Development of a New Diet for Kodiak Bears

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What is a good diet for Kodiak bears?

Cover picture: Kodiak bear, all rights by Emmen Zoo

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Preface

This report has been prepared within the scope of the Bachelor programme in Animal Management at Van Hall Larenstein, Leeuwarden. The research project was supported mainly by Emmen Zoo and Van Hall Larenstein, both located in the Netherlands.

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Jolanda Polet and Timo Weber
Leeuwarden, June 2008

Summary

Nutrition is an important consideration in zoos, as it affects the physical and mental wellbeing of the animals. To satisfy all aspects of the nutritional needs of animals, diet protocols are carefully designed. Kodiak bears are one of the largest land predators in the world, with males weighing up to 680 kg or even more. This size can probably be attained because of the bears' isolated situation on the Kodiak Archipelago and the rich source of fish that makes up a substantial part of their diet.
The islands of the archipelago comprise a hugely diverse habitat, including mountains, wet tundras and miles of shoreline, which results in a wide variety of food resources. The climate on the islands is moderate, with mild winters and cool summers.
Kodiak bears are rarely kept in zoos or similar institutions, especially not in Europe. This has to do with the policy of the European Association of Zoos and Aquaria (EAZA), which does not support this subspecies of bear and does not recommend breeding them.

Emmen Zoo maintains three Kodiak bears, but the zoo authorities were not entirely satisfied with the animals' current situation. They wanted to improve the bears' diet protocol, reproduction success, seasonal weight fluctuation and hibernation process.
Most of the above-mentioned points of interest were recommended for long-term studies. However, this research project began with an analysis of the present circumstances at Emmen Zoo and in other institutions, as well as the Kodiak bear's in situ situation.

The objective of the research project was 'To formulate the nutritional needs of Kodiak bears to design a new feeding protocol'. With the help of this new protocol, Emmen Zoo hopes to improve the quality of life for their Kodiak bears. The main research question was:

'What is a good diet for Kodiak bears in ex situ situations?'

To accomplish this research objective within the five-month period from February until June 2008, information was gathered relating to both in situ and ex situ situations. Researchers were contacted, a survey was sent to other zoos and digestibility analyses of the Kodiak bear diet at Emmen Zoo were carried out.

The survey was returned by 16 institutions, although none of them recommended a specific diet that could serve as an example. In total, they reported more than 70 food items used. Almost every institution included a concentrate feeder in the feeding regime and therefore no nutritional deficiencies were expected. The majority of the diets involved seasonal fluctuations, although the fluctuations in ex situ diets were much lower than those in the in situ diet.
Energy supply in the ex situ diet covered a wide range, with an annual average of 0.64 MJ per body weight $(BW)^{0.75}$/day. Comparing this to the calculated amount of energy contents in the in situ diet of 0.35 MJ per $BW^{0.75}$/day, it was seen that the amount of energy present in the ex situ diet is much higher. Also in comparison to the recommended energy allowance for a normal active dog of 0.40-0.55 MJ per $BW^{0.75}$/day, the ex situ bears were provided with a higher amount of energy. It can therefore be expected that many bears are overweight and some suffer from obesity, resulting in the same health problems that dogs have with weight-related diseases. Another dietary issue concerns dental problems such as caries, which can be caused by too little fibre in the diet as well as by too many sweet food items like fruits, honey, jam or other products containing a number of mono- and disaccharides.

Bears do not hibernate when they are fed the same amount of food throughout the year. It can be said that fluctuations in the diet, with a peak in late summer or at the beginning of autumn and a decrease in late autumn, stimulate the occurrence of hibernation.

Kodiak bears use nutrients in a manner similar to that of dogs. The digestibility analyses of the diet resulted in a digestibility coefficient (DCFI) of 82% for crude protein (CP) and 95% for crude fat (CFat), which is in accordance with what has been reported in the literature for dogs. For fibre, there is only a small difference between the DCFI of dogs and the results from the diet digestibility analyses. It is not possible to compare the DCFI for minerals between dogs and the results from the diet digestibility analyses, as the latter are unreliable. However, it can be expected that it is similar to DCFI values for dogs.

It can be said that a good diet features aspects of seasonal fluctuation in quantity and quality, which stimulates the bears to carry out natural activities and supports their physical and mental health. For a comprehensive overview of the feeding situation, the weight of the bears should be monitored on a regular basis. Furthermore, communication between zoo keepers must be improved, as it is essential that all people working with the Kodiak bears or their diet have the same level of interest, knowledge and understanding.

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1. Introduction

Nutrition plays an important role in the running of zoos, because it affects the physical and mental health of the animals. Thus, diet protocols are designed to satisfy all aspects of the animals' nutritional needs. The information on which these diet protocols are based is most often a combination of practical experience, literature and in situ data. Hence, one diet can be based mainly on in-situ-like products, whereas another is based on commercial concentrates and supplements that satisfy the animal's nutritional needs (pers. comm. Berndt, 2008).

