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SUMMARY OF FINDINGS ON THE INVESTIGATION OF THE STINKY WHALE CONDITION IN EASTERN NORTH PACIFIC GRAY WHALES

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Background

In 1998, Chukotka Native hunters began reporting an increase in the number of hunted eastern North Pacific (ENP) gray whales that exhibited a strong medicinal odor (defined as stinky whales). Stinky whales had been noticed since the late 1960s, but in 1998 a noticeable increase in landed whales were determined to be stinky. Some whales are noted as stinky from their blow and attempts to strike these individuals are abandoned, however remote detection is not possible on all occasions. Tissues from these stinky whales are deemed inedible (not palatable) by people and not consumed by sled dogs. The hunting communities have expressed concerns about the safety of tissues from stinky whales. In 1999 at IWC/SC/51, the Scientific Committee (SC) received information about the increased number of stinky gray whales in the Russian aboriginal harvest that caused hunters to not utilize the carcasses. During the same period (1999-2000), the ENP gray whale population sustained a die-off (strandings) across most of the migration route. Due to the issues raised, subsequent discussions began within the SC regarding causes of this condition and development of research strategies to investigate the cause(s). At the 58th session of the IWC, an investigation team of scientists from Russia, USA, Norway, Mexico, and Japan was established by the IWC Conservation Committee and the IWC Aboriginal Subsistence Whaling Committee to evaluate the analytical data on stinky whales.

For several decades, hunters and communities in Russia have also noted an odor that is similar to that observed in stinky gray whales in the meat of ringed seals, bearded seals, walruses, and the eggs of Murres. More recently fishers have noticed a similar odor in some cod. No data or samples from these species have been evaluated by the investigative team.

Hunter perspective

Hunters have noted that some free swimming whales have a noticeable odor in their breath which may be detected by hunters from a boat approach. The odor is detectable at a distance from the whale if the conditions are favorable (e.g. wind direction) and the hunters are experienced. When detected, hunters avoid striking those whales, but in some cases stinky whales are still inadvertently taken. Hunters report that sometimes the stinky whale odor appears only during butchering whales or cooking whale meat.

Because smell has significant influence on perception of taste (palatability), these whales are not normally consumed by the people or sled dogs in these communities. In some cases people have tasted the blubber or meat and have noted numbness of the oral cavity and reported skin rashes or stomach aches. In some cases, stinky whale meat has been eaten and no numbness was reported but people developed stomach aches. No actual evaluation by public health officials has been done on the clinical symptoms reported by hunters. In all cases of the above mentioned symptoms, the person recovered with no reported long term medical consequences. It will be important for health care professionals to evaluate the signs and symptoms reported.

Investigative approach

The initial approach to investigate this condition was to collect samples from stinky whales and from non-stinky whales from the Russian aboriginal hunt and to submit samples to several laboratories for analysis of the following: persistent organochlorines (OCs), polyaromatic hydrocarbons (PAHs), heavy metals (HM), stable isotopes (SI), and volatile organic compounds (VOCs). The basic plan was to compare chemical concentrations of stinky and non-stinky whale tissues for obvious differences to provide leads for further investigation into the cause of the offensive odor. Table 1 indicates the number of stinky whales reported landed and the samples collected from each for analysis by USA and Russian toxicologists. Tissues (blubber, skin, muscle, liver, kidney, feces and stomach contents) from 17 hunted gray whales (one stinky whale and 16 non stinky whales) were collected from the 2001 aboriginal harvest and stored frozen until export permits could be obtained. In 2003, these samples were shipped to the University of Alaska Fairbanks, USA and were subsequently analyzed at various laboratories. In 2004, samples were collected from an additional two stinky whales and were submitted to Lomonsov Moscow State University for analysis of PAHs and OCs. In 2005, samples were collected from three additional whales (two stinky whales [blubber, liver, muscle] and one non-stinky whale [blubber only]). Samples from these three whales were submitted to the National Institute of Standards and Technology in the USA and to Lomonosov Moscow State University in Russia for analyses. These samples underwent analyses for VOCs, PAHs, and OCs. Finally in 2006 samples (tongue, liver, blubber, muscle, lung) were collected from an additional stinky whale and were submitted for OCs and VOCs to Lomonsov Moscow State University in Russia. Results of the analyses from the Russian laboratory have been reviewed by Japanese and Norwegian toxicologists.

In addition to this effort, the US and Mexico have initiated a pilot project to evaluate the chemical composition of whale breath from ENP gray whales in the breeding lagoons of Mexico. Field efforts were undertaken in 2006 and 2007 and samples from over 25 whales are currently undergoing analysis for VOCs by the same laboratory in the USA that performed the analyses for VOCs in stinky whales. These data will be available for comparison to the VOCs obtained on samples from non-stinky and stinky whales through the Russian aboriginal hunt.

Results

From 1998 to 2006, more than 20 stinky whales have been reported landed in the Russian aboriginal harvest, with the highest annual number of landed whales reported as stinky occurring in 1998 (n=10) (see Table 1). Of the 21 stinky gray whales in Table 1, six have been reported from Yanrakynnot or Novoe-Chaplino and 14 from Lorino, with one from an unknown location. There have been 5 females and 4 males reported with lengths ranging from 9.1 to 13.5 meters. Landed stinky whales have been reported in various months from June to October, but hunters have reported the detection of stinky whales as early as May. In addition, no data has been provided on prevalence of this stinky condition in other species or on analyses from bird eggs, ringed seals, bearded seals or walruses.

The true prevalence of this stinky characteristic in the gray whale population is unknown, since hunters will avoid striking whales if they can detect a foul or irritating smell in the vicinity of the animals. The stinky whale condition has continued while the other factors noted during 1999-2000 (calf production and higher stranding rates) returned to background levels in 2001. No stinky whales have been noted in free swimming whales in the lagoons in Mexico, in research study areas of the U.S., Mexico or Canada or by the stranding programs in the U.S. or Mexico, but it must be noted that no specific studies to detect stinky whales have occurred along the U.S. coast. However, stinky whales have been reported by hunters as early as May which is early in the migration to the Chukotka coastline. Thus, this odor phenomenon may be a regional or seasonal event. Prey consumption may be more opportunistic in the breeding grounds and migration corridors, (e.g., outside of the Arctic) so exposure to a prey born chemical is less likely than in areas where gray whales routinely feed (e.g., in the Arctic). Of note, the stomachs of stinky whales were reported to contain seaweed (genus and species unknown) and in some cases cod whereas that has not been observed in the stomachs of non-stinky whales and has not been observed in stranded gray whales along the U.S. coast. There are no available data on whether stinky whales have any other disease factors compared to non-stinky whales, because body condition measures or tissues for disease investigations were not collected. There remains no information on whether the same animals are "stinky" year to year or whether the stinky whale syndrome is increasing in the population (proportion of whales that are stinky increasing in the population).

Based on the samples evaluated thus far, there were few differences noted between stinky whale tissues and non-stinky whale tissues using OC, PAH, and lipid analyses. The blubber lipid percentage of the stinky whale samples were within the range of blubber samples of non-stinky whales obtained during 2001 and 1994 aboriginal hunts. Sum PCBs and DDTs were found to be similar in stinky whale blubber compared to non-stinky whale blubber from the Russian Aboriginal hunts in 1994 and 2001 (Tables 2a, 2e, 2f). In addition, levels of these chemicals were lower than levels seen in stranded gray whales and subsistence hunted bowhead whales from the U.S. Based on samples from whales taken in the 2001 aboriginal hunt, trace elements or stable isotopes in stinky whale samples were not different from those in non-stinky whales. There were no detectable petroleum hydrocarbons found (either *n*-alkanes or selected PAHs) in any of the 12 samples analyzed (3 tissues-liver, blubber, muscle from 4 animals: 3 non-stinky whales and one stinky whale) by a U.S. laboratory. However, low concentrations of these chemicals were detected in samples analyzed by the Russian laboratory (Table 2e). The blubber lipid percentage of the stinky whale sample was within the range of samples obtained from Russian subsistence hunted non-stinky whale during 2001 and 1994.

The most intriguing results to date involved the volatile organic analyses that were undertaken in two laboratories (Tables 2b, 2c, 2d). More than 100 volatile compounds, including numerous aldehydes, ketones, alcohols, nitrogen containing compounds, sulfur compounds, hydrocarbons, acetates, amines, and acids, were found in the tissues of the whales. The two laboratories performing VOC analyses used different methods and reported different specific compounds. However, ketones, aldehydes and some alcohols were elevated in the stinky whale tissues compared to the tissues from non-stinky whales. Some of the compounds detected in the samples may be a result of repeated freeze thawing of the samples prior to analysis or other aspects of sample handling. Many of the compounds detected are also odorants with varying detection levels (thresholds) by human noses. One compound (1-penten-3-ol) that was found in higher amounts in stinky whale tissues by the U.S. laboratory is known to occur during lipid oxidation of plant materials. That compound must be at relatively high concentrations to be detected by humans. Whereas other compounds found by the U.S. laboratory at lower concentrations in the stinky whale samples can be more easily detected by humans (lower detection threshold concentration). The Russian laboratory also found ketones and aldehydes emanating from the stinky whale samples as compared to the non-stinky whale samples. In addition they found elevated levels of trimethylamine in samples from one whale. The variety of compounds that were found in samples from stinky whales makes determining the actual compound or compounds that are responsible for the odor detected by the hunters difficult. Having identified some compounds that are unique to stinky whale samples, it would be informative to have hunters experienced in detecting the stinky whale odor smell isolated compounds or mixtures of these compounds at relevant concentrations to determine which one or combination most matches the smell from the stinky whales. Most of the compounds determined to be different in the stinky whales do not have food consumption safety guidelines, thereby making interpretation of food safety very difficult.

Review for food safety

Data from the Russian chemical analyses were provided to toxicologists from The Institute of Cetacean Research in Japan for evaluation with special interest on whether tissues were safe to eat. The Japanese submitted the following review of the Russian data from the 2005 and 2006 stinky whale samples:

> "*Although toxicological information, such as 50% lethal dose and carcinogenic risk by the International Agency for Research on Cancer (IRAC) is available for some compounds, we could not find data available for volatile chemical levels in food products. Some volatile chemicals in the report are categorized into the "no carcinogenicity in humans" and "unclassified as to carcinogenicity in humans" by IRAC carcinogenic risk evaluation, and for some chemicals there is no toxicological information available. Propenal, benzene dimethyl and isopropanal were categorized into "possibly carcinogenic to humans" and acetic acid ethenyl ester was categorized into "possibly carcinogenic to humans". Most volatile chemical levels detected in the stinky whale tissues were not more than 1 ppm (fresh wt) or lower than detection limits. Therefore, the health risks for humans and dogs by the volatile chemicals in stinky whales may be low.*
>
> *Levels of trimethylamine, ethanol, isopropanol and propanal in some tissues of stinky whales were higher than 1 ppm. These chemicals, except for isopropanol, are generally produced by putrefaction of fishes. There are reports of trimethylamine in the forage being found in leghorns and their eggs. Stinky smell in the gray whales may be attributed to putrefaction of fishes. In very rare cases, metabolic abnormality associated with a catabolic enzyme for trimethylamine induced malodor for humans.*
>
> *Major components, such as PAHs, benzenes and paraffins, of oil spills were low in stinky whales. In general, oil spills have contributed to bad smells in marine environments, however this is not believed to be likely in the stinky whales. Therefore, the most reasonable interpretation of stinky smell in gray whales is that they feed unfortunately on putrefied fish, while they primarily feed on benthic gammaridean amphipods.*
>
> *The health risk from the volatile chemicals and PAHs in stinky whale meat may be low for human and dog, while toxicological information available is not enough. And, the odd smell in the gray whales may be originated volatile chemicals such as trimethylamine, from biological processes rather than anthropogenic pollutants from oil spill, etc."*

The interpretation of the volatile organic chemicals detected in stinky whale tissues in the U.S. laboratory also indicate that for most of the chemicals, there are insufficient data on toxicological effects from ingestion but some have been noted to produce skin or eye irritations. Given the compounds detected and the levels detected in the analyses, no food safety issues are apparent. No samples were tested for biotoxins, therefore no statements can be made at this time as to whether biotoxins may be involved.

Discussion

The determination of what is responsible for the "stinky" odor from the gray whale tissues is not as conclusive as would be desired. The array of compounds released by the tissues is complex and differed between the two laboratories. This is not unexpected considering the differences in sample handling, tissue processing and analytical techniques that complicate interpretation. However, using these very preliminary results and assuming that such compounds are responsible for the stinky condition noted in living whales; two hypotheses have been developed to potentially explain the presence of selected higher concentrations of predominantly ketones, aldehydes, and alcohols in stinky whale tissues. It must be noted that this analysis is based on a limited number of samples from 6 animals and a long elapsed time between harvest and sample analysis.

Hypothesis 1: The presence of such ketones, aldehydes and alcohols are a result of altered metabolism in the whales, perhaps due to a limited food supply, new food source or prey consumed, disease, or abnormal metabolic pathway (i.e., genetic anomaly).

Hypothesis 2: Specific bacteria, fungi, and/or biotoxins may contribute to these elevated levels of specific odiferous compounds found in these whales as well as the "numbing" sensation reported by hunters.

Of note is the continued issue of tingling and numbness reported by some hunters who have eaten stinky whale blubber or meat. The compounds and processes that are responsible for the stinky odor in these whales may not be the same compound(s) responsible for the numbness or other clinical signs. It is important to pursue the potential for a biotoxin, or a secondary metabolite, in the tissues in addition to compounds that may be responsible for the odor. Biotoxins often have serious human health risks.

In conclusion, the cause of the stinky whale odor has not been narrowed to a single chemical or process but the results of the analyses do not appear to indicate an obvious anthropogenic source. Stinky whale meat has not been evaluated for biotoxins. Most of the compounds detected in stinky whale meat have minimal to no toxicological information making risk assessment impossible, however tissue concentrations are the low ppb range. To date there is no direct evidence of long term health consequences of consumption of stinky whale meat, but the meat is unpalatable and causes apparent short term health effects in some people.

Finally, there is no information available to determine whether the stinky whale condition is indicative of a negative population level effect. No stinky whales have been detected elsewhere in the migration corridor or in the breeding lagoons, therefore the odor might be temporary, seasonal, or only noted in specific feeding areas in certain years. Of interest is that gray whales appear to be at carrying capacity and have shown evidence in the last decade of a large die-off, fluctuations in reproduction, changes in feeding areas, and changes in migration. It would be informative to ensure that any further stinky whale investigations are coordinated to evaluate environmental change and gray whale populations. Appendix 1 outlines a research strategy for further evaluation of the stinky whale condition in ENP gray whales.

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Table 1. Summary of stinky gray whales reported landed in the Russian aboriginal hunt 1998-2006

Whale Information							PAH		OCs		VOCs		HM	SI
Number	Year	Month	Date	Location	Sex	Length (m)	Russia	US	Russia	US	Russia	US	US	US
1	1998	Unk.	Unk.	Lorino	Unk.	Unk.								
2	1998	Unk.	Unk.	Lorino	Unk.	Unk.								
3	1998	Unk.	Unk.	Lorino	Unk.	Unk.								
4	1998	Unk.	Unk.	Lorino	Unk.	Unk.								
5	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
6	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
7	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
8	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
9	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
10	1998	Unk.	Unk.	Yanrakynnot or Novo-Chaplino	Unk.	Unk.								
11	2001	10	16	Lorino	F	11.05								
12	2001	Unk.	Unk.	Unk.	Unk.	Unk.		**X**		**X**		**X**	**X**	**X**
13	2004	6	18	Lorino	M	12.2								
14	2004	7	20	Lorino	M	10.5			**X***		**X***			
15	2004	7	20	Lorino	M	11.6			**X***		**X***			
16	2004	8	27	Lorino	F	11.8								
17	2004	9	4	Lorino	F	10.8								
18	2004	9	10	Lorino	F	13.5								
19	2005	9	11				**X**	**pend.**	**X+**		**X+**	**X**		
20	2005	9	19	Lorino	F	11	**X**	**pend.**	**X+**		**X+**	**X**		
21	2006	7	11	Lorino	M	9.1	**X**		**X+**		**X+**			

Norwegian Review indicated by *
Japanese Review indicated by +
PAH: Polyaromatic Hydrocarbons
OCs: organochlorines
VOCs: Volatile Organic Compounds
HM: Heavy Metals
SI: Stable Isotopes

Table 2a. Mean concentrations (± SD) of HCB, total PCBs (∑PCBs) and summed DDTs (∑DDTs) measured in blubber sampled at various depths on gray whales collected during a 2001 Russian subsistence harvest.

Age class and sex	Whale type	Number of samples	Blubber depth†	%lipid‡	ng/g, wet weight HCB	ng/g, wet weight ∑PCBs	ng/g, wet weight ∑DDTs	ng/g, lipid weight HCB	ng/g, lipid weight ∑PCBs	ng/g, lipid weight ∑DDTs
Adult female (n = 2)	"non-stinky"	n = 2	0 - 3 cm	38 ± 12	51 ± 46	69 ± 45	26 ± 18	120 ± 84	170 ± 64	64 ± 27
		n = 2	3 - 6 cm	24 ± 9.9	27 ± 12	41 ± 15	13 ± 0.0	130 ± 110	200 ± 140	59 ± 24
		n = 2	> 6 cm	9.4 ± 11	8.9 ± 5.9	15 ± 9.6	12	170 ± 130	300 ± 240	71
		n = 6	*Mean**	*24 ± 15*	*29 ± 28*	*41 ± 32*	*18 ± 11*	*140 ± 87*	*220 ± 140*	*53 ± 31*
		n = 2	Full depth	21 ± 0.71	29 ± 19	39 ± 14	15 ± 6.4	140 ± 98	200 ± 78	72 ± 33
Adult male (n = 4)	"non-stinky"	n = 4	0 - 3 cm	54 ± 11	310 ± 180	610 ± 230	370 ± 120	590 ± 430	1,100 ± 440	690 ± 240
		n = 4	3 - 6 cm	50 ± 9.9	310 ± 220	650 ± 260	380 ± 160	580 ± 330	1,300 ± 490	750 ± 250
		n = 3	> 6 cm	30 ± 12	210 ± 110	440 ± 260	230 ± 140	750 ± 380	1,700 ± 1,000	860 ± 540
		n = 11	*Mean**	*46 ± 15*	*280 ± 170*	*580 ± 240*	*330 ± 140*	*630 ± 350*	*1,400 ± 620*	*760 ± 310*
		n = 4	Full depth	37 ± 5.9	250 ± 190	490 ± 190	290 ± 130	650 ± 460	1,300 ± 420	780 ± 300
Juvenile (n = 10)	"non-stinky"	n = 10	0 - 3 cm	55 ± 10	240 ± 180	290 ± 130	130 ± 58	450 ± 300	540 ± 230	250 ± 110
		n = 10	3 - 6 cm	44 ± 22	200 ± 220	230 ± 170	110 ± 84	420 ± 240	520 ± 200	250 ± 120
		n = 3	> 6 cm	44 ± 30	99 ± 89	100 ± 71	43 ± 33	340 ± 290	280 ± 150	150 ± 120
		n = 23	*Mean**	*49 ± 19*	*200 ± 190*	*230 ± 150*	*110 ±73*	*420 ± 260*	*500 ± 220*	*240 ± 110*
		n = 10	Full depth	42 ± 15	190 ± 150	220 ± 110	110 ± 51	470 ± 250	550 ± 220	270 ± 110
Unknown (n = 1)	"non-stinky"	n = 1	0 - 3 cm	62	91	130	53	150	210	85
		n = 1	3 - 6 cm	53	100	130	56	190	250	110
		n = 1	> 6 cm	50	63	88	30	130	180	60
		n = 3	*Mean**	*55 ± 6.2*	*85 ± 19*	*120 ± 24*	*46 ± 14*	*150 ± 32*	*210 ± 35*	*84 ± 23*
		n = 1	Full depth	45	59	68	32	130	150	71
Unknown (n = 1)	"stinky"	n = 1	0 - 3 cm	36	270	340	160	750	940	440
		n = 1	Full depth	36	270	340	160	750	940	440

†Measured from bottom of epidermis

‡Pentane/hexane extraction with TLC/FID lipid analyses

*Mean values of percent lipid and POP concentrations are determined from all blubber depths except "full depth" samples.

Table 2b-USA laboratory
Comparison of Mean values for Major VOC compounds measured in the gray whale samples

Mean values with 1 sigma n = 5 samples, unless otherwise noted.
Concentrations = ppbC

Blubber	Tissue from Stinky whales		Tissue from Non-stinky whales	
	mean	1S	mean	1S
Acetone	162	42	146	124
Propanal	264	142	82	42
1-Penten-3-one	80	30	18	12
1-Penten-3-ol	856	298	140	82
2,3-Pentanedione	60	24	64	36
Pentanal	46	58	44	30
1-Pentanol	52	14	6	4
2-Penten-1-ol	84	24	22	14
Hexanal	168	78	66	52
Heptanal	28	16	18	8
Muscle				
Acetone	196	236	86	42
Propanal	114	46	116	66
1-Penten-3-ol	302	98	194	172
2,3-Pentanedione	114	24	122	122
Hexanal	170	110	312	228
Heptanal	52	40	172	174
Liver				
Acetone	74	50	60	*
Propanal	68	68	8	*
1-Penten-3-ol	82	62	98	*
2,3-Pentanedione	68	103	30	*
Hexanal	248	50	150	*
Heptanal	80	114	18	*

* Only one Clean sample available for comparison

Table 2c. The levels of VOCs measured in the tissues of gray whales (µg/kg) from 2005 from Russian laboratory

		Pure whale september 2005	Stinky Whale 1 11. 09.2005			Stinky Whale 2 19.09.2005		
	Compound	blubber	liver	muscle	blubber	liver	muscle	blubber
2	Isopropylamine	920	-	-	-	-	-	-
3	Propenal	-	-	-	-	-	-	340
4	Propanal	-	1370	4040	830	3530	2190	1920
5	2-propen -1-ol	-	-	-	-	-	160	-
6	Propanal, 2-methyl	-	90	70	20	630	390	-
7	Acetic acid ethenyl ester	-	40	50	30	140	120	110
8	Butanal	-	140	130	50	300	270	150
9	Methylethylketone	-	50	40	-	310	-	-
10	2-methylfurane	-	-	-	-	60	50	-
11	2-butenal	-	-	-	-	-	130	70
12	Butanal,3-methyl-	-	200	50	20	510	340	60
13	Butanal,2-methyl-	-	80	30	-	340	160	-
14	1-penten-3-ol	-	240	100	140	720	1120	660
15	Ethylvinylketone	-	20	10	20	-	-	150
16	2,3-pentanedione	-	330	200	70	930	530	390
17	Pentanal	-	80	50	20	290	220	50
18	3-hexanone	-	-	-	-	30	250	-
19	2-ethylfurane	-	70	80	-	540	280	80
20	2-methyl-2-buthenal	-	-	-	-	-	110	-
21	Pentenal	-	20	20	10	50	180	80
22	1-butanol,3-methyl	-	20	10	10	60	140	-
23	2-penten-1-ol	-	10	10	40	60	240	40
24	Diisopropylketone	-	10	10	-	60	50	-
25	Hexanal	-	400	70	-	960	610	20
26	2.4-octadiene	-	-	-	-	-	-	-
27	2-methyl-2-pentenal	-	20	20	-	30	140	-
28	2-hexenal	-	20	20	-	-	220	-
29	2-pentanol-4-methyl	-	-	-	-	-	20	-
30	Benzene, dimethyl	-	-	-	-	50	20	-
31	Benzene, dimethyl	-	-	-	-	110	-	-
32	Heptanal	-	80	70	-	180	130	-
33	Benzaldehyd	-	20	-	30	80	60	90
34	5-pentyloxy-2-pentene	-	10	-	-	60	-	-
35	Octanal	-	20	-	-	60	50	-
36	Nonanal	-	20	-	-	10	10	-

Table 2d. The levels of volatile organic compounds in the tissues of stinky gray whales (µg/kg) in 2006 from Russian laboratory

Peak	Compound	Lung	Liver	Blubber	Muscle	Tongue
1	Trimethylamine	441	200	32000	2900	-
2	Ethanol	3987	4200	36000	3200	7900
3	Isopropanol	639	1700	3300	2800	780
4	2-Thiapropane	-	130	-	-	60
5	Methylacetate	112	5800	-	-	90
6	Isobutanal	269	560	880	380	150
7	2-Methylbutanal	35	220	-	-	170
8	2-Butanol	-	400	-	-	-
9	Ethylacetate	22	210	-	-	40
10	Methylpropanoate	71	960	-	-	50
11	3-Methylbutanal	557	540	300	370	180
12	1-Butanol	-	50	60	600	-
13	Pentanal	233	70	-	-	-
14	Methyl-2-methylpropanoate	37	90	-	-	-
15	Methylbutanoate	186	290	-	-	-
16	Toluene	23	80	-	-	-
17	Ethylpentanoate	21	160	-	-	-
18	Ethylhexanoate	-	-	350	-	-
19	Benzaldehyde	32	170	-	100	-

Table 2e. Results from PAH and OC analyses on gray whales in 2005 from Russian laboratory

		Pure whale september 2005	Whale 1 11.09.2005			Whale 2 19.09 2005		
Peak #	**Name**	**Blubber**	**Blubber**	**Muscle**	**Liver**	**Blubber**	**Muscle**	**Liver**
	PAH							
1	Naphthalene	210	50	60	10	220	50	30
2	Naphthalene, 2-methyl	50	20	20	10	40	10	20
3	Naphthalene, 1-methyl-	20	10	10	10	20	20	10
4	Naphthalene, C2	10	40	70	70	50	60	60
5	Naphthalene, C3	10	40	10	10	50	110	110
6	Phenantrene	195	40	30	30	30	50	20
	Pesticides							
1	Benzene, hexachloro-	20	30	10	10	10	10	10
2	DDE	480	20	10	10	10	10	10
3	Trans-Nonachlor	60	10	10	10	10	10	10
4	Hexachlorohexane	10	10	10	10	10	10	10
	Polychlorobiphenyles							
1	Biphenyl, tetrachloro-	130	60	80	60	110	100	90
2	Biphenyl, pentachloro-	480	80	130	150	90	140	110
3	Biphenyl, hexachloro-	240	90	80	40	50	20	60
	Σ	**850**	**230**	**290**	**250**	**250**	**260**	**260**

Table 2f. The levels of polychlorinated organic compounds in the tissues of stinky gray whales (µg/kg) in 2006 from Russian Laboratory

Peak #	Name	Blubber	Liver	Lung	Muscle	Tongue
1	Hexachlorobenzene	9,6	23	6,4	5,4	0,12
2	DDE	2.1	1.3	0.80	1.0	0.47
1	Tetrachlorobiphenyl	1.1	1.3	-	1.1	-
2	Tetrachlorobiphenyl	0.4	-	-	0.3	-
3	Tetrachlorobiphenyl	0.6	0.4	0.45	0.75	-
4	Tetrachlorobiphenyl	0.2	-	0.3	0.3	0.7
5	Tetrachlorobiphenyl	0.7	0.35	0.95	0.7	-
6	Tetrachlorobiphenyl	-	2.2	0.85	0	1.5
7	Tetrachlorobiphenyl	2	-	0	0	-
8	Tetrachlorobiphenyl	0.5	0.2	0	0	-
9	Tetrachlorobiphenyl	-	-	0.25	1.1	0.25
10	Pentachlorobiphenyl	1	1.5	0	0.85	-
11	Pentachlorobiphenyl	-	-	0.15	0	0.1
12	Pentachlorobiphenyl	-	-	-	-	0.4
13	Pentachlorobiphenyl	1.2	1.4	1.9	1.1	2.0
14	Pentachlorobiphenyl	1	1.2	1.5	1.2	2.0
15	Pentachlorobiphenyl	-	0.4	-	-	0.005
16	Pentachlorobiphenyl	0.25	0.4	0.65	0.3	0.55
17	Pentachlorobiphenyl	0.3	0.5	0.65	0.8	0.75
18	Pentachlorobiphenyl	0.55	0.4	0.6	0.55	0.65
19	Pentachlorobiphenyl	1.6	1.6	2.5	1.6	2.6
20	Pentachlorobiphenyl	-	-	-	-	0.15
21	Pentachlorobiphenyl	2.1	2.0	3.3	1.8	3.4
22	Pentachlorobiphenyl	0.4	0.95	-	-	-
23	Pentachlorobiphenyl	1.6	0.85	1.5	1.3	1.2
24	Pentachlorobiphenyl	0.75	3.9	-	-	-
25	Pentachlorobiphenyl	0.75	-	-	-	-
26	Hexachlorobiphenyl	1.2	0.35	1.5	1.1	0.9
27	Hexachlorobiphenyl	0.6	0.8	0.55	0.7	0.4
28	Hexachlorobiphenyl	0.3	-	-	-	0.2
29	Hexachlorobiphenyl	0	0.4	-	-	-
30	Hexachlorobiphenyl	1.2	-	-	0.8	-
	Σ	**20**	**21**	**17**	**16**	**18**

Appendix 1. Research Strategy

I. Are the compounds found to be unique, or at higher concentrations, in stinky whales responsible for the odor detected by the hunters?
   a. At some point humans must determine which of the suspicious chemicals, or chemical, is similar in smell to that of the odor emitted from stinky whales
   b. Obtain chemicals standards and have hunters assess (smell) them under controlled conditions

II. Is the odor associated with other species (seals, seabirds, and cod) the same as that in stinky whales?
   a. Collect tissues and stomach contents from other species in a standardized manner, stored appropriately, and have them assessed by the same laboratories for VOCs and biotoxins
   b. Assess the overall condition (e.g., lipid content or profiles and thickness of blubber, girths) of the animals from which samples are analyzed
   c. Include stomach contents analyses from the other species (high priority)
   d. Collect gases emanating from fresh carcasses and analyze for VOC s

III. Is the numbness reported by hunters a result of biotoxins in tissues or an irritant mechanism?
   a. Collect tongue, lungs, liver, blubber, stomach contents, urine and muscle for biotoxin analyses from non-stinky and stinky whales
   b. Proper clinical assessment or interview to best describe physiological responses

IV. Are stinky whales abnormal in other physiological parameters and what is the source of the odor?
   a. Collection of tissue samples from stinky whales and non-stinky whales to evaluate VOCs, biotoxins, nutritive state, disease and consumed prey (stomach contents)
   b. Collect air from carcasses for VOC analyses to reduce sample handling artifacts
   c. Collect gray whale prey (benthic, epibenthic, and pelagic) from feeding areas in which stinky whales are reported and analyze for VOCs [collect sediments as well?]
   d. Continue collection and analyses of whale breath from animals in the breeding and feeding grounds
      Evaluate the breath of skinny whales
      If possible collect and evaluate the breath of whales in feeding areas in US and Russia
      Evaluate the breath of stinky whales