of the specific sediment type to gray whale prey habitat is apparent. Fine sands are clearly a critical component of both the Piltun and offshore feeding areas; medium or coarser sands predominate in non-feeding areas (CEA - Food Resources p. 4). Even the proportional composition of sediments may be critical. For example, the proportion of silt in the most productive feeding areas of the shallow strip close to shore and around the entrances of Piltun and Odoptu bays is about 6%; similarly, it is 5-6% in the fine sands of the offshore feeding area (CEA – Food Resources p. 4).

The Dobrynin *et al.* (2004) study provides the most comprehensive description of local Piltun hydrodynamics and nutrient flow processes to date. It is the first description of the inshore eddies that may play a major role in sediment distribution on the feeding grounds but no reference is made to this work in the CEA. The CEA discussion of physical influences on habitat is confined to the broader-scale, more regional forces such as runoff from major (distant) rivers, ice cover, waves, and tidal streams, as well as localised oceanographic features (CEA-Food Resources p. 1). As noted in section 3.1.2.5, transport of detrital effluent from Piltun Lagoon to adjacent benthic habitats outside the lagoon may be fundamentally important in understanding the persistent use of the Piltun feeding area by gray whales.

4.2   Summary of activities and likely changes

4.2.1   Dredging to bury pipelines
4.2.1.1   EXCAVATION
Pipeline construction involves the dredging of a trench in the seabed, piling the spoil on the side of the trench, laying the pipelines and then burying them with the dredged and imported materials. Three pipeline routes have been considered. The base case route (42km; CEA p.13) begins at the planned PA-B Platform, runs southward to the vicinity of the PA-A platform, connects with the pipeline from that platform, and then runs almost due west to the shore just south of the southern tip of Piltun Lagoon. Alternatives 1 (72km) and 2 (61km) also begin at the planned PA-B platform, run westward to deeper water, and then southward to the vicinity of the PA-A platform, connect with the pipeline from that platform, then continue southward for 8km (alternative 2) to 16km (alternative 1) before turning nearly due west and running to the shore. The base-case route comes directly onshore from PA-A and crosses the southern reaches of the Piltun feeding habitat. The alternate routes come ashore south of the Piltun feeding habitat.

Two habitat issues arise from the pipeline construction: (1) direct elimination of feeding habitat due to excavation; and (2) suspension of sediments during dredging and their re-deposition, potentially having a smothering effect on benthic species (gray whale prey). The CEA describes the former in more detail than the latter.

Ice scouring of the seabed occurs in water shallower than 30m and the pipeline must be buried to depths between 2m (in water 25m deep) and 7m (at shore) to protect it from the ice. The CEA notes (p. 4, 13) that as the ice scour is deeper than initially thought and seabed mobility greater than originally estimated, the offshore pipeline will have to be buried deeper than first proposed.

Between the PA-B and PA-A platforms, the trench dimensions will be 10m wide at the base and 30m at top (in water depths less than 30m). From the PA-A platform to shore (in waters less than 30m deep) the trench will be 20m at the base and 40m at the top (CEA, p.15). Dredged material will be piled along the sides of the trench and used to backfill. The CEA (p. 15) indicates the total width of the construction corridor will be 250m, but the International EIA (p. 2-26) states that the dredge material will be dumped 450-500m from the trench centre-line. This implies a corridor width of at least 500m if all material is dumped on one side of the trench, or about 1,000m if dumped on both sides.

The pipeline dredging and construction activity will affect at least 610,000m^2 of seabed, with a permanent land take of 57,200m^2 (International EIA, p. 2-26). The International EIA (p. 2-26) states that dredging activities in Piltun will produce 1,457,000m^3 of material. Presumably, these values pertain to the base-case (shortest) pipeline route.

Approximately 1,017,000m^3 of dredge spoil will require disposal. Appropriate sites will be identified during the detailed engineering phase (International EIA p.2-29). Dredged material from the shoreline to a water depth of 7m will be dumped offshore in water ≥10m deep 'where the dumped material should remain stable' (International EAI, p. 2-29). Material excavated in water depths greater than 7m will be dumped either directly or through discharge hoses on one or both sides of the trench, depending on the prevailing direction of sediment transport and on feasibility.

Backfilling will require 438,000m^3 of onsite material and 40,000m^3 of rocks. Onsite gravel and sand will be used, as well as rocks from onshore quarries to ensure pipeline stability. Thus, 1,017,000 m^3 of dredged material will be left after backfilling. The amounts of dredge spoil and other materials involved in the other pipeline routes would probably be higher due to increased offshore length, but this would depend on the actual length in waters shallower than 30m where burial is necessary (International EIA, pp. 2-29). In order to illustrate the quantities of sediments to be dredged, as well as the amounts required for backfill and to be dumped, it may be helpful to consider that approximately 8m^3 equals one large dump-truck load. The dredging for the base-case pipeline route will thus produce about 182,000 dump-truck loads of which some 127,000 will require disposal, i.e. will not be used for backfill. In addition, the equivalent of roughly 5,000 truckloads of rock will be imported.

If the pipeline route crosses the feeding habitat, the portion of the benthos that is dredged from the Piltun feeding ground will be removed. The base-case pipeline route crosses the known nearshore feeding area at its southern extremity. The calculations vary somewhat as to how much feeding habitat will be directly affected by this excavation, but it is probably safe to estimate < 1%. This loss is considered acceptable in the CEA, based on the assumption that the loss will prove temporary and the habitat will recover in 1-3 years.

The direct loss from the excavated area will occur for at least the season of construction, and for an unknown period afterwards depending on the potential for (and rates of) re-colonistion by the local benthic community. The CEA (Food Resources, p. 11) predicts recovery within 1-3 years; the western gray whale EIA (p. 62) predicts 2 years. The CEA (Food Resources, p. 10) suggests that 'recovery will proceed by re-colonization from either side of the narrow pipeline route, to supplement the natural regenerative processes that operate there annually following the natural disturbances from WGW feeding, ice scour and wave action'. The rationale given is that because the benthic communities are 'naturally subject to major physical disturbance' (CEA Food Resources p. 10), they will be able to recover relatively easily from the industrial disturbance. That may be true. However, adaptation to natural disturbances having characteristics with which benthic organisms have coevolved does not mean that benthic communities can accommodate readily to disturbances that are unnatural and novel in size, frequency or intensity.

4.2.1.2   SMOTHERING EFFECT OF SEDIMENTATION

The dredging activity, whether adjacent to or somewhat distant from the prime feeding area, will disturb and mobilise a large quantity of sediment that is likely to re-settle on the surrounding benthic community. The impact of this deposition on gray whale prey species is uncertain, but it could be significant, (e.g. by affecting tube-construction materials, feeding mechanisms, or the small planktonic food sources of relevant invertebrate species). The potential for damage by suspended sediments through benthic smothering is well documented (e.g. Davies-Golley and Smith 2001)

The degree to which sediment is suspended by dredging will depend on the fineness of the materials and strength of the currents. The CEA (Food Sources, p. 9) indicates that all three pipeline routes pass over similar benthos with patchy sediments dominated by medium to fine sands, with fine sands prevalent in water depths of <15-20m. Fine sediments are more likely to be suspended for longer periods and re-distributed over wider areas than coarser materials. Observations of feeding plumes during gray whale surveys off Sakhalin indicate that feeding-ground sediments readily go into suspension.

References to seabed stability in the SEIC documents are not entirely consistent. For example, the CEA (Food Resources, p. 10) states that, 'the recovery of disturbed seabed is likely to proceed relatively quickly because of the dynamic and heterogeneous nature of the area', whereas the International EIA (2-29) indicates that 'dredged material will be dumped offshore in water ≥ 10m deep where the dumped material should remain stable….' As stated above, large quantities (over 1,450,000 m^3) of sediments will be dredged during pipeline construction. It is thus not clear whether this material will, as suggested in the International EIA (pp.2-29), drop to the bottom in a limited corridor and remain there permanently (70%) or until used for backfill (30%) or, alternatively, a significant portion of it will remain suspended and be redistributed by the currents, tides, waves and wind (CEA, Food Resources, p. 9). The implications of these scenarios are quite different from the perspective of gray whale habitat.

The CEA (Food Resources p. 9) addresses the benthic smothering issue between platforms PA-B and PA-A by noting that 'as sediment will be released into the water column during dredging and re-suspended from the spoil heap, a worst case potential benthic smothering effect has been estimated at 500m in width for this section of pipeline.' With respect to the pipeline routes downstream of PA-A, the CEA notes that 'the potential benthic smothering effect has been estimated at 1000m in width.' The CEA concludes its treatment of this issue with the statement, 'In general the east west section of the pipelines in water depths <30m will have a smothering effect over a wider area than the north-south section both because of the greater volume of dredging and hence spoil, and the

effect of the predominantly north to south prevailing current.' (CEA Food Resources p. 10). The basis for these assessments of the smothering effect is not given and therefore the assessments are impossible to evaluate. However, given the quantities of material to be dredged and the complex dynamics of the marine system, it is possible that the CEA has substantially underestimated the area that will be affected. The CEA's conclusion, that 'for the greater part of all proposed routes, the seabed disturbance will not affect western gray whale feeding habitat or areas supporting potential western gray whale food resources…' (CEA Food Resources, p. 10), is not well supported by the data and analyses presented.

The WGW EIA (p. 62) also considers the increased turbidity caused by dredging activities. With respect to the gray whales themselves it notes that turbidity fluxes are within the everyday experience of gray whales. The WGW EIA states, 'increased turbidity may have indirect negative effects on whales that feed on the invertebrates. However, any increase in turbidity will be short term, and it is estimated that turbidity associated with underwater construction is relatively low when compared to the turbidity caused by a large storm…. Also, gray whales frequently encounter areas of increased turbidity generated by their own bottom-feeding activity.'

In conclusion, the potential for smothering of benthic communities by sedimentation has not been adequately described in the CEA or the EIAs. The CEA states (Food Resources p. 9), 'For each of the pipeline routes the main disturbance will arise through the dredging and backfilling activities necessary to bury the pipelines…. The severity, extent and duration of the disturbance…is determined by the size of the area affected, presence of a potential food source and proximity to known feeding areas….' All true, and perhaps consideration of the sedimentation issue is implicit in these statements. However, the next sentence in the CEA states that 'only the base route alternative has some potential to impact currently utilised WGW food resources' (CEA, p. 9), which suggests that sedimentation was not seriously considered in the analysis. Sedimentation is clearly an issue that deserves careful consideration with all pipeline routes.

4.2.1.3 PIPELINE ALTERNATIVES
Gray whales and their prey species occur in the nearshore portions of all three proposed pipeline routes. However, feeding activity and food abundance are almost certainly less in the two alternate routes (CEA, Food Resources, p. 11) and therefore the effects on gray whale habitat and food resources from construction and repair activites are likely to be less serious for either alternate route than for the base-case route.

4.2.2 *Oil Platform Installation*
The creation of two 10,000m^2 islets – the oil platforms – in close proximity to the nearshore feeding ground constitutes a substantial physical change in important habitat. There is no doubt that these will have ecological consequences; however, the question is whether such changes will have an impact on the western gray whale population.

The PA-A platform (Molikpaq) was installed in 1998. It is 17km offshore in water 30m deep. The structure is an 111m × 111m solid platform (frame filled with bottom sediments). The operation includes 6 water-injection wells, 4 production wells and 3 gas-injection wells. The PA-B platform, to be installed in 2005, is 12km offshore and also in water 30m deep. PA-B is 94m × 91m, with a solid base rising 11.5m from the seafloor. Four 39m shafts support the working platform. The PA-B will have 45 well slots designed to accommodate 20-30 producing wells and up to 18 water-injection wells. The PA-A platform is 24km southeast of the Piltun Lagoon entrance, and according to the CEA (p. 7-11) 10km east of the Piltun (nearshore) feeding area. The PA-B platform will be 7km east of this prime feeding area (which extends 5km from shore). Both platforms are or will be solid structures embedded in the ocean floor (CEA, p. 7-11).

For the PA-A platform, bottom sediments were excavated and used to build the base of the structure. For the new PA-B platform, the ocean floor is not integral to its construction but its installation will include some manipulation of the seabed. The CEA states that site preparation will be 'minimal' and largely confined to dredging to level the site substrate. A trailing suction hopper dredger equipped with suction pipe and drag head will be used to level an area of about 12,000 m^2 (110 m × 110 m) and in the process approximately 7,500 m^3 (about 940 dump-truck loads) of sand will be removed and relocated east of the platform site (CEA, p. 11). Rock and gravel will be placed around the base of the platform for scour protection and/or to prevent washout from the seabed around the structure (CEA, p. 11). This embankment will be 1-4m high and 10-15m wide at the sides, increasing to around 20-30m at the corners. The rock and gravel will be obtained from either Primorski krai (Russia) or Hong Kong (CEA, p. 11).

In addition to being 7-10km offshore of the outer edge of the Piltun feeding ground, the platforms are situated in water depths at least 10m deeper than the primary feeding depth in the Piltun area. Since these locations apparently do not support benthos of the type favoured as food by western gray whales, the CEA concludes that the direct

impact of excavation and installation of the platforms on the current prey base of the whales will be minimal. In its examination, the CEA does not consider the potential impacts of the platform-related dredging activities, which will result in substantial amounts of sediment re-suspension in the water column, with the final distribution of the sediment dependent (primarily) on current patterns. The CEA statement (p. 8) that 'placement of PA-B will have no significant impact on the benthos and no impact on the potential food sources of the grays' may be more absolute than is warranted.

However, a longer-term, and potentially more significant, ecological change caused by the platforms is the creation of artificial reefs in an open sandy-beach-type habitat. Each platform is the size of two football fields, side by side, surrounded by boulder fields up to 30m (3 stories) high, and associated with expansive vertical walls and columns. As artificial reefs, these structures will change the composition of marine species present in the region. Perhaps implicitly acknowledging the potential for this effect, the CEA (p. 7) mentions changes in the abundance of three invertebrate species within the spoil area of PA-A, presumably simply due to the increase in the proportion of gravel on the seafloor.

Presence of platforms on otherwise low-relief sedimentary locations is known (e.g. see Wolfson *et al*., 1979 and Davis *et al*., 1982 who examined offshore platforms in California) to produce the ecological effects summarised below.

- Attraction of invertebrates and predatory fish to the platform vicinity and subsequent additional predation on adjacent sedimentary environments on a scale of tens to hundreds of linear metres from the platform.
- Modification of the pattern of particle size distribution in natural sediments near the platform due to deposition of shells and other debris produced by 'fouling' organisms. This may reduce fitness of some species and/or increase the abundance if other species previously rare or absent. Such effects can extend for tens to hundreds of linear metres.
- Modification of the pattern of organic carbon content in natural sediment near the platform with similar effects to (2) above, although the scale would be somewhat smaller.
- Modification of sediment profile and characteristics resulting from hydrodynamic modifications to natural habitat caused by platform presence. Effects can includes sediment scour or accumulation near the interface of platform structure with natural sediments, and spatial asymmetries in effects listed above. Scouring affects from one up to tens of metres from the platform; current-related asymmetries may be apparent on scales of tens of metres.

The CEA notes that, at one point, as many as five platforms had been planned for the PA field. Although only two are currently approved, it is an open question as to how many platforms eventually may be constructed in this area, whether by SEIC or other companies.

4.2.3   *Pipeline landfall and shoreline disruption*
The International EIA describes the proposed Piltun pipeline landfall. The onshore trench will be 13.5m wide and require the excavation of 28,000m^3 of material (around 3,700 dump-truck loads). Excavated material will be stored temporarily along both sides of the trench. The materials stored onshore will be used to refill the trench and reinstate onshore sites.

According to the CEA (p. 16, Fig. 2.6), the pipeline landfall will involve the construction of a 'cofferdam' to a water depth of approximately 7m. This looks like a canal through the beach from sea to inland with a wharf-like embankment on either side. The soil within the cofferdam will be removed to a level required for pipeline burial prior to installation. It is unclear from the report whether this is to be a temporary structure for construction purposes or permanent. If temporary, and the pipeline is buried to a depth of 7m near shore, the landfall is likely to have little ongoing effect on shoreline currents, however if permanent, several issues may arise.

If permanent, the landfall may disrupt shoreline currents and sediment flows around the cofferdam structure. The extent to which this might occur, or its impact, if any, on gray whale habitat, is uncertain. Clearly, current flows and sedimentation are critical to the formation of gray whale habitat, and anything that changes these hydrodynamic processes by increasing, decreasing or otherwise changing flow patterns could be significant. This issue is not addressed in the CEA.

4.2.4   *General changes in natural disturbance regimes*
The periodic disturbance of bottom prey communities during foraging, followed by re-colonisation, recovery and re-use at a later time has been proposed as a key aspect of gray whale ecology (Nerini 1984; Oliver and Slattery 1985). Amphipod-dominated communities in exposed nearshore habitats are known to be well adapted to physical

disturbances of small spatial scale, even if they occur frequently. Areas depopulated by bottom-feeding animals such as gray whales may be quickly re-colonised by nearby populations of amphipods, and depressions caused by feeding whales may actually be preferred sites for release of young by adult females. The depressions may be sites for accumulation of detrital material rich in microbial food significant to the amphipods, and may also provide a 'microclimate' that protects animals from wave surge and currents and, as a result of the original disturbance, minimises interactions from competitors. It is reasonable to speculate that localised disturbance to the sediment from grounded sea ice may provide similar opportunities in amphipod-dominated communities, although documentation is lacking. The importance of these disturbance regimes for maintaining the life history of the prey and productivity of an area is not known.

In this regard, the CEA (Food Resources, p. 10) states with respect to pipeline trenching, 'Recovery will proceed by re-colonization…to supplement the natural regenerative processes that operate there annually following natural disturbances from WGW feeding, ice scour and wave action.' While this may be the case, pipeline construction could affect natural disturbance regimes by: (1) reducing disturbance by displacing gray whales away from their feeding grounds, whether as an avoidance response to industrial activities or because of the loss of prey from sediment smothering, or (2) increasing disturbance well beyond natural levels through dredging. In either case, the natural ecological processes that currently support high densities of gray whales could be affected, potentially reducing local productivity and, therefore, availability of gray whale prey.

4.3   Potential effect on gray whales

The overall conclusions of the CEA and other EIAs are that physical changes in habitat due to development activities will have little or no significant ecological effect on gray whales or related key elements of biodiversity. However, based on the information presented above, physical changes in habitat could have significant effects, summarised below.

- Elimination of feeding habitat primarily from pipeline-related dredging operations. Small portions of the nearshore feeding habitat may be lost, at least temporarily, if the base-case pipeline is chosen. The disturbance from dredging and pipeline installation may result in longer-term or even permanent changes to the benthic communities (e.g. habitat structure and faunal composition). The assumption that the affected benthic communities will recover over time is not wholly consistent with experience.

- Suspension of sediments and smothering of benthic communities due to dredging and disturbance. The ecological effects of sediment redistribution will depend on the pipeline alternative chosen, sediment characteristics, current dynamics and recovery potential of the affected benthic communities. The effects of smothering may be significant if sediments are transported by currents to the nearshore foraging habitat.

- Development of altered ecological communities around the platforms, the effects of which will depend on the species involved and their natural history traits. The ecological changes may reach beyond the immediate vicinity of the platforms. It is important to clarify that this does not imply 'enhanced ecological diversity' but rather simply a change from the pre-development conditions with uncertain consequences for gray whales and related key elements of biodiversity.

- Disruption of nearshore hydrodynamics, thereby changing the underlying physical processes conducive to the biological communities upon which gray whales depend.

Once again, from the perspective of gray whale conservation, the available information precludes a conclusive assessment of the effects on primary feeding habitat. The CEA and other documents do not adequately reflect the uncertainty that exists and in many cases reflect an overly optimistic view.

4.4   Mitigation

The only mitigation measure proposed by SEIC in regard to the potential ecological effects of physical changes to gray whale habitat is the alternative pipeline routes, which serve to increase the distance between pipe-laying activities and the primary foraging area. Indeed, maximising the spatial and temporal separation of the construction activities from the whales and their prey appears to be the best mitigation approach available.

Pipeline Alternative 1 is the most distant from the feeding grounds and therefore achieves the greatest spatial separation. Choice of the most effective temporal separation is less clear and there are at least two possibilities: (1) construction early in the open-water season before substantial numbers of whales arrive (if that is possible due to timing of ice break-up and whales returning to the area); or (2) construction late in the season after feeding activity

has waned. Construction in the early season, even if it does not affect the whales directly, could still have significant effects on their prey, which are present and presumably beginning seasonal growth and reproduction. However, it is difficult to judge when the risk of ecological damage is least because of the limited understanding of prey life cycles and whale behaviour.

Judging by the CEA, the potential smothering of benthic communities due to resuspension of sediments from dredging does not appear to be regarded as a serious concern, hence no specific mitigation measures are proposed for it. The Panel, however, considers smothering of benthos a serious issue that deserves careful consideration. The more distant (from the primary feeding ground) pipeline routes would reduce but not entirely eliminate concern about smothering. It should be possible to model the potential blanketing effect of dredged sediments taking into consideration particle size, currents and suspension physics. An analysis of the percentage of feeding ground that may be affected under different current and wind scenarios would be valuable in assessing the risk of dredging activity to the benthic communities. The CEA does not include this type of analysis.

One way to address the smothering problem would be to plan dredging, for both platform and pipeline construction, with consideration of the currents (including the nearshore eddies described in Dobrynin *et al.* 2004), winds and tides. If dredging activities occur only in conditions when the suspended materials are swept offshore and away from the Piltun feeding area, or to the south rather than onshore and northwards, this should reduce some of the risk of smothering benthic communities on the Piltun feeding ground. Once operations are underway, monitoring from air and surface of the direction and coverage of the suspended sediments could be used to determine whether sediments are flowing towards the feeding ground, and if necessary, operations could be suspended until ocean conditions change.

The issue of the artificial reef effect of the platforms is not addressed in the CEA. Mitigation to prevent changes in the composition and abundance of marine organisms around the platforms is probably not feasible, but monitoring those changes may be important to future interpretation of changes in the broader Sakhalin Shelf ecosystem.

The CEA does not address any potential ecological effect from the construction of the pipeline landfall and no mitigation is proposed. However, depending on nearshore conditions, including winds, tides and aperiodic currents, the disruption of alongshore currents by 'berms' or breakwaters can have significant downstream effects on distribution of sand and erosion. In order to achieve the least possible shoreline impact, it would be necessary to: (a) consider alongshore currents in landfall design; (b) conduct surveys of the downstream shoreline prior to installation; and (c) monitor these areas following installation so that if major changes beyond the natural dynamics of the shoreline were to occur, the landfall could be redesigned.

4.5   Monitoring

Monitoring is essential for determining the ecological effects of physical disturbance on the abundance, distribution, demography and productivity of gray whale prey and their associated habitats. Elements of a monitoring programme are described under Item 3.4 of this chapter.

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Chapter V: Factors potentially affecting the survival of western gray whales in addition to those associated with Sakhalin oil and gas development

1 DIRECT CATCHES

As indicated in Chapter II, the western gray whale population's currently small size is mainly the result of past whaling (Kato and Kasuya 2002). In spite of the population's legally protected status, some recent direct killing has been documented. In May 1996 a western gray whale was killed off western Hokkaido[3] (Brownell and Kasuya, 1999). The carcass bore numerous harpoons and lines similar to those used in the (legal) hunt for small cetaceans (particularly Dall's porpoises, *Phocoenoides dalli*) in Hokkaido. Baker *et al.* (2002) reported gray whale products obtained from commercial markets in Japan in 1999. It is unknown if those whale products came from the whale killed off western Hokkaido in 1996.

2 BYCATCHES IN FISHING GEAR

Uni and Kasuya (2002) reviewed the 19th century net whaling operations that took western gray whales at various locations along the coast of Japan, mainly in the Sea of Japan. Net whaling was deliberate and involved specially constructed nets, strategically placed to intercept migrating whales, with active 'driving' and killing of the entangled animals. The fact that gray whales were taken regularly suggests they are vulnerable to set nets generally.

Since 1930, the taking of western gray whales in set nets along the Japanese coast of the Sea of Japan has been recorded on several occasions. The most recent case was in Toyama Prefecture in 1970 (Tadasu Yamada, pers. comm.). Common minke whales (*Balaenoptera acutorostrata*) are taken regularly in set nets in Japanese waters of the Sea of Japan, most of them in the same region where gray whales were taken historically.

Although large numbers of minke whales are also taken in set nets in Korean waters, no western gray whales have been reported by the fishermen (Z. G. Kim per. com.) or detected from Korean markets through DNA surveillance (Baker *et al.,* 2002)

Urbán *et al*. (2004) reviewed observations of eastern gray whales without flukes between 1958 and 1997. They proposed that these whales lost their flukes as a result of entanglement in fishing gear, specifically due to fishing lines wrapped around the caudal peduncle (tail stock). Such whales appear to have adapted to the loss of their flukes and managed to survive for some time. No western gray whales without flukes have been reported but at least one individual is missing a large portion of one fluke.

3 VESSEL COLLISIONS

Commercial vessel traffic throughout the postulated range of western gray whales is expected to continue to increase (Wignall and Womersley, 2004) as part of industrial growth in the region. Numerous high-speed ferries are already operating between Pusan, South Korea and several Japanese ports (Weinrich, 2004). For details on collision risks in the Sakhalin region, see Chapter IV, Section 2.

4 DISEASE, TOXIC ALGAL BLOOMS AND EXPOSURE TO CONTAMINANTS

These are discussed in Chapter II.

5 PREDATION

This factor is discussed in Chapter II.

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Chapter VI: Cumulative effects of the factors discussed under Chapters IV and V

The terms of reference for this review required that it 'focus on Phase 2 of the Sakhalin II Project, in particular activities in and around Piltun and Lunskoye Fields and associated coastal zones, over its expected lifespan'. The terms also stipulated that the review should be conducted 'in the context of all industrial development potentially affecting WGW in the Sakhalin area'. The Panel interprets this to mean the review must consider the effects of all pertinent factors, including their cumulative effects.

Chapters IV and V discuss a number of factors that could have negative effects on survival and reproduction of western gray whales. It is clearly insufficient to examine only the effects of each of these factors individually. Several minor individual effects may become significant when added together and in some cases the cumulative effect may be greater than the sum of the effects (synergistic) or less than the sum of the effects (countervailing). Although difficult to investigate, the concept of cumulative effects is well established and widely accepted and it is considered in the modelling exercise undertaken in Chapter VII.

The possibility of cumulative effects is of particular concern for such a small population, which is likely to have little tolerance for adverse effects resulting from human activities or natural variability (e.g. stochastic events). Following the US National Research Council approach (2003), this section briefly reviews the:

- relevant factors to be considered;
- spatial and temporal ranges over which the relevant actions take place;
- 'receptors' whose responses to the actions are to be assessed; and
- magnitude of the effects on the different receptors and whether those effects are accumulating or interacting with other effects.

1 FACTORS TO BE CONSIDERED

The risk factors can be assigned to at least three categories. The first category includes the multiple risk factors arising from Sakhalin II alone, which includes platforms PA-A and PA-B and associated pipelines, the Lunskoye platform and the oil and LNG plant and export terminal at Prigorodnoye with associated tanker traffic. Those factors include the risk of collisions between ships and whales; noise from vessels, equipment, and aircraft; unfavourable ecological changes; and exposure to oil and gas from spills.

The second category includes the multiple risk factors arising from all oil and gas exploration and development beyond Sakhalin II (i.e., Sakhalin I and V which are underway, and III – IV and VI – IX which are in the planning stages; Fig. 2 Chapter III). The dangers of ship collisions increase incrementally with each additional vessel operating in waters inhabited by gray whales, as do the dangers of oil and gas spills with additional platforms and pipelines, of noise disturbance with additional construction and oil and gas production, and of habitat degradation with expanding development of all kinds on and near the northeastern Sakhalin Shelf. Exxon's plan to dredge and install a pipeline across Piltun Lagoon to transport oil from Sakhalin I is an obvious example. If such dredging is undertaken and it alters water and nutrient flow out of the lagoon, or if oil is spilled into the lagoon from a pipeline, it could add significantly to the risk of habitat degradation in the nearshore foraging area near and immediately north of the mouth of the lagoon.

The third category of risk factors includes those that affect the survival and reproduction of western gray whales throughout their range such as risk of ship strikes from other vessels, degradation of habitat (including noise), exposure to contaminants and disease, bycatch in fishing gear, illegal take and predation.

2 SPATIAL AND TEMPORAL SCALES

2.1 Spatial

The risk factors associated with Sakhalin I and II are in close proximity to important feeding areas. These factors also may affect migration routes off the southern and eastern shores of Sakhalin. Activities associated with oil and gas developments in other regions around Sakhalin Island may pose less direct risks to feeding areas (although this would depend on platform and facility locations and on a number of environmental features such as currents, tides,

winds, and other weather conditions) but greater risks to the animals migrating to and from the feeding grounds. By definition, the third category of factors has the potential to affect the animals throughout their range, with those factors related to habitat particularly important for the (unknown) breeding and calving grounds.

2.2   Temporal

Oil and gas activities typically include an initial period of exploration that involves seismic profiling and test drilling (presumably completed for Sakhalin I and II), a relatively short (several years) period of construction, a relatively long (several decades) period of production (including occasional or regular seismic monitoring), and finally a relatively short (several years) period of decommissioning. These phases are not synchronous around Sakhalin, as exploration and production are in different stages for different projects. The Sakhalin II project is expected to take three more years for construction and then have an active life of perhaps 40 years. The total period of oil and gas production around the island remains uncertain because not all oil and gas deposits have been identified and because conditions affecting the profitability of operations may change considerably over the next several decades.

Although difficult to predict, risk factors other than those related to oil and gas may be expected to remain fairly constant (e.g. fishing activity, exposure to disease, predation) or increase (e.g. vessel traffic in nearshore waters, exposure to pollution) with increasing coastal development in eastern Asia. On Sakhalin Island, the development of infrastructure (e.g. roads, communication systems, runways for aircraft) may lead to socioeconomic development with implications for gray whales (e.g. the development of a fishing port in northeastern Sakhalin would increase vessel traffic, pollution, bycatch risk and noise).

3   RECEPTORS (WHALES) AND THEIR RESPONSES

Western gray whales and their habitat are the key 'receptors' for the purposes of this report. Important potential responses include: changes in distribution (e.g. abandonment of important habitat), behaviour (e.g. less efficient foraging, increased movement between feeding areas, more time spent at the surface), condition (e.g. from decreased foraging efficiency or increased energy expenditure) and health (e.g. from increased exposure to toxicants, decreased energy reserves, physiological stress). These responses may result in decreased reproductive success (e.g. fewer successful pregnancies), increased juvenile mortality (e.g. from decreased female success in nursing and weaning calves) and/or decreased survivorship (e.g. directly from ship collisions or indirectly due to poor health). Table 6 illustrates the relationships among activities, associated risk factors and response variables.

4   MAGNITUDE OF EFFECTS AND THEIR INTERACTIONS

The individual effects of the various factors and their possible magnitudes have been considered under Chapters IV and V. Cumulative effects reflect the combined influence of these multiple risk factors on the gray whales and/or their habitat.

Although the CEA (Cumulative, p.1) recognises the concept of cumulative effects, examination of this issue is superficial. In effect, the CEA reviews and dismisses the individual risk factors (noise, food source disturbance, collisions, oil spills) without adequately considering how they might combine and whether any such combinations might be significant. With regard to noise, the WGW EIA (pp. 20, 152) states that there was 'no reason to believe that the cumulative effect would be greater than the predicted effects of the individual sources' but no rationale is given to justify this conclusion. Similarly, the 2003 WGW PP (p. 23) states that all relevant Sakhalin II impacts and impacts from other projects were taken into account in planning by SEIC, but no evidence is given to indicate that the potential cumulative effects have been thoroughly examined and considered.

One example of a synergistic interaction is: a noise-caused shift in whale distribution from nearshore foraging habitat to secondary habitat, leading to greater risk of vessel collision and later to decreased successful pregnancy or calf survival due to nutritional stress of the mother.

The Panel recognises that examination and prediction of the magnitude of potential cumulative effects is difficult, even with good information on the magnitude of the effects of individual factors. It is particularly difficult for western gray whales for which information is limited. Monitoring to verify predictions is also difficult.

The approach taken here is first to examine the individual factors (summarised in Table 5 based on discussions under Chapters III and IV) and then to consider ways in which these may be combined (Table 6) for investigation by simulation modelling (see Chapter VII). In this approach we recognise the inherent difficulty in quantifying even individual effects. Few studies of individual factors have had sufficient statistical power to detect an effect (e.g. on behaviour, physiology, health etc.) even if there was one (the design of such studies is particularly difficult even with

sufficient resources). It is more difficult still to assign any observed changes in population parameters, should they be detected, to single or multiple factors.

The difficulties of detecting changes in cetacean population parameters and abundance over short time periods, given the wide confidence intervals usually associated with these estimates, are well known and they can be accentuated for small populations. This must be taken into account in designing monitoring programmes to assess whether the predictions of effects on western gray whales that formed the basis of decisions concerning the Project have been met in practice. In addition, the implications of the power-to-detect issue, combined with the difficulties of assigning cause-effect relationships to any observed changes, must be taken into account in designing appropriately precautionary management strategies.

To explore the problem of cumulative effects on western gray whales, the Panel adopted the philosophy behind the development of the IWC's Revised Management Procedure and Aboriginal Management Procedure. That is, we considered a range of plausible scenarios (conditioned on the available data) rather than trying either to develop precise values or to use information only when statistically significant differences have been shown. This is discussed further in Chapter VII. The implications of the results of the simulations for decisions on the Project and for subsequent monitoring and management actions are discussed in Chapters VII and VIII.

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Table 5

Factors that may combine to contribute to cumulative effects on western gray whales.

Activities	Risk factors							
	Noise	Collisions	Oil/gas spills	Habitat degradation	Biotoxins	Entanglement	Contaminants	Disease
Sakhalin II oil and gas	Disturbance may lead to habitat abandonment, changes in behaviour, physiological stress, masking or temporary hearing loss	Serious injury and mortality	Ingestion, contact with eyes, baleen, skin, loss of prey and/or habitat	Changes in biological diversity, particularly prey, may lead to decreased foraging efficiency with multiple secondary effects		Displacement of whales could increase their risk from other factors, including injury and mortality from entanglement in fishing gear	Decreased health, immune function, reproduction	Increased susceptibility to disease from decreased immune function
Sakhalin I-IX oil and gas	Disturbance may lead to habitat abandonment, changes in behaviour, physiological stress, masking or temporary hearing loss	Serious injury and mortality	Ingestion, contact with eyes, baleen, skin, loss of prey and/or habitat	Changes in biological diversity, particularly prey, may lead to decreased foraging efficiency with multiple secondary effects			Decreased health, immune function, reproduction	Increased susceptibility to disease from decreased immune function
Fisheries	Vessel operation, sonar may contribute to overall noise disturbance	Serious injury and mortality	Vessels may release oil or fuel, increasing exposure of whales	Fisheries development (e.g., bottom trawling) may lead to habitat alteration with secondary effects on prey availability		Serious injury and mortality, secondary reduction in reproduction	Possible exposure secondary to vessel accidents	
Coastal industrial development	Disturbance may lead to habitat abandonment, changes in behaviour, physiological stress	Nearshore activity may increase risk of collisions	Development may release oil and other pollutants, increasing exposure of whales	Noise, pollution, disturbance from human activities may lead to habitat degradation and abandonment		Serious injury and mortality	Decreased health, immune function, reproduction	Increased susceptibility to disease from decreased immune function
Shipping and transportation	Disturbance may lead to habitat abandonment, changes in behaviour, physiological stress, masking or temporary hearing loss	Serious injury and mortality	Vessel spills may lead to oil and gas exposure with ingestion, contact with eyes, baleen, skin, loss of prey and/or habitat	Vessel traffic may increase exposure to noise and disturbance, resulting in effective habitat degradation		Serious injury and mortality	Vessel accidents may increase exposure of whales to contaminants	

Table 6

Potential interactions of factors potentially affecting western gray whale reproduction and survival.

Activities	Noise	Collisions	Oil spills	Habitat degradation	Entanglement	Biotoxins	Contaminants	Disease
Noise		Noise could lead to changes in distribution, behaviour, physiological stress, or hearing capability of whales, any of which could increase their vulnerability to ship strikes	Noise could displace whales and alter their avoidance of oil, thereby increasing the risk of direct exposure to oil	Noise could displace whales causing them to forage in suboptimal habitat with inadequate prey			Noise could result in physiological stress that suppresses the immune system, exacerbating the immuno-suppressive effects of contaminant exposure	Noise could result in physiological stress that suppresses the immune system and increases susceptibility to infectious disease
Collisions							Vessel accidents may release contaminants and thereby increase risk of exposure	
Oil spills	Increased traffic of oil spill response vessels could increase sources of noise with subsequent adverse effects	Oil spill response vessels could increase risk of ship strikes; damage to the nervous system, eyes or ears could decrease whale detection and avoidance of ships; avoidance of spilled oil could displace whales into shipping lanes and increase collision risk.		Sedimentation of oil may change the abundance and composition of prey in foraging habitat		Spilled oil and by-products could increase micronutrient availability in the water increasing frequency of harmful algal blooms	Ingestion and inhalation of oil and its metabolites may result in effects on metabolism that exacerbate the effects of exposure to organochlorine contaminants	Oil ingestion and inhalation could damage organs increasing susceptibility to disease
Habitat degra-dation						Alteration of currents, micronutrients or water temperature could increase incidence and extent of blooms of toxigenic algae		Changes in prey base resulting in malnutrition could lead to increased susceptibility to infectious disease
Biotoxins		Exposure to biotoxins could cause nervous system dysfunction and reduce the ability of whales to avoid ships	Exposure to biotoxins could cause nervous system dysfunction and reduce the ability of whales to avoid oil spills				Exposure to immunosuppressive biotoxins could potentiate the immunosuppressive effects of contaminant exposure	Exposure to immunosuppressive biotoxins could increase susceptibility to infectious disease

Contaminants			Effects of contaminants on metabolism and reproduction, as well as carcinogenic effects, could be potentiated by effects of ingested or inhaled oil and its metabolites					Immunosuppressive effects of contaminants may increase susceptibility to infectious diseases
Disease		Sick animals will be less able to avoid ships	Sick animals may be less able to avoid oils spills, so will ingest or inhale more oil.					

Chapter VII: Use of simulation modelling to assess the implications of various industrial and other scenarios on western gray whale survival and recovery

1   INTRODUCTION

We used a quantitative model to predict the potential consequences of Sakhalin II Phase 2 oil and gas development on the western gray whale population. The model incorporated available data on the current population (e.g. abundance, vital rates) including uncertainty and variation in these data, and projected the population forward to predict its response to a set of plausible adverse scenarios associated with oil and gas development.

The mechanisms by which oil and gas operations and accidents will affect individual animals are themselves uncertain, as discussed in previous chapters. We therefore specified model scenarios based on our best judgement of plausible effects on individual animals, and examined the consequences of these for the population as a whole over time. We did not use the model to evaluate whether or not such scenarios will occur but rather to evaluate the population-level consequences if they did occur.

1.1   Modelling approach

The modelling approach consisted of two main steps. First, the model and population data from 1994 to 2003 were used to estimate frequency (probability) distributions for important population parameters (such as birth and death rates). Once those distributions had been estimated, they were used to project the population forward from 2004 to 2050, first without oil and gas effects, and then under different effect scenarios. The scenarios were constructed to examine possible added impacts on the population, *i.e.* impacts in addition to those that currently may be occurring.

A Bayesian probabilistic model (Annex F) was used to estimate probability distributions for population parameters by fitting (comparing) sighting data predicted by the model to actual sighting data from recent studies (1994-2003). The approach was individual-based and structured to capture variation about the essential parameters of the gray whale life cycle without requiring more data than are available. The approach accounted for sources of uncertainty, including uncertainty in parameter estimates, natural or environmental variation in those parameters, and demographic variation (e.g. randomness expressed in the lives of individual animals, such as the sex of a newborn calf or the probability that an individual will survive a given year).

For each scenario of adverse effects, the model generated multiple samples of 2004 population states and parameter values based on their estimated probability distributions. Each sample was then used to project the population forward in time. The results from all projections under a given scenario were combined into probability distributions reflecting both uncertainty about the current population state and parameter values, and the inherent randomness in the projections due to chance events in the life of each individual (e.g. death, calving, sex of a calf). The distributions constitute our best prediction of the population consequences of that scenario.

1.2   Input data for fitting the model

The model was fitted to data collected over the last 10 years; thus, the estimated parameters of the model reflect the processes affecting the population during this period. For example, the estimated mortality rate implicitly included all sources of mortality operating over this period, including predation, kills by humans (deliberate or otherwise) and accidents (e.g. ship strikes). If the population was subject to inbreeding depression due to having passed through a very low population size ('bottleneck') during the 20th century, then the effects of this were in principle reflected in the population parameters estimated from the data.

The purpose of model 'fitting' was to align model predictions as closely as possible with observed data. For this purpose, the most informative quantitative data on the population are from photo-identification and biopsy studies conducted annually by the joint Russia-U.S. programme from 1994 to the present, with the exception of 1996 (Weller *et al*. 2000, 2001, 2003a,b, 2004, Wursig *et al*. 1999, 2000). The data for the seasons 1994-2003 have been processed to date, and were made available to the panel by the Russia-U.S program for the purpose of this review. During this period, a total of 265 days of survey have been conducted in the Piltun area, plus one day in the offshore area (Fig. 3). Since no whales were seen exclusively in the offshore area, model input is based on sightings in the Piltun area only. The sighting history of each whale during this period provides information on the year it was first seen (as a calf or older), its sex (if known; sex determination was based on genetic analysis of biopsy samples), whether it was seen in each subsequent year and, if seen, whether it was with a calf, and if a calf whether it was in the company of its mother. A total of 130 individuals (65 males, 44 females and 21 animals of unknown sex) had

been identified in the Piltun area by the end of the 2003 feeding season. A total of 42 calves have been identified, of which 26 were male, 11 female and 5 of unknown sex. Twenty-three individual females, none of known age, have been observed with a calf. Five identified calves could not be assigned to a mother. Fourteen inter-birth intervals have been observed, consisting of four 2-year intervals, eight 3-year intervals and two 4-year intervals. The apparently 4-year intervals may be genuine, or may be the result of failure to observe or assign a calf to its mother, or the loss of a calf before it could be observed and recorded. Longer inter-birth intervals may not be fully represented in the data because the time series is relatively short.

For each parameter in the model, we did not attempt to obtain a single estimate, but rather a distribution of values. Possible values were drawn from uniform 'prior' distributions, which were then sampled in proportion to their likelihood (based on the data) to produce posterior distributions of the parameters. The posterior distributions reflect the information in the data and the residual uncertainty. Details of the fitting process are described in Annex F.

1.3 Structure of the model

1.3.1 Population structure

Gray whales, like other large whales, have a multi-year calving cycle. Multi-stage models that take account of an individual female's reproductive stage (immature, calving, resting) have been successfully fitted to photo-identification data for right whales in the northern and southern hemispheres (Caswell *et al.* 1999; Best *et al,* 2001; Cooke *et al*, 2001). The right whale stage-structure approach was adapted for application to western gray whales by re-casting it on an individual basis, which can be important for such a small population.

By correcting for the probability of sighting each whale, the model attempted to simulate the entire population, and not only those whales that have been photo-identified to date. During any given simulation, each individual whale was represented in a manner that reflected its age, sex and reproductive status (Table 7).

Table 7

'Age' classes used in the model

Females	Males
Calves	Calves
Age 1	Others (age 1+)
Age 2	
Age 3	
Age 4	
Age 5+, pre-mature	
Receptive or Resting (year after a calving, or before first calving)	
Receptive or resting, having already rested for at least 1 year	
Calving (adult, had a calf this year)	

Males were not modelled in detail because we assumed they are sufficiently abundant for reproduction. Females, on the other hand, were modelled in some detail. Each year, female individuals stayed in their class or moved to another one according to four estimated transition parameters (Table 8): the maturation probability (for immature whales aged 5+) a; the calving probability b for mature females that have not had a resting year; the (somewhat greater) calving probability c for mature females that have had at least 1 resting year since the last calving; the survival probability Sj for calves to age 1; and the non-calf survival probability S. The 'calf' survival rate Sj represents survival from the animal's first summer season to the next summer season (*i.e.* age 6-18 months). Calf mortality before the first summer season is subsumed into the calving probability, which reflects the probability of producing a calf that survives to the first summer season.

The youngest age at which a female could become mature under this model was 6 years, based on observations of the eastern gray whale population (Rice and Wolman, 1971). From age 5 onwards, a constant probability of maturing the next year was assumed, resulting in a range of individual ages at first maturity. The youngest age that a female could have its first calf was 7 years.

The calving probability parameters b and c determined the average inter-calf interval for breeding females. The effects of environmental variability were modelled by allowing the b and c parameters to fluctuate randomly from year to year. Changes in inter-calf interval are the only inter-annual changes that are feasible to detect from data of

this nature. All other parameters were assumed constant in the undisturbed case but were varied in specific ways in different impact scenarios as detailed below.

Table 8

Transition probability matrix for female whales

From	Age 1	Age 2	Age 3	Age 4	Age 5+	Receptive/resting	Rec./resting after 1 yr rest	Calving	Dead
Calf	Sj								$1-Sj$
Age 1		S							$1-S$
Age 2			S						$1-S$
Age 3				S					$1-S$
Age 4					S				$1-S$
Age 5+					$S(1-a)$	Sa			$1-S$
Receptive/resting							$S(1-b)$	Sb	$1-S$
Receptive/resting (after 1+ yr rest)							$S(1-c)$	Sc	$1-S$
Calving						S			$1-S$

Transition parameters

Sj Calf survival probability S Survival probability (non-calf) a Maturation probability (age 5+)

b Calving probability c Calving probability (after resting)

1.3.2 Detection of whales

Not all identified whales are present in the study area every year (Bradford *et al.* SC/55/BRG14) and the model allowed for whales to be absent in some years. Younger whales (aged 1+) are often absent, as are females in years when they do not have a calf. Since data were collected from the nearshore (Piltun) feeding ground, the detection probability of whales depended on their residence in the study area, among other factors, and was liable to differ between components of the population. The detection probability also could vary from year to year due, for example, to differences in the length of the research season.

The detection probability was modelled as a combination of an annual factor and a factor specific to the population component. For this purpose the population components are

- mothers and calves,
- pre-reproductive females,
- resting and receptive females (between calvings), and
- males (excluding calves).

The detection probabilities played no role in the demographic elements of the model, but were required for the purpose of determining the likelihood of model output, and were therefore important for estimating the most likely population trajectories. Some calves were weaned before the study season, and their mothers could not be identified. This implies that some females will have had calves in years in which they were not recorded as mothers. To accommodate this feature of the data, it was necessary to include the proportion of calves weaned before the season as an extra parameter in the model. Details are given in Annex F.

1.3.3 Sex ratio

The imbalanced sex ratio in the population, with an apparent bias towards males, was noted in Chapter I. It presented the panel with an conundrum. While a male bias in whales not observed as calves could potentially be explainable in terms of selective mortality or selective availability for censusing, the male-biassed sex ratio amongst biopsied calves (26 male calves to 11 female calves during 1994-2003) is hard to explain other than by an unlucky chance, or by an intrinsic male bias in calf production. The probability of such an unbalanced calf ratio occurring by chance when the long-term average ratio is 50:50, is approximately 0.02 (based on a two-tailed binomial probability calculation).

In the life sciences, it is conventional to reject explanations based on chance when the probability is below 0.05 on a two-tailed test. Given the potentially serious effects of a male-biased sex ratio on the recovery rate of the population, it would be incautious to assume that the current male bias amongst calves is due to pure chance, and that the bias will not continue. On the other hand, such cases of sex bias are rare among wild mammal populations. Both alternatives, a chance phenomenon or a real effect, seem rather unlikely.

A male bias, if it exists, is not very likely to be due to sex bias in sperm, but may occur if female embryos are less likely to develop successfully, possibly due to a genetic defect caused by a population bottleneck in the 20th century. Such an effect would lengthen inter-calf intervals because of the greater proportion of failed pregnancies. This would be consistent with the longer average inter-calf intervals in western gray whales compared with eastern gray whales.

To be duly cautious, the Panel decided to allow for the possibility that the apparent sex bias is a genuine effect, and not to assume that the future sex ratio of calves will be balanced. The sex ratio of calves was accordingly treated as a free parameter of the model, that varies about the current ratio.

1.4   Results: parameter estimates

Estimated distributions for the key population parameters are shown in Table 9 (see Annex F for the full set of distributions). The median parameter estimates are approximately 0.97 for the annual adult survival rate, 0.73 for the 'calf' survival rate (i.e. survival from first to second summer season), 0.41 for the sex ratio (female proportion) and approximately 3% per annum for the rate of population increase. Approximate 90% confidence limits are 0.96-0.98 for the adult survival rate, 0.61-0.83 for the calf survival rate, 0.34-0.47 for the sex ratio and 1-5% for the annual rate of population increase.

Table 9

Prior ranges and estimated posterior distributions of selected parameters

PARAMETER	Prior Range Min	Max	Percentiles								
			1	5	10	25	50	75	90	95	99
Annual survival	0.8	1	0.947	0.955	0.959	0.964	0.969	0.975	0.980	0.982	0.987
Calf survival (6-18 mo.)	0	1	0.561	0.608	0.629	0.681	0.732	0.773	0.809	0.827	0.864
Female sex ratio	0	1	0.315	0.338	0.355	0.380	0.407	0.436	0.462	0.474	0.504
Maturation prob.	0.2	0.5	0.241	0.259	0.276	0.312	0.354	0.407	0.467	0.494	0.499
Median calving prob.	0	1	0.076	0.148	0.172	0.225	0.296	0.379	0.474	0.529	0.615
Median calving prob. after 1+ yr rest	0	1	0.482	0.619	0.679	0.757	0.845	0.901	0.936	0.963	0.986
Population 1994	50	250	59	63	66	69	75	81	86	89	94
Rate of Increase			0.009	0.015	0.019	0.026	0.033	0.040	0.047	0.050	0.055

The distribution of the estimates of annual maturation probability of age 5+ females is hardly different from the assumed prior range (0.2–0.5). This implies that the data contain essentially no information on this parameter. This is because no known-age western gray females have yet been observed to have a calf. The prior range corresponds to a range for the mean age at maturity from approximately 7 to 10 years, which is based on information from eastern gray whales (Chapter II). If the series of western gray whale surveys are continued, then we should start to see known age females reproducing over the next few years, which will substantially improve estimation of this parameter.

The distributions for most of the other population parameters are clustered well within the prior ranges, and hence are not constrained by the assumed prior ranges. However, the data do not seem to place a well-defined upper bound on the variance of the annual calving probabilities.

The data indicate a positive annual rate of population increase (a derived parameter for which no prior range was specified) but the estimated 90% confidence range of 1-5% per annum show that after nearly 10 years of data collection (1994-2003, with 1 year missed) there is only just enough information to distinguish an increasing population from a decreasing one. Even with continued, uninterrupted annual surveys, statistical verification of a substantial change in trend may take of the order of 10 years. Because it will be essential to detect and respond to any downturn in population trend, future monitoring efforts cannot be less frequent or effective than they have been.

Unfortunately, the loss of one year of data cannot be fully redressed by more intensive survey in other years. Because annual detection rates are estimated to be over 50%, adding additional effort in years in which there already is a survey will be of less benefit than ensuring that there are no gaps (years missed) in the data series. Furthermore, when years are missed, animals enter the population without being seen as calves, and thus are not of known age. This increases the uncertainty over the population component to which they belong, and hence diminishes the extent to which observations of these animals contribute to improving the precision of population parameter estimates.

1.5   Projections without additional disturbance

The posterior distribution of population projections is shown in Fig 1a-d for (a) the mature female population; (b) the age 1+ male population (*i.e.* non-calf males); (c) the female 1+ population; and (d) the total 1+ population. The median, lower quartile, and lower 10%, 5% and 1% tails of the population distribution by year are plotted. Trajectories above the median are of less conservation concern and are not shown.

The results indicate that in the undisturbed case, the population is quite likely to increase significantly by 2050, albeit still remaining well below pre-whaling levels. The 5th percentile of the projected female population size is approximately level, which means that there is an approximately 95% chance that the population will increase and an approximately 5% chance of a decrease. We use this scenario as the reference case against which the various impact scenarios described below will be compared.

As expected, the range of uncertainty over the projected population size increases over time. Even the current population is subject to some uncertainty because we do not know: (i) the number of whales that have not been identified to date and (ii) the number of whales identified to date that may already have died. The median estimate for the age 1+ population size in 2004 is 102 whales with 90% confidence limits 94 to 110.

1.6   Impact scenarios

1.6.1   General issues

As discussed in the foregoing chapters, potential project-related and cumulative impacts on the population can be of various kinds and operate over different time scales. To investigate and illustrate the potential impacts, the Panel chose various scenarios that, in their best judgement, were both realistic and pertinent to decision-making related to the Project.

The time-scales of most interest are ~3 years (construction phase) and ~45 years (whole lifetime of the Project including the operational phase and potential associated developments). Projections for impact scenarios are presented in terms of the female age 1+ component of the population because females are the more significant sex for the viability of the population.

1.6.2   Additional deaths

Four scenarios were modelled to predict the possible consequences of direct mortality. The first scenario involved the added deaths of three randomly selected whales per year during 2005-2007 (construction phase). The second involved the added deaths of three randomly selected females per year (plus an unspecified number of males) during 2005-2007 (construction phase). Since we present projections only for the female population, it is not necessary to specify the numbers of males killed. This may be more or less than the number of females, depending on sex-specific vulnerability, if any, to sources of mortality.

The third and fourth scenarios involved the added death of one random animal or one female, respectively, per year from 2005 to 2050. An elevated risk of accidental death may be expected both in the short term (construction phase of the Project) and in the medium term (whole Project lifetime) due to ship strikes or acute exposure to oil. Although the Panel did not have sufficient data to quantify these risks, the model provides a means of determining the consequences for the population of the accidental loss of a given number of whales per year for a given period. It should be note here that oil and gas operations may not account for all the additional mortality in these modelled scenarios, but they may contribute significantly to them and the end result for the population will be the same.

1.6.3   Impacts on feeding and reproductive success

Two scenarios were modelled to predict possible impacts on feeding and reproductive success. The first involved reduction in reproductive rate of one-third (33%) over 2005-2007. The second involved a 33% reduction in reproductive rate from 2005 through 2050. The rationale for these scenarios is given below.

During 2005 to 2007, disturbance of the whales by the presence of construction activities or noise could result in stress and reduce foraging success. As a result, whales could be excluded from the main feeding areas for all or part of the feeding season, resulting in time spent foraging in less productive areas. Alternatively, whales could be excluded from part of the feeding area, resulting in greater crowding of the remaining area and reduced foraging efficiency per whale. If such stress does not result in total reproductive failure, but lengthens the inter-calf interval within the normal range (e.g. from 2 to 3 years), then the population effect will depend on the proportion of the breeding population that is affected. Construction for the 'base case' pipeline route for Sakhalin II Phase 2 is estimated to involve ensonification of up to 50% of the nearshore feeding ground, which is the primary ground for reproductive females and calves. Assuming a similar or greater noise production by the Sakhalin I project, virtually the entire nearshore feeding ground could be ensonified during the 3-year construction period of Sakhalin II Phase 2.

The relationship between feeding success and reproductive success is not clear for gray whales. Perryman *et al.* (2002) reported a strong relationship between calf production in eastern gray whales and the length of the feeding season in the Chirikov Basin, which is assumed to be determined mainly by ice cover. A reduction of about 50% in calf production was associated with a reduction of about 20% in the length of the feeding season. However, this conclusion should be viewed with caution, because feeding in Chirikov Basin may no longer be as important for eastern gray whales as it was in the 1980s (Moore *et al*, 2003) and the results reported by Perryman *et al* (2002) may not reflect a true cause-and-effect relationship.

The relationship between feeding and reproduction is likely determined, at least in part, by energy requirements. Lockyer (1987) found that for fin whales the production of a calf (including both pregnancy and lactation) adds about 50% to the annual energy requirement of a female. If that is true, then a reduction of 10% in total energy intake in a whale normally reproducing every two years would result in a 50% reduction in the surplus available for reproduction. As a consequence, this female would only reproduce every four years, assuming that the calf receives the same amount of energy. Alternatively, the frequency of calf production could be less strongly affected, but only by reducing the energy provided to the calf and thereby lowering its chance of survival. During 2005 – 2050 the same kind of effects might persist if disturbance during construction results in permanent changes in habitat use and foraging patterns or if support/maintenance activities are sufficient to perpetuate such avoidance of prime habitat areas. In addition, exposure to low levels of contaminants could negatively affect reproduction, as appears to have been the case for polar bears in the northeastern Atlantic Arctic (Derocher *et al*. 2003, Haave *et al*. 2003).

1.6.4 Major accidents

One scenario was modelled to predict the potential consequences of a major accident that could lead to both mortality (i.e. death of 20% of the population at the onset of the accident) and temporary reproductive failure (i.e. five years).

The rationale for this scenario was the potential for an oil spill, as described in Chapter IV. Although the probability of a major oil spill is low in any one year, such an event is not unlikely over the lifetime of the Project. A major spill could have an immediately catastrophic effect, potentially killing a portion of the population (particularly whales that are young or in poor condition). In addition, a spill could kill gray whale prey populations and contaminate habitat to the extent that prey biomass and productivity could be reduced over a prolonged period. To predict the consequences of this scenario, we assumed that the immediate effect would be the death of 20 percent of the population followed by a five-year period of reproductive failure. The estimated duration of failure (five years) is based on the assumption that it could take 2-3 years for prey abundance to recover and a further 2-3 years for females to recover body condition sufficient for successful reproduction. The effects of oil spills elsewhere in the range of western gray whales, and not affecting the main feeding ground, would be less.

1.6.5 Cumulative effects

To predict the consequences of combined risk factors, we modelled a scenario involving a prolonged reduction of 10% in reproductive success and the accidental death of a female whale once every three years.

1.7 Results of impact scenarios

1.7.1 General issues

The impact scenarios are listed in Table 10. The population trajectories for each impact scenario are illustrated in Figs 3-9. In all scenarios the range of possible population trajectories is quite broad, indicating that predictions of risk from simple deterministic population projections can be misleading.

Table 10.

Summary of impact scenarios run

	Type of impact	Size of impact	Duration
Fig. 2	Additional deaths	3 random animals per yr	2005-07
Fig. 3	Additional deaths	3 females per yr	2005-07
Fig. 4	Additional deaths	1 random animal per yr	2005-50
Fig. 5	Additional deaths	1 female per yr	2005-50
Fig. 6	Reduction in breeding success	33%	2005-07
Fig. 7.	Reduction in breeding success	33%	2005-50
Fig. 8.	Combination (major spill)		
	mass mortality 20% of pop.		one-time
	+ reproduction fails for 5 years		(random yr)
Fig. 9	Combination		
	Additional deaths	1 female per 3 yr	2005-50
	Reduction in breeding success	10%	2005-50

1.7.2   Additional deaths
Accidental deaths averaging up to 3 whales per year during 2005 to 2007 only (Fig. 2) are not predicted to significantly alter the chance of net population increase over the period to 2050. The added deaths during 2005-2007 would increase the time that the population remains at a critically low level, although the effect would not be severe unless combined with other effects. For example, the median date for recovery to a 1+ female population size of 50 females is postponed from 2016 in the reference scenario to 2020 in this scenario.

The death of an average 3 female whales per year during 2005 to 2007 (Fig. 3) would cause a longer delay in recovery. The median date for recovery to a population size of 50 females (age 1+) is postponed from 2016 to 2027.

The effects of a longer-term risk of accidental death are more severe. Random additional losses averaging one random whale per year from 2005 to 2050 would increase the chance that the population would not grow beyond its current level from around 5% to between 10% and 25% (Fig. 4).

The effects are more severe if the extra annual death is a female. The average loss of one extra female per year would be very likely to reverse the increase of the population and drive it towards extinction (Fig. 5).

1.7.3   Reductions in reproductive success
A reduction in reproductive success of one-third (33%) over the construction period (2005-2007) alone would probably not have a significant impact on the long-term recovery prospects of the population, but the population would be quite likely to fail to increase during the three-year period in which the effects occurred (Fig. 6). If the 33% reduction persisted through 2050, the risk that the population will fail to increase over this period may be substantially elevated (from around 5% in the reference scenario to over 25% in this scenario) (Fig. 7).

1.7.4   Major accident scenario
Just one major accident during the 45 years of construction and operation could raise the risk that the population will fail to increase by 2050 from about 5% in the reference scenario to about 25% (Fig. 8).

1.7.5   Cumulative impacts
If reproductive success is persistently reduced by 10%, and an average of one accidental death of a female occurs every three years, then the risk that the population will fail to increase by 2050 is raised from 5% in the reference scenario to over 25%. Such low levels of impact would not necessarily be detected on an annual basis, even with a high level of monitoring. This indicates the importance of long-term monitoring capable of detecting changes in population trend.

1.8   General conclusions from modelling

This limited modelling exercise shows that persistent effects on the population are potentially more serious than shorter-term effects of larger magnitude. Even in the undisturbed case, there is some risk that the population will not increase, and this risk is substantially enhanced in some impact scenarios.

The effects of additional deaths are potentially most serious. Again, t**he loss of an average one additional female per year (over and above the death rates estimated in recent years) would be sufficient to drive the population towards extinction with high probability.**

Even effects that may be too small to be detected in the short term (such as a 10% reduction in breeding success and the average loss of one additional female every three years) could, with a significant probability, prevent increase of the population if they persist. This result emphasises the importance of anticipating and avoiding potential risks to the population. A wait-and-see approach, acting if and when there appears to be an impact on the population, would not ensure its conservation. The survival of the western gray whale population cannot be assured until all impacts, including but not limited to oil and gas effects, can be better quantified and shown, using a demographic model such as the one employed here, to be within the limits that the population can sustain with high probability.

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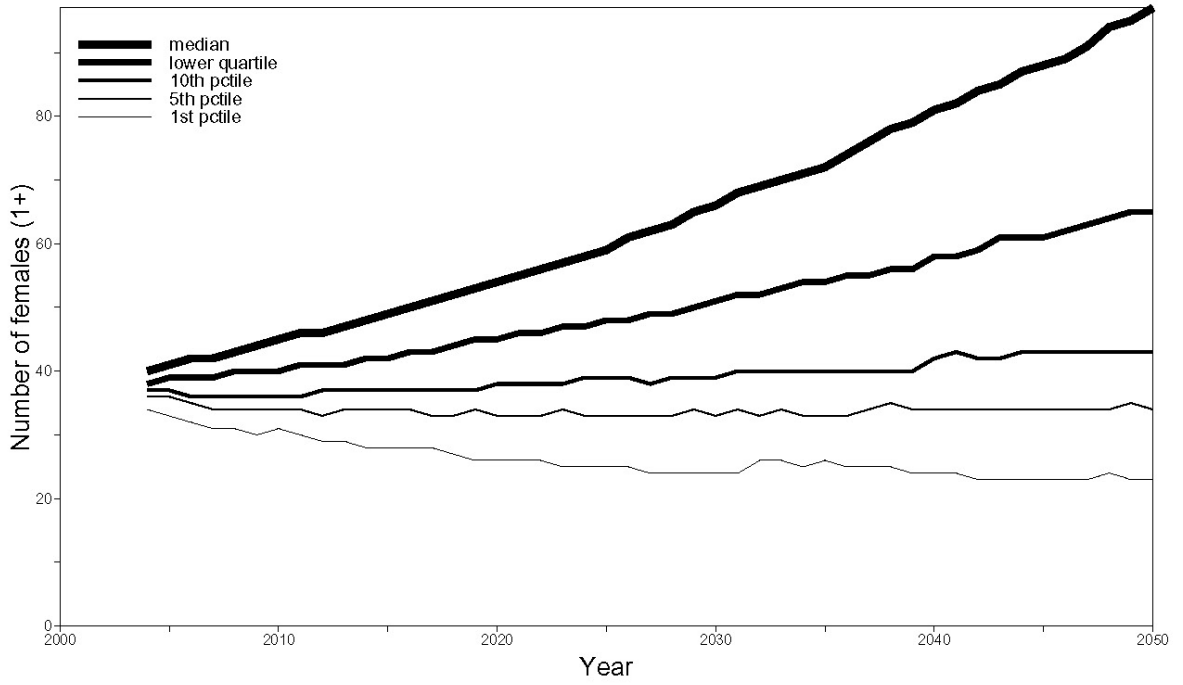
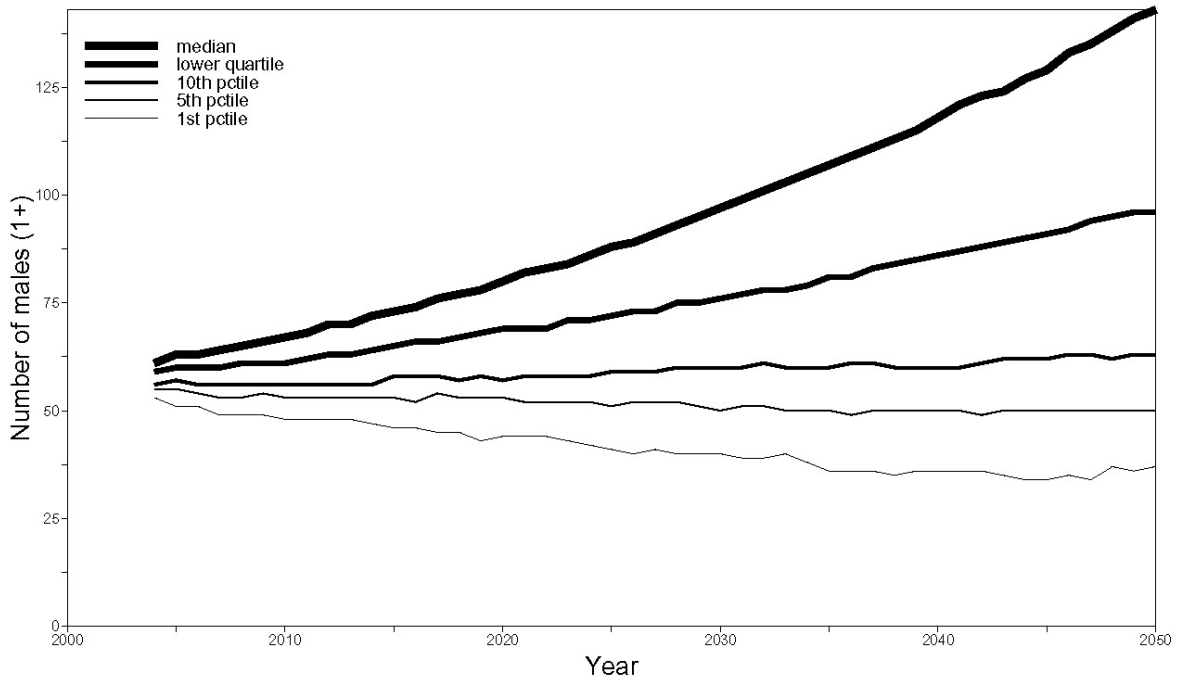Fig. 1a. Scenario with no extra impacts. Projection of females (age 1+).

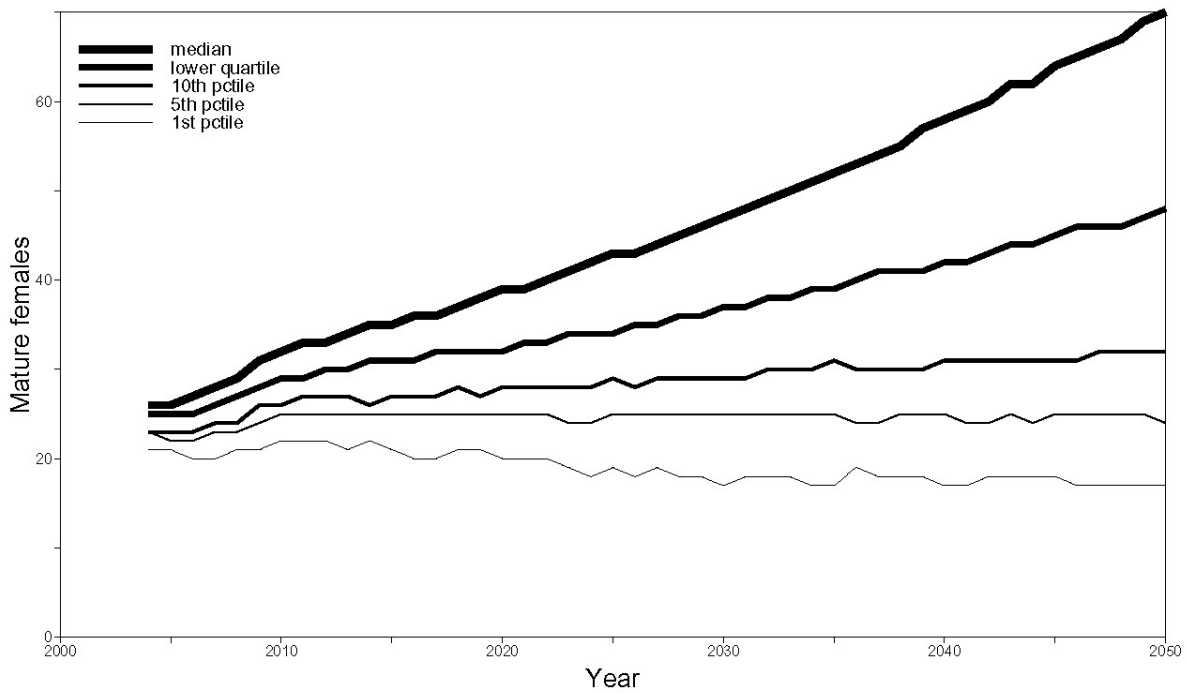Fig. 1b. Scenario with no extra impacts. Projection of males (age 1+).

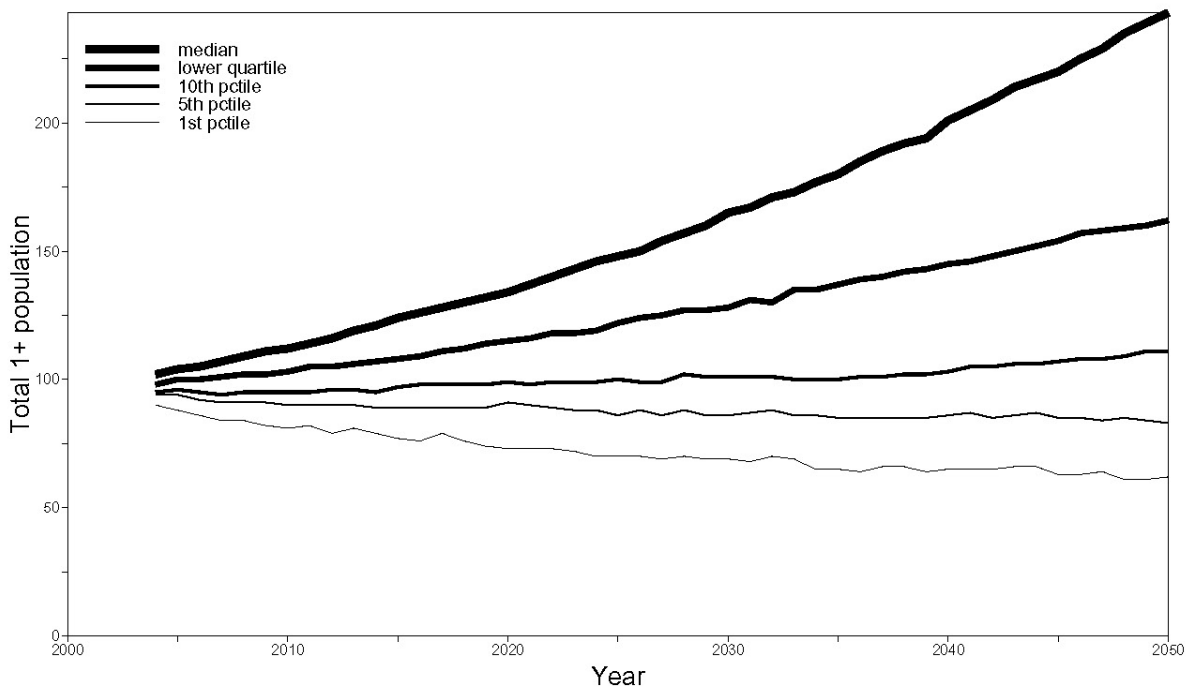Fig. 1c. Scenario with no extra impacts. Projection of mature females.

Fig. 1d. Scenario with no extra impacts. Projection of total population (age 1+).
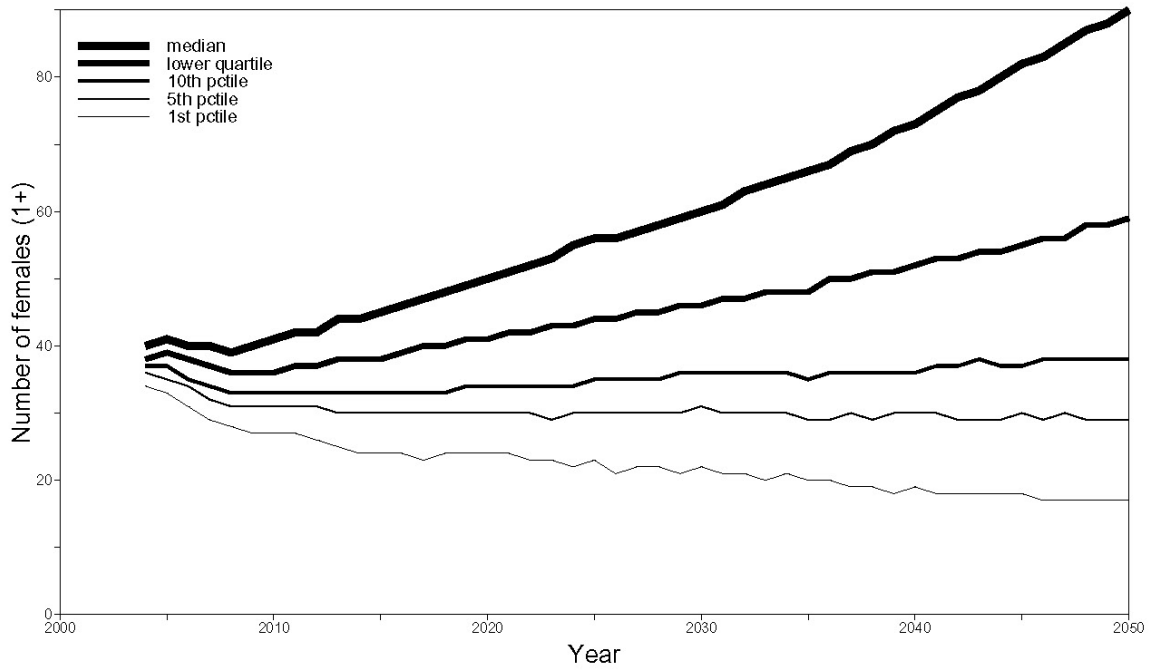
Fig. 2. Impact scenario: 3 random animals killed per year during 2005–07.
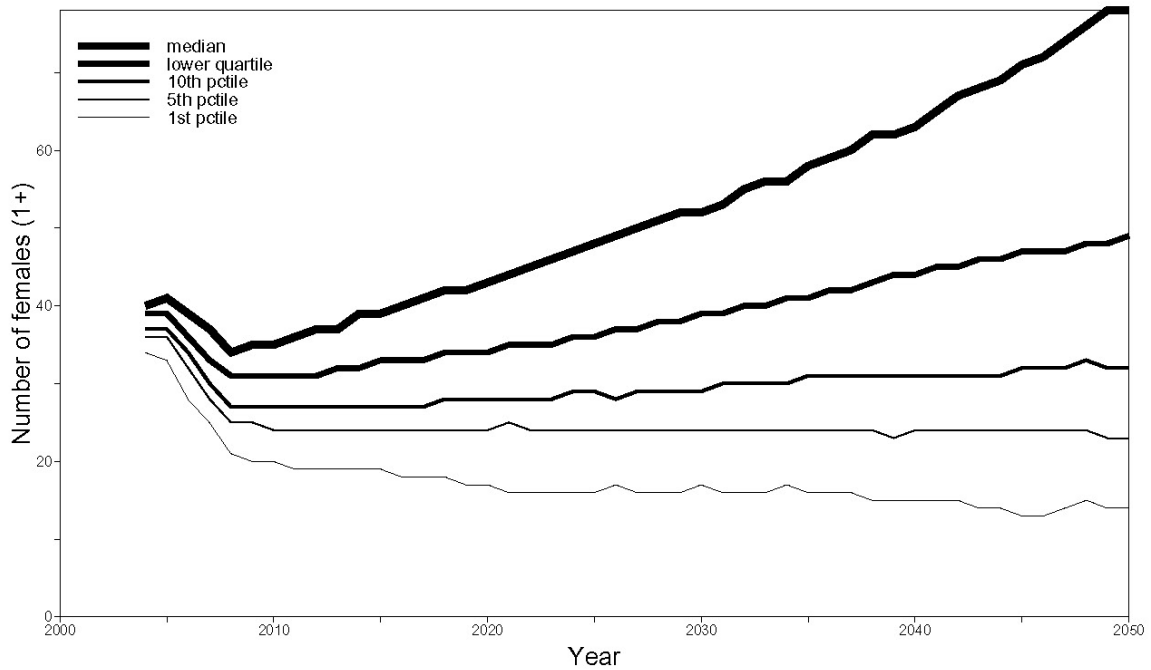

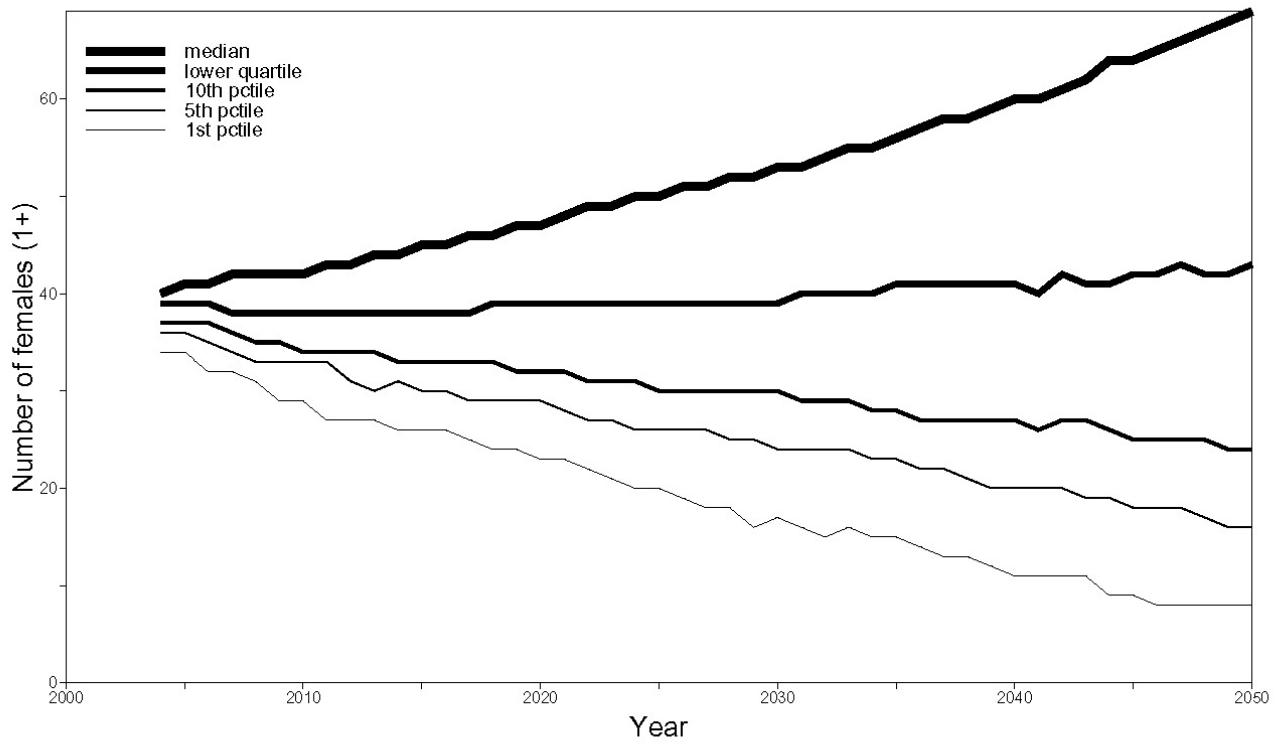Fig. 3. Impact scenario: 3 females killed per year during 2005–07.

Fig. 4. Impact scenario: 1 random animal killed per year from 2005 onwards.
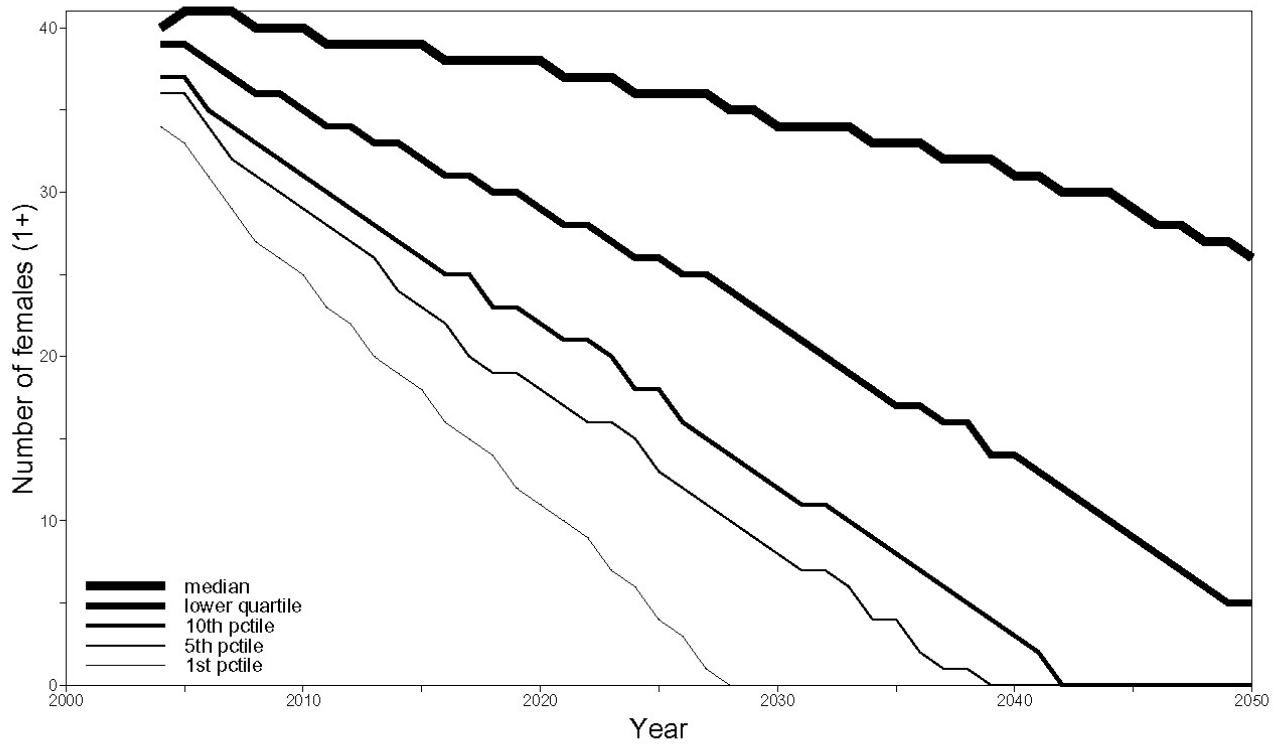
Fig. 5. Impact scenario: 1 female killed per year from 2005 onwards.

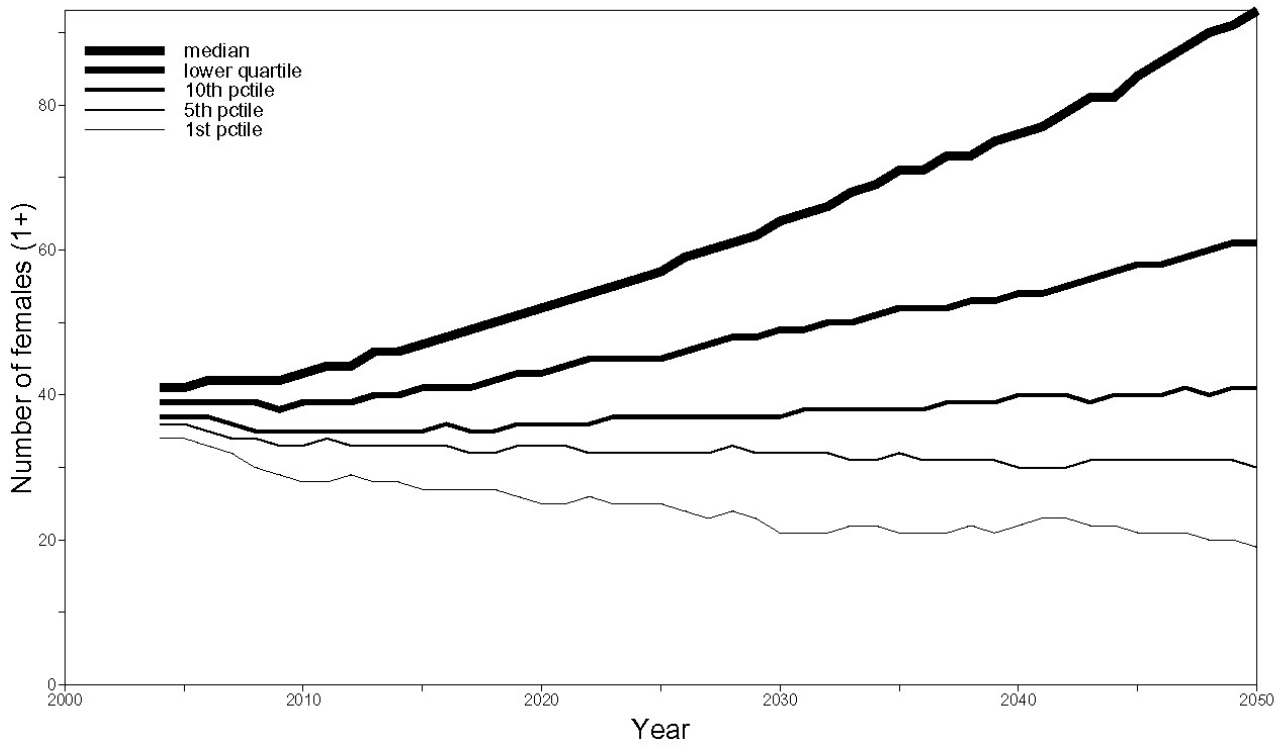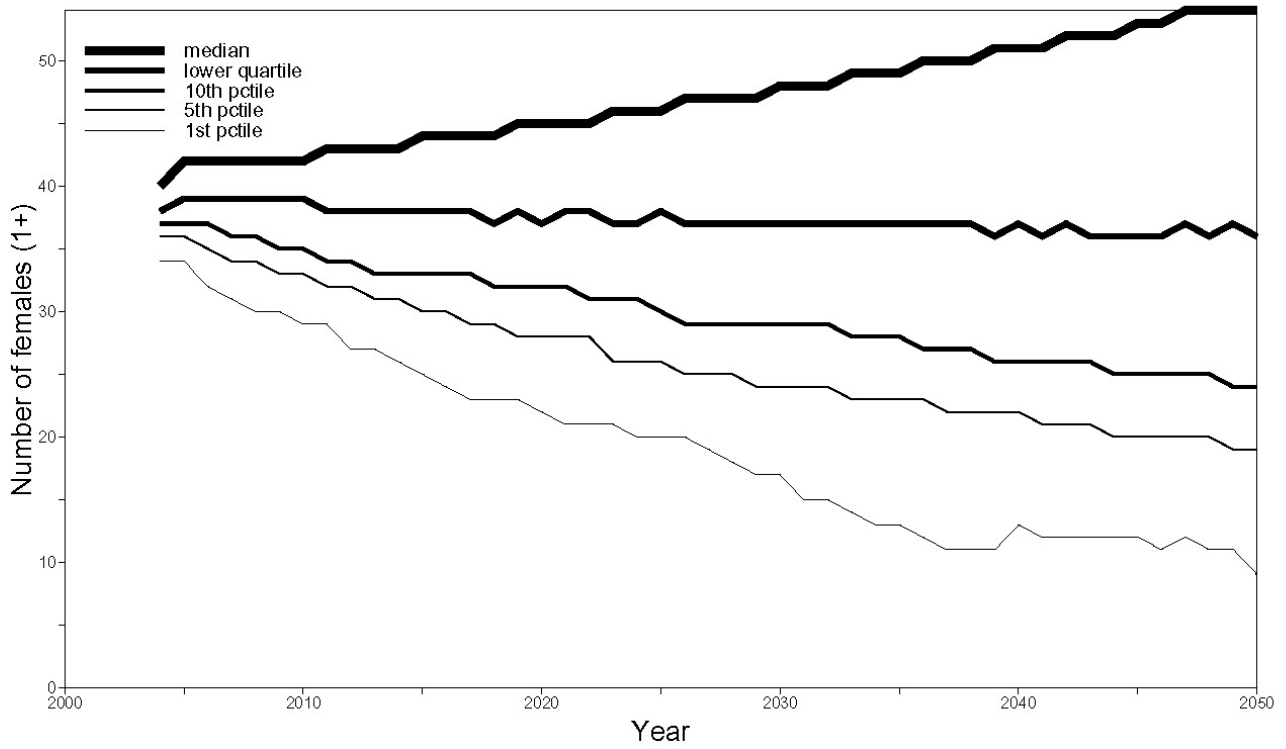Fig. 6. Impact scenario: 33% reduction in reproductive success during 2005–07.

Fig. 7. Impact scenario: 33% reduction in reproductive success from 2005 onwards.
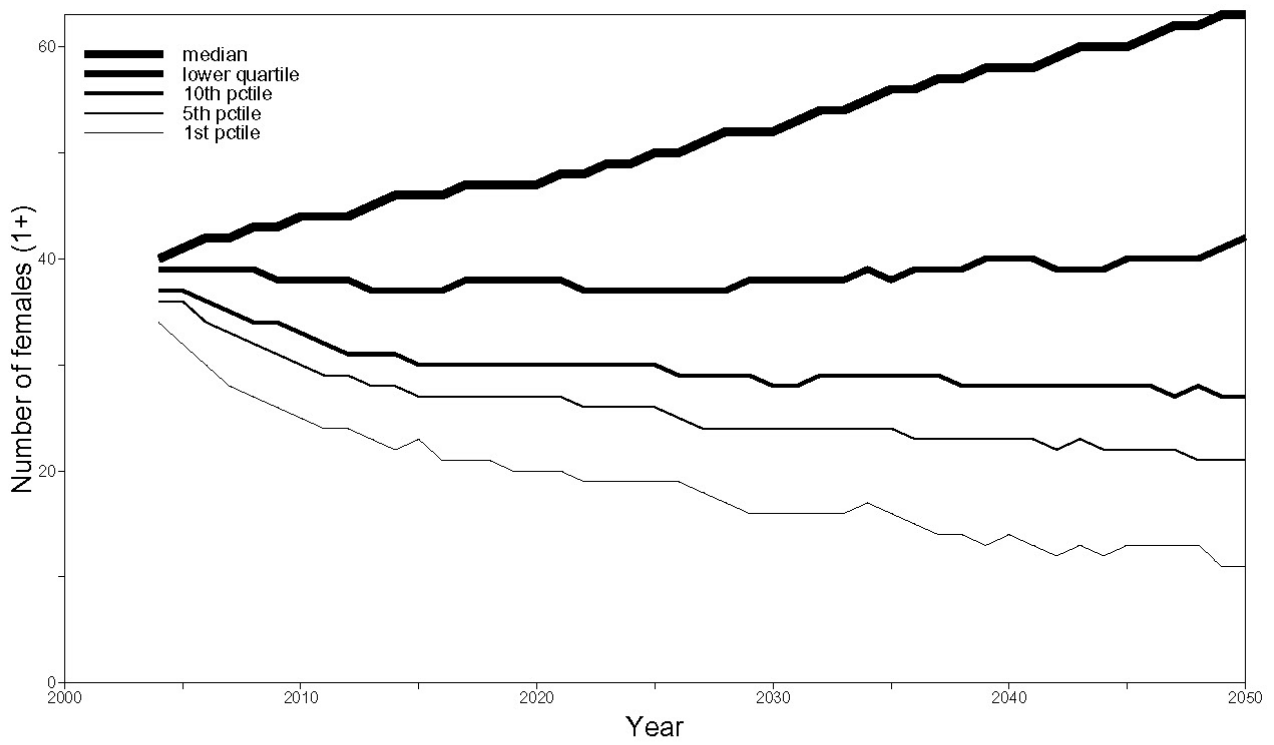
Fig. 8. Scenario with major accident at random time during 2005–50:
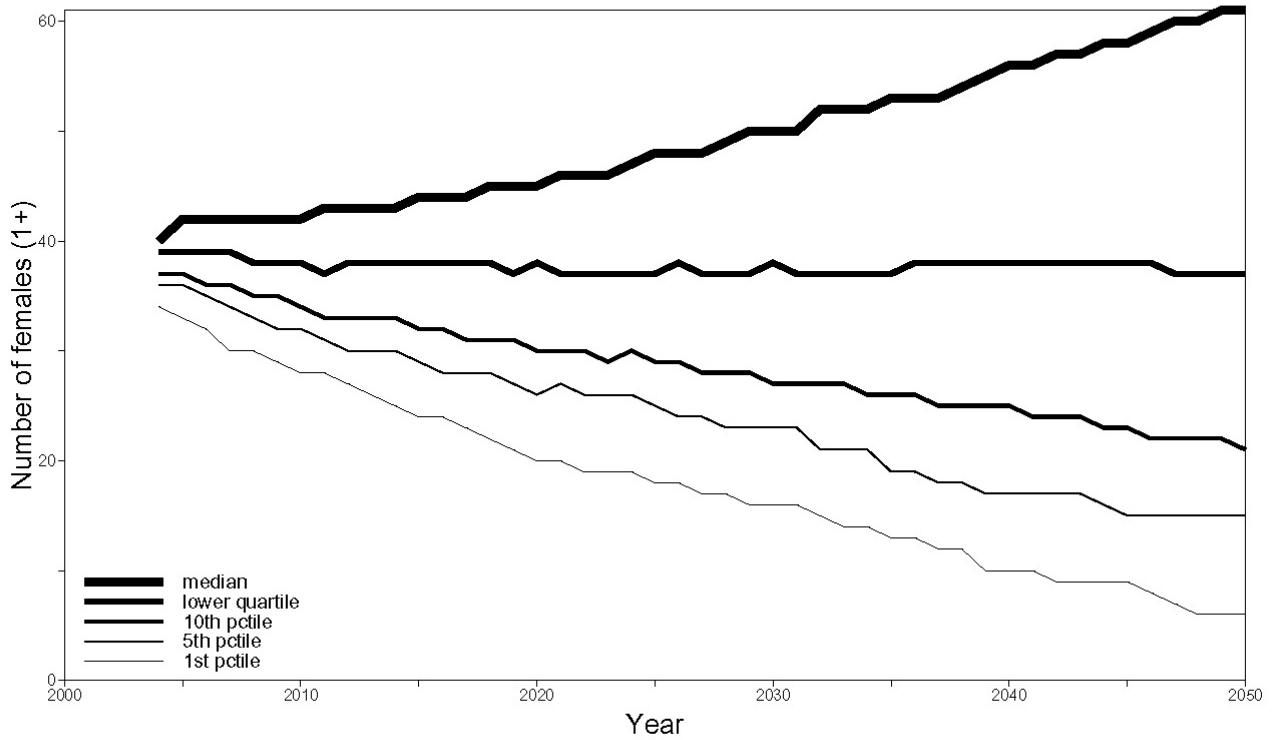20% immediate mortality and reproductive failure for 5 years.

Fig. 9. Low level impacts during 2005–50: 10% drop in reproduction
plus one extra female lost every 3 years.

Chapter VIII: Overall conclusions

The small population of western gray whales, numbering only about 100 animals, is on the edge of survival. It was reduced to such low numbers by commercial whaling that in the mid 20th century it was thought to be extinct. The few surviving animals (possibly including only 23 reproductively active females) face a number of hazards throughout their range. It is particularly unfortunate that the only known foraging grounds for the population lie along the northeastern coast of Sakhalin Island, where both existing and planned large-scale offshore oil and gas activities pose potentially catastrophic threats to the population. These include the possibility of direct kills from collisions as well as reduced reproductive success and survival through the degrading of this crucial habitat as a result of physical disturbance, oil contamination of the whales and their prey, and the introduction of loud underwater noise. Two major development projects – Sakhalin I and Sakhalin II – occur close to the nearshore and offshore feeding areas and their activities are of great conservation concern. Other projects add to the concern.

The Panel had been asked in particular to review phase 2 of the Sakhalin II project, which will greatly enhance the project's economic productivity. The Panel received and reviewed a tremendous amount of documentation from SEIC and was thoroughly briefed by SEIC representatives concerning the company's ongoing and planned operations for Sakhalin II (although see Item 6 below). It was clear that SEIC had put considerable sums of money into research on western gray whales, assessing the risks to this population associated with Sakhalin II, and developing risk-reduction (mitigation) measures. The Panel noted that once completed and fully operational, Phase 2 will considerably reduce certain types of risk to gray whales, specifically those associated with the current procedure of transferring oil from the PA-A platform into tankers for transport to distant markets. However, a number of other risks will increase as Phase 2 construction activity proceeds, and some of those risks will remain throughout the lifetime of the Project.

The underlying question before the Panel was whether the risks are being, or will be, managed in an effective manner to allow oil and gas development to proceed off northeastern Sakhalin without further jeopardising the survival and recovery of this critically endangered whale population. In the preceding chapters of this report, the Panel has presented its detailed consideration of the risks, the options for mitigation and the need for monitoring as and if development proceeds. A feature of this review was that important information gaps left considerable uncertainty over many aspects of risk evaluation and the efficacy of proposed mitigation measures. Those gaps pertained not only to important scientific information on the whales, their prey resources and their habitat, but also to the SEIC decision-making process. SEIC have applied a conventional risk-reduction standard, whereby risks are to be reduced to levels 'as low as reasonably practicable' (ALARP). The Panel often was unable to determine just what that meant, and how various considerations (e.g. cost-effectiveness, conservation) were considered and weighed in decision-making. The lack of specificity associated with SEIC's application of the ALARP standard to important decisions, such as location of the proposed PA-B platform, effectively precluded the Panel from completing a reasoned and rigorous evaluation of many of the risks and mitigation strategies associated with Phase 2.

Given the potential effects of the identified risks, as well as the large amount of uncertainty surrounding them and the questionable efficacy of proposed mitigation measures, the most precautionary approach would be to suspend present operations and delay further development of the oil and gas reserves in the vicinity of the gray whale feeding grounds (including both Sakhalin I and II), and especially the critical nearshore feeding ground that is used preferentially by mothers and calves. This would allow much-needed refinement of risk assessment and further development of appropriate, independent mechanisms for monitoring and verification of mitigation practices. If for some reason this is not deemed possible, decisions to reduce risks to the whales, and particularly to females with calves in the nearshore foraging area (occupied from June-November), need to be conservative (i.e. precautionary, from the perspective of western gray whales and their feeding habitat). Moreover, substantial effort will need to be put into monitoring the effects of those decisions on gray whales, with the understanding that subsequent modification of procedures will take place in response to the monitoring results.

1 CUMULATIVE EFFECTS AND MODELLING (CHAPTERS VI AND VII)

The fate of western gray whales will ultimately depend on their ability to cope with the cumulative effects of multiple anthropogenic and natural factors on both the whales themselves and on 'related key elements of biodiversity', notably the prey communities that sustain the whale population. The Panel focussed on Sakhalin II Phase 2 but it also considered the cumulative effects of the entire Sakhalin II project, other oil and gas projects,

particularly Sakhalin I, and other human activities in the region and the various threats faced by the whales elsewhere in their range.

The only way to examine this issue properly is through population modelling under various assumptions of threats and their possible effects. Among other things, the modelling showed that:

- even with no additional anthropogenic risks beyond those it faces at present, there is some risk that the population will not recover;

- this risk is increased, in some cases substantially so, under the various impact scenarios considered plausible by the Panel (which were not necessarily 'worst case scenarios');

- persistent effects are more serious than acute (short-term) effects of larger magnitude;

- additional whale deaths, regardless of the cause, have the most serious consequences for the population – most importantly, the loss of one additional female per year (over and above the death rates experienced in recent years) would be sufficient to drive the population towards extinction with high probability.

- effects that may be too small to be detected in the short term (such as a 10% reduction in breeding success combined with the loss of one additional female every 3 years) can prevent population recovery if they persist.

Perhaps the most important lesson to be learned from this modelling exercise is that the anticipation and avoidance of potential risks to the population is essential. Waiting for conclusive scientific proof that a particular activity or set of activities is having a population-level effect is not an appropriate approach for ensuring the conservation of this population. Action to prevent or mitigate risk needs to be taken based on the assumption that an impact will occur, until it is shown that it will not. The survival of the population in the context of development impacts cannot be assured until the potential extent of impacts can be better quantified and shown, using a demographic model such as the one employed here, to be within the limits that the population can sustain with high probability.

In this context, annual monitoring of the population, through uninterrupted continuation of the collection of photo-identification data, biopsy sampling of new individuals and refinement and updating of the population model, is essential. The loss of a single year of data would limit our understanding of critical population parameters and our attempts to evaluate, detect and predict the cumulative impact of threats to the population.

The following sections highlight what the Panel considers to be the key points in the report regarding the individual threats, in the order they were addressed in the report.

2   NOISE (SEE CHAPTER IV, ITEM 1)

SEIC have invested substantial resources in trying to model the noise fields in gray whale habitat in the vicinity of oil and gas activities. However, the Panel believes that their efforts have not yet proven successful, and determining to what degree noise will significantly affect western gray whales remains confounded by two major uncertainties: (1) the sound fields that gray whales will actually experience, which will be influenced by the whales' movements, characteristics of the sources, and sound propagation in shallow coastal waters; and (2) the hearing abilities of gray whales and their behavioural and physiological responses to different sound fields. Therefore, a reliable forecasting tool for assessing and managing the impacts of industrial noise on western gray whales is not available.

Noise levels will be greatest and most persistent during the construction phase of the project. Despite the uncertainties, given the almost complete spatial and temporal overlap between ongoing and planned development activities (including those of both Sakhalin I and II) and the feeding habitat used by gray whales off Sakhalin, the Panel concludes that the potentially significant threats from noise associated with Sakhalin II Phase 2 must be taken very seriously. SEIC documents err on the side of optimism in the face of uncertainty and lack specificity in their proposed mitigation measures. Every effort must be made to separate the development activities from the whales in space and time. Real-time monitoring of whale behaviour and habitat use in the presence (and absence) of measured noise levels and other characteristics is required as well as the development and following of strict criteria for the cessation of operations to prevent whales from being exposed to high noise levels. The limitations of onboard observers, particularly in poor visibility conditions, also must be recognised (and see Item 3 below).

3   COLLISIONS/SHIP STRIKES (SEE CHAPTER IV, ITEM 2)

Ship strikes can and do kill whales. Even if such events are rare, the modelling results show that if, due to any number of factors, only one female is killed per year the probability of extinction of the population is high. Although not quantifiable, the probability that ship strikes will constribute to such mortality will increase with the transition from Sakhalin II Phase 1 to Phase 2 simply because there will be more traffic and vessel activity associated with construction of the proposed PA-B platform and the platform-to-shore pipelines (as well as the traffic associated with Sakhalin I construction and operations). Although traffic in the vicinity of the nearshore feeding area should decrease with the end of construction and once the FSO/tanker-based transportation system has been replaced, a certain amount of vessel support will be required for the two Sakhalin II platforms over the long term. In addition, the risk of ship strikes on migrating gray whales at the southern end of Sakhalin Island will certainly increase as tankers begin moving oil and liquid natural gas from the new terminal at Prigorodnoye.

SEIC have described a number of mitigation measures to prevent ship strikes in the Piltun area, including closed areas around feeding habitat, speed limits or guidelines, onboard observers to detect whales and allow necessary speed and course changes, and partial curtailment of vessel activities at night or in inclement weather. The Panel is encouraged that SEIC recognise the potential for collisions and that they have prescribed mitigation measures. However, in the absence of necessary details on implementation and enforcement of these measures, the Panel is unable to judge their effectiveness.

Cautious vessel operation in the presence of whales is essential, but likely not sufficient because collisions often occur before the whale is observed. It is insufficient to rely on onboard observer programmes alone. Even if one assumes the observers are experienced and attentive, the ability to see whales is compromised in poor weather and sea conditions, reduced daylight etc. Clearly, measures that increase the likelihood of spatial separation of whales and ships (e.g. through the use of no-entrance zones, ship traffic lanes) are the most effective means of reducing the risk of ship strikes. Mandatory reductions in speed to specified levels (with even lower levels specified for nighttime and periods of restricted visility) are also prudent in light of published evidence concerning ship strikes on other whales, including eastern gray whales.

4   OIL EXPOSURE (SEE CHAPTER IV, ITEM 3)

The potential effects of oil on gray whales, either through direct exposure or through damage to their prey, are poorly known. Observations of the direct effects of oil on other marine mammals and the well-documented effects of oil on benthic invertebrates indicate that there is reason for serious concern. The consequences for gray whales of oil spills in the Sakhalin marine environment could vary from minor to catastrophic depending on the location, timing and size of the spill, the prevailing conditions and the ability of the benthos to recover. All available information indicates that western gray whales are almost completely dependent on benthic communities for feeding.

The Panel recognises that the oil spill risk from Sakhalin II will be reduced considerably by the transition from Phase 1 to Phase 2. Nevertheless, when viewed over the lifetime of the project, the risks of a spill's occurring associated with Phase 2 are considerable. For example, the probability of at least one blowout occurring at either platform over the 40-year project lifetime is about 3% and the probability of at least one pipeline spill could be as high as 24%, based on data provided in the CEA.

Of particular concern is that spill trajectory modelling (in the CEA) revealed a high level of risk to the two gray whale foraging areas off Sakhalin even though the modelling did not consider worst-case scenarios involving platform blowouts and winter spills (under ice). In addition, a spill or release of oil in or near Piltun Lagoon is a major concern because it could alter the ecological processes that maintain the Piltun (nearshore) foraging area where female gray whales nurse and wean their calves. This concern applies to both Sakhalin II and Sakhalin I, which includes plans for a pipeline crossing of the lagoon itself.

Given these concerns, the Panel believes that spill prevention is key. Although the ability to respond rapidly to an oil spill is important, the overall efficacy of spill response in the face of a major spill is doubtful because of the conditions in which a large spill is most likely occur (e.g. severe ocean conditions, storms, winter, ice) and the remoteness of the platforms and pipelines from possible response centres.

Although the SEIC documentation on prevention and mitigation measures is extensive, the Panel found that a lack of specificity made it difficult to evaluate. Similarly, it proved difficult to evaluate some of the decisions taken (such as the location of the PA-B platform in this context). Clearly, from the perspective of gray whale conservation, the farther away the platform is from the foraging grounds the better. Despite the information gaps, the Panel has made a

number of general suggestions and comments on how spill risks could be further reduced (e.g. with respect to low-level leakage detection, rules for contractors, the oil spill response plan, the location of platforms and pipelines (and see Item 8 below), the use of double-hulled tankers and the suspension of oil production at the PA-A platform until the pipeline is in place).

5   PHYSICAL DISTURBANCE (SEE CHAPTER IV, ITEM 4)

As noted above, western gray whales appear to be completely dependent on benthic invertebrates to meet their annual energy requirements. Therefore, it is essential that their foraging areas off the northeastern coast of Sakhalin Island remain unspoiled and productive. Physical disturbance of the seabed is unavoidable as part of offshore oil and gas development and therefore this aspect of Sakhalin II Phase 2 deserves close scrutiny. The Panel is disappointed at the relatively superficial consideration given to this issue by SEIC.

Apart from the potentially serious impacts of oil (see Item 4 above), benthic communities can be disrupted or transformed by physical removal (e.g. a patch of sandy plain becomes an elevated concrete platform), smothering with dredge spoil and other debris or alteration of nearshore current patterns and flows. In the present context, any disruption of exchange mechanisms between Piltun Lagoon and the Piltun foraging area is a special concern. Siting decisions, e.g. for platforms and pipelines, represent the most reliable avenue to mitigation of these effects. Therefore, in deciding where to install the PA-B platform and which pipeline configuration to use, it would have been appropriate to conduct a careful and detailed assessment of the associated risks to the integrity and productivity of the benthic communities on which gray whales depend, with particular attention to the biological and ecological processes that create the Piltun foraging area. This was not done. Instead, the risks of damage to gray whale feeding habitat from development activities are dismissed as insignificant.

6   PIPELINE SITING DECISION

SEIC did not provide a comprehensive, quantitative comparison of the three pipeline alternatives under consideration for transportation of oil and gas from the PA-A and PA-B platforms to shore (see Chapter III, Section 2.2 for a description of the three alternatives). The 'base case' route poses additional risk because, among other things, it crosses the southern portion of the primary gray whale foraging area and is in close proximity to the mouth of Piltun Lagoon. The two proposed alternatives pass farther south and avoid that problem. Although all three proposed routes eliminate important risks associated with the Phase 1 FSO/tanker-based transportation system, each carries its own array of risks. The Panel identified four pipeline-associated risks: (1) noise and disturbance of whales during construction, (2) ship strikes during construction, (3) physical damage to benthic habitat during construction and (4) potential exposure of gray whales, their prey or ecologically important habitat (e.g. Piltun Lagoon) to oil spills and gas releases. Alternative 1 appears to be the safest wth regard to the first three of those risks. It also provides an advantage with regard to the fourth risk in that any oil spills and gas releases would likely occur farther away from the Piltun feeding ground and Piltun Lagoon. A spill occurring in the east-west component of this alternative would: (1) take longer to reach the Piltun Lagoon and foraging area, thereby allowing more time for an effective response; (2) be more dispersed when it reached those areas, and therefore less likely deposit large amounts of oil in sensitive nearshore habitats; and (3) have lost a larger portion of its volatile components and therefore be less toxic to whales and their prey. The only obvious disadvantage of Alternative 1 appears to be that the probability of a leak or rupture would be increased somewhat due to its greater overall length.

7   ADEQUACY OF DOCUMENTATION

Despite the considerable documentation provided, the Panel was precluded by a lack of information and specificity from completing a comprehensive review of a number of important Sakhalin II Phase 2 elements. These included certain risks for which little or no information was provided, e.g. those associated with extraction and transportation of natural gas, the new export terminal in Aniva Bay, past performance of the SEIC partners and contractors with regard to oil operations and accidents, and oil spill response alternatives in winter conditions. Very importantly, the Panel lacked detailed information on many of the proposed mitigation measures, their likely efficacy and the procedures to ensure compliance with those measures.

8   INFORMATION GAPS AND ESSENTIAL MONITORING

Scientific investigations of the western gray whale population since 1995 have provided a remarkable amount of information regarding the population's abundance and composition (age/sex structure), reproduction, survival, condition, foraging patterns and behaviour on the feeding grounds. The available information provides a strong,

albeit preliminary, basis for understanding the biology of these animals in their Sakhalin habitat and their potential vulnerability to oil and gas development. However, much remains to be learned through annual monitoring of the population and its habitat, and through directed studies into the potential effects of Sakhalin II Phase 2.

With regard to the potential effects of noise, collisions, oil and gas spills and habitat destruction, research and monitoring are needed to characterize both the risk factors and the dependent variables (i.e. whale, prey or habitat response). Due to uncertainty regarding potential effects and their detection, monitoring and research efforts will require careful and rigorous design to ensure that there is a high probability of detecting changes in demography that will have a significant effect on the recovery of the population. The Panel's review identified the following general areas for future research, including some that will require annual monitoring and some that will depend on circumstances (e.g. in the event of a spill):

- continued, uninterrupted annual monitoring of important population parameters including abundance, trends, survival rates, reproductive rates and age (size)/sex structure - analysis of the resultant time series of data may provide an early warning of problems within the population;
- annual monitoring of gray whale foraging and habitat use patterns, including prey, habitats and variability in foraging patterns over space and time - the resultant time series of data may identify changes in habitat correlated with certain development activities;
- real-time monitoring of behavioural and (if possible) physiological responses by the whales during periods when levels of underwater noise increase noticeably (e.g. during construction and seismic surveys);
- recording and monitoring of whale/ship encounters (including strikes, near misses and safe avoidance) to determine if adjustments are needed to vessel traffic based on ship size, location, speed, daylight or other pertinent variables;
- surveys at regular intervals during the open-water season along the eastern Sakhalin coast to detect stranded gray whales (or floating carcasses), coupled with a serious effort to investigate cause of death in the event of finding a dead gray whale;
- investigation of the ocean dynamics (currents, tides, winds) in the vicinity of Sakhalin II, the Piltun and offshore feeding habitats and Piltun Lagoon - *inter alia* this will allow for better modelling of the dynamics of oil spills and improved response strategies;
- investigation of the ecology of Piltun Lagoon and the Piltun foraging area, and the links between them; *inter alia* this will provide a more secure basis for evaluating the likely risks to gray whales and their prey, and better inform decisions on siting pipelines and other activities;
- investigation of the biomass, distribution and ecology of gray whale prey populations and the effects of oil on them;
- if one or more spills or releases occur, investigation of (1) any direct, acute effects of oil and gas on whales and (2) the effects of chronic exposure should spilled oil remain present for a prolonged period;
- periodic monitoring of contaminant levels in the habitats exposed to potential (and actual, should they occur) leaks and spills.

9   THE NEED FOR A COMPREHENSIVE STRATEGY TO SAVE WESTERN GRAY WHALES AND THEIR HABITAT

The Panel's review focused on just one of a number of major oil and gas development initiatives around Sakhalin Island (Chapter III). Importantly, threats to the western gray whale population do not arise solely from oil and gas development, nor are they limited to the Sakhalin region (Chapter V). Further, the threats do not occur in isolation but rather they are cumulative (Chapter VI). Most, if not all, western gray whales spend approximately half the year elsewhere in eastern Asia, passing through waters within the EEZs of Japan, the Republic of Korea, the Democratic People's Republic of Korea, and China. Development and use of marine resources throughout the range of these whales, including but not limited to offshore oil and gas, involves a wide array of financial interests and technical support from Russia and other countries in eastern Asia, North America and Europe.

Previous analyses and expressions of concern by major international bodies such as the International Whaling Commission and the 3rd World Conservation Congress have made it clear that there is serious, widespread interest in the issue of western gray whales and Sakhalin oil and gas development. The Russian stake in western gray whale conservation is clear, given that the entire population derives almost all of its annual sustenance from waters within

the Russian EEZ. Nonetheless, a number of other countries will play direct and potentially decisive roles in determining the fate of population.

A comprehensive international strategy (including research) is essential for saving this whale population. During its deliberations regarding the potential effects of Sakhalin II Phase 2, as well as Sakhalin I and V, the Panel recognised the need for a comprehensive strategy that addressed not only oil and gas development, but also other threats to the population. The results of population modelling (Chapter VII) showed that quite small impacts on the animals or their habitat, if they are persistent, could lead to the population's extinction. A piecemeal approach, based on assessment of the impacts of one development project at a time, will not adequately address the western gray whale conservation problem, because the accumulated total of impacts may prevent recovery of the population even if the impact of each project can be limited to levels judged to be acceptable according to some standard. The survival of the population cannot be assured without a protection regime for the nearshore feeding habitat, aimed at limiting the combined impact of all current and future developments (including but not limited to oil and gas developments) on this habitat and the whales feeding there.

Although the subject of a comprehensive strategy was outside the Panel's terms of reference and therefore no attempt was made to develop it, this report may provide at least a partial basis for development and oversight of such a strategy by an independent international organisation. In this context, we note and commend the ongoing regular reviews of population status and research needs of western gray whales by the International Whaling Commission's Scientific Committee, as well as the less regular but important consideration of these matters by the Russian Group for Strategic Planning of Gray Whale Research and the IUCN Species Survival Commission's Cetacean Specialist Group. These bodies may provide the foundation for a comprehensive strategy that includes strong international, independent planning and oversight.

Annex A

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Annex B

Terms of Reference

1. Introduction

Sakhalin Energy Investment Company Limited (SEIC) is a consortium of companies developing oil and gas reserves in the Sea of Okhotsk off the northeast coast of Sakhalin Island in the Russian Far East. The shareholders in SEIC are:

- Shell Sakhalin Holdings B.V. (Shell) 55%
- Mitsui Sakhalin Holdings B.V. (Mitsui) 25%
- Diamond Gas Sakhalin, (Mitsubishi) 20%

SEIC is implementing the Sakhalin II Production-Sharing Agreement (PSA), an agreement between the Government of the Russian Federation, the Sakhalin Oblast, and SEIC. Sakhalin II is a phased development project. Phase 1, an oil-only development, went into production in 1999 and produces approximately six months of the year during the ice-free period. Phase 2 is an integrated oil and gas development that will allow year-round oil and gas production, and includes two additional offshore platforms, offshore and onshore pipelines, and onshore processing and exporting facilities. Production from Phase 2 of the Sakhalin II Project is planned to commence in 2007.

The project's potential impacts on environment, particularly on the Western Gray Whales (WGW) which is a critically endangered population, are a major concern with marine scientists, environmental organisations, potential lenders and with SEIC. The environmental organisations and the potential lenders have been calling for an Independent Scientific Review (ISR) to assess the WGW issues as related to the proposed development. IUCN – The World Conservation Union, as a knowledge-based convening organisation was approached to organize the review. IUCN has accepted the responsibility. Following are the Terms of Reference (TOR) for the review.

2. Overall Purpose:

To evaluate the scientific aspects of issues pertinent to the conservation of the Western Gray Whale population and related key elements of biodiversity in the context of Phase 2 of Sakhalin II, , hereinafter referred to as the Project.

3. Specific Objectives:

(i) Establish an independent expert view of the issues and scientific knowledge pertinent to the conservation of WGW and related key elements of biodiversity in the context of proposed development under the Project:

(a) What are the key scientific issues pertinent to the ecology and conservation of WGW and related key elements of biodiversity, based on the scientific knowledge and evidence that is currently available? How much is scientifically known about them?

(b) What are the main gaps in knowledge for assessing the impacts of the Project?

(ii) Analyse the potential risks and impacts of the project for the conservation of WGW and related key elements of biodiversity. The analysis will cover, *inter alia*, the proposals for siting, routing and operation of the oil and gas exploration, production and transportation infrastructure, as well as for demolition, removal or rehabilitation of infra-structure under the Project:

(a) What are the potentially serious impacts of the Project?

(b) What is the range of uncertainty associated with each?

(c) What are the main gaps in information that limit ability to assess the potential impacts?

(d) What cumulative impact can be expected, given other existing and planned oil and gas developments around Sakhalin? What is the expected contribution of the Project to the cumulative impact?

(e) To what extent can the effect of the potential impacts on the survival and recovery prospects of the WGW be estimated?

(iii) Assess the projected effectiveness of the proposed mitigation measures and identify alternatives if necessary:

(a) Are the project studies, assessments and proposed mitigation plans for the conservation of WGW and related key elements of biodiversity adequate for the project not to have significant negative impacts on them? Do they take account of the best available scientific knowledge, identify information gaps, and treat both existing knowledge and information gaps in a manner that reflects the precautionary principle?

(b) Will the proposed measures have the intended effect?

(c) What are the residual uncertainties? Do the proposed control and mitigation measures adequately address these uncertainties?

(d) What project alternatives or additional mitigation measures could be considered and what would be their expected effect?

(iv) Assess the requirements for monitoring of the impacts of the Project on biodiversity, and especially on the health and survival of WGW, in terms of the adequacy of what has been proposed and any additional or alternative monitoring measures that could provide useful information:

(a) Which aspects of WGW and related key elements of biodiversity need to be monitored and over what time frame?

(b) Which specific parameters of the WGW population need to be monitored?

(c) Are the current and proposed monitoring measures adequate and what are the gaps, if any?

(d) Under what circumstances could results from monitoring indicate a need for corrective action and/or additional monitoring?

4. SCOPE

- The review is established pursuant to the above mentioned purpose and objectives

- To ensure a focussed review, the panel, in its first meeting, will establish a list of the 'related key elements of biodiversity' that the review will address alongside the issue of WGW which remains at the centre of the review.

- The term 'related key elements of biodiversity' used herein refers to key biota other than WGW that share the same habitat or can potentially be affected by the mitigation actions for the conservation of WGW or by the lack of such actions. The review will evaluate whether mitigation plans proposed by SEIC for WGW avoid collateral damage to the other key biota and highlight where such damage is likely or inevitable.

- The review will focus on Phase 2 of the Sakhalin II Project, in particular activities in and around Piltun and Lunskoye fields and associated coastal zones, over its entire expected lifespan. The review will be conducted in the context of all industrial development potentially affecting WGW in the Sakhalin area.

- For the purpose of this review, the term 'key stakeholders' is defined to include the Project proponents (SEIC), potential lenders, government organisations in the Russian Federation and Sakhalin Region, and non-governmental and inter-governmental organisations (local and international) that have demonstrated interest in the project and related conservation issues by way of their substantive participation (e.g. consistent queries and comments) in earlier discussion.

- The review report will provide an evidence-based analysis of the issues and options, but does not seek to provide prescriptive conclusions.

- The final report of the review is time-bound to ensure that the results are available for use in key decisions associated with project development.

5. Structure

- In its first meeting, or through communications before that, the review panel will establish its rules and procedures for the panel's working including, *inter alia*, the schedule and process for conducting the review, field visits, transparency, potential conflict resolution among the panel members, distribution of responsibilities

for the review and eventual report writing, and providing for the minority views in the event of lack of a consensus. This shall be done in consultation with IUCN.

- The review panel will convene and meet in person or through conference calls as needed to identify key questions, review relevant data and information, discuss findings, and structure and prepare the report. Meetings may be open or closed-door at the discretion of the panel's chair.

- If practical the panel will visit the project site, where a meeting of the panel may be held.

- The review panel may also hold meeting(s) with key stakeholders, separately or together, or consult them otherwise, as might be needed and useful.

- The review panel will consult relevant project documents and other literature on the subject to ensure that its assessment and findings are well informed, and based on evaluation of the best available scientific knowledge and information. The panel will be provided with all relevant project documents by SEIC, the process of which will be co-ordinated by IUCN.

- Members of the independent scientific review panel will be bound by a confidentiality agreement that ensures confidential commercial information is kept within the group; however, the agreement will not preclude the panel from reporting any conclusions relevant to the review that it may draw from such information, providing none of the commercially sensitive or proprietary information is disclosed in such conclusions, whether they be verbal or wriiten.

- The Review Panel will catalogue all the documents that it may have or may be made available to it for the purpose of the review retaining the confidentiality of documents so marked.

- The review panel will hold its first meeting as soon as possible after the establishment of the panel

- The end date for completion of the report is 30 November 2004.

6. Information and Feedback

- In the interest of transparency, information about the panel's composition, TOR and review schedule will be made publicly available on a website that IUCN will establish and maintain during the currency of the review.

- The chair of the panel may, at any time during the review process and the preparation of the report, co-opt specialists to assist with reviewing report drafts or parts thereof. Such reviews would be for the purpose of confirming facts or identifying omissions so as to assist the panel in arriving at its final conclusions. Persons co-opted for these tasks will not comment on whether they concur with the panel's findings. They will be acknowledged in the panel's final report.

- At all times the panel's work and draft reports are to be considered as confidential. Persons co-opted to review the panel's work and draft reports may not release confidential information of any nature, written or verbal, to organisations to which they may be affiliated or any other parties. They will return all documents provided to them to the Chair of the panel or destroy such documents on completion of their work.

- The panel will submit its draft report to IUCN by 15 November 2004.

- IUCN will appoint 2 secretariat staff to review the report for compliance against the TOR. Their feedback will be provided to the chairperson by 20 November 2004.

- The panel will consider the comments provided by the IUCN and submit its final report to IUCN by 29 November 2004.

- A copy of the final report will be delivered to SEIC by IUCN at 12:00 GMT on 30 November 2004. This only for SEIC to be prepared to respond to media queries. SEIC will not seek to make any changes to the report in any way nor make any comments prior to the public release of the report.

- The report will be made publicly available on the IUCN website at 12:00 GMT on 01 December 2004.

- IUCN will make the final report, along with any stakeholder responses to the report, available to all stakeholders and the public through the website.

7. Participants

- The review panel will consist of ca.10 members, and will be chaired a respected scientist with acknowledged credibility. Additional experts could be brought in for specific issues by the chair or by IUCN on request from the chair.

- The review panel will have expertise in all pertinent aspects of baleen whale ecology and population conservation

- The review panel shall be international and preferably cover the diverse geographic interests in the project and related conservation issues.

- Panel members shall be:

    - Renowned experts in their field;

    - Independent of previous involvement with any significant aspect of SEIC's activities, thus facilitating an unbiased and independent review of the Phase 2 Project;

    - Connected to a broad spectrum of relevant scientific organisations concerned with the protection and ecology of baleen whales.

- Review Panel members will be participating based on personal expertise and will not represent the views of their organisations or affiliations.

8. Resources

- The review panel will be supported by the IUCN Secretariat that would provide the services to run the panel.

- Costs of establishing and running the review will be borne by SEIC, through IUCN, with possible support from other interested stakeholders to be investigated by IUCN.

Annex C

The question of related key aspects of biodiversity

G.R. VANBLARICOM

1   INTRODUCTION

The terms 'diversity' and 'biodiversity' have different meanings, depending on the context of application and the perspective of the user. The terms of reference for this review focus on 'western gray whales and related key elements of biodiversity.' The purpose of this appendix is to review different definitions of 'diversity' and 'biodiversity,' and to clarify the intended use of these terms in the present context.

Use of the terms 'diversity' and 'biodiversity' falls into two broad categories. The first, here designated the 'information context', includes methods for indexing both the number of species and the number of individuals by species, within a specified quantity of habitat space. This type of application appears most frequently in technical descriptions of ecosystems, such as those reported in environmental impact assessments or in the peer-reviewed technical ecological literature. Information-based diversity indices have been used in the technical ecological literature dating from the early twentieth century, with a traditional focus on number of species and number of individuals by species as the units of measure. The information-based approach is further discussed in Section 2. The second broad category, here termed the 'conservation context', is discussed under Section 3.

2   INFORMATION CONTEXT

Applications of diversity terms in the information context typically involve two components – (1) the number of species within a space and (2) the 'evenness' of individuals by species within the space. 'Evenness' is considered *high* if each species observed in a space is represented by a similar number of individuals, and *low* if the number of individuals by species within the space is highly variable. The physical space linked to an index is typically a sampling unit, such as a quadrat, transect, or benthic core sample. The most sophisticated diversity indices employ information theory to integrate both species number and number of individuals by species into a single index. Simpler indices include number of species per unit area or per unit volume, and number of species per individual within the designated habitat space. Often both of these simpler indices are reported for a given habitat space. Information-based diversity indices may be applied to all species within a space, or to a specified taxonomic subset of all the species identified within a space. Thus, a given study may generate estimates of plant diversity or amphipod diversity per unit of space.

Interpretation of diversity terms in the information context is strongly dependent on spatial scale. It is most common for the terms to be applied to samples from small areas or volumes. In such cases, characterizations of diversity pattern require collections of samples from an area of interest, with diversity indices reported as means with associated variances. In principle, complex information-based diversity indices also can be generated for large areas or volumes of habitat, but in fact they are usually limited to samples from small spaces. When larger areas are involved (scales of hectares up to whole habitat units such as lakes or islands), it is common for information-based diversity indices to be simplified to species number within the focal area. For example, in studies that test hypotheses emerging from island biogeographic theory, data often are reported as numbers of species by island and through time.

In the information context, diversity terms often are viewed without prejudice. That is, changes in diversity indices over time or among locations are considered without associated valuations, either positive or negative. It is recognized that a number of natural ecological processes can influence diversity without raising concerns about conservation. For example, successional processes that follow localized natural disturbances may result in fluctuations of diversity indices within the disturbed area over time. Similarly, natural spatial differences in supplies of limiting nutrients may be associated with spatial variation in indices of diversity.

Information-based indices of diversity may be applied to studies of environmental impacts of anthropogenic activity. In such cases, calculations of diversity indices follow the same protocols as in studies of effects of natural processes.

However, measured patterns in diversity indices may be linked to anthropogenic processes, leading to valuation judgments and the possible emergence of conservation concern and management response.

3   CONSERVATION CONTEXT

The second category is designated the 'conservation context'. Here the term 'diversity' has been replaced with the more recently emerged term 'biodiversity.' Measures of biodiversity in the conservation context differ in several important ways from measures in the information context. First, biodiversity data in the conservation context tend to focus on species number, and rarely incorporate 'evenness' indices or complex multivariate indices based on information theory. Second, conservation-oriented measures of biodiversity typically focus on large habitat features, such as lakes, mountain ranges, islands, or kelp forests, without explicit reference to quantitative measures of habitat space. Third, variations in conservation-based species diversity in time or space tend to be linked to anthropogenic activities and often elicit strong, typically negative value judgments. Such cases often lead to demands in the political realm for management responses focused on curtailment or mitigation of the relevant anthropogenic activity. Fourth, and perhaps most important, reductions over time in conservation-oriented measures of biodiversity typically are linked directly to perceptions of increased risks and increased rates of extinction.

In recent years, applications of conservation-based indices of biodiversity have expanded beyond the traditional metrics – number of species or number of individuals by species. The expanded perspective on biodiversity is based both in contemporary science and in western political and cultural evolution. Although the expanded perspective incorporates more variables as inputs to the characterization of biodiversity, it is clearly not compatible with computation of simple numerical diversity indices. Biodiversity in the conservation context is now applied to questions of genetic structure and evolutionarily significant units (ESUs) within species. The concept of biodiversity also may be applied to the integrity of natural food webs, considering number of trophic levels, number of species within trophic levels, number of trophic linkages, and specific details about species pairs or clusters linked trophically. Finally, biodiversity in the conservation context may be applied to the totality of co-occurring species, ESUs, biological interactions, natural disturbances, and physical and chemical habitat features that collectively define a natural ecosystem. There are strong contemporary political incentives to pursue such expansive formulations of biodiversity measurement, particularly in the relatively wealthy cultures of North America and Europe, and to transfer findings into management action. Such incentives are a strong challenge to scientists who find that such formulations are difficult to produce at best, and are frequently intractable for want of adequate data or accepted models for syntheses of data.

For purposes of this report, we interpreted the terms of reference as referring to biodiversity in a conservation context. We therefore interpreted 'related key elements of biodiversity' to include both typical features and spatial and temporal variation in the following aspects of ecosystems linked, in a substantive ecological context, to the western gray whale population: prey species, physical and chemical habitat characteristics, sources and characteristics of nutrient and fixed carbon supplies, predators, parasites, disease processes, natural ecological disturbances, and food web structure and dynamics.

This focus should not be construed to mean that the Panel considered the gray whale to be the only species of concern in relation to oil and gas development around Sakhalin. In fact, at least to some extent, the whales were viewed as proxies for other species and populations at risk from human activities associated with onshore and offshore development in this region. It was hoped that protection of gray whales would provide an 'umbrella' of protection that could benefit many other organisms (*sensu* D. Simberloff, 'Flagships, umbrellas, and keystones: is single-species management passé in the landscape era?' *Biol. Conserv.* 83:247-257, 1998). The Panel noted, in particular, that two other species native to Sakhalin Island and surrounding waters are on the IUCN Red List of Threatened Animals: the Sakhalin sturgeon (*Acipenser mikadoi*; Endangered) and Steller's sea eagle (*Haliaeetus pelagicus*; Vulnerable). According to Red List documentation (www.redlist.org), ongoing major threats to the latter include habitat loss and degradation caused by extraction and infrastructure development, accidental deaths and pollution – all of which may be associated with oil and gas development.

Annex D

Synopsis of benthic communities in the summer feeding range of the western gray whale population.

G. R. VANBLARICOM

Fadeev (2003) presents results of benthic ecological studies in the known feeding areas of the western gray whale population, with benthic data and observations collected from 5-60m in depth, using both divers and remotely deployed benthic samplers. To our knowledge, Fadeev's data represent the most comprehensive recent summary of benthic communities for the region. Kusakin et al. (2001) provide a longer-term perspective on benthic community structure on the northeastern Sakhalin shelf. The following summaries are based entirely on Fadeev's data.

Fadeev collected data from five spatial categories. 'Piltun Area' (hereinafter PA) is the area offshore from Odoptu Bay and Piltun Lagoon, extending across depths from 5-30m. 'Intermediate Area' (IA) extends southward from PA to the mid-point of Chayvo Lagoon. Samples were collected at depths of 8-23m. 'Offshore Area' (OA) extends southward from IA to Niyskiy Bay with sites located 25-40km offshore at depths of 20-60m. Fadeev also sampled from 'Control Stations' located offshore of PA and IA sites respectively, and inshore of OA sites. Finally, Fadeev sampled opportunistically from sites at which gray whales were seen feeding. Such sites are termed 'Feeding Points'.

Here we discuss data from all spatial categories, but we focus most attention on PA sites, known to be within the area used by gray whales for feeding over many years. The OA sites are within an area apparently used only recently (first observed in 2001) for feeding by gray whales. Gray whale feeding activity has not been reported from IA or Control Station sites.

1   PILTUN AREA AND NEARBY CONTROL STATIONS:

The substratum in area PA is primarily fine sand with relatively low concentrations of organic carbon. The sediments and associated benthic communities are generally unconsolidated and mobile, with local exceptions noted below. Fadeev reports no significant macroalgal patches or beds in the area. Therefore, it is likely that principal sources for nutrition of benthic animals are benthic and planktonic microalgae such as diatoms and dinoflagellates, along with detrital organic material either produced locally or advected from nearby regions of high productivity. Fadeev reports local areas of coarse sediment (gravel and pebble concentrations along with coarse sand), but these areas form a small proportion of the total bottom area and are not typical for the known gray whale feeding areas.

Within area PA the predominant benthic organism is the sand dollar *Echinarachnius parma*, constituting an estimated 60-70% of the benthic biomass in the region. Other predominant taxa are crustaceans (an estimated 13-17% of benthic biomass), bivalve mollusks (8-13%) and polychaete worms (4%).

Fadeev reports striking stratification by depth in the benthic communities of area PA. Sand dollars comprise an estimated 13% of benthic biomass in depths less than 15m, increasing to an estimated 87% at 30m depth. Pericarid crustaceans (defined and characterized below) constitute about 54% of benthic biomass at 11-15m depth, but only 2% at 30m. Among the pericarid crustaceans, the most abundant species are amphipods. Fadeev reports a sharp decline in amphipod biomass between 15 and 20m of depth. Bivalve mollusks are about 24% of total biomass at 11-15m but only 2% at 30m. Polychaete worms do not vary substantially with depth in the study area. Sand dollars clearly dominate the biomass of deeper substrata in the study area. Gray whales are not known to consume sand dollars as food, and available data indicate that their feeding in area PA occurs predominantly in substrata shallower than those supporting dense sand dollar beds, with benthos dominated by crustaceans and bivalve mollusks.

Fadeev also reports striking spatial variation within depth strata in area PA. In both 2001 and 2002, amphipod and isopod crustaceans showed highest densities in areas immediately adjacent to the single entrance to Piltun Lagoon. Such patterns suggest an important role for export of benthic nutritional resources from the lagoon proper to the adjacent offshore waters used for feeding by gray whales.

The dominant species in shallow portions of area PA are listed in Table 1. The list includes nine amphipods, two isopods, one cumacean, one polychaete, and four bivalve mollusks.

Table 1

Common benthic species in portions of area PA likely to be used or influenced by feeding gray whales

Group	Species
Crustacea:	
Amphipods:	*Ampelisca eschrichtii*
	Anisogammarus pugettensis
	Anonyx nugax
	Atylus collingi
	Eogammarus schmidti
	Eohaustorius eous eous
	Pontharpinia longirostris
	Pontharpinia robusta
	Pontoporeia affinis
	Westwoodilla sp.
Isopoda:	*Synidotea cinerea*
	Saduria entomon
Cumacea:	*Diastylis bidentata*
Polychaeta:	*Onuphis shirikishinaiensis*
Mollusca, bivalvia:	*Megangulus luteus*
	Macoma lama
	Siliqua alta
	Spisula voyi

Control Stations adjacent to area PA were located offshore of PA sites in depths from 32-51m. Although intended as control data for effects of gray whale feeding, interpretation of data in a comparative context is unavoidably compromised by the depth covariate. Fadeev reports that benthic communities in Control Stations offshore from PA are dominated consistently by sand dollars, in a pattern similar to deeper stations (> 20m) of area PA.

2   INTERMEDIATE AREA AND NEARBY CONTROL STATIONS

Data from IA stations are generally similar to those from PA, with a few exceptions. As in PA, shallower stations are dominated by pericarid crustaceans, and deeper stations by sand dollars. IA stations sorted into three spatial categories with differing patterns of taxonomic dominance. The first is a group of shallow stations (8-15m) dominated by amphipod and isopod crustaceans and bivalve mollusks. Predominant species are largely those present in shallow PA stations and listed in Table 1. The second category is a group of deeper stations dominated by sand dollars as noted. The third category is a group of stations dominated by the benthic ascidian tunicate *Ascidea vegae*. Fadeev reports that sites with benthic community categories 2 and 3 are patchy and localized in distribution, with variable substratum composition and the possible presence of large detrital accumulations.

Shallow IA stations also show a spatial trend of decreasing biomass density from the vicinity of Piltun Lagoon southward to the mid-point of Chayvo Lagoon. The trend is particularly marked for benthic species thought to be important prey for gray whales.

Control Stations for IA were located offshore from IA stations in depths ranging from 24-33m. As with PA and Control Stations near PA, the depth covariate compromises interpretation of effects of other ecological processes that may differ between IA and adjacent controls. Control Stations for IA are highly variable in benthic community structure, with specific stations dominated variously by amphipod crustaceans, bivalve mollusks and polychaete worms.

3   OFFSHORE AREA

Of 36 OA stations sampled, 13 were characterised by well-sorted fine sandy substrata, 10 by more poorly sorted medium and fine sands and 13 by mixed gravel and sand with detrital accumulations. Most common taxa throughout the area were amphipod and cumacean crustaceans, bivalve mollusks, polychaete worms and anemones. For all stations averaged, amphipods were the predominant component of sampled benthic biomass, comprising about 40% of the overall mean total biomass.

Fadeev used cluster analyses to identify three recurring benthic assemblages in OA stations. The first is dominated by sand dollars in the manner described above for other locations. Seven stations were of this type, with a mean depth of about 30m. The second is dominated by an amphipod, *Ampelisca eschrichtii*, and a cumacean, *Diastylis bidentata*. The second type of assemblage was found at four stations with a mean depth of about 28m. The combined mean biomass of *Diastylis* and *Ampelisca* was 90% of mean total benthic biomass at these four stations. The third type of assemblage was strongly dominated by *Ampelisca eschrichtii* alone, with mean biomass at 96-99% of total mean biomass for type 3 stations. There were 23 stations with the *Ampelisca*-dominated assemblage, with an average depth of about 40m. Sites strongly dominated by *Ampelisca* are frequently used for feeding by gray whales in other locations. The occurrence of feeding by gray whales in OA since 2001 almost certainly reflects discovery by the whales of the dense *Ampelisca* populations present. The absence of whale feeding activity prior to 2001 suggests that the dense *Ampelisca* populations may vary substantially over time.

For OA, Fadeev presents Control Station data from three sites actually located in the group of Control Stations for IA, as summarized above. This was done in order to reduce effects of substratum depth as a complicating covariate for contrasts of OA data with other locations. The three sites chosen have a depth range similar to OA sites. Of the three sites, one was dominated by sand dollars, the other two by beds of *Ampelisca eschrichtii*.

4   FEEDING POINTS:

PA: Whale feeding points were located at bottom depths of 8-24m. The feeding points were aggregated into three larger areas termed 'feeding areas'. The three areas were located in portions of the nearshore area known to have high densities of benthic biomass of amphipods and isopods as noted above.

OA: Whale feeding points were located at bottom depths of 33-46m. As with the data from nearshore area, whale feeding points identified in the offshore area were aggregated into feeding areas. Four feeding areas were identified. All were in locations with high abundances of *Ampelisca eschrichtii*.

5   CHARACTERISTICS OF LIKELY AND POTENTIAL PREY SPECIES OF GRAY WHALES

Available information indicates that gray whales forage preferentially on aggregations of crustaceans on sedimentary bottoms off Sakhalin Island (western gray whales) and in the Bering and Chukchi Seas (eastern gray whales). Most known benthic crustacean prey of gray whales are gammaridean amphipods, a diverse and highly successful marine taxon, particularly in nearshore marine benthic communities. The amphipods are part of a crustacean taxon known as the pericarids, a group that also includes mysids, isopods and cumaceans, all of which are known to represented in gray whale diets.

Pericarids include both parasitic and free-living forms. The free-living pericarids, including the gammaridean amphipods, are consistent and conservative with regard to life history pattern. In all species, adult females brood young in ventral pouches formed from oöstegites (flattened extensions of the thoracic appendages). Larval development is direct and occurs entirely within the brood pouch. Thus, young pericarids hatch as fully formed juveniles with the same body form as adults. A key ecological correlate is that dispersal of pericarid species is done primarily by adults rather than juveniles, and that the geographic scale of dispersal is less for free-living pericarids than for invertebrate species with planktonic larval forms. The prevailing pattern of life history in the pericarids is important in evaluating potential responses to disturbances, such as those associated with offshore petroleum development. The capacity of amphipods and other pericarids to return to disturbed areas is influenced largely by the swimming capabilities of adult females, and by the proximity of adult females to disturbed habitat at the time of the disturbance.

Gray whales are thought to prefer dense aggregations of benthic amphipods as prey when feeding on the sea bottom. Available information suggests that western gray whales are benthic feeders, and typically do not rely on midwater or sea surface planktonic species for food.

Here we provide brief synopses of life history and ecological information for the amphipod, isopod, cumacean, polychaete and bivalve molluscan taxa abundant in areas PA and OA. These species are chosen based on known or likely occurrence in diets of western gray whales. For many of the species recognized as abundant in benthic communities of the northeastern Sakhalin shelf, few or no data are available in the technical literature. However, some of the species and all of the genera of species thought to be important gray whale prey off Sakhalin are circumpolar in distribution and have been studied in some detail in other locations, particularly the Baltic Sea. Thus, we have drawn on a geographically broad base of literature to develop characterizations for species thought to be important prey for western gray whales. We focus here on species described by Fadeev as abundant in area PA and

listed in Table 1, and for the amphipod *Ampelisca eschrichtii* and the cumacean *Diastylis bidentata*, the latter known to be abundant in area OA. The crustacean species discussed here are typically in the range of 10-30 mm in maximum body length and are thought to be of the appropriate size for consumption by gray whales.

5.1 Amphipoda (listed alphabetically):

Ampelisca eschrichtii: Ampelsicids are known to be a primary prey for eastern gray whales in the Chukchi and eastern Bering seas, in addition to their likely importance for western gray whales foraging on OA. Ampeliscids are colonial tube-dwelling filter feeders, living in tube mats that tend to stabilize sediments and confer colony-scale resistance to physical disturbance. Adult ampeliscids reach a few cm in length and may live at densities of thousands of animals per m^2. Ampeliscids are highly productive, with rapid growth rates and relative short life spans (1-2yr). Although primarily sessile, adults can swim strongly. Swimming is most commonly seen in adult males in search of mating opportunities, and in gravid females dispersing to sites favorable for brood release.

Anisogammarus pugettensis: *Anisogammarus pugettensis* is generally abundant off Sakhalin Island, and comprises an important component of the diets of anadramous fishes, including salmon and smelts off Sakhalin (Budnikova 1995), and in Canada (Chang and Parsons 1975. *Anisogammarus* is omnivorous, feeding on benthic and epiphytic diatoms and on macroalgae (Levings 1976, Parsons et al 1985, Titlyanova et al 1995), fish carrion (Chang and Parsons 1975) and culicid larvae in rock pools (Hossack and Costello 1979).

Anonyx nugax: *Anonyx* is abundant in area PA as reported by Fedeev**.** *Anonyx* is a lysianassid, a family of amphipods known for aggressive scavenging of dead or injured organisms at sites of local disturbance. Most lysianassids probably are capable of predatory feeding as well. Oliver and Slattery (1985) describe responses of *Anonyx* to excavations created in dense mats of ampeliscid amphipods by foraging gray whales in the Bering Sea and along the west coast of Vancouver Island. *Anonyx* rapidly colonize disturbed locations and attack injured and dislodged fauna not ingested by whales, especially polychaete worms and other benthic crustaceans. *Anonyx* densities may be 20-30 times greater within fresh excavations than elsewhere. *Anonyx* remain within excavations only briefly, dispersing within hours of arrival to search for other localised disturbance events. *Anonyx* probably feed on living or dead benthic crustaceans in areas lacking local disturbance events.

Atylus collingi: *Atylus* is an epibenthic omnivorous genus known to occur in gray whale diet (Darling *et al.* 1998). *Atylus* occurs frequently in midwater at night (Dauvin *et al.* 2000) and appears to be relatively mobile.

Eogammarus schmidti: *Eogammarus* is primarily herbivorous, feeding primarily on attached benthic diatoms (Aikens and Kikuchi 2002), and detritus derived from marine macroalgae and vascular salt marsh vegetation (Pomeroy and Levings 1980). Aikens and Kikuchi (2002) report that an inverse relationship in abundances of *Eogammarus* and benthic microalgae in Gamo Lagoon, Japan, suggest that grazing by *Eogammarus* may contribute to control of microalgal abundance. *Eogammarus* may be consumed by juvenile crabs (Iribarne 1996)

Eohaustorius eous eous: *Eohaustorius* is a highly derived group of amphipods confined to the North Pacific. They are typical of exposed, unconsolidated sandy habitats and are thought to be filter feeders on epibenthic phytoplankton and detritus.

Pontharpinia longirostris and *Pontharpinia robusta*: *Pontharpinia* spp. are common phoxocephalid amphipods in the North Pacific. They occur in the nearshore benthos of exposed open-coast sandy habitats. Phoxocephalids are mobile omnivores, foraging on benthic microalgae, detritus and the larvae and juveniles of other small benthic animals. In some regions phoxocephalids are a numerically dominant benthic species (e.g., VanBlaricom 1982).

Pontoporeia affinis: *Pontoporeia* (also known as *Monoporeia*) is among the most abundant of amphipods in area PA off northeastern Sakhalin. There is a substantial ecological literature for *Pontoporeia* spp., including *affinis*, across the northern hemisphere. *P. affinis* is a mobile selective deposit feeder (Lopez and Elmgren 1989, 1990, Elmgren et al 2001, Byren 2004), typically dwelling at the sediment surface and feeding primarily on planktonically derived phytodetritus (Moore 1979, Byren et al 2002). *P. affinis* also consume clam larvae and, where abundant, appear to limit densities of clam populations (Segerstrale 1978, Elmgren et al 1986, Ejdung and Elmgren 1998, Byren 2004). Burrowing activities of *P. affinis* reduce hatching success of zooplankton species that produce benthic eggs (Albertsson and Leonardsson 2000). *P. affinis* populations in the Baltic region are considered to be food-limited (Elmgren 1978, Uitto and Sarvala 1990, Elmgren et al 2001). Population dynamics are strongly density dependent, resulting in cyclic shifts in dominance of population age structure by juveniles and adults (Andersin et al 1978, Sarvala 1986, Hill 1992). *P. affinis* populations have measured annual ratios of production to biomass ranging from 1.3 to 4.8 (Wildish and Peer 1981, Sarvala and Uitto 1991, Cederwall and Jermakovs 1999), indicating a high

potential for benthic productivity if food suuply is adequate. Lipid content of whole-body *P. affinis* ranges from <25% in winter to 35% during June and July (Hill et al 1992, Lehtonen 1995) indicating high value of the species as prey. Maximum seasonal values for lipid content coincide with the foraging season of the western gray whale population. Daily rates of total biomass production in *P. affinis* also occur in early summer (Sarvala and Uitto 1991). *P. affinis* remains within sediments during daylight hours and forages primarily during the day (Lopez and Elmgren 1989). Many individuals swim into the water column at night, likely in search of mating opportunities, improved foraging patches, and reduced intraspecific competition for food (Cederwall 1990). Female *P. affinis* are semelparous, with a typical lifespan of 2yr (Steele and Steele 1978). Breeding occurs in fall, and brood release in the subsequent spring (Steele and Steele 1978). In addition to likely significance in the diet of western gray whales, *P. affinis* is known to be consumed by fish, predatory polychaetes, and the isopod *Saduria entomon* (Abrams *et al.* 1990, Hill and Elmgren 1992, Sandberg and Bonsdorff 1996). *Saduria* (see below) also is abundant in the PA area and is known to occur in the diet of western gray whales (Fadeev 2003).

***Westwoodilla* sp**.: The genus *Westwoodilla* is part of the amphipod family Oedocerotidae. The family is widely distributed and includes species that are highly mobile and tend to respond positively to local disturbances (e.g. VanBlaricom 1982). The life history of a Scottish species, *W. caecula*, is summarized by Beare and Moore (1998). Sexes are dimorphic with the females larger. Female *W. caecula* can be found in gravid condition year round, with the highest proportions from mid-summer to fall. Females can produce up to three broods over a lifetime. Brood size increases with female size and age. Known populations of *W. caecula* fluctuate broadly within years and do not show characteristic trends of any sort. Oedocerotid amphipods occupy the surface of unconsolidated sediments. They are capable of strong swimming in the water column and are probably opportunistic consumers of microalgae and detritus.

5.2   Isopoda

Synidotea cinerea: *Synidotea cinerea* is the most abundant of the isopods in PA, with maximum densities at depths of 15 m or less. The genus is broadly distributed in the North Pacific and is described as eurytopic (Rafi and Laubitz 1990) and tolerant of sediments with high concentrations of organic detrital matter (Levin et al 2000). *Synidotea* species are often associated with accumulations of large detritus such as drifting fragments of macroalgae or marine grasses.

Saduria entomon: *Saduria entomon* is a large predatory isopod common in area PA, and is known to occur in the diet of western gray whales. Much of the literature on the ecology of *Saduria* focuses on its role as a predator in benthic communities, based primarily on studies in the Baltic region. *Saduria* preys on a number of benthic species, but is known to prefer *Pontoporeia affinis* (Sparrevik and Leonardsson 1995, 1999, Edjung and Elmgren 2001, Bergstroem and Englund 2002). Large *Saduria* are known to cannibalize smaller conspecifics (Leonardsson 1990, 1991, Sparrevik and Leonardsson 1998, Sparrevik 1999). *Saduria* also prey on polychaetes and small clams (Edjung and Bonsdorff 1992, Bonsdorff et al 1995, Sparrevik and Leonardsson 1995, Edjung and Elmgren 2001), and sediment disturbance by burrowing Saduria can increase mortality rates of small clams beyond those directly consumed (Bonsdorff et al 1995). Trophic interactions of *Saduria* with conspecific juveniles and with varying densities of *Pontoporeia affinis* are complex and raise the possibility of several different stable benthic assemblages, varying in both size distributions and densities (Sandberg and Bonsdorff 1990, Leonardsson 1991, 1994, Sparrevik and Leonardsson 1998). *Saduria* also are consumed by benthic fish, and are known to adopt cryptic behaviors in the presence of predatory fish (Edjung 1998).

5.3   Other taxa

Diastylis bidentata (a cumacean crustacean): Species in the genus *Diastylis* are known to feed both on microalgae, particularly diatoms, and detritus obtained by filtering from the epibenthic water column (Yang 1998, Blazewicz-Paskowycz and Ligowski 2002). *Diastylis* populations remain on the sediment surface during daytime hours, but swim actively at night (Anger and Valentin 1976, Hesthagen and Gjermundsen 1979, Habermehl et al 1990, Wang and Dauvin 1994, Grabe 1996). The proportion of a population involved in nocturnal swimming may increase as planktonic food supplies dwindle seasonally (Habermehl et al 1990). Annual ratios of production to biomass are estimated at 2.0 for populations in the western Baltic Sea (Jarre 1989). Breeding occurs in the fall, with gravid females releasing broods in the following spring. Male life spans are about 6mo, females about 12mo (Corey 1983). In at least one species a short, highly fecund summer generation alternates with two longer but less fecund winter generations (Corey 1976). *Diastylis* species are often eaten by demersal fish, and are a primary food source for fish in a number of locations (Valentin and Anger 1977, Arntz 1978). *Diastylis* will quickly colonize experimentally provided vacant substratum in large numbers (Brunswig et al 1976, Arntz and Rumohr 1982).

Onuphis shirikishinaiensis (a polychaete worm): *Onuphis shirikishinaiensis* is common in most areas surveyed by Fadeev off northeastern Sakhalin. Onuphid polychaetes are relatively large tube-dwelling worms typical of open coast sediments (Fauchald 1977). Tubes are parchment-like, protrude several centimeters from the sediment, and often are recurved such that the tube opening faces downward toward the sediment surface. Onuphids may aggregate at high densities near discontinuities in substratum, such as areas near the interface of sandy substrata with rock outcroppings or anthropogenic structures on the sea floor (Davis et al 1982). In some areas onuphids are significant prey for benthic fishes (Watanabe et al 1992, Nishikawa et al 2000).

Common bivalve mollusks off northeastern Sakhalin (***Megangulus luteus***, also known as *Peronidia lutea*, ***Macoma lama***, ***Siliqua alta***, and ***Spisula voyi***): Little ecological information is available for the four common bivalve species reported by Fadeev (2003) for the northeastern Sakhalin shelf. The four listed species are common to clean, well-sorted sandy substrata of open coasts in the North Pacific. *Megangulus* and *Macoma* are tellinid bivalves (Foster 1991), feeding by selective ingestion of detrital accumulations on the sediment surface. *Siliqua* (family cultellidae) and *Spisula* are also filter feeders typical of outer coast sandy habitats. To our knowledge, the significance of the four listed bivalves as gray whale prey is unknown.

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Annex E

Detailed considerations on aspects of modelling noise

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Modelling sound transmission in shallow-water habitats, such as those occupied by western gray whales off Sakhalin Island, is exceedingly difficult. Internal waves and coastal fronts in shallow areas add frequency- and time-dependent complexity to acoustic propagation, sometimes 'trapping' and sometimes 'spreading' acoustic waves (see Kuperman and Lynch 2004: their Figs. 3b and 4). This results in regional 'hotspots' of noise, the precise locations of which are virtually impossible to predict in shallow water (Fig. 1). After reviewing SEIC's methods and plans for modelling noise in gray whale habitats, three areas of concern were identified: (1) measurement accuracy and reliance on noise spectra, (2) source level determinations and (3) use of a modified Range-dependent Acoustic Model (RAM). Each of these topics is discussed in some detail below.

Measurement Accuracy and Reliance on Noise Spectra

SEIC contracted JASCO Research Ltd. to measure underwater noise associated with construction activities at the Lunskoye site and to use the data obtained to construct a model of received levels (RL) that could be anticipated in all western gray whale habitats, including the nearshore waters off Piltun Lagoon. A robust sampling programme was conducted in the 2004 open-water season off northeastern Sakhalin, and noise radiating from transport vessels, dredges, pipe-laying barges and overflying helicopters were measured along a 6-track grid extending from 10m to about 45m of water depth (JASCO 2004a: their Map 1). Source levels from 19 vessels were measured, but using *only* a single hydrophone (CEA, Section 4.3.1.2). While developing and testing the Acoustic Model (AM) to predict RL, these data were combined with opportunistic measurements of noise from various sources during construction at Lunskoye in 2004 and with previous measurements of underwater noise (1999-2003) made in the Odoptu-Piltun region by acousticians from the Pacific Oceanologic Institute (POI) (summarised in Section 4.2 of the CEA) and the P. P. Shirshov Institute of Oceanology (Vedenev et al. 2004). A significant problem identified in the Lunskoye 2004 Noise Modelling Plan was that of measurement accuracy. Specifically, estimating the distance to a specific RL, with uncertainty of 20% or less, requires measurement accuracy of 0.7dB at 3km and 0.9dB at 30km (JASCOa 2004: their Section 5.3). However, the report states, 'These accuracies may likely not be directly attainable because they are less than POI's stated hydrophone calibration nominal uncertainties of 1.5 dB' (JASCO 2004a, p. 11).
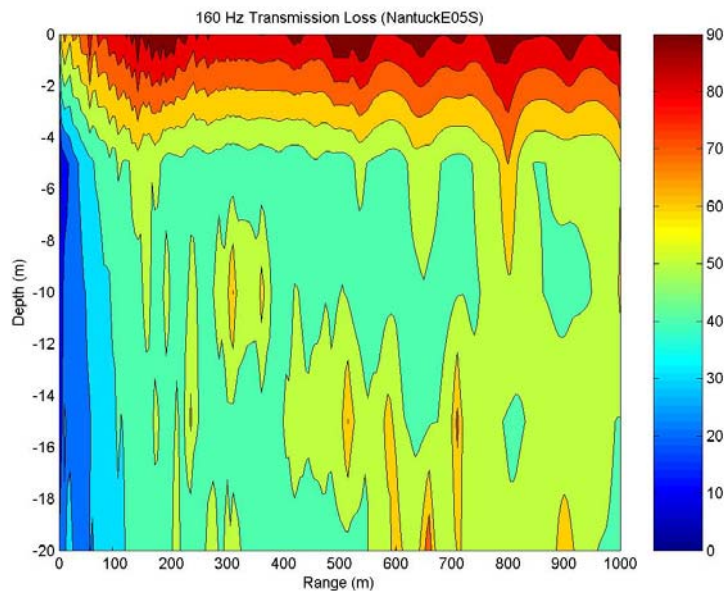

Fig.1. CASS-GRAB results of transmission loss through a shallow-water environment for a 160Hz source. The high levels of loss at the surface are due to 'surface interference' effects, which are related to the pressure release near the surface, wavelength effects and downward refraction, which is less important in these shallow depths. Note extreme variability across range at 4-20m depths.

This large instrument error cannot be reduced by inter-calibration of the hydrophones after the experiment, contrary to the suggestion made in the Lunskoye 2004 Noise Monitoring Plan (JASCO 2004a: Section 5.3; hereafter the JASCO plan). The inter-calibration data show additional scattering of values relative to the mean due to differences in hydrophones, preamplifiers and other equipment based sources of variability. The JASCO plan goes on to state that accurate measurements may be available from Digital Radio Buoys (DRB) but are unlikely from data acquired using Analog Radio Buoys (ARBs). Finally, the data collected during the 2004 Lunskoye sampling program were apparently 'sub-sampled' such that only the noise power spectra, not the original waveforms, were made available to JASCO for use in model development. This is a potential source of error if these spectra are used to construct and/or ground-truth the propagation model because the sub-sampled power spectra cannot accurately recreate the original waveforms, essential components for future model runs upon which the multiple-source model is to be constructed.

Source Level (SL) Measurements

JASCO are developing a multiple-source 'noise model' with the goal of predicting distances at which received levels (RL) will reach ≥110 to 130dB at frequencies below 2kHz (JASCO 2004a: their Section 7.2). The foundation of the model (i.e. amplitudes and frequency spectra of the different vessels and activities) is data from the extensive source level (SL) measurement program undertaken by JASCO and POI (Hannay *et al*. 2004). These measurements augmented data collected during the Lunskoye programme and were then used in JASCO's 'Noise Modelling Strategy' (JASCO 2004b), which ultimately produced the estimates of sound levels on the gray whale feeding grounds during various activities. JASCO endeavoured to measure the SL of all of the vessels involved in construction, drilling and production associated with the Sakhalin II program. However, in addition to the measurement imprecision introduced by the hydrophones (see above), there are three additional, potentially significant, sources of error in the reported SL measurements.

First, many of the measurements were taken in the acoustic 'near field', which can lead to gross inaccuracies, especially at low frequencies (Urick, 1983). Indeed, Urick (1983, p. 72) stated that in the near field, the sound field is irregular, which makes accurate measurements difficult or impossible to obtain. In some cases JASCO took measurements in the far field and then attempted to calculate the SL @ 1m by modelling the TL back to the source, although the TL modelling was not ground-truthed or otherwise calibrated. The error in these SL calculations is further compounded by the difficulty of estimating the distance to the acoustic centre of the source accurately (i.e. for a 100m ship the acoustic centre is not necessarily predictable or consistent).

Second, in taking measurements to calculate SL, JASCO did not use a consistent filtering scheme. High-pass filters are necessary for this work but JASCO used filters set at 10, 20 or 30Hz, without any apparent pattern. Very low frequencies, e.g. 10Hz, are difficult to measure due to flow noise around the hydrophone. Unfortunately, this is in the frequency range (10-30 Hz) where most of the noise is generated by large ships. As an example of this inconsistency, in Hannay *et al*. (2004), the measurements for the transiting *JFJ De Nul* were taken with a 10Hz high-pass filter but measurements of the same vessel's dredging and anchoring operations were taken with a 30Hz high-pass filter**.** As with almost all of the SL measurements, the loudest measurements recorded were in the lowest 1/3 octave, centred at 31.5Hz in this case, but the noise below 30Hz was likely to be louder still. Given the difficulties of recording these very low frequencies, it would be understandable if all recordings were made with a 30Hz high-pass filter, but JASCO apparently had enough confidence in their equipment to make recordings at 10-20Hz. Without the 10-30Hz measurements**,** the final models depicting RLs in the gray whale feeding areas remain questionable.

Third, radiated noise from ships can be directional; indeed some of the measurements in Hannay *et al*. (2004) bear this out. While measurements were taken from different aspects and showed directionality, there is no accounting for directionality in the JASCO model. Relevant to this discussion is the difference in SL with different activities, e.g. side-thrusting by the *Setouchi* or spud drops by the *JFJ De Nul*. The CEA (Section 4.3.1.2) states that SLs for some extremely loud activities were measured (e.g. dynamic positioning of *Pompei, Christoforo Colombo, Gerardus Mercator*) but these results were neither reported nor presumably used in the noise modelling exercises. Also, impulse noise from activities like spud dropping should be provided as peak pressure or energy flux density, and should *not* be averaged. Finally, measurements for other loud activities (e.g. helicopter MI-8 flyover) have yet to be conducted. Neither the activity nor the directionality of the source used for the final model runs is stated, again leaving considerable doubt about the accuracy of noise level predictions in the gray whale feeding areas.

These SL measurements are to be used to predict ranges at which the 120dB RL threshold would be breached. Such ranges will be highly dependent on water depth, source level accuracy and bottom loss characteristics, as explained further in the Appendix, below.

Use of the Range-dependent Acoustic Model (RAM)

JASCO are using a modified Range-dependent Acoustic Model (RAM) to estimate 'safe' distances between noisy activities and gray whales. Some details on the RAM, as described on the Naval Research Laboratory website (http://www.nrl.navy.mil/content.php?P=03REVIEW212) include:

> ...the Range-dependent Acoustic Model (RAM), developed at NRL by Michael Collins... is based on a user-selected multiple-term Padé approximation of the PE operator. Because this solution allows range steps much greater than the acoustic wavelength and does not require fine vertical gridding, RAM is a very fast research model. Additionally, RAM's grid can be tuned to smoothly trade accuracy and speed as the operational situation requires.

There are at least three significant problems with the RAM for this application. The first and main problem is that it does not involve elastic properties of the sea bottom; instead, a simplified bottom model is used. Indeed, as stated in the CEA (Section 4.3.2.3), '...the original RAM model does not account for shear wave losses caused by the significant bottom interactions that occur in shallow-water environments'. JASCO took a series of measurements at Lunskoye and attempted to account for the shear waves resulting from sediment variations. In their report, JASCO state that the RAM accounts for shear wave losses using the 'complex density approach' given in Zhang and Tindle (1995). Adding the attenuation of the shear waves into the RAM i.e. applying the complex density approach (CDA), is a widely used procedure (Tappert, 1985) that changes the simple bottom model to a 'liquid-CDA' bottom model. However, this does not change the situation appreciably. The RAM cannot adequately simulate sound propagation in the shallow sea over the infra-low frequencies if the bottom sediment includes elastic layers with abrupt changes in the sound velocity and strong reflection of sound at the layer boundaries, i.e., reflection coefficients in the 'basement' or shelf underlying the sediment. This has direct implications for modelling in the Piltun area where seismic survey data (Report N00027/07, 2000) definitely show that a high-speed layer is located at depths of up to 60m below the bottom.

The inadequacy of the TL calculations using the soft bottom model can be demonstrated by the results of the Piltun acoustic research conducted at the request of SEIC. In 1999, POI FEB RAS obtained acoustic background measurements in the gray whale feeding area (Sobolevsky 2001). The acoustic records revealed a nearly continuous noise component of 130dB re 1 μPa at $\approx$26Hz. This noise component was generated on the Molikpaq (PA-A) platform at a distance of $\approx$20km from the receiver. To investigate the very small TL at this frequency in the Pitun area, directed measurements and model calculations using a 2-layer, elastic bottom model were conducted (Borisov *et al*. 2004). Low-frequency (< 25Hz) measurements were made from a location offshore at 28m depth to the receiver near shore at 11m depth. On the basis of these measurements and numerical modelling, Borisov *et al.* concluded that decrease in the TL at frequencies less than 25Hz results from transmission of the acoustic energy by surface waves. Even if bottom layer shear waves exist, surface waves will propagate along the boundary of this layer without any restriction on frequency. So, tonal components of infrasonic ship noise can propagate effectively through the shallow-water zone.

The second deficiency of the RAM using CDA is that it incorporates insufficient and inappropriate geoacoustic bottom parameters (i.e. 3 parameters instead of 15 as in Dozier and Cavanagh, 1993) in the model runs for predicting noise propagation within the Piltun feeding area. The characteristics of the bottom in this shallow-water environment are a dominant factor in determining the transmission of sound (Urick, 1983; Kinsler *et al*. 2000; Kuperman and Lynch, 2004; Hamilton, 1976). We cite several references here because in section 4.3.2.3 of the CEA, specifically Table 4.1, the influence on modelling results of sound velocity vertical profile is treated as only 'moderate' and the influence on sound attenuation vertical profiles as 'low' (see Appendix, below, for an example of the influence of sediment type on transmitted sound). Sound energy can propagate through this environment via several pathways including: (a) a direct path from source to receiver, (b) surface reflection and (c) bottom reflection. Bottom reflection, off both the sediment surface and the hard bottom (i.e. through the sediment), pathways are the most complex. The sediment layer is likely to be quite thick, e.g. ~100 m, and therefore hospitable to long wavelengths (Hamilton, 1976; Hamilton and Bachman, 1982). JASCO attempted to include shear wave loss but they did not use

measurements of the geophysical properties in the Piltun area (CEA, 4.3.2.5). Application of the average geoacoustic properties of a seabed given in Hamilton (1976, 1980) in order to calculate TL in the Piltun –Astokh area, where these parameters have been investigated for more than 15 years, is not justified. For example, compression sound speed profiles in bottom layers can be obtained using data from seismic surveys and the analysis of core samples from boreholes received during engineering-geophysical research in the Piltun-Astokh area (Report N00027/079, Pacific Eng. Co, 2000; TEO Phase 1, 1997). In particular, shear speeds for this area were measured in test boreholes MC-1 - MC-4 and MB-5 - MB-6 (TEO Phase 1, Exhibits 5-9, 1997). These and other pertinent reports are the property of SEIC and it is unclear why these data were not used.

The third deficiency of the RAM is two-part. First, the results produced by the RAM are highly dependent on initial conditions (i.e. accuracy of the source characteristics at the point of production). Second, the RAM depends on another model to generate its 'starter vector'. This starter vector is essentially a mathematical representation of the initial signal (i.e. a distribution in depth of the frequency and amplitude of the source) that is then propagated by the model through the environment. The distribution and level of sound that are contained in this vector must be generated by a model other than the RAM. Because of the RAM's dependence on initial conditions, its results can be difficult to interpret. JASCO recognised the sensitivity of the RAM to initial conditions and stated that they had replaced the 'self-starter' with 'a weighted Gaussian approach, called 'Green's starter'', which is actually 'Greene's starter'. This 'enhanced' starter is used 'to account for the partially depth-distributed nature of noise from large vessels in the near field'; that is, it should produce better estimates of RL at close ranges. However, there is no way to verify the performance of the RAM using Greene's starter, and this starter is actually not the best one to use in shallow water. In shallow water, a normal mode starter should be used (Dozier and Cavanagh, 1993). Indeed, it is not clear why JASCO did not use a full normal mode model for the whole exercise. When calculating routes followed by sound with decreasing bottom depth (coastal wedge), it is necessary to take into account interactions between the normal waves. In general, normal mode models are cumbersome due to the fact that pathways have to be calculated for each frequency at each depth, but in this case the frequencies and depths of interest are rather limited. In any case, a full normal mode model would be preferable to a PE model, although with poor SL data and insufficient geoacoustic data no model can give reliable results.

Finally, as mentioned above, the RAM is optimised to provide quick results. User-selected parameters that speed the calculations can significantly affect the propagation of the source vector through the environment. The vertical and horizontal steps used can have a significant effect on the results because the plotting routine interpolates between the calculated values. In the extremely shallow waters being considered here, two points at even 1m depth difference may experience significantly different RL (Fig. 1). Setting the model to calculate large range or depth steps may speed the calculation but may result in misleading conclusions about both the amplitude and frequency of the received sound.

Appendix

To show the extreme dependence of TL modelling results on either the choice of different geophysical parameters for the bottom sediments or SL, we provide here an example of a TL calculation for the Piltun area as presented in Vedenev (2002). Vedenev (2002) used a PE model to compute the TL (i.e., similar to the model used by SEIC). The vector of the initial sound source field defined at the distance of 0.5km from the source, depth of source was 5 m and the RL values were averaged within the water column at points similar to those used in the SEIC model.

Attenuation of sound depends on the sediment type as well as the frequency of the sound of interest. Figure A1 shows the TL at 60 Hz for the track from the proposed location of the PA-B platform towards shore to the point 12km from PA-B where the water depth is 10 m, i.e., in the gray whale feeding area. In this example, we have varied only one parameter, the compression wave attenuation (α). If we assume dependence of the compression wave attenuation in bottom sediment (α) on frequency f to be linear: $\alpha = \beta f$, we can then test how changes in the sediment properties will affect attenuation. Specifically, Figure A1 shows three TL curves for different values of the attenuation coefficient β.

To illustrate the effect that changes in this one parameter can have on RL, we consider a source of 190 dB at 60Hz and show the range at which the RL from this source violates the 120dB threshold. For the values of α resulting from varying values for β (i.e., 18 dB/km, 6 dB/km, 1.8 dB/km), the 120 dB threshold is violated, respectively, at b1 or

4.1km from the source, b2 or 7km from the source, and b3 or11km from the source (Figure A1). From this exercise, we see that the isoline of 120 dB RL shifts from 4.1km to 11km simply by the difference in attenuation associated with sandy vs. silt sediment.

The shift in the distance estimation for the 120dB isoline boundary by 7-8km due to the uncertainty in the value of the attenuation coefficient in the bottom sediment is worrisome. The problem is compounded by the aforementioned concerns regarding measurement accuracy, underestimation of the SL due to high-pass filtering and the lack of SL data for some noisy activities. Thus, we conclude that the noise contour zones resulting from JASCO's multiple-source model have little practical value. The level of uncertainty in the acoustic model parameters is too high to conclude that the existing acoustic model is a sufficiently reliable forecasting tool for noise-mitigation planning and for decision-making.
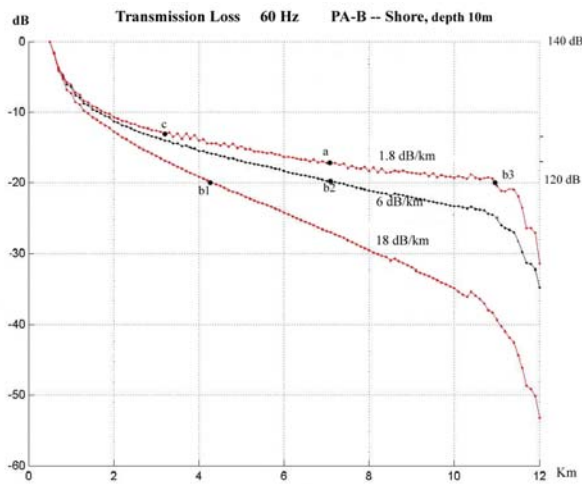

Figure A1. Transmission loss (TL) calculated with a PE model, as reported in Vedenev (2002). The three curves show the TL that results from varying the compression wave attenuation in bottom sediment. β(silt-clay) = 0.03 dB/Km*Hz (α = 1.8 dB/Km at 60Hz – upper curve), β (mixed particles)= 0.1 dB/Km*Hz (α = 6 dB/Km at 60Hz -middle curve), β(sand)= 0.3 dB/Km*Hz (α = 18 dB/Km – lower curve). Note that the JASCO model used an intermediate value of β = 0.085 dB/Km*Hz =0.14dB/ λ.

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Annex F

Technical specifications of population modelling for western gray whales

J.G. COOKE

1   INTRODUCTION

This Annex contains the technical specifications of the model used to generate the population projections presented and discussed in Chapter VII.

Due to the very small population size (~20-30 breeding females) the WGW population is vulnerable to the combined effects of random demographic events and external influences. In order to encompass the true extent of risk to the population, it is appropriate to model the population as a collection of individuals rather than as a bulk process. For practical reasons, an hybrid approach was taken, involving elements of both an individual-based approach and a population-base approach.

The population is modelled from 1994 through to 2050. This period is divided into the fitting period (1994-2003) for which data are available, and the projection period (2004-2050) for which no data are available. The two periods are treated somewhat differently because of the need to condition on the data during the fitting period. During the fitting period, the unidentified population is modelled in terms of the expected numbers of whales of each type (such as calves, immatures, mothers, resting females, males) while the identified whales are modelled individually in terms of the annual probabilities that each individual is in different possible states (such as calving, resting, dead etc). During the projection period, random realizations of the lives of each individual in the entire population are simulated.

The analysis is Bayesian. Uniform prior distributions are specified for each unknown model parameter. The joint prior distribution is sampled in proportion to the likelihood to yield a joint posterior distribution of the parameter values and the states of the population. The posterior distribution of parameters and population states is sampled to provide a range of states and parameter sets that are used to provide a sample of population projections.

The fitting of the model to the data makes use of the matrix population methods of Caswell (2000), which have been successfully applied to right whales (Caswell *et al*, 1999; Cooke *et al*, 2001; 2003) . For the purpose of projections the model is projected forward on an individual , stochastic basis, in the natural way.

2   THE POPULATION MODEL

2.1   Population structure
The modelled population is structured into the categories as shown in Fig. 1. The male population is divided into just three classes: calves (weaned and unweaned) and animals aged 1+. On the assumption that reproduction is not limited by the number of males, more detail is not needed for the males. The female population is divided into: calves (weaned and unweaned); age classes 1 through 4; immature animals aged 5+; mature animals which are resting or receptive (before their first calf or between calves); mature animals which have been resting for at least one year; and calving mothers (divided into those still accompanying their calf and those who have already weaned it). The time resolution of the model is one year, and the classes refer to the state of animals during the summer study season at Piltun.

Once a female has reached age 5, it is assumed thereafter to have a constant annual probability a of becoming mature. On maturity it then enters the first Resting/Receptive class where it has an annual probability b of having a calf the following year, and a probability $1 - b$ of entering the second Resting/Receptive class (females which have been resting for at least one year). After resting for a year, the whale has a probability c of having a calf the following year, and a probability $1-c$ of resting for a further year. The youngest age a female can become mature is 6 years and the youngest age it can have a calf is 7 years. After having a calf, females return to Receptive/Resting class.

The probabilities b and c ff 'having a calf' actually refer to the probability that a calf is born and survives the migration to the study area. The minimum interval between calves in the data and the model is two years. The modal calf interval in the data is 3 years, which implies that the probability of calving is elevated after a rest year ($c > b$).

The distinction between weaned and unweaned calves has no demographic significance. It merely refers to whether calves are accompanied or not at the time of the census at Piltun, and is relevant to the interpretation of observations.

Some of the calves are no longer accompanied on arrival at Piltun, and cannot be assigned to a specific mother (although planned genetic analysis of existing biopsy samples may make this possible in retrospect). Likewise, some mothers of the year will not be identified as such, because their calf has already separated. Each calf has a probability w of being 'weaned' (actually: separated) before the study season such that their mothers are not identified.
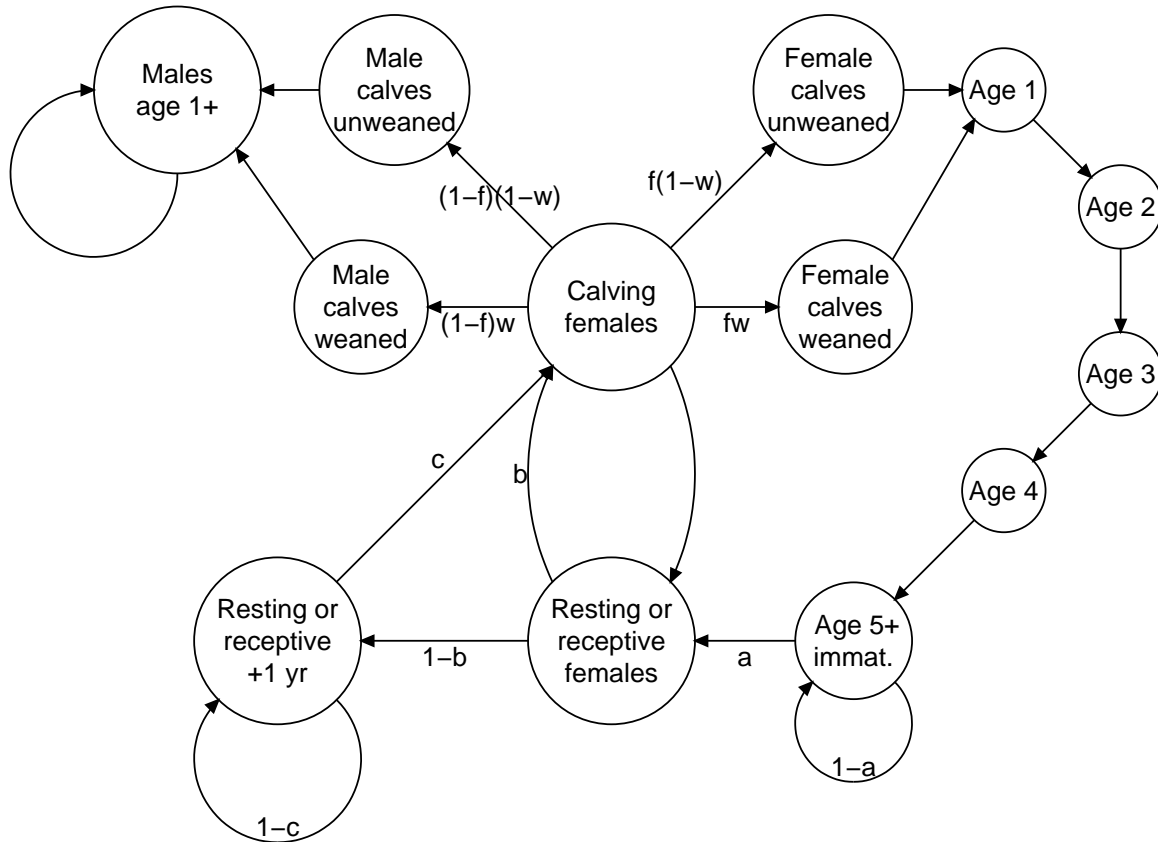

Fig. 1. Structure of population with transition probabilities/rates between classes (exluding mortality).

2.2 Transition matrix

The state of a given individual in a given year is the class to which it belongs. Apart from reproduction, passage of individuals between states is governed by the transition probability matrix **T,** given in Table 1**.** The transition matrix entry $\mathbf{T}_{ij}$ represents the probability that an animal in class i in year t will be in class j in year $t+1$. The entries are non-zero only for state pairs (i,j) for which a one-step transition is possible, as indicated by an arrow in Fig. 1. Mortality is represented by adding an additional 'dead' state (not shown in Fig.1.). The annual mortality probability is the transition probability to the dead state. There are $m = 15$ states including the dead state, when calving females before and after separation of the calf are counted as distinct states.

We allow some of the transition probabilities to vary between years by writing $\mathbf{T}_{ij}(t)$, but assume that they are independent between individuals and between years.

Suppose the state of an individual in year t is uncertain, and that it is in state i with probability $\mathbf{x}_i$. The vector $\mathbf{x}(t)$ is the state probability (row) vector for that individual in year t. The state probability vector for that individual in year $t+1$ is given by $\mathbf{x}(t+1) = \mathbf{x}(t)\,\mathbf{T}(t)$ where matrix multiplication is implied.

2.3   2.3. Leslie matrix
The Leslie matrix **L** describes the evolution of the expected population, rather than of specific individuals. If the expected numbers of animals alive in the population by class in year t are given by the row vector **n**(t), then the expected number in year t+1 is given by

$$\mathbf{n}(t+1) = \mathbf{n}(t)\ \mathbf{L}(t).$$

Conventionally, dead animals are not considered part of the population, so that **L** contains no row or column for the dead state. The Leslie matrix is given by $\mathbf{L} = \mathbf{T}^{\#}\ (\mathbf{I} + \mathbf{R})$ where $\mathbf{T}^{\#}$ is the transition matrix with the row and column for dead animals stripped off, and **R** is the reproduction matrix shown in Table 1. **R** contains only 4 non-zero entries, relating to the four calf categories (male/female, weaned/unweaned).

2.4   2.4. Annual variability
The only population parameters that we allow to vary by year are the calving probabilities b and c. Since b and c must take values between zero and one, their variation is modelled on the logit scale. We write:

$$b = \frac{\exp(\beta)}{1+\exp(\beta)} \qquad c = \frac{\exp(\gamma)}{1+\exp(\gamma)}$$

$$b_t = \frac{\exp(\beta + \sigma v_t)}{1+\exp(\beta + \sigma v_t)} \qquad c_t = \frac{\exp(\gamma + \sigma v_t)}{1+\exp(\gamma + \sigma v_t)}$$

where β is a parameter determining the median calving probability without resting, γ is a parameter determining the median calving probability after resting, and σ determines their inter-annual variance. For each year, v_t is an independently distributed standard normal random variable which expresses the extent to which the favourability of environmental circumstances for reproduction differ from the average. b and c are the 'standard' values of b_t and c_t, respectively, for a year of median conditions. We use b and c as parameters of the model rather than β and γ, so that we can give them the natural prior distribution (0,1). Note that the calving probability in a median year is not equivalent to the calving probability in a random year. The latter quantity is equal to the mean calving probability, which is closer to 0.5 than is the median.

2.5   Time evolution of the expected population
Let **n**(t_0) denote the vector of the expected initial population by state at the start of the fitting period (t_0 = 1994). The ith component of **n** is the expected number of animals in state i, where i = 1, ..., m-1 and the dead state is not included. In accordance with standard practice, the expected population at t_0 is assumed to have the stable state distribution given by the primary eigenvector of the Leslie matrix. The corresponding eigenvalue has the value $1 + \lambda$ where λ is the annual rate of population increase (decrease if negative) corresponding to the given parameter values under stable, median conditions. The initial vector **n**(t_0) is scaled so that it sums to the current value of the initial population size parameter, P_0.

The expected population evolves with time as follows:

$$\mathbf{n}(t+1)\ =\ \mathbf{n}(t)\mathbf{L}(t) \text{ (matrix multiplacation)}$$

However, as explained below, we do not use this equation directly, because we track the known und unknown individuals separately.

It was not considered necessary to include density-dependent effects in the model, because the projected populations in 2050 were still at a small fraction (<20%) of historical (pre-whaling) levels.

2.6   Parameters of the population model

The parameters of the population model to be estimated include: constant entries in the transition matrix (survival rates, sex ratio, maturation probability); the median and variance of time-varying entries in the matrix (calving probabilities) ; and the initial (1994) population size. The parameters of the population model and their assumed prior ranges are listed in Table 2. The rate of population increase λ is not an input parameter: its value is determined by the values of the other parameters.

3   THE OBSERVATION MODEL

An animal is 'observed' in year t if it is seen and identified at least once in that year. The observation probability depends on the state of the animal but may also vary from year to year, due to differences in survey effort and other factors. In years with no survey, the observation probability is set to zero. In other years, the observation probability in year t for animals in state i is given by:

$$\mathbf{p}_i(t) \ = \ \frac{\exp(\pi_i + \tau\zeta_t)}{1 + \exp(\pi_i + \tau\zeta_t)}$$

where π_i is a state-specific parameter, τ is a parameter determining the extent of annual variability in detection probability and ζ_t are standard independent random normal variables, one per year. We express the state-specific parameters in terms of the corresponding median observation probabilities $q_i = \exp(\pi_i)\big/(1 + \exp(\pi_i))$. The median observation probabilities are not equal to the mean observation probabilities, which are closer to 0.5 than are the medians.

To reduce the number of parameters to be estimated, common observation probability parameters are estimated for groups of states as follows: (i) mothers and calves; (ii) resting females; (iii) immature females; (iv) males 1+. It is assumed that dead whales are not seen: the observation probability corresponding to the dead state is zero.

We considered the weaned probability for calves, w, to be a parameter of the observation model, because it has no demographic significance: it affects the interpretation of observations of calves and known or possible mothers.

The parameters of the observation model and their prior ranges are also listed in Table 2. The prior range for each of the q_i and for w is (0,1). The prior range for τ is (0,2).

4   DATA USED FOR FITTING THE MODEL

The data consist of a number (130) of individual observation histories. Each observation history consists of a history 'type', a starting year, and a sequence of annual 'observations' of that individual.

There are three 'types' of history:

- 'child' histories, which begin with an observation as an accompanied calf of a known mother;
- 'orphan' histories, which begin with an observation as an unaccompanied calf (mother unknown) ;
- 'non-calf' histories, which being with an observation as a non-calf (animal of unknown age).

There is considered to be up to one observation per animal per year, regardless of the actual number of times the animal is seen in a given year. Annual observations are either 'negative' (the whale not seen in that year at all), or 'positive' (whale seen). Each positive observation is one of four types:

- seen as an accompanied calf in that season
- seen only as an unaccompanied (weaned) calf in that season
- seen as non-calf without an accompanying calf in that season
- seen as non-calf with an accompanying calf in that season

Each positive observation may additionally involve a sex determination (*i.e.* the taking of a biopsy). Whales seen accompanied by a calf are assumed to be female, such that for the purpose of this analysis, a biopsy taken from such whales is redundant.

Each observation history is considered to continue through to the final year of data, regardless of the last time the whale was seen (*i.e.* a history can end with a sequence of one or more negative observations, which implies that there is a non-zero probability that the whale died before the end of the data period).

Each positive observation has an associated vector **v** whose *i*th component is 1, if the observation is consistent with the whale being in state *i* in that season, and 0 if the observation is inconsistent with that state. No positive observation is consistent with the dead state. If an observation includes a sex determination, then those components of the observation vector relating to states of the opposite sex to the observed sex are set to zero.

For example, an observation of an unaccompanied calf of unknown sex is consistent with states 'Male calf (weaned)' and with 'Female calf (weaned)' but with no other states. An observation of a non-calf animal of unknown sex is consistent with all living non-calf male and female states except the state 'Mother (with calf)' .

Let $\mathbf{v}(t; h)$ denote the observation vector in year t for observation history h, assuming that there was a positive observation in this year.

The mere fact that an observation, taken alone, is consistent with a state does not imply that the individual has a non-zero probability of being in that state, because the possibility might already have been ruled out by a previous observation. For example, the observation of a non-calf female without a calf is consistent with all non-calf female states, but it if the whale had already been seen two years earlier as a female calf, then all states except 'Age 2' have zero probability. For a given observation, the vector **v** has zero entries only for those states that are ruled out by that particular observation.

We do not model the probability of sex determinations: inference proceeds conditional on the sex determinations actually performed. This is legitimate if we make the following assumption: when an animal of unknown sex is observed, the probability that the given observation includes a sex determination might depend on what is observed (e.g. calf/non-calf; with/without mother; with/without calf), but is, for a given type of observation, independent of the true sex. With this assumption, it turns out that the likelihood calculated for a given history does not depend on which particular observation(s) in the history involved a sex determination, but merely on whether the sex was determined at some point in the history.

This assumption does not imply that males and females have equal probabilities of having their sex determined during their lifetime, because they will have different probabilities of being observed, and hence different numbers of opportunities for a sex determination, and furthermore females have the possibility of being sexed through being accompanied by a calf. The sex ratio of the animals of unknown sex will, therefore, not in general reflect that of the population as a whole.

5 FITTING THE MODEL TO THE DATA

5.1 Unidentified whales

At the start of the season, unidentified whales are all calves, and all non-calves that have not been identified in any previous season. Let $\mathbf{u}(t)$ be the vector of expected number of unidentified whales by state at the start of study season t. At the start of the data period in 1994, all whales are unidentified, hence $\mathbf{u}(t_0) = \mathbf{n}(t_0)$. The probability that an animal in state i remains unidentified at the end of the season is $1 - \mathbf{p}_i(t)$.

The expected unidentified population evolves with time as follows:

$$\mathbf{u}_j(t+1) \;=\; \sum_i \Big(\mathbf{u}_i(t)\big(1 - \mathbf{p}_i(t)\big)\, \mathbf{T}_{ij}(t) \;+\; \mathbf{n}_i(t+1)\mathbf{R}_{ij} \Big)$$

5.2 Identified whales

In the case of non-'child' histories (i.e. 'orphan' and 'non-calf' histories), we seek an expression for the expected number of whales with a given observation history. For a given observation history, h, starting in year t^*, let the vector $\mathbf{x}(t; h)$ represent the vector whose ith component is the expected number of whales in state i in year t which have had observation history h up to and including year t. The vector **x** has m components including a component for the dead state. For the starting year:

$$\mathbf{x}_i(t^*;h) = \mathbf{u}_i(t^*)\mathbf{v}_i(t^*;h)\mathbf{p}_i(t^*)$$

Thereafter, the vector $\mathbf{x}$ evolves with time as follows:

$$\mathbf{x}_j(t+1;h) = \sum_{i=1}^{m}\mathbf{x}_i(t;h)\mathbf{T}_{i,j}(t)\mathbf{p}_j(t+1)\mathbf{v}_j(t+1;h) \quad \text{if the whale is seen in year } t+1;$$

$$\mathbf{x}_j(t+1;h) = \sum_{i=1}^{m}\mathbf{x}_i(t;h)\mathbf{T}_{i,j}(t)\big(1 - \mathbf{p}_j(t+1)\big) \quad \text{otherwise.}$$

The expected number of whales with observation history h is given by:

$$E_h = \sum_{j=1}^{m}x_j(t_1)$$

where t_1 is the final year of data. The dead state is included in the sum. The expression for E_h cannot evaluate to zero for an observed history unless the history is incompatible with the model in some respect.

A 'child' history is conditional on the corresponding observed calving event in the mother's history. The expected number of such histories is already accounted for in the analysis of the mother history. We require only an expression for the probability of the child history, given that one starts in the given year. The $\mathbf{x}$ vector starts with all components set to zero for except the components corresponding to unweaned calves. If the sex is unknown, the components for male and female calves respectively take the values $1–f$ and f respectively. If the sex is known, the component for the wrong sex takes the value zero, while the component for the correct sex takes the value $1–f$ or f according to sex. Thereafter, the $\mathbf{x}$ vector evolves with time in the same way as for the other types of history. The probability of the history is given by:

$$P_h = \sum_{j=1}^{m}x_j(t_1)$$

For either type of history, the components of $\mathbf{x}(t;h)$, when scaled to sum to unity, give the probabilities that the identified individual is in the various states in year t given the history up to and including that year. When $t = t_1$ this is the probability distribution across final (2003) states for that individual given the entire observed history. This is used later for making projections, as described below.

5.3 Likelihood of the data
The total expected number of non-child observation histories is equal to the total expected number of distinct whales observed, excluding those first observed as accompanied calves. This quantity is given by:

$$E = \sum_{t=t_0}^{t_1}\mathbf{u}^*_i(t)\mathbf{p}_i(t)$$

where the vector $\mathbf{u}^*(t)$ is the vector of the expected number of unidentified whales in year t, but excluding accompanied calves.

The log-likelihood of the data, assuming a Poisson distribution of the numbers of each possible non-child observation history, is , ignoring constant terms, given by:

$$\Lambda = \sum_{\substack{child \\ histories}} \log(P_h) + \sum_{\substack{non-child \\ histories}} \log(E_h) - E$$

where the summations are over all observed child and non-child histories respectively.

6 PROJECTING THE POPULATION

6.1 Projection method
During the projection period (2004-2050), we do not compute the expected numbers of unidentified whales or the probability distributions of states of identified whales, but simulate random realisations of all individuals' lives directly.

In any given projection, the integer number of individuals in state i in year t is given by $\mathbf{N}_i(t)$. The projection is started in 2004 as follows:

- First, the unidentified population in 2004 is constructed by setting $\mathbf{N}_i(t)$ to a Poisson random variate with mean $\mathbf{u}_i(t)$. The assumption of a Poisson distribution for the numbers of unidentified individuals is not strictly justified, but in practice this is a minor issue, because in all simulations, projections, the unidentified population was very small by the end of 2003, there being between zero and five expected individuals remaining unidentified.

- The identified whales are then added in as follows. The state probability vector $\mathbf{x}(2004)$ for each identified individual whale is normalised to sum to unity. A random state is drawn from this vector. If this is the dead state, this whale is discarded. Otherwise, one whale is added to the corresponding component of $\mathbf{N}(t)$.

- For each year t thereafter, the new population vector $\mathbf{N}(t+1)$ is initialised to zero. A random new state is drawn for each individual whale with probabilities given by the transition matrix $\mathbf{T}(t)$. If the new state is the dead state, the individual is discarded, otherwise one whale is added to the corresponding component of $\mathbf{N}(t+1)$. If the new state is the 'Mother (with calf)' or 'Mother (calf weaned)' state, a random binomial variable with probabilities $(1 - f, f)$ is drawn to yield the sex of the calf, and one new whale is added to the component of $\mathbf{N}(t+1)$ corresponding to male or female calves accordingly.

6.2   Generation of probability distribution of projections

The probability distribution of simulations is generated as follows. A random sample of sets of parameter values is drawn from the prior distribution of parameters. For each parameter set, a random sample of annual effects is drawn for each of those parameters that vary annually. The resulting sample is sub-sampled in proportion to its likelihood (Sampling-Importance-Resampling algorithm). For each member of the resulting sub-sample, a random projection is conducted as detailed above.

From the resulting sample of projections, selected percentiles (1, 5, 10, 25 and 50) were extracted from the distribution of the following population components in each year: mature females, 1+ females, and 1+ males (see Figs 1a-c of Chapter VII). Note that a given percentile does not necessarily correspond to a single trajectory: trajectories can cross each other. For example, the 5th percentile in 2040 might not lie on the same trajectory as the same percentile in 2020.

6.3   Projections with impact scenarios

- The projections are modified as follows in impact scenarios.

- For those scenarios with a given expected number of additional mortalities in given years, a random Poisson variate with mean equal to the expected additional mortality is drawn in each year with additional mortality. This number of animals is then drawn randomly, without replacement, from the components of the population assumed to be affected.

- For those scenarios with a given percentage additional mortality for the whole population for a year, each animal is randomly removed from the population with the given probability.

- For those scenarios with a given percentage drop in reproductive success over a given period, each calf born in that period is removed with a probability equal to the specified drop in reproductive success.

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Table 1
Transition probability matrix **T** and reproduction matrix **R** for the western gray whale population model

Transition from / to	Calf: male unweaned	Calf: male weaned	Calf: female unweaned	Calf: female weaned	Male age 1+	Immature female age 1	Immature female age 2	Immature female age 3	Immature female age 4	Immature female age 5+	Female Receptive/ resting	Receptive/ resting + 1 yr	Mother with calf	Mother (calf weaned)	Dead
Male calf, unweaned					Sj										$1 - Sj$
Male calf, weaned					Sj										$1 - Sj$
Female calf, unweaned						Sj									$1 - Sj$
Female calf, weaned						Sj									$1 - Sj$
Male age 1+					S										$1 - S$
Female age 1							S								$1 - S$
Female age 2								S							$1 - S$
Female age 3									S						$1 - S$
Female age 4										S					$1 - S$
Female age 5+ immature										$S(1 - a)$	Sa				$1 - S$
Fenmale, receptive or resting												$S(1 - b)$	$Sb(1 - w)$	Sbw	$1 - S$
Receptive/resting + 1 yr												$S(1 - c)$	$Sc(1 - w)$	Scw	$1 - S$
Mother (with calf)	**1 - f**		f								S				$1 - S$
Mother (calf weaned)		**1 - f**		f							S				$1 - S$
Dead															1

Parameters

Sj Survival probability: calf to age 1
S Survival probability (age 1+)
a Maturation probability (age 5+)
b Calving probability
c Calving probability (after 1 or more years resting)
f Calf female sex ratio
w Proportion of calves weaned before season

Entries left blank are zero.
***Bold** entries are reproduction matrix **R**.*
*Non-bold entries are transition matrix **T**.*

Table 2

Parameters of the models, prior ranges and percentiles of posterior distributions

Parameter	Prior range		Percentiles of posterior								
	Min	Max	1	5	10	25	50	75	90	95	99
Population model parameters											
Population 1994 P_0	50	250	59	63	66	69	75	81	86	89	94
Annual survival non-calf S	0.8	1	0.947	0.955	0.959	0.964	0.969	0.975	0.980	0.982	0.987
Calf survival Sj	0	1	0.561	0.608	0.629	0.681	0.732	0.773	0.809	0.827	0.864
Female sex ratio f	0	1	0.315	0.338	0.355	0.380	0.407	0.436	0.462	0.474	0.504
Maturation probability a	0.2	0.5	0.241	0.259	0.276	0.312	0.354	0.407	0.467	0.494	0.499
Median calving prob. b	0	1	0.076	0.148	0.172	0.225	0.296	0.379	0.474	0.529	0.615
Median calving prob. c (rested)	0	1	0.482	0.619	0.679	0.757	0.845	0.901	0.936	0.963	0.986
Calving prob SD σ	0	2	0.424	0.603	0.706	0.912	1.249	1.588	1.907	1.945	1.984
Derived parameter											
Annual rate of increase λ			0.009	0.015	0.019	0.026	0.033	0.040	0.047	0.050	0.055
Observation model parameters											
Probability weaned w	0	1	0.076	0.092	0.102	0.119	0.146	0.177	0.205	0.226	0.263
Sight prob SD τ	0	2	0.740	0.882	0.953	1.055	1.224	1.454	1.634	1.764	1.841
Median sight prob. Cows&Calves	0	1	0.317	0.361	0.384	0.433	0.488	0.552	0.610	0.648	0.696
Median sighting prob. immatures	0	1	0.407	0.501	0.539	0.600	0.669	0.732	0.783	0.811	0.872
Median sighting prob. Resting	0	1	0.350	0.402	0.425	0.469	0.521	0.587	0.631	0.660	0.738
Median sighting prob. Males 1+	0	1	0.404	0.434	0.454	0.492	0.532	0.584	0.638	0.661	0.719

PANEL COMPOSITION

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Alexander Burdin
Justin G. Cooke
James D. Darling
Gregory P. Donovan
Frances M. D. Gulland
Sue E. Moore
Douglas P. Nowacek

Timothy J. Ragen
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