Over the years, diet protocols have been subject to changes, and studies performed recently have become a significant resource with regard to optimising them. In zoos, however, particular groups of species are rarely the subject of studies on a regular basis. Instead, most research is done on the basis of trends. For example, when a zoo has a given problem with a species, other zoos will be contacted. If the problem is known to exist in these other zoos as well, a chain reaction might occur and a research project may follow (pers. comm. Berndt, 2008).

The Kodiak bear species, *Ursus arctos middendorffi*, has not yet been the subject of many ex situ research projects. Instead, information obtained from studies on other bear species like *Ursus arctos arctos* and *Ursus arctos horribiles* has been implemented in research on the Kodiak. Personal knowledge and the experiences of keepers from other zoos are also used when examining Kodiak bears ex situ. In some cases, diet protocols implemented in zoos overlook the in situ situation. Therefore, an overview of the in situ situation including seasonal fluctuation in behaviour and feeding ecology should be a standard with regard to the way that Kodiak bears are kept ex situ. A second standard should deal with the feeding ecology of ex situ bears that are in a healthy condition and have successful reproduction capabilities.

Emmen Zoo keeps three Kodiak bears, of which two are males and one is female. The in situ situation of all species in captivity at Emmen Zoo plays a major role in this institution's concept and is implemented in its mission statement [1].

> "To provide information about and to stimulate interest in nature and the environment."

The perception of an interconnected completeness with regard to animals' life in the wild is the most important component of this mission statement. It is incorporated in the form of keeping large groups of animals, if possible, in an exciting environmental display with natural vegetation, to create the illusion that the visitors themselves are in the wild. Central themes further integrated into the concept held by Emmen Zoo are animal welfare, hospitality towards visitors, a high level of awareness and a dedicated responsibility towards the environment [2].

1.1. Kodiak bear

The Kodiak bear, a subspecies of the brown bear, is found only on the islands of Kodiak, Shuvak and Afognak on the south coast of the U.S. state of Alaska in the Gulf of Alaska (Clark, 1958, p.576), see Figure 1. The isolation of this species occurred after the last ice age and resulted in larger bears and a denser population than exists on the mainland (Buckner and Reneau, 2005) [3].

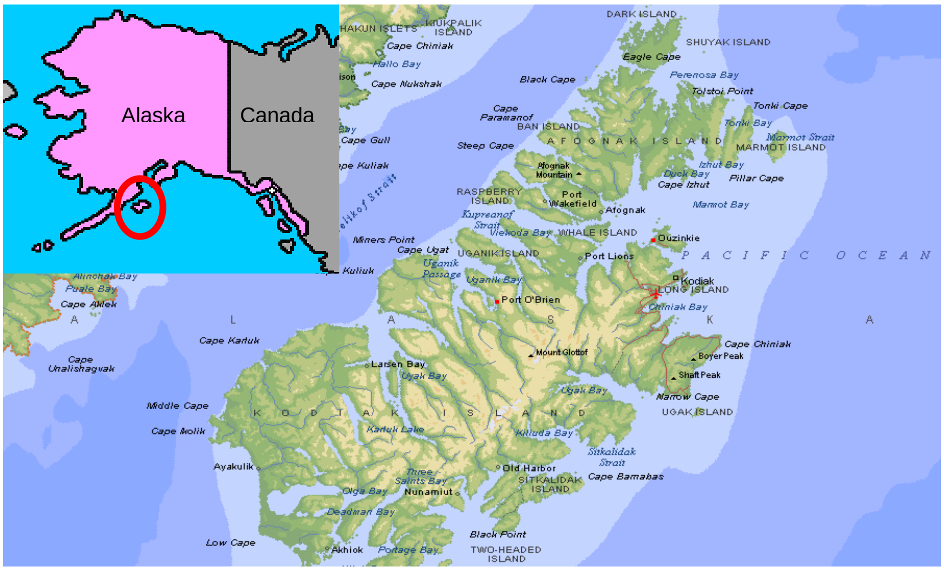

Figure 1 – Map of Alaska [4], in which the red circle indicates the location of the Kodiak Archipelago; beside it, the Kodiak Archipelago is shown enlarged [5].

Kodiak bears are one of the largest land predators in the world, with males weighing up to 680 kg or even more [6]. The bears are probably able to reach this size because fish, such as salmon, is a rich dietary source (Wittenberg and Wenzelides, 2000, p.109; Hilderbrand et al., 1999c). The behaviour of Kodiak bears is not significantly different from that of bear populations on the mainland. In addition, Kodiak bears hibernate and most of the time live a solitary existence [7 8].
The islands cover a large variety of habitat including mountains, wet tundras and miles of shoreline (Daele, 2007, pp.4-6) [9]. Kodiak Island has a surface area of around 9293 km^2 [10], an estimated human population of around 14,181 (in 2003) (Daele, 2007, p.4) and about 3000 Kodiak bears (Barnes and Smith, 1998). The climate on the islands is moderate, with mild winters and cold summers. In general, the humidity is high and the weather can change very quickly (Daele, 2007, pp.4-6) [11].
Kodiak bears are rarely kept in zoos or similar institutions. Worldwide, only 20 institutions that are associated with the International Species Information System (ISIS) keep Kodiak bears. Of these, only eight are situated in Europe. This is related to the policy of the European Association of Zoos and Aquaria (EAZA), which does not support this subspecies and does not recommend breeding them (Smith and Kolter, 2003, p.89).

1.2. Problem of description and analyses

Kodiak bears are rarely kept in captivity, which might be one of the reasons that little is known about these animals in ex situ situations. And the scanty in situ information does little to contribute to keeping captive bears in as healthy a condition as possible. As a result, persons involved with the Kodiak bears at Emmen Zoo were not totally satisfied with the state of affairs and therefore wanted to improve the following aspects:

- Diet protocol: this was very strict and assumed colder winters than had occurred over the past few years. Thus, it was not possible for zoo keepers to stick to the diet protocol.
- Reproduction: this had been unsuccessful over the past few years, although copulation did occur.
- Seasonal weight fluctuations: it was possible to realise these by preserving the seasonal diet protocol, but the weight of the bears could not be controlled, because no weighing facility was available.

- Occurrence of hibernation: there are certain factors that restrict the occurrence of hibernation at Emmen Zoo, which should be taken into account for the improvement of seasonal fluctuations. Males are not allowed to hibernate, though this is not a problem when the bears are lethargic in the outside enclosure. However, the female is allowed to hibernate, in association with reproduction. Another restricting factor is the temperature in the inside enclosure; it is not possible to regulate and is dependent upon the outside temperature. If winters remain the same as in previous years, the temperature in the inside enclosure does not drop below 6℃, which is recommended in the Emmen Zoo protocol.

The above-mentioned points were recommended for long-term studies. The present research project began with an analysis of the current diet implemented at Emmen Zoo, as well as of diets applied in other institutions and of the Kodiak bear's diet in situ. This was augmented by performing a literature search regarding the in situ situation and by contacting other zoos and institutions to collect information about health problems, reproduction, weight fluctuation and hibernation, all of which were possibly influenced by diet. These data were the starting point with regard to optimising the feeding regime.
It was also important to analyse the digestibility of foods provided in the current diet, as this process indicates how Kodiak bears utilise the food items they are fed. By analysing the digestibility, an indication of the energy level, amount of protein, crude fat and crude fibre of the products can be obtained. When the diet is changed, the same analyses can be executed in a sequel study and a comparison can be made between the two diets.

1.2.1. Objective and research question

The objective of this research project was 'To formulate the nutritional needs of Kodiak bears to design a new feeding protocol'. With the help of this new feeding protocol, Emmen Zoo hopes to see its own goal fulfilled: namely, an improvement in the seasonal weight fluctuation, reproduction successes and the wellbeing of the bears.

The main research question was:

'What is a good diet for Kodiak bears in ex situ situations?'

Sub-questions:

- What comprises the in situ diet of Kodiak bears?
- What comprises the ex situ diets of Kodiak bears?
- How can diet influence hibernation, health and reproduction?
- How can Kodiak bears use the different nutrients?

1.2.2. Clarification

Nutritional needs	=	Need for energy, nutrients and other dietary factors.
Natural	=	Natural includes the way Kodiak bears live and behave in an in situ situation with its seasonal fluctuations.
Good diet	=	A good diet covers all nutritional and natural needs of Kodiak bears, resulting in physically and mentally healthy animals.
High-quality food	=	Food that is easy to digest and with a high energy concentration.

1.3. Research population

Two research populations were used in this project: in situ and ex situ (see Table 1). The in situ population was used to collect information about the in situ situation, including the habitat the bears live in, their behaviour and their diet.
The ex situ population was used to gain an overview of the ex situ situation, including general information and existing problems concerning reproduction, feeding, weight and diseases. Kodiak bears at Emmen Zoo were also used for the digestibility analysis.

Table 1 – Population size of different Ursus arctos subspecies in situ and ex situ.

Different Population	Total number	♂♂, ♀♀ unknown/cubs	In how many zoos
In situ population			
Ursus arctos middendorffi	2800 – 3500		
Ursus arctos horribillis	~ 50,000		
Ursus arctos berungianus	~ 10,000		
Brown bear ex situ population [12]			
Ursus arctos berungianus	14	6,7,1	6
Ursus arctos gyas	2	1,1,0	2
Ursus arctos horribillis	75	41,33,1	40
Ursus arctos middendorffi	36	17,19,0	20
Ursus arctos richardsoni	1	0,1,0	1
Digestibility analysis			
Ursus arctos middendorffi	3	2,1,0	1

1.3.1. In situ population

The in situ Kodiak bear population was always the first choice for the gathering of information. Furthermore, data about Kodiak bears will be used as a more important source than information relating to other brown bear subspecies.
If no data from Kodiak bears was available, information was taken from brown bear subspecies that live in a similar habitat with a similar food supply. The diet of the bears must contain a large amount of fish and the bears must display a similar behaviour. Grizzly bears living close to the shore and Kamchatka bears are examples of species that belong to this population (see Figure 2).
For general information about brown bears, or in the event that no data were available from the above populations, data from other brown bear subspecies or other bear species were taken.

Figure 2 – Map presenting the distribution of Kodiak, grizzly, Kamchatka and brown bear species [13].

1.3.2. Ex situ population

From the ex situ brown bear population, the Kodiak bear was the first choice of species about which to collect information with regard to feeding, diseases and other relevant data. This population is very small and consists of only 36 animals in 20 zoos worldwide [14]. A population of this size could not provide enough pertinent data. The next species that were used, termed research population two, were grizzly and Kamchatka bears. These subspecies were selected because of the similarities in habitat and food supply.

If too little data were collected from the first two research populations, information about brown bears, *Ursus arctos*, and European brown bears, *U. a. arctos*, was used.

For the digestibility analysis, the faeces and feed intake of the three Kodiak bears at Emmen Zoo were measured.

2. Materials and methods

Four main methods were used to formulate what constitutes a good diet for Kodiak bears. These involved discussions with the zoo keepers, undertaking a study of the literature, conducting a research based on a survey and analysing the digestibility of the bears' current diet.

2.1. Discussion with keepers at Emmen Zoo

Keepers of the Kodiak bears work with the animals on a daily basis and therefore probably are the persons who spend the most time with them. Assuming that they know a great deal about their behaviour and feeding habits and probably have ideas for improvement, the zoo keepers' knowledge of and opinions about the situation of Kodiak bears at Emmen Zoo were inventoried with the help of a survey presented during a meeting.

Along with the survey, a letter that included an introduction to this project was sent to the keepers before the actual meeting took place (see Appendix X). With the help of the answers and the meeting, the keepers' points of view were recorded and their recommendations were processed within the research project.

2.2. Literature study

To obtain an overview of available in situ and ex situ data on Kodiak bears and their habitat, a study of the literature was carried out. In the search for information, sources like the libraries of Van Hall Larenstein, Wageningen University and the internet were used; bear researchers were contacted as well. Keywords used to search for data are listed in Tables 3 and 4 and the names of researchers who were contacted are found in Table 2.

Table 2 – Research institutions contacted for specific information.

Research Institution contacted for information	**Contact Person**
Kodiak National Wildlife Refuge	Gary Wheeler
Washington State University Bear Center	Dr. Charles Robbins
Wildlife Conservation Society (WCS)	John Paczkowski

Table 3 – Keywords used to search the libraries; in the period of February 2008 until June 2008.

Library	**Keyword**	
Van Hall Larenstein	Brown bear	Kodiak Island
Wageningen University	Digestion	Nutrition
	Dog obesity	Physiology *Ursus*
	Grizzly bear	*U.a**
	Kamchatka	*U.a berungianus*
	Kamchatka brown bear	*U.a horribillis*
	Kodiak bear	*U.a middendorffi*

* *U.a = Ursus arctos* for searching

Table 4 – Internet search databases and the keywords used; in the period of February 2008 until June 2008.

Internet search databases	Keyword	
Biological Abstracts (SP)	Bear vertebral column	Hibernation in relation to
CAB Abstracts (SP)	Brown bear	reproduction *U.a*.
Google	Diet of bears	Kamchatka
Google Scholar	Diet in relation to hibernation	Kamchatka brown bear
JSTOR	*U.a**	Kodiak bear
OAlster	Digestion	Kodiak Island
PubMed	Digestive tract *Ursus* Feeding	Nutrition
ScienceDirect (Elsevier)	ecology *U.a*	Obesity in bears / *Ursus*
SCIRUS (Elsevier)	Gastrointestinal tract *Ursus*	Obesity in dogs
SCOPUS (Elsevier)	Grizzly	Physiology *Ursus U.a*
Web of Science (ISI)	Hibernation ecology *U.a*	*U.a berungianus*
	U.a middendorffi	*U.a horribillis*

**U.a* = *Ursus arctos* for searching

2.3. Survey

To compile an optimised diet, food items fed to Kodiak bears in different institutions were compared. In addition, information about reproductive successes was collected, as Kodiak bears at Emmen Zoo have failed to reproduce over the past few years. Furthermore, information was gathered concerning health problems in relation to the ex situ diet known for Kodiak bears. These subjects were integrated into the survey (see Appendix IV), which was then sent to institutions that kept Kodiak bears or closely related species.

Meetsma and Pfauth (2005) conducted a research project to inventory the diets of Brown bears, *Ursus arctos*, in Large Bear Enclosures (LBE) in Europe, as a part of the 'International Bear Foundation' project. The in situ diet, based on seasonal fluctuations, played an important role in this project and in the survey. The research populations in this study were brown bears kept in LBEs in Europe, and the material gathered was used as background information. To obtain information from institutions that keep Kodiak bears and related species not only in LBE, a new survey was created, based on that of Meetsma and Pfauth (2005).

Before the survey was sent to the different institutions, however, it was first tested at Emmen Zoo. Institutions that housed Kodiak bears and closely related species in February 2008 were found on the ISIS homepage[12] and were included in the mailing list.

2.4. Digestibility analysis

To assess the digestibility of the current diet at Emmen Zoo, samples of the food items and faeces of the three bears were collected and analysed. Because the bears are kept in one outdoor enclosure and receive part of their food spread out over the enclosure, in which they also defecate, it was not possible to analyse digestibility for the individual bears. Instead, mixed samples of the food and faeces were collected (n = 1). The sampling method is described in paragraph 2.4.1. and a description of the analyses is given in paragraph 2.4.2.

2.4.1. Sampling

Three keepers at Emmen Zoo collected the food and faeces samples for the digestibility analyses. A work protocol was handed over to the keepers (see Appendix XI), in which it was stated how to collect, prepare and preserve the samples. An overview of the activities for the purpose of the sample taking is shown in Table 5. The authors and the zoo keepers collected the first diet samples together; subsequently, the keepers collected the samples by themselves.

Sampling of food items

The fed food items were weighed accurately each day for seven days, and leftovers were weighed on the following day. Five percent of each food item fed was taken away: in total, a mass between 400 to 900g per day. The collected food items were placed in labelled plastic freezer bags and stored in the freezer at a temperature of -18℃ until they were u sed for the analyses.

Sampling of faeces

A day after the sampling of food items began, the collection of faeces started. All excrement found inside and outside the enclosure was collected daily, then was weighed and mixed to a homogeneous bulk. From this bulk, 200-250g was removed, placed in labelled plastic freezer bags and stored in the freezer at a temperature of -18℃ until it was used for the analyses. The keepers also made an estimation of the percentage they collected from the total amount of faeces.

Table 5 – Planning of activities executed for the purpose of taking samples of food and faeces.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Weigh food items	x	x	x	x	x	x	x	
Fed food collection	x	x	x	x	x	x	x	
Weigh uneaten food items		x	x	x	x	x	x	x
Leftover collection		x	x	x	x	x	x	x
Faeces collection		x	x	x	x	x	x	x

2.4.2. Analysis

To gain a clear insight into the digestibility of the current diet, analyses as described in Table 6 were executed. Because little is known about the digestive system of Kodiak bears, the standard analyses for digestibility were chosen (VVR-bundel, 1995). The results would indicate the digestibility of the current diet provided to the Kodiak bears at Emmen Zoo.

All chemical analyses were performed in duplicate, and between the duplicates ± 3% relative of the mean was permitted (see Formula 1 below). The energy and carbohydrate content were not chemically analysed but were calculated.

Formula 1 – Example for calculating the acceptable difference between replicates.

(Sample 1 + Sample 2) / 2 = Average
(13.40% + 14.20%) / 2 = 13.80%

Average * 1.03 = +3% Average	Average * 0.97 = -3% Average
13.8% * 1.03 = 14,21%	13.8% * 0.97 = 13.39%
Sample 1 ≥ -3% Average	Sample 2 ≤ Average +3%
13.40% ≥ 13.39%	14.20% ≤ 14.21%

Table 6 – Executed nutrient analyses and the method used.

Nutrient	Analysis method
Dry Matter (DM)	Weende analysis
Ash	Weende analysis
Sand	Weende analysis only for faeces
Crude Protein (CP)	Weende analysis
Crude Fat (CFat)	Weende analysis
Neutral Detergent Fibre (NDF)	Van Soest analysis
Acid Detergent Fibre (ADF)	Van Soest analysis
Crude Fibre (CF)	Van Soest analysis
Non-fibre Carbohydrates (NFC)	Calculation
Minerals	
Calcium (Ca)	Atomic Absorption Spectrometer
Magnesium (Mg)	Atomic Absorption Spectrometer
Sodium (Na)	Flame Photometer
Potassium (K)	Flame Photometer
Phosphorus (P)	Spectrophotometer
Energy	Calculation

Weende analysis

Dry matter (DM), ash, sand and crude protein (CP) nutrients were determined by using the Weende analysis, described in VVR-bundel (1995). An analysis to determine crude fat (CFat) nutrients was performed using ANKOM Technology. The method used for each element is indicated.

DM: Performed according to VVR-bundel (1995, pp.1a.1-1a.6).

Ash: Performed according to VVR-bundel (1995, pp.4a.1-4a.3).

Sand: Performed according to Kuiper (1994 pp.10-11). Sand was only analysed in faeces samples, as no sand was expected to be in the food samples.

CP: Performed according to VVR-bundel (1995, pp.2.1-2.4).

CFat: Performed on the ‘ANKOM^{XT10} Extractor’ from ANKOM Technology, Rapid Determination of Oil/Fat Utilising High Temperature Solvent Extraction [15].

Van Soest analysis

Crude fibre (CFibre), Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) were determined by using the Van Soest analysis, performed on the ANKOM^{200} Fibre Analyser from ANKOM Technology. The method used is indicated for each element.

CFibre: Crude Fibre Analysis in Feeds, Filter Bag Technique, (ANKOM^{200}) [16]

NDF: Neutral Detergent Fibre in Feeds, Filter Bag Technique, (ANKOM^{200}) [17]

ADF: Acid Detergent Fibre in Feeds, Filter Bag Technique, (ANKOM^{200}) [18]

Atomic absorption spectrometer

The minerals calcium (Ca) and magnesium (Mg) were determined by using the Atomic Absorption Spectrometer PU0100X from Philips. The analyses were performed according to VVR-bundel (1995, pp.12.1-12.3).

Flame photometer
The minerals sodium (Na) and potassium (K) were determined by using the Flame Photometer 410 from Corning. The analyses were performed according to VVR-bundel (1995, pp.8.1-9.3).

Spectrophotometer
The mineral phosphorus (P) was determined by applying the spectrophotometer analysing method using the Spectrophotometer Novaspec® II from Pharmacia LKB. The analysis was performed according to VVR-bundel (1995, p.10b.1).

Non-fibre carbohydrates
Formula 2 was used to calculate the non-fibre carbohydrates (NFC).

Formula 2 – Calculating the non-fibre carbohydrate content of a sample.

NFC = 100% – CP% – CFat% – NDF% – ash%

CP = Crude protein, CFat = Crude fat, NDF = Neutral Detergent Fibre

2.4.3. Calculation of energy

To calculate energy, the formula for the dog was used, as it is not known for the brown bear. The brown bear and the dog have a similar digestive tract and probably also a similar energy usability (Wallach and Boever, 1983, p.561). The different stages of energy use in a dog, from gross energy to real energy value, are shown in Table 7. To calculate the metabolic energy, 14.7 kJ for NFC and CP and 35.6 kJ for CFat were used (Pibot et al., 2006).

Table 7 – Energy content for NFC, CP and CFat of the dog (Pibot et al., 2006).

	1g NFC		**1g CP**		**1g CFat**	
Gross energy (GE)	*4.2 kcal	17.6 kJ	5.4 kcal	22.6 kJ	9.4 kcal	39.4 kJ
Digestibility energy (DE)	3.7 kcal	15.5 kJ	4.8 kcal	20.1 kJ	8.5 kcal	35.6 kJ
Metabolic energy (ME)	3.5 kcal	**14,7 kJ**	3.5 kcal	**14,7 kJ**	8.5 kcal	**35.6 kJ**
Net energy (NE)	3.2 kcal	13,4 kJ	2.2 kcal	9.2 kJ	8.2 kcal	34.3 kJ

NFC = None fibre carbohydrates, CP = crude protein, CFat = crude fat
**1 kcal = 4.1867 kJ*

Formula 3 – Calculation example of the digestion coefficient (DCFI) of crude protein (CP).

DCFI CP = (fed CP – faeces CP) / fed CP

Fed CP = The amount of CP present in the total diet provided on a dry matter basis.
Faeces CP = The amount of CP present in the estimated total of produced faeces on a dry matter basis.

3. Literature review

As previously mentioned, a review of the literature was carried out to obtain an overview of available in situ and ex situ data on Kodiak bears and their habitat. Results pertaining to both are described in this chapter.

3.1. In situ

To describe and to convey a complete picture of the Kodiak bear's in situ situation, it is necessary to look at several important aspects. Of course not everything is known about the way Kodiak bears live, but by using different information sources, as complete a picture as possible can be given. First of all, the biology of the Kodiak bear is discussed, followed by an examination of its diet and then by a mention of the hypothetic relations between several of the significant aspects.

3.1.1. Biology

Before the way an animal lives can be discussed, it is necessary to know what kind of animal is being dealt with. This will be discussed in the section on taxonomy, in which it is also made clear which sub-species are recognised for this study. Next, the isolated habitat in which Kodiak bears live is described, followed by the anatomy and physiology of this large animal. The bear's seasonal behaviour is then described, followed by the last aspect of the in situ situation, which involves the characteristics of reproduction.

3.1.1.1. Taxonomy

The Kodiak bear (*Ursus arctos middendorffi*) is a subspecies of the brown bear (*Ursus arctos*). Among taxonomic researchers, it is not clear how many subspecies of the brown bear exist. In general, apart from the Kodiak bear, only the grizzly bear, which is found mainly in the interior areas, is recognised as a brown bear subspecies. These two species differ in dietary choice. Kodiak bears feed to a much greater extent on salmonid resources than do grizzly bears. Classification is based mainly upon skeletal characteristics and the fact of isolation for 12,000 years [6]. The list of subspecies maintained by the International Species Information System (ISIS) shows a group of nine subspecies. There is no homogenous maintenance of subspecies between researches and the number of all subspecies together reaches 232 (Kitchener, 2000, p.10). As the brown bear has an extremely large home range, many differences can be found between bears, and new subspecies can originate (many of which include the name of the researcher as an acknowledgment). In this research project, the ISIS classification is used.

The Kodiak bear belongs to the genus *Ursus* and to the family *Ursidae*. To this family belong animals like the giant panda (*Ailuropoda melanoleuca*), the sun bear (*Helarctos malayanus*) and the sloth bear (*Melursus ursinus*). Kodiak bears belong to the order *Carnivora,* a group that contains around 260 species. A pedigree of some carnivores is shown below in Figure 3, and the scientific classification of the Kodiak bear is given in Table 8.

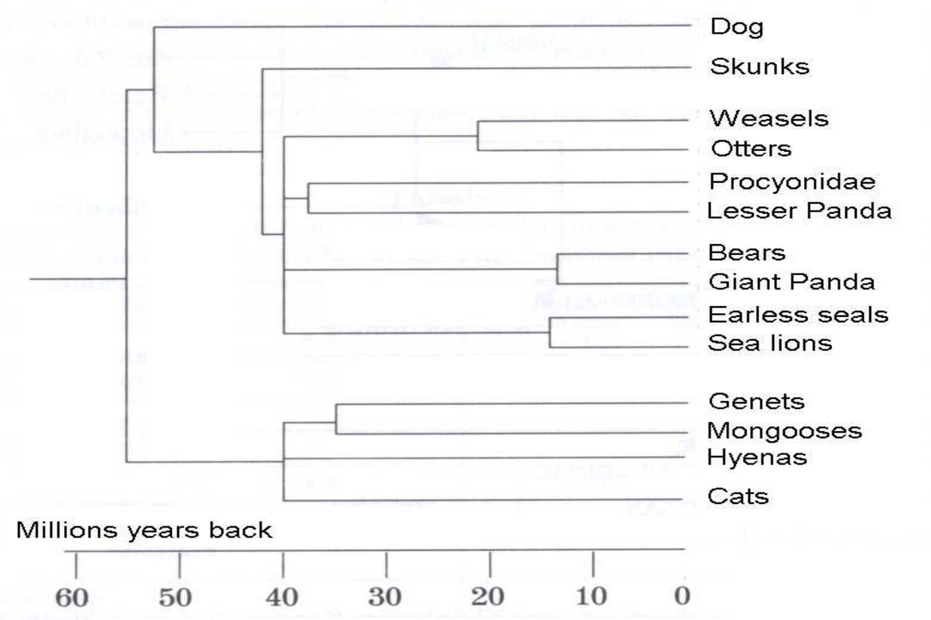

Figure 3 – Pedigree of carnivores from a DNA hybridisation study (Wayne et al., 1998).

Table 8 – Scientific classification of the Kodiak bear.

Class	*Mammalia*
Order	*Carnivora*
Suborder	*Caniformia*
Family	*Ursidae*
Genus	*Ursus*
Species	*Ursus arctos*
Subspecies	*Ursus arctos middendorffi*

3.1.1.2. Habitat

Kodiak bears live on the Kodiak Archipelago, which is situated in the western Gulf of Alaska. The Archipelago consists of a number of different islands, but the Kodiak bear occurs only on the Kodiak, Afognak and Shuyak islands and other larger islands close by, except for the southwestern Trinity Islands or other smaller islands some distance offshore (Clark, 1958, p.576). Kodiak Island has a length of up to 160 km and a width ranging from 15 to 130 km (Daele, 2007, p.4).

The northeastern part of Kodiak Island differs from the southwestern area in habitat structure. Southwest Kodiak is mainly tundra and is less rocky than the main part of the island, with its steeply sloped bays and rocky peaks that range in height from 600 to 1000 metres. Along the streams, black cottonwood, *Populus thrichocarpa*, is found except for the southwestern part of the island. In the same range, the only conifer present on the island is the Sitka spruce, *Picea sitchensis*. Most slopes on the island are covered with willows, *Salix spp.*, and alder, *Alnus crispa*. Different kinds of berries are quite common, in particular the elderberry, *Sambucus racemosus pubens*. During the summer season, a luxurious herbaceous growth of bluejoint grass, *Calamagrostis Canadensis*, and fireweed, *Epilobium angustifolium*, covers low areas (Daele, 2007; Atwell et al., 1980, p.298; Troyer and Hensel, 1964; Clark, 1958).

Climate

The Kodiak Archipelago has a sub-arctic maritime climate, and weather can change rapidly due to the different landscapes on the island. During the main part of the year, eastern winds bring cool and moist weather, but now and then northwestern winds bring drier weather with more extreme temperatures. Weather data covering the period 1973-2003 is available from Kodiak city (see Table 9), and indicate that February is the coldest month and August the warmest. Weather conditions are similar on the eastern part of the island, but the southern and western areas have a drier climate with the same temperature (Daele, 2007, p.5).

Table 9 – Climatic information, provided by Kodiak city, covering the period 1973-2003 (Daele, 2007, p.5).

	Lowest	Highest
February*	-3.7℃	2.1℃
August*	9.4℃	16.7℃
Extremes	-26.7℃	26.7℃
Precipitation	138 cm	270 cm
Daylight	6 h 29 min	18 h 9 min

**February is seen as the coldest month and August as the warmest.*

3.1.1.3. Anatomy and physiology

Brown bear species are heavily built animals with large skulls, short necks and well-developed muscularity at the shoulders, biceps and triceps (Veldhuis Kroeze and Vente, 2000, p.9). Large male Kodiak bears can have a weight of 680 kg or more, but most males weigh between 360-635 kg and females between 230-320 kg [6]. Shoulder height ranges from 1220 to 1370 mm (Nowak, 1999, pp.685-688; Burt and Gossenheider, 1976). The oldest known wild male was 27 years old and the oldest known wild female was 34 [19]. The life expectancy for bears is 15 to 20 years in the wild and 30 years or more in captivity [20]. Other features of the bear's body are the strong legs, claws and snout for grubbing and digging to search for food (Kolter, 1998 p.1-7, 1-8). Each foot has five long, curved, non-retractable claws. These claws and legs are also used to climb trees; although the bears are plantigrade, they are also able to run up to 50 km per hour (Veldhuis Kroeze and Vente, 2000, p.9).

The advantage of a large body size is the reduced loss of energy from the body surface and the relatively lower need for energy. As well as on salmonid products, Kodiak bears feed on herbaceous products, of which not all nutritional values can be used, so a relatively lower need for energy is favourable (Kolter, 1998, p.1-7). Kodiak bears have a comparatively shorter gut than ungulates and lack a fermentation chamber, which results in less time needed to digest herbaceous products and a lower amount of energy released than occurs in ungulates (Ramsay, 1993). As well as these features, brown bear species have no caecum and their stomach is too acidic to encourage the microflora and microfauna needed for digestion cellulose (Rogers, 1976, p.183). It is possible that bears can digest cellulose in the colon, but this has not yet been confirmed. Furthermore, ungulates have an herbivorous dentition, with jaws that can move in the horizontal plane, which is impossible for Kodiak bears. Moving the jaws in the horizontal plane is nevertheless a condition to make optimal use of the cell content (Kolter, 1998, p.5-5; Ramsay, 1993). The dentition of Kodiak bears is well adapted to the omnivorous diet insofar as their premolars are smaller than those of other carnivores. In addition, the fourth upper premolar is more broadened and flattened to crush and grind the herbaceous products instead of slicing through meat in the manner used by other carnivores (Kolter, 1998, p.1-8). Apart from this information, little is known about the gastrointestinal tract of bear species. Therefore, the dog, which has a similar gastrointestinal tract, will be used for more specified information.

The physiology of bears during the hibernation period is unique for animals (some features are listed in Table 10). Brown bears can hibernate without eating, drinking, defecating or urinating. Waste products are recycled, like urea, which is produced from protein catabolism. Carbon dioxide and ammonia are produced during protein catabolism. Next, the ammonia is converted by urea and other nitrogen-containing compounds. After absorption from the bladder, the urea and other nitrogen-containing compounds are reused for the anabolism of proteins (Nelson, 1980; Lundberg, 1976). Due to the metabolism of body fat during hibernation, the cholesterol level is twice as high as during the summer when the bears are active (Bagget, 1984). However, no hardening of arteries or gallstone development results from this, as would be the case with humans. This is probably due to the role of the bear's liver, which secretes a substance that is able to dissolve human gallstones. Another characteristic feature of bear hibernation is that the bone mass stays the same during this period. All other mammals that maintain non-weight-bearing positions for an extended period suffer from osteoporosis or a weakening of the bones (Wickelgren, 1988).
Bears shed the keratinized pads of their feet during hibernation. Rogers (1974, pp.672-673) studied this phenomenon, but could not find the cause, although temperature was excluded. Portions of old foot pads were found in the scat of bears, which suggests that reports of bears licking and eating their pads were correct. Hallowell (1926) could not find the same evidence on the north Pacific coast or in the southern United States where bears usually do not hibernate for long periods. Wallach and Boever (1983, p.555) reported that B-complex deficiencies may cause the shedding of keratinized foot pads during hibernation. They state that this "tender foot" syