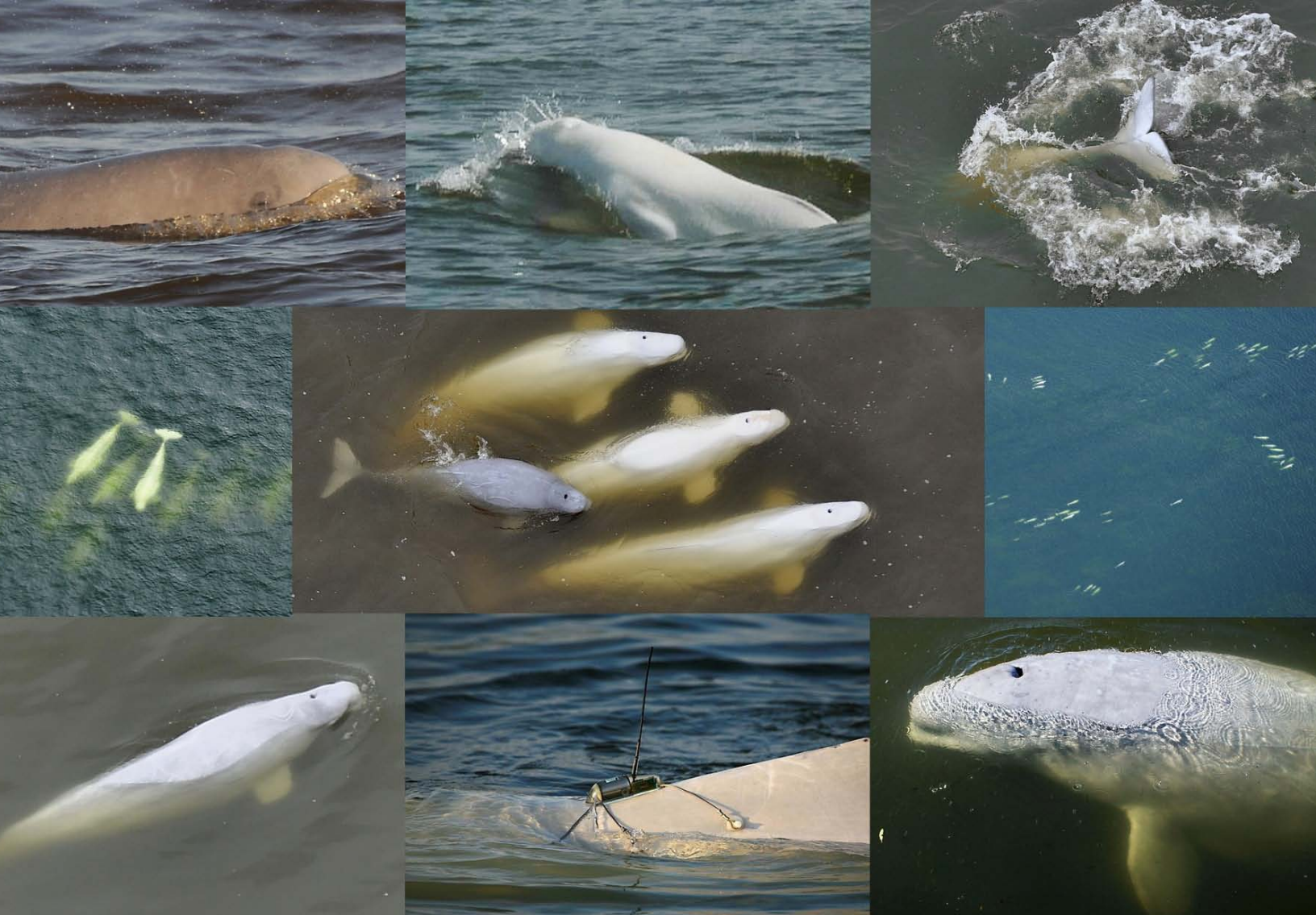




# Sustainability Assessment of Beluga (*Delphinapterus leucas*) Live-capture Removals in the Sakhalin–Amur Region, Okhotsk Sea, Russia

Report of an Independent Scientific Review Panel

Randall R. Reeves, Robert L. Brownell, Jr., Vladimir Burkanov, Michael C.S. Kingsley, Lloyd F. Lowry, and Barbara L. Taylor



Occasional Paper of the IUCN Species Survival Commission No. 44

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Cover photos (left to right, from top): 1. Juvenile beluga near Baydukov Island, 2. Adult beluga in Nikolaya Bay, 3. Beluga diving along Baydukov Island, 4. Belugas off Chkalov Island, 5. Adult belugas and a juvenile along Baydukov Island, 6. Aggregation of belugas in Ulbansky Bay, 7. Beluga with natural markings, 8. Release of a beluga tagged with satellite transmitter at Chkalov Island, 9. Young beluga captured near Baydukov Island. Photos by O. Shpak (2-7), D. Kuznetsova (1, 9), S. Gendron (8).

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## 1. Introduction and Background

An independent scientific review panel (hereafter, the Panel) was formed under the auspices of the International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) to review the results of research on belugas (*Delphinapterus leucas*), or white whales, in the Sakhalin–Amur region of eastern Russia (Fig. 1) and to assess the sustainability of recent live-capture removals. This research (hereafter, the Beluga Project) was sponsored by five public-display institutions (oceanaria).<sup>1</sup> The SSC accepted a request by Ocean Park Corporation (OPC, acting on behalf of the five sponsoring oceanaria) to convene the panel and thus provide an independent evaluation of the results of the research carried out from 2007 to 2010. According to Suzanne Gendron of OPC, the main goals of the research program (which is planned to continue in the summer and autumn of 2011) are to understand the status of beluga populations in the region, assess the sustainability of recent removals, and develop a conservation action plan for the putative Sakhalin–Amur stock.<sup>2</sup>

The terms of reference for the Panel were set out in a contract between IUCN and OPC (Annex 1). The Panel composition (Annex 2) was determined by Randall Reeves, chairman of the IUCN/SSC Cetacean Specialist Group, who also chaired the Panel.

The Panel was established in January–February 2011 and met in Chicago, Illinois, USA, on 6–7 March 2011. Prior to the meeting, the Panel was provided with a document summarizing the results of the research to date—“Report for 2007-2010 Stages: Results of 4 years of study and preliminary conclusions” (including 5 appendices), compiled by Olga Shpak (Principal Investigator and Coordinator of the Beluga Project). This report included separately authored appendices by N.G. Chelintsev (“Estimation of beluga number on the data of aerial count in the Okhotsk Sea in August-September 2009”), Rod Hobbs (“Calculating the Allowable take Rate ( $\frac{1}{2} R_{\max}$ )”), and D. Kuznetsova (“Overview

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<sup>1</sup> Ocean Park Corporation, Hong Kong; Georgia Aquarium Inc., Atlanta, USA; Sea World Parks & Entertainment, USA; Mystic Aquarium and Institute for Exploration, Connecticut, USA; Kamogawa Sea World, Japan.

<sup>2</sup> The term “stock” is used here to refer to demographic units that are considered to represent the appropriate level for conservation management. The term “putative” is meant to convey the provisional nature of stock designations, in recognition of the fact that they reflect current thinking and could change with better information.

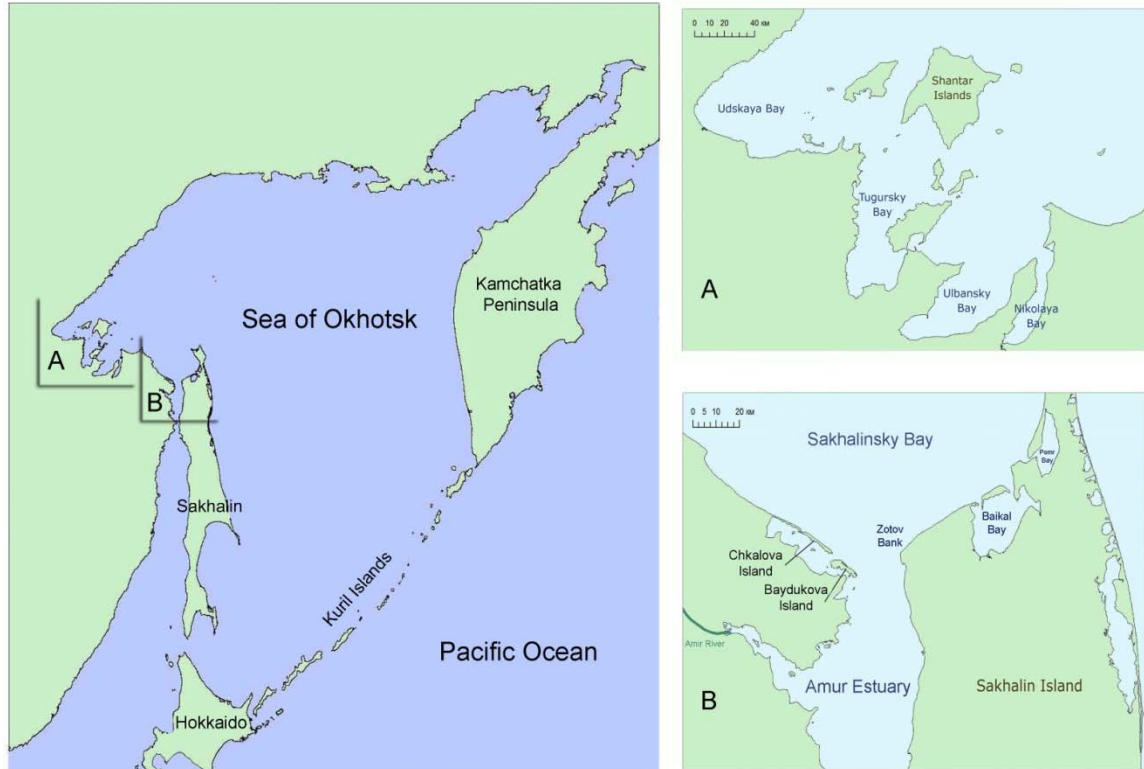


Figure 1. Sea of Okhotsk with insets of the Shantar region (A) and the Sakhalin-Amur region (B). Courtesy of Olga Shpak.

on the beluga historic whaling in Sakhalin-Shantar area”). Several other relevant documents—Melnikov (1999), Meschersky et al. (2008), and Russkova et al. (2010; 2011)—were circulated to the Panel in advance.

During the Chicago meeting, Robert Michaud (Independent Expert of the Beluga Project) provided background information on the origin and development of the project. Shpak gave an introductory presentation with an overview of the project, the study area, methods of data collection and analysis, and preliminary results. These included results from satellite tagging, genetic analyses, and aerial surveys as well as an assessment of the Potential Biological Removal (PBR) level for what was defined as the Sakhalin–Amur stock. The assessment incorporated a model developed by Rod Hobbs (Independent Expert of the Beluga Project) to account for age and sex selectivity of the removal regime.

The agenda of the Chicago meeting followed the guidelines for population assessment (in relation to any live-capture removals) outlined in the IUCN/SSC Cetacean Action Plan (Reeves et al., 2003) and in a report published by the SSC on Solomon Islands dolphins (Reeves and Brownell, 2009).<sup>3</sup> This report is organized according to the step-by-step

<sup>3</sup> The Solomons report was prepared in response to concerns about the numbers of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) live-captured from a small area and exported to oceanaria and “swim-with-the-dolphins” facilities.

assessment procedure outlined in the aforementioned IUCN/SSC documents and reflected in the Chicago meeting agenda (Annex 3).

## **2. Definition and Geographic Boundaries of the Unit to Conserve (Stock)**

Three lines of evidence are pertinent to evaluating the appropriate unit to conserve. The first relates to site fidelity. All well-studied populations of belugas have shown strong fidelity to summering areas, a trait possibly mediated by behaviour learned by juveniles from their mothers. Such learned migratory behaviour is known in various cetacean species and results in patterns in the maternally inherited genetic marker called mitochondrial DNA (mtDNA). When there is little or no gene flow between two groups, some haplotypes will be found in only one of the groups and not in the other, but if some gene flow occurs between groups or their separation is relatively recent, the pattern manifests as frequency differences in the occurrence of different sequences of mtDNA (haplotypes). When learned migratory patterns exist, the different summering destinations will result, at a minimum, in different haplotype frequencies. This general pattern—i.e. differences in haplotype frequencies between groups summering in different areas, often not very far apart, and showing maternally mediated demographic separation—is seen in belugas elsewhere in the Arctic (Brown-Gladden et al., 1997; O’Corry-Crowe et al., 1997), and therefore the default hypothesis for belugas in the Sea of Okhotsk would be the same: discrete summering groups, demographically independent, with internal population dynamics far more important in determining their numbers than exchange between them. However, even when it is assumed that multiple groups exist within the Sea of Okhotsk, the degree of demographic independence of those groups must be determined.

The other two lines of evidence—direct genetic data and satellite tagging—help determine the scale of the unit that is experiencing (and is expected to sustain) the removals. The mitochondrial genetic data obtained by the Beluga Project confirm that the Okhotsk Sea belugas have been separated from other beluga populations for long enough to acquire some unique haplotypes. Haplotype frequencies in the whales sampled in the Sakhalin region differed enough from those sampled in the *western* Shantar region to show that they are demographically independent; if belugas were extirpated from either of these two regions, it would likely not be recolonised for a considerable time (at least decades). Samples from the south-eastern Shantar region (Nikolaya and Ulbansky bays) are too few to support any conclusions as to whether it hosts a third independent aggregation in the peak summer months (June through mid-September), or hosts whales that belong to the summering aggregations to the east or the west or both (a mixed area).

The evidence from satellite tagging indicates that most individuals remain in Sakhalinsky Bay throughout the period when live-capture removals occur (July–September). Some tagged whales moved eastward from Chkalov and Baydukov Islands to Zotov Bank or Baikal Bay (i.e. north of the Amur estuary) and others southward into the northern part of the Amur estuary. In the autumn, most of the tagged belugas moved to the eastern Shantar region (Nikolaya and Ulbansky bays). Also two individuals previously tagged in Sakhalinsky Bay were photographed in Nikolaya Bay in a subsequent summer (July

2009) and one of them again in Nikolaya Bay in July 2010. All satellite-tagged individuals that were tracked into the winter months moved to the central and northern Sea of Okhotsk, which implies that contact and interbreeding among belugas from different summering areas may occur. The nuclear (microsatellite) genetic data presented in the report by Shpak et al. (2011) are consistent with such a scenario and the genetic homogeneity that would be expected to result, but because only nine markers were used, there was little power to detect heterogeneity. In spite of this, the overall  $p$ -value of the test for differences was fairly low (0.12), and furthermore one of the markers did show statistically significant frequency differences between the Sakhalin–Amur and Shantar regions.

However, the Panel had some reservations about the results of statistical tests of the genetics results, as it was not clear to what extent the sampling designs and methods approached the ideal of equiprobable (random and independent) sampling. Evidence that repeated tissue samples had been taken from some of the same groups was disquieting. Obtaining random and independent samples is always difficult, but the effect of sampling a few close relatives traveling together will lessen as sample sizes and the number of sampling occasions increase.

The sustainability of removals from Sakhalinsky Bay does not depend on whether there is interbreeding, or mixing, outside the season when belugas are captured. Thus, although it would be biologically interesting to determine whether separate gene pools of belugas exist within the Sea of Okhotsk, differences in nuclear markers are not necessary for there to be demographically independent summering aggregations.

Even though the current project has provided new and important data of relevance for defining the stock of concern, there are still several credible alternative hypotheses concerning stock boundaries. The largest area occupied by the Sakhalin–Amur stock would include Sakhalinsky Bay, the Amur region, and the south-eastern Shantar region. The smallest would be only that used by tagged whales during the live-capture season (basically between Chkalov Island and Zotov Bank). A credible medium-sized area would include Sakhalinsky Bay (including Zotov Bank and Baikal Bay) and the Amur estuary and river (the preferred hypothesis in the analysis presented in Shpak et al.'s summary document and also the working hypothesis used in this report).

#### *Recommendations on future sampling and write-up*

Further genetic sampling and satellite tagging within the Sakhalin–Amur region should be a high priority. Belugas in the Amur River and estuary (i.e. northern Tatar Strait) have not been adequately sampled (the attempts to obtain biopsies have so far resulted in a single sample) and whales tagged in Sakhalinsky Bay did not often go there. Biopsy sampling and tagging on Zotov Bank and in Baikal Bay would also be informative. The boundaries of the next stock to the west (Shantar region) are also in question. Sampling in Nikolaya and Ulbansky bays would be useful. Given the amount of haplotypic diversity in the existing samples, there should be a goal of obtaining at least 30 samples from each area.



Obtaining, from a summering aggregation of belugas, a sample that is statistically satisfactory for genetic comparisons is difficult because belugas are social animals, they move in groups, and their grouping probably reflects relatedness. If so, sampling repeatedly in few groups would tend to give samples with a greater concentration, of fewer genetic types, than would be expected for samples taken equiprobably from the entire summering aggregation. Such samples would tend to show spurious differences, and spuriously high significance levels in statistical tests, when compared with samples taken (by similarly faulty methods) from other aggregations. There was some evidence—repeated sampling of some of the same individuals, and reported concentration of sampling effort near the live-capture site—that genetic sampling in Udkaya Bay and Sakhalinsky Bay might have been more concentrated than would have been consistent with equiprobable sampling, and the statistical significance of differences in genetic make-up might therefore be somewhat less than the tabulated values. The Panel suggests that researchers strive to obtain biopsies from free-ranging belugas over a broad geographic range during the summer months, using boat operators and biopsy collectors who have had the best results in past seasons. The Panel also suggests that the exact locations of future biopsies should be recorded as they are taken, as well as other ancillary data such as the number of samples obtained from each sampling episode, and the presentation of results supported by full descriptions of sampling protocols (e.g. Chivers et al., 2007).

### 3. Current Estimate of Abundance

Significant effort was put into aerial surveys in the Shantar and Sakhalin–Amur regions in 2009 and 2010 (Shpak et al., 2011). Surveys were flown on nine days during 3 August–13 September 2009 and seven days during 4–24 August 2010. Belugas were located and counted on each survey, with areas of particularly dense concentrations of whales in Udkaya Bay and Sakhalinsky Bay. Line-transect methods were used in recording and analysing the sightings to produce estimates of the number of animals visible at the surface within the study area at the time of survey (see Shpak et al., 2011, their Appendix 3).

Three survey efforts provided reasonably complete and uniform coverage of the Sakhalin–Amur stock area and the data from those surveys were used to estimate abundance (see Appendix 1 of this report). Results are summarised in Table 1.

Table 1. Estimates of beluga numbers in the Sakhalin/Amur region of the Okhotsk Sea (from Shpak et al., 2011; see Appendix 1 of this report, Table A1).

Estimate	13 Sept. 2009	8 Aug 2010	23–24 Aug 2010	Mean
$2N_{estimated}$	4602	3154	4128	3961
$N_{min}$	3433	2533	2700	2891

The “best” estimate of abundance is 3,961, derived from the average of the values of  $2N_{estimated}$  for the three surveys. The  $2N_{estimated}$  values were derived from the survey

counts, extrapolated to the unsurveyed areas between transects and corrected by a factor of two to account for diving belugas unavailable to be seen at the surface. The minimum abundance ( $N_{min}$ ), 2,891, was calculated as the average of the values for  $N_{min}$  for the three surveys (see Appendix 1).

The Panel's review of the aerial survey programme raised the following concerns (also see Appendix 2):

- Survey methods have not been well described; in particular it is difficult to discern which of three analysis methods—total count, line transect without extrapolation to areas between transects, line transect with inter-transect extrapolation—was applied to which flown segments.
- The analysis software used (Belukha2) is not described in a way that inspires complete confidence in its methods or algorithms. In particular, there are many complex formulas containing fractional powers of constants for which no explanation was available to the Panel. A back-calculation of “operational effective strip width (ESW)” from results tabulated in Table 7 of the Chelintsev Appendix (Shpak et al., 2011, their Appendix 3) yielded ESWs that appeared to be small and variable. On the other hand, simple sightings curves fitted to data tabulated in Tables 2 and 5 of that appendix gave ESWs of similar widths to those derived by Belukha2.
- The practice of estimating a different sighting curve for each transect even when the entire survey was flown with the same methods is not common practice in line-transect analysis and is to be discouraged. In a number of cases it entailed estimating a sighting curve from as few as two or three sightings. The Panel **recommends** estimating one sighting curve for all sightings on a survey, or on sets of surveys carried out with common methods.
- A method used to analyse some flight segments comprised fitting an ESW and the resulting density estimate to a (truncated) sighting strip defined by Belukha2 software, and extending the resulting density estimate to a strip whose width was defined by the sighting farthest from the trackline. (For many other segments, the area to which the density estimate has been applied is not explained at all.) However, this method has been applied to data gathered on lines—sometimes quite short ones—that were not randomly placed with respect to the distribution of the animals (which is a necessary condition in line-transect analyses), but instead were intentionally flown either over known concentrations, or over areas where concentrations were expected. It is likely that such estimates are biased upwards.
- The reliability of estimates of group size made by visual observers has not been considered as a source of error, and measures have not been taken to control it.
- The potential for belugas to be missed close to the trackline has not been considered. In some aerial surveys for marine mammals, even using aircraft with bubble windows, such bias has been found to be significant. Density, and numbers, are likely to be underestimated if the line-transect methods used incorrectly assume no loss of sightings close to the trackline.

#### **4. Selection of a Value for Maximum Population Growth Rate ( $R_{max}$ )**

$R_{max}$  is defined as the maximum theoretical or estimated net annual productivity rate of a stock, where the term net productivity rate means the annual rate of increase resulting from additions due to reproduction less losses due to natural mortality.  $R_{max}$  is expected to be reached when populations are greatly reduced below their carrying capacity. For the calculation of PBR in assessments of cetacean stocks in U.S. waters, a default value of 0.04 is used when there are insufficient data on  $R_{max}$  specific to the stock in question (NMFS, 1995).

There are no data that can be used to calculate  $R_{max}$  specific to belugas in the Okhotsk Sea. Lowry et al. (2008) estimated the rate of increase of the beluga population in Bristol Bay, Alaska, over the 12-year period 1993–2005 as 0.048/year (95% CI = 0.021–0.075). As that population was not known to be greatly reduced at the time of the surveys, 0.048 may be somewhat less than the maximum possible net productivity for belugas. Thus  $R_{max}$  for the putative Sakhalin–Amur stock may be somewhat higher than the general cetacean default of 0.04, but for purposes of this review the default value will be used.

#### **5. Human-caused Mortality (including Live-capture Removals)**

Kuznetsova (Shpak et al., 2011, their Appendix 4) summarised the history of exploitation of belugas in the west central Sea of Okhotsk. Of greatest significance is the large-scale commercial whaling, using haul seine nets, beginning in about 1917 in the Amur region and in about 1925 in Sakhalinsky Bay. Hundreds to thousands of belugas were taken each year (with a break between 1918 and 1925). The reported catch reached a peak of more than 2,800 in 1933 and declined to hundreds per year thereafter. Little information is available on beluga catches from the late 1930s until well after World War II. According to Kuznetsova, by the late 1950s most of the commercial whaling for belugas in the Sea of Okhotsk took place in Tugursky and Udskeya bays, where 800–1,000 animals were taken per year. Large-scale commercial exploitation of belugas in the southern and western Sea of Okhotsk had ended by about 1963. Melnikov (1999) reported that hunting of belugas in the Okhotsk Sea ceased by 1963 because there were few left to catch and because of the expansion of commercial whaling for large whales.

A beluga live-capture operation for oceanaria was initiated in the Sakhalin–Amur region by Nikolay Marchenko for TINRO (Pacific Scientific Research Fisheries Centre, Vladivostok) in 1986. In 1989, Marchenko sold belugas to a dolphinarium in Ukraine (Kazachya Buhta). In the late 1990s, Marchenko started catching belugas for Utrish Dolphinarium Ltd. in Moscow. Since 1992, when Canada stopped live-capturing and exporting belugas, Russia has been the sole regular supplier of belugas to the oceanarium industry, with exports to Japan, Canada, and other countries (Fisher and Reeves, 2005). In 2009, belugas were captured for Pavlovskaya Sloboda, Ltd. in Moscow. Complete details on the numbers of live belugas removed from the wild prior to 2000 are not available, but complete catch data starting in 2000, as made available to the Panel by Shpak et al. (2011), are presented in Table 2. Data on the sex ratio of the live-captured

whales are incomplete, and no data are available on capture mortality prior to 2007 (see later).

Table 2. Number of belugas from Sakhalin–Amur stock live-captured by year, 2000–2010. Source: Shpak et al. (2011).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean 2006–2010
For Moscow	10	16	10	20	25	18	20	0	25	14	12	<b>14</b>
For Vladivostok	0	6	0	6	0	13	0	0	0	10	18	<b>9</b>
Total	10	22	10	26	25	31	20	0	25	24	30	<b>20</b>

In 1999, fisheries officials in Russia issued a permit for 200 belugas to be hunted in the Okhotsk Sea. Thirty-one were taken (L. Mukhametov, pers. comm. to Burkanov), and their meat was exported to Japan for human consumption (see IWC, 2001, p 53) before the Russian authorities withdrew the hunting permit and the CITES export permit. A single shipment of 13 tons of meat arrived in Hakodate, Japan, in the middle of September 1999 before the trade was halted. All of these whales were from the Sakhalin–Amur stock and were taken by the Marchenko live-capture team (N. Marchenko, pers. comm. to Burkanov). The removals for meat export would have been in addition to those live-caught for oceanaria, all of them also presumably from Sakhalin–Amur. We have only export data from 1999; 26 live belugas were exported that year according to CITES data. Assuming that all 26 were caught in 1999, and that no additional animals caught that year went to facilities within Russia, the total 1999 catch would have been 57.

There is little information on unintentional human-caused mortality (such as bycatch in fishing gear). It is interesting that the directed commercial haul-seine fishery for belugas originated as a result of the incidental capture of belugas (accounts vary on the number, from 16 to 48) in a haul seine for chum salmon at Lyugi on the west coast of Sakhalin Island in 1915 (Shpak et al., 2011, their Appendix 4). Since then, few cases of entanglement have been reported. Shpak told the Panel of specific instances when single belugas were taken incidentally in coastal salmon traps, beach-set salmon gillnets, and illegal sturgeon nets. Belugas occasionally depredate coastal salmon traps and manage to enter and exit such traps without becoming entangled. On one occasion mentioned by Shpak, a beluga stayed alive inside the trap (pocket) of an 800 m long salmon net during low tide and was then pushed into deeper water and released. On another occasion, a whale was drowned in an illegal salmon gillnet. Also, a biopsy was obtained from a beluga beach-cast south of the Amur River estuary, reportedly after dying in fishing gear. Shpak told the Panel that, according to local fishermen, belugas get tangled and drown in illegal nets set for sturgeon, but rarely.

Experience in several other areas supports the idea that belugas are exceptional among cetaceans in their ability to avoid entanglement. Bycatch mortality in the St. Lawrence beluga population in Canada is considered low and very few animals bear scars judged to

be related to entanglement (Bailey and Zinger, 1995; Lair, 2007). Belugas occupy Bristol Bay, Alaska, during the red salmon run when the salmon are being caught by more than a thousand fishermen using both drifting and anchored gillnets. Although some entanglement does occur, the rate is low considering the intensity of this fishery (Frost et al., 1984) and the beluga population in the region has been increasing (Lowry et al., 2008). A fishery observer program was conducted for two years in Cook Inlet, Alaska, another region where belugas co-occur with intensive salmon gillnet fisheries, and no entanglements were observed (Manly, 2006). Similarly, Burkanov has found no evidence (e.g. scarring) of belugas being taken as bycatch in the coastal salmon fisheries along the west coast of Kamchatka over the last three decades.

Another possible cause of mortality is accidental drowning of animals during live-capture operations. Michaud advised the panel that he and his staff who participated in the fieldwork in 2007, 2008, and 2010 were favourably impressed by the way the experienced capture team caught and handled the whales. The team reportedly targets small groups passing near shore and slowly forces the seined whales into shallow waters. The live-captures are all made by a single team working at familiar sites where conditions are favourable for the technique employed. Shpak and Michaud told the Panel that they were aware of only one death related to capture operations (a newborn calf that was accidentally entangled with its mother) over the last four years (2007–2010).

Another possible cause of mortality is vessel strikes. Owing to the tortuous and shallow channel between Sakhalin Island and the mainland (Tatar Strait and the Amur estuary), there is very little traffic of large ships or barges in the Sakhalin–Amur region. There is considerable traffic of small fishing boats in the Amur estuary but Shpak has found no evidence of belugas being struck by these vessels. Again, this is consistent with observations in at least some other parts of the beluga’s range with intensive vessel traffic. Lowry is not aware of instances of belugas being struck by vessels in Alaska. In western Kamchatka, belugas occur only near shore and in river mouths where there is no large vessel traffic and relatively little traffic of small fishing boats with outboard engines. During more than 25 years of research in that area, Burkanov has never observed vessel strikes on belugas or observed belugas with injuries or scars that could have been attributed to such strikes. Nor has he received any information on vessel strikes second-hand. In the heavily trafficked St. Lawrence estuary of Canada, vessel strikes on belugas do occur: between 1983 and 2004, 11 of 166 necropsied carcasses had “traumatic lesions”, such as vertebral fractures, deep lacerations of the skin or pulmonary lacerations, that led to inferences of ship strikes (Lair, 2007).

Any animals taken by humans, including those killed or injured in fishing gear, struck by vessels, or accidentally drowned during live-capture operations, should be considered when evaluating the sustainability of any level of intentional removals.

The Amur River—tenth longest in the world—drains the Amur Oblast in Russia and also most of Heilongjiang Province in north-eastern China, which includes the cities of Harbin, the tenth largest in China, and Qiqihar. The province has a dynamic economy with diverse industry, and chemical contamination of the Amur and its tributaries is at

least episodic. For example, an explosion at a chemical plant in Jilin in 2005 caused serious contamination of a tributary with benzene and nitrobenzene (International Chemical Industries Service News 14.11.2005; Environment News Service 25.11.2005). Also, the lower reaches of the Amur are contaminated by an array of organic and inorganic pollutants from non-point upstream sources such as surface flow from urban areas, agricultural runoff and forest fires (Rapoport and Kondrat'eva, 2008). Although the Panel had no basis for integrating pollution into its assessment of the sustainability of live-capture removals, given the rapid development underway in the catchment region, it seems appropriate to check levels of fat-soluble contaminants in beluga blubber as well as to test beluga blood for hormonal reactions to toxins.

## **6. Conclusions Concerning the Sustainability of Removals from the Sakhalin–Amur Beluga Stock**

### *Background*

The following definition of “sustainable” is used here as it applies to the conservation of natural resources: “of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged” (from the Merriam-Webster Dictionary). In considering the array of precedents for managing removals of marine mammals from natural populations, there is a consistent goal of keeping cetacean populations above roughly 50% of what the environment could support if there were no human-caused mortality. Differences in levels of human-caused removals/mortality that are allowed by different management regimes result either from different criteria for designation as “depleted” or “permanently damaged,” or from differences in treating uncertainty in numbers, defining the unit to conserve, or estimating mortality (see Reeves and Brownell, 2009 for more detail).

The Panel presumed that institutions whose mission includes educating the public about marine mammals and conservation would want to show a relatively high level of conservation awareness and commitment and would therefore want to achieve at least the same goal as the least restrictive of the methods. That means maintaining numbers in the stock at greater than 50% of what they could reach, under present habitat conditions, in the absence of human-caused removals.

### *Potential Biological Removal (PBR)*

The PBR approach was developed to estimate levels of annual removals that are compatible with the goals of the U.S. Marine Mammal Protection Act and that can be computed using minimal data. This approach has been adapted for use in several other management regimes with somewhat different goals (Reeves and Brownell, 2009). For example: in New Zealand, the bycatch of New Zealand sea lions (*Phocarctos hookeri*) has been managed under the New Zealand Marine Mammal Management Act using a scheme similar to the PBR (Harcourt, 2001); PBR-type methods have been proposed for evaluating bycatch of Hector's dolphins (*Cephalorhynchus hectori*) (Slooten and Dawson, 2008); Japan's National Research Institute for Far Seas Fisheries has proposed a PBR-type method to set limits on the takes of Dall's porpoises (*Phocoenoides dalli*) (Okamura et al., 2008); and PBR calculations have been used

to determine the sustainability of subsistence takes of dugongs (*Dugong dugon*) in Australia (Marsh et al., 2004).

The PBR approach used by Shpak et al. (2011) and by the Panel meets the above definition of “sustainable” and considers uncertainty in both the abundance estimates and the status of the population. The approach was created to meet management objectives that include treating all stocks of marine mammals similarly regardless of the precision with which numbers are known. The management objective was to have a 95% chance of maintaining a stock above 50% of carrying capacity for 100 years when allowable removals were calculated from estimates of numbers, including their uncertainty, and of population growth rate. Algorithms were tuned and tested with extensive simulations. The algorithm finally chosen uses a lower 20<sup>th</sup> percentile of estimated population size (called  $N_{min}$ ) and one-half of the maximum rate of population increase, or  $R_{max}$ , given the assumption that  $R_{max}$  itself prevails only when the population has been reduced to well below the environmental carrying capacity. The result is the standard PBR calculation for stocks considered in good condition,

$$\text{PBR} = N_{min} \cdot R_{max} / 2 = N_{est} / \exp(0.842 \cdot (\ln(1 + \text{ECV}(N_{est})^2))^{1/2}) \cdot R_{max} / 2,$$

where  $N_{est}$  is the best estimate of the number in the stock and  $\text{ECV}(N_{est})$  is its error coefficient of variance, i.e. the standard error (a measure of uncertainty) divided by estimate. The full PBR algorithm also includes an adjustment for the status of a population, intended to ensure greater protection and more rapid recovery for those known, or thought, to be endangered. This adjustment, applied to the allowable take, is called a “recovery factor,” and is required to be set to 0.1 for stocks designated as endangered, threatened or depleted, while a value of 0.5 is recommended for stocks whose status is unknown (Wade and Angliss 1997).

Potential biases of concern when applying any guideline for sustainability of takes are under-estimation of human-caused mortality, over-estimation of  $R_{max}$ , and estimating the wrong numbers for the population size by incorrectly including more than a single stock.

#### *The Sakhalin–Amur beluga case*

The available guidelines for assessing the sustainability of removals, with their simple numerical approach, ignore some aspects of the biology of social animals. For example, the selective removal of socially important individuals or classes can devastate social structure: a known example is the matriarch in a group of elephants (e.g. Foley et al., 2008). We know little, as yet, about how beluga society functions, although matrilineal transfer of knowledge on migration routes, feeding sites, and summering areas is thought to be important. Juvenile whales—weaned and independent, but not reproductively mature—are preferred by the live-capture trade. The preference for removing juveniles, even if long continued, may not result in a progressive loss of knowledge or affect the functioning of beluga society as these young animals are not known to play key social roles.

A second concern is the fidelity of belugas to summering sites, which elsewhere is known to be high at the level of the bay or estuary. It is not known whether site fidelity also operates at finer spatial scales. If it operates on a very local scale, capture operations long continued at one or two favoured sites where captures are easy and safe might deplete a local, but thus far unrecognised, community.

Available guidelines for assessing the sustainability of removals from marine mammal populations (including PBR) assume that all sex and age classes are equally vulnerable. However, the live-capture effort tends to concentrate on juveniles and therefore the average reproductive value of caught whales is probably greater than the average reproductive value of individuals in the population. The Appendix by Hobbs in Shpak et al. (2011, their Appendix 5) included results from a simple model of stock dynamics showing only a trivial difference due to the preference for juveniles; for example, an age- and sex-independent PBR of 29 captures became 28 when only 3-year-olds were removed. The sex ratio of catches is more significant. There has been a slight preponderance of females in the catches over the last few years, and if this preponderance were to increase, it would require a reassessment of the sustainability of removals.

Shpak et al. (2011) calculated a value for PBR that used a non-standard method for estimating  $N_{min}$ . The decision rule was to use the standard method (lower 20<sup>th</sup> percentile of the abundance estimate) except in cases where the count multiplied by two (to account for animals below the surface and not visible) was greater than the  $N_{min}$  based on the lower 20<sup>th</sup> percentile of the estimate of numbers (also corrected for visibility by a factor of two), in which case the doubled count was used as  $N_{min}$ . The Panel did not consider this method acceptable because it falls outside the spectrum of algorithms tested during development of the PBR approach (Wade, 1998) and therefore its consequences are unexplored. Presumably such a method would, on average, generate larger allowable takes than the standard one would, and therefore it might not achieve the management objectives that PBR was designed for. Simulations using this method could be run to find out to what degree it meets the PBR objectives.

Belugas in the Sakhalin–Amur region were intensely exploited from 1915 at least through 1937 (Shpak et al., 2011, their Appendix 4), and it appears that whaling stopped at least partly because few whales were left to catch. Some beluga populations that were reduced to low numbers have failed to recover at the expected 4% default annual rate after exploitation stopped; notable cases are the stocks in Cook Inlet, Alaska (Hobbs et al., 2006; Hobbs and Sheldon, 2008) and the St. Lawrence estuary, Quebec (Hammill et al., 2007). It is not known why those two stocks have not recovered, but from their example it appears possible—especially in view of the total reported catches from 1927 to 1937, which would imply pristine numbers perhaps in the low tens of thousands—that recovery of the Sakhalin–Amur stock has been slow and is still not complete, and that the present status should be considered at best as “unknown.” If this view is accepted, it implies that a recovery factor of 0.5 should be used in the PBR calculation.

#### *Sustainable removal calculation*



The Panel's calculation of PBR for the Sakhalin–Amur beluga stock uses the average value of  $N_{min}$  (2,891) as follows:

**PBR (sustainable annual removal) =  $1/2 * 0.04 * 2891 * 0.5 = 29$  belugas.**

Removals vary from year to year. As the basis for a general statement about their sustainability, it is reasonable to average them over recent years. A 5-year window adequately smoothes the variation without giving too much weight to past data. The Panel concluded that the sustainability of recent removals could reasonably be evaluated by comparing the 2006–2010 mean of removals with a PBR of 29 derived from the results of the 2009–10 aerial surveys in the Sakhalin–Amur region.

Using PBR requires both estimates of numbers and estimates of their uncertainty. As estimates of numbers become older (i.e. become increasingly outdated), the uncertainty as to whether they accurately represent the current state of the population increases, and the calculation of  $N_{min}$  should be adjusted to reflect this. Recent changes to the U.S. Guidelines for the Assessment of Marine Mammal Stocks prescribe such downward adjustment to  $N_{min}$  when the PBR calculation is based on estimates of numbers more than 8 years old. For this reason, and because it is in any case wise to monitor a resource that is subject to ongoing exploitation, it will be appropriate for a regular survey programme to be maintained in the Sakhalin–Amur region. The Panel **recommends** that intensive surveys be conducted in two consecutive years, followed by a gap of not more than 7 years. Surveying in consecutive years allows for better estimation of year-to-year variation in survey results.

Survey design should seek to be able to detect a precipitous decline, for example a 50% decline in 15 years (which would result from a population declining at 5%/year). The PBR approach was designed for populations that are experiencing normal (i.e. unaffected by anthropogenic factors) birth and death rates. Assuming that environmental change due to global climate disruption will continue indefinitely, it must be assumed that populations of marine mammals in high-latitude regions will experience (and likely have already begun to experience) major changes in their habitat (e.g. changes in the timing and nature of ice formation/disintegration and changes in the numbers and movements of prey, predators, and competitors) that could lead to changes in life history parameters. This reinforces the need for regular monitoring in order to make timely and appropriate adjustments in management standards (i.e. what level of removals is sustainable).

#### *Considerations for refining parameters used in the PBR calculation*

A number of steps could be taken in both the short and medium term to refine parameters that have been used in the PBR calculation made above. In the short term, the overall error coefficient of variation (ECV) could be reduced analytically, and this would increase  $N_{min}$ . Shpak et al. (2011) chose to estimate  $N_{min}$  separately for each survey area (for example, Baikal Bay separately from Sakhalinsky Bay), and this yielded a lower total  $N_{min}$  than if a total estimate had been made for the entire area and the  $N_{min}$  based on the ECV for that total. The ECV could be further reduced by pooling the survey data

across surveys (including years) to get an average total number for the Sakhalin–Amur region for the 2009-2010 period. It appears that the finite population correction has not been applied in calculating ECVs. Especially in the case of systematic transect surveys with closely spaced transects, doing so would reduce the calculated ECV.

In the medium term, dedicated research could be carried out to better quantify the correction factor for the proportion of belugas visible at the surface and available for counting as the aircraft passes overhead. However, studies to estimate availability correction factors properly can be difficult and costly, and they should include estimation of variance in the correction factor which then should be accounted for in calculations of  $N_{min}$ .

In order to manage removals from the Sakhalin-Amur stock and ensure their sustainability based on present understanding of the unit to conserve, the most efficient use of survey resources would be to develop and apply effective, intensive, standard survey methods to the Sakhalin–Amur region, and expend less effort on the Shantar region. It would also be appropriate to develop an application of PBR that used a forward extrapolation of survey series estimates, with the uncertainty of the extrapolation, as a basis for  $N_{min}$ ; this would automatically reward frequent and effective surveys and would correct the estimate of sustainable take for apparent trends in numbers.

## **7. Recommendations for Follow-up Research and Monitoring**

In addition to the items recommended in the above text (highlighted in **boldface**), the Panel prepared the following list of priorities for future consideration.

### *I. Better define the boundaries of the unit to conserve*

Belugas are live-captured in south-western Sakhalinsky Bay. It will be easier to evaluate whether the removals are sustainable if there is more confidence in the boundaries of the affected stock (management unit), and in particular if there is a better understanding of whether summering aggregations of whales in the eastern Shantar region have frequent exchange with those in the Sakhalin–Amur region. Therefore, the Panel **recommends**:

- additional genetic sampling, especially in Nikolaya and Ulbansky bays and also Sakhalinsky Bay, with the objective of obtaining adequate samples over the entire Sakhalin–Amur region;
- effort to obtain biopsies from free-ranging belugas over a broad geographic range during the summer months, using boat operators and biopsy collectors who have had the best results in past seasons;
- use of additional microsatellite markers to improve the statistical power of genetic analyses;

-more satellite tagging in early summer in Sakhalinsky Bay and in the eastern Shantar region.

## II. *Better evaluate the effects of continued removals*

The same live-capture sites are used repeatedly, year after year. Knowing more about the movements (both local and long-range) of animals summering in south-western Sakhalinsky Bay would enable evaluation of the potential population-level implications of the geographically fixed character of the catching operation (such as possible “local depletions”). Therefore, the Panel **recommends**:

–analysis of summer home ranges of tagged belugas in Sakhalinsky Bay.

## III. *Improve methods for estimation of numbers*

Given a defined unit to conserve, the PBR method depends largely on current, or at least recent, estimates of numbers and their uncertainties. The Panel therefore **recommends**:

–that surveys be flown in two consecutive years at intervals of not more than seven years. Using the experience gained in 2009–2010, the surveys should be precise enough to confirm a decline if numbers were to decrease by 5%/year over 15 years;

–improving aerial survey methods by

- . stratifying the study area and applying appropriate, and if necessary different, methods in different strata,

- . reporting transect spacing, flying height, and other flight details in descriptions of surveys,

- . analysing survey data using internationally accepted, peer-reviewed methods,

- . incorporating a finite population correction in the calculations of uncertainty,

- . emphasising the use of systematic parallel transects, randomly placed with respect to the distribution of belugas and at clearly defined spacing, and

- . using photography or other methods to get more accurate counts in strata containing dense aggregations;

–allocating most survey effort to the Sakhalin–Amur region and less to the Shantar region unless, or until, other information leads to redefinition of the boundaries of the management unit.

## **Final Note and Acknowledgments**

Effectiveness of international conservation agreements depends on credible population and removal data and on accurate reporting of trade in wildlife and wildlife products (e.g. Phelps et al. 2010). It is rare that the beneficiaries of such trade are seen to invest in the research and monitoring needed to ensure long-term sustainability. In the case of Sakhalin-Amur beluga live-captures, it is important to acknowledge the institutions that supported the work under review, and also to commend them for making the methods and results available for critical, independent scientific evaluation. The Panel thanks Suzanne Gendron of Ocean Park for her personal commitment to this process. It also wishes to record its appreciation to Olga Shpak for her patient and effective presentation of the beluga research programme and its results at the Chicago meeting, as well as her evident dedication to conservation of Okhotsk Sea belugas through the pursuit of good data and appropriate analyses, and to Robert Michaud and Rod Hobbs for the solid technical support and guidance they have given the Beluga Project. All three of them made significant contributions during this review. Finally, the Panel thanks Dena Cator of the IUCN Species Programme for her conscientious and effective efforts to facilitate the review.

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**Annex 1 - Terms of Reference for Independent Scientific Review Panel (excerpt from contract between IUCN Species Survival Commission and Ocean Park Corporation)**

The purpose of the review will be to produce an independent scientific assessment of beluga research in Sakhalin-Amur region and the sustainability of recent removals of belugas from the wild in the Okhotsk Sea, following guidelines in the IUCN/SSC cetacean action plan (Reeves et al. 2003, p 17) and the IUCN/SSC report on Solomon Islands dolphins (Reeves and Brownell 2009, pp 29-30). The scope of the information/data requirements for the assessment will be as defined in those two documents. (Note: Data on removals should include all takes by hunting, live-capture, bycatch etc. back to ca. 1980). The review panel will not address questions related to the ethics of removing whales from the wild for public display, nor will it review legal, transport, husbandry and other aspects of the proposed capture and importation.

The review will be led by Dr. Randall Reeves, who chairs the IUCN/SSC Cetacean Specialist Group. Dr. Reeves will be responsible for selecting five to six panel members and ensuring that they are independent (i.e. not affiliated in any way with the collecting operations, the potential importers or the Contractor itself in terms of being a beneficiary of its grants within the past 12 months, i.e. in 2010 or presently) and that they have relevant expertise for judging the quality and conclusiveness of the research under review. The review panel will not be expected to conduct research or compile information, but will instead be expected to critically review the data and information supplied by the Contractor (“Current Status of the Sakhalin-Amur Beluga Aggregation” by Olga Shpak, supplemented by verbal presentations at the Chicago meeting). This may include evaluation of the credibility and conclusiveness of findings and the identification of gaps in knowledge that need to be filled in order to improve the assessment.

Dr. Reeves will be responsible for chairing the review meeting and producing a final report, with support from the panel members. A 2-day meeting will be needed to facilitate the review. The cost of this meeting, including the meeting venue and all participants’ travel, accommodation and meal expenses, will be covered by the Contractor. In addition, the Contractor will pay for the salary time of the review panel members and relevant IUCN Species staff that will be involved in the review of the report or administration of the project, as outlined in the detailed budget of section 4 in this Contract.

Dr. Reeves and the review panel will have full independence and decision-making authority in terms of how the report is developed and the report will be communicated as specified in the section “communication of results.” Immediately upon completion by Dr. Reeves and the review panel, the draft report will be sent to the Contractor for an opportunity to provide comments within two weeks. Dr. Reeves and the panel will then have one week to consider any comments received before submitting their final report for review by (a) IUCN’s Chair of the Species Survival Commission, Dr. Simon Stuart, and (b) Head of Species Programme, Dr. Jane Smart. Dr. Stuart and Dr. Smart will have one week to provide comments on the report and if they have none of substance (i.e. beyond editorial), the report will be published as an IUCN document and made publicly available

by posting it on the SSC and Cetacean Specialist Group websites within one week after it has been received and accepted by the IUCN SSC and Species Programme. If Dr. Stuart and Dr. Smart suggest any substantive changes on the report to the review panel and these lead to substantive changes in the final report by the Panel, the Contractor will be notified and there will be an extra week before the report is released publicly. To ensure a completely independent and objective report (and thus scientific credibility), the report authors (Dr. Reeves and the review panel) and the Contractee are not obligated to accept the comments on the draft report provided by the Contractor, and full payment of the Contractee for its services will not be predicated upon such acceptance.

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### **Annex 3 - Agenda for Meeting to Review Beluga Research in Sakhalin-Amur**

Hotel Four Points by Sheraton at O'Hare, 6-7 March 2011

Saturday 5 March – Participants arrive at hotel

Sunday 6 March –

08:30 Meeting begins

- Introductions etc.
- Discussion of nature and scope of review
- Reporting procedures

09:15 Slide presentation by Olga Shpak

10:30 Break for coffee

11:00 Continuation of Shpak presentation with questions and discussion

12:15 Lunch

13:15 Resume discussion in following order

- Definition and geographic boundaries of population(s) (unit(s) to conserve)
- Current estimate(s) of abundance, with associated uncertainty
- Selection of a value for maximum(?) population growth rate
- Understanding of human-caused mortality (including live-capture removals)
- Final assessment regarding potential impact on population from human-caused mortality (including live-capture removals)
- Follow-up monitoring and periodic reassessment to track population trajectory

14:45 Break for coffee

15:15 Resume discussion as above

16:15 Private panel session

Evening: The meeting room will be available for an evening panel-only session if needed.

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Monday 7 March –

08:30 Meeting begins

- Opportunity for more question-answer and discussion between panel members and researchers/advisor

- Agreement on strategy for remainder of day

10:30 Break for coffee

11:00 Continuation per agreed strategy

12:15 Lunch

13:15 Continuation per agreed strategy

14:45 Break for coffee

15:00 Private panel meeting

Evening: Again, the meeting room will be available all evening for our use, as necessary/feasible.

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**Appendix 1 - Summary of aerial survey analysis to determine  $N_{\min}$  for Sakhalin-Amur belugas -- Prepared for this report by Olga Shpak and Boris Solovyev (see Shpak et al. (2011) for further details)**

Description of aerial surveys used for abundance estimates

*13 September 2009 (3 h 50 min flight time) – White Whale Program data – see Figure A1*

Goal: Abundance survey in Sakhalin-Amur region (to compare to 12 September survey for precision count, different design).

Design: Parallel tracklines. Line frequency was doubled in the area of high concentration of belugas.

*8 August 2010 (2 flights, 4 h 40 min flight time) – see Figure A2*

Goal: Abundance survey in Sakhalin-Amur region.

Design: Zigzag (saw-tooth) lines in Amur mouth and estuary, parallel tracklines in Sakhalinsky Bay with a loop into Baikal Bay.

*23 August 2010 (2 flights, 7 h 05 min flight time) – see Figure A3*

Goal: Repeat abundance survey in Sakhalin-Amur and Shantar regions.

Design: Due to closure of the base airport (Nikolaevsk) and the airport in Udkaya Bay (Kiran), start-finish from Okha (Sakhalin Island) and no coverage of Udkaya Bay. Parallel tracklines in Sakhalinsky Bay, with a loop into Baikal Bay; coastal flight along the heads of Tugursky, Ulbansky, and Nikolaya bays, with additional circles over beluga concentrations.

*24 August 2010 (4 h 05 min flight time) – see Figure A3 (and note in caption)*

Goal: Amur estuary abundance survey and plane/team delivery to Khabarovsk.

Design: Via Baikal Bay, zigzag lines in the estuary, overland flight to Khabarovsk.

Table A1. Aerial survey results used to estimate  $N_{min}$  for Sakhalin-Amur; analysis by Belukha2 software.

Date	Region	Total number counted <sup>1</sup>	Extrapolation <sup>2</sup>	Estimated surface-visible number ( $N_{est}$ )	Relative statistical error (ECV) (%) <sup>3</sup>	$N_{min}$ <sup>4</sup>
13.09.09	Baikal Bay	89	no	97	78.0	
13.09.09	Sakhalin–Amur	1278	yes	2204	36.9	
13.09.09	<b>Total Sakhalin–Amur</b>	1367		2301	35.5	<b>3443</b>
8.08.10						
2010	Amur outfall	35	yes	38	29.7	
8.08.10	Amur estuary	40	yes	108	45.3	
8.08.10	Sakhalinsky Bay	1063	yes	1305	31.8	
8.08.10	Baikal Bay	126	no	126		
8.08.10	<b>Total Sakhalin–Amur</b>	1264		1577	26.5	<b>2533</b>
23.08.10	Sakhalinsky Bay	658	yes	1930	57.4	
24.08.10	Amur estuary	50	yes	134	51.	
23–	<b>Total Sakhalin–Amur</b>	708		2064	53.9	<b>2700</b>
24.08.10						

<sup>1</sup>Of these, not all had measured distances, and of those that did, not all were used in line-transect analysis, Belukha2 truncating the data at a distance considered optimal.

<sup>2</sup>That is, for unsurveyed areas between systematic sample survey transects.

<sup>3</sup>Includes uncertainty of effective strip width as well as, for extrapolated results, sampling error in encounter rate.

<sup>4</sup> $N_{min}$  calculated from:  $N_{min} = 2 \cdot N_{est} / \exp(0.842 \cdot (\ln(1 + \text{ECV}(N_{est})^2))^{1/2})$ ; the factor of 2 is applied to correct for animals presumed unseen because under water.



Figure A1. Aerial survey tracklines and beluga sightings in the Sakhalin–Amur region, 13 September 2009.

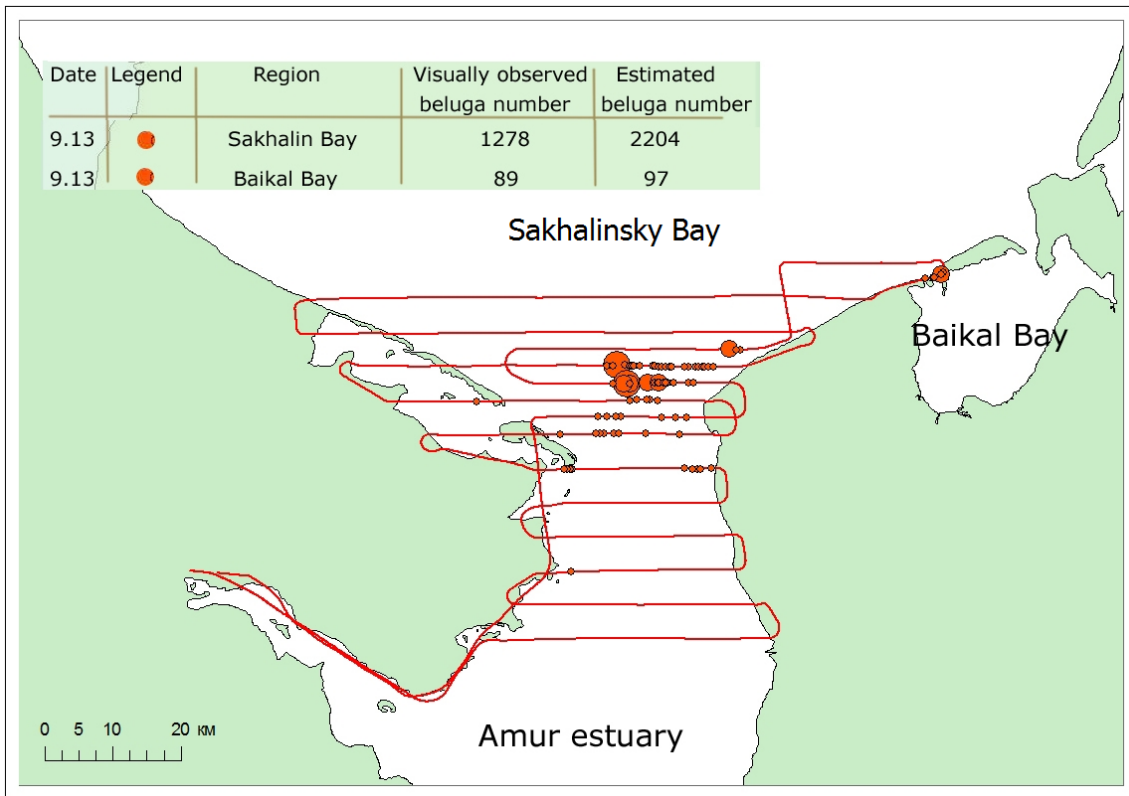


Figure A2. Aerial survey tracklines and beluga sightings in the Sakhalin-Amur region, 8 August 2010.

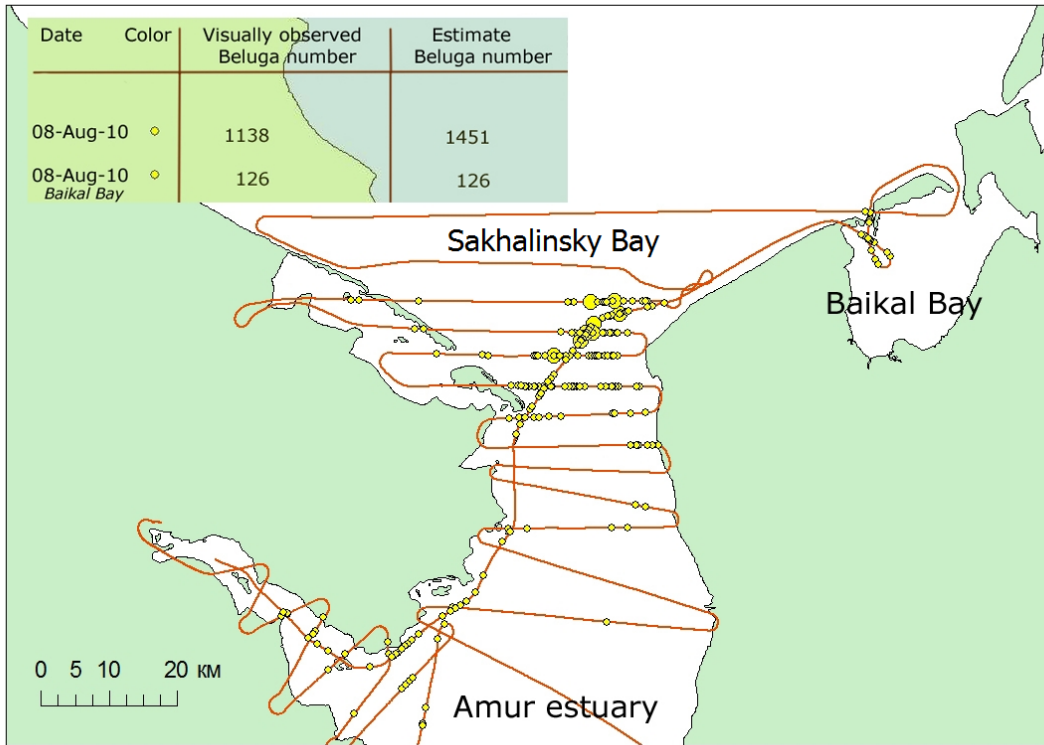
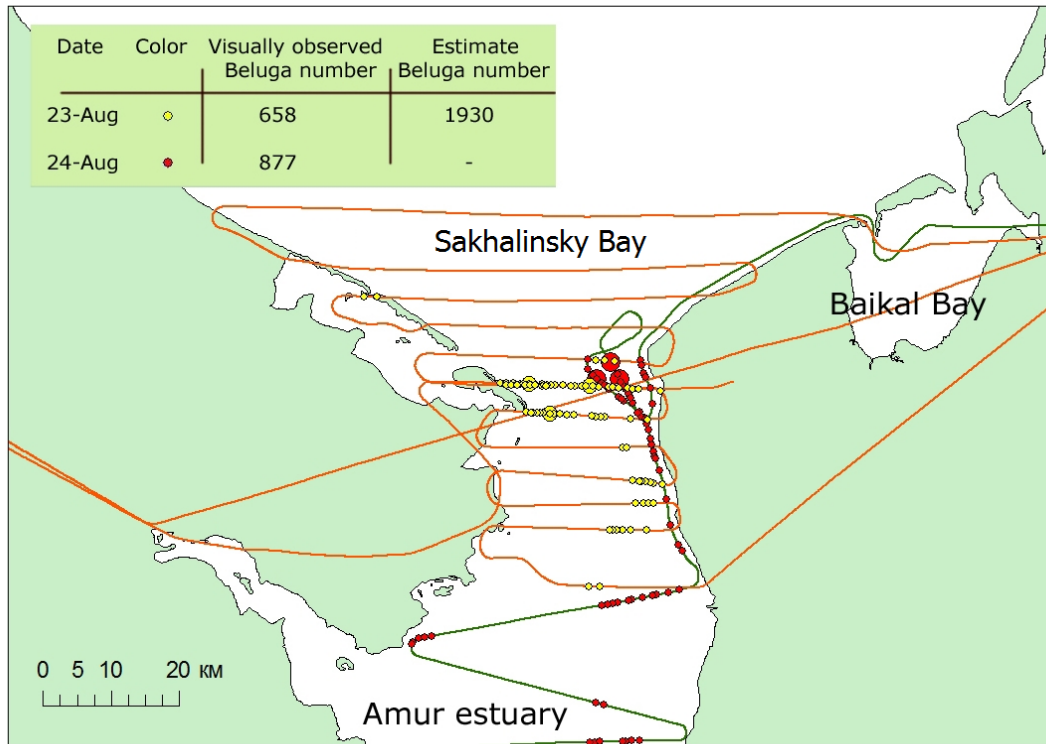


Figure A3. Aerial survey tracklines and beluga sightings in the Sakhalin-Amur region, 23-24 August 2010. On 24 August, only sightings on zigzag (saw-tooth) tracklines (50 belugas) were included in analysis.



## Appendix 2 -Verification of the analysis of survey data

The Belukha2 software used for analysing the line-transect survey data was difficult to follow, as the Panel did not have available the source documents. It is not clear whether the mathematical methods used have been peer-reviewed and published. The expressions that Belukha2 uses are complex, and fractional powers of different constants occur frequently. The impression given is that the expressions are more complex than should be necessary in line-transect analysis, which is not a very complex operation.

As it was difficult to follow through the calculations that were used, some independent checks were carried out. The first was a back-calculation from results in Table 7 of Appendix 3<sup>4</sup> to the Project Report. From the final estimated number and the stratum area, a final estimated density was calculated (Table A2). From this density, the transect length and the number seen, an “operational” effective strip width (ESW) was calculated. The truncation distance used by Belukha2 was tabulated in Chelintsev’s Table 7, and comparing that with the operational ESW gave a presumed visibility within the truncation strip. This was compared with Chelintsev’s tabulated visibility.

Table A2: Chelintsev Table 7--Estimation of numbers from aerial counts, 5–10 August 2009.

	Final estimated number	Stratum Area	Final estimated density	Transect length	Total number seen	Operational ESW (one- sided, m)	Truncation strip tabulated (m)	Presumed visibility	Tab. vis.
Tugur B.	313	156	2.006	78	135	431.3	585	0.74	0.64
Nikolai B.	42	48	0.875	26.2	34	741.5	912	0.81	0.80
Ul'ban B.	601	11	54.636	13.7	465	310.6	403	0.77	0.77
Udskaya B.	2451	189	12.968	82.5	954	445.8	572	0.78	0.75
Baykal B.	43	27	1.593	66.6	33	155.6	200	0.78	0.78
Baydukov I.	320	108	2.963	45	163	611.3	1866	0.33	0.59
–Amur	312	10496	0.030	515.3	69	2252.3	2538	0.89	1.00
Amur Est.	142	1931	0.074	143.3	10	474.5	477	0.99	1.00

The operational ESWs were smaller than would be expected for a beluga survey, especially using bubble windows, and were variable from one stratum to another. This is probably due to the fact that lines were not placed randomly with respect to the distribution of the animals, but over concentrations or areas where concentrations were expected; the result would be a concentration of sightings close to the flying line, a small ESW, and probably an overestimate of numbers. The “presumed visibility” was generally correlated with the tabulated visibility, but was rarely equal to it.

Data from systematic line-transect surveys in Sakhalinsky Bay on 13 September 2009 and 23 August 2010 were re-analysed using the following methods:

<sup>4</sup> N.G. Chelintsev, *Estimation of beluga number on the data of aerial count in the Okhotsk Sea in August–September 2009.*

–a 3-parameter hazard-rate sighting curve defined by

$$p = 1, 0 < x < k_1$$

$$p = 1 - \exp\left(- (1 + k_2)/k_2 \cdot ((k_3 - k_1)/(x - k_1))^{k_2}\right), x > k_1$$

and fitted to the distance distribution of individual belugas by maximum likelihood (results obtained are conditional on the use of this sighting curve);

–assumed no loss of sightings close to the flying line;

–a bias-reduced estimate of ESW, and its error coefficient of variation, were calculated using the ordinary jackknife, treating sightings as the observational units;

–standard error of encounter rate was calculated using nearest-neighbour differences to generate the sum of squares for error;

–transect spacing was assumed to be 5000 m on 13 Sept. 2009 and 4500 m on 23 August 2010;

–a finite population correction was applied to the encounter-rate component of uncertainty; and

–no truncation of the data; all sightings were used.

The data from 13.09.2009 were poorly suited to line-transect analysis. 5% of the sightings, accounting however for 32% of the animals seen, lacked distance records; and a single large group accounting for nearly 30% of the animals with distance records strongly influenced the estimation of the sighting curve. The effective number of sightings overall was 12.8; for calculating the ESW, 9.2. The data from 23.08.2010 were more amenable to fitting a sighting curve, but the effective number of sightings was still only 13.7.

Results obtained from this re-analysis were:

	13.09.09		23.08.10
	Sparse transects	Dense transects	Overall
Belugas w. distances			865
Bias-reduced ESW (m)			642
ECV of ESW (%)	15.7	15.7	15.7
No of transects	5.5	6	11
Transect spacing (m)	5000	2500	4500
Belugas sighted	22.5	1255.5	1278
Surface-visible estimate	87.6	2445.4	2533

ECV of encounter rate (%)	44.0	27.5	26.6	54.8
Overall ECV (%)	46.7	31.7	30.9	58.2
Surface-visible $N_{min}$			1965	1447
Table. surface-visible estimate			2204	1930
Table. ECV of estimate (%)			36.9	57.4
Table. surface-visible $N_{min}$			1659	1263

The re-analysis gave estimates that were some 15% higher for both surveys; this is conditional on the transect spacings, which are not exactly known so the values used in the re-analysis might be slightly in error. Overall ECVs are not very different; the re-analysis corrected the uncertainty of encounter rate for a finite population. This made a large difference in the 2009 result, where large counts, accounting for most of the estimate of numbers, were made on closely spaced transects and the finite population correction roughly halved the error variance.

Given that these analyses used methods somewhat different from those of the Belukha2 software, the results are not disconcertingly different. The transects in these two systematic surveys were, apparently, placed randomly with respect to the distribution of the belugas, and it should therefore be legitimate to apply conventional line-transect sample-survey methods in analysing the data. This is not necessarily the case in surveys of other areas, such as the concentrations at the heads of bays in the Shantar area, where flights were made over the concentration areas and the use of line-transect methods is likely to produce over-estimates.

Sightings curves that included loss of sightings near to the flying line were not tried, but for both of these surveys it looked as though there were fewer sightings than the fitted curve would have predicted out to 350–450 m from the line. Fitting a sightings curve that included loss of sightings near the line would increase the estimate of numbers.



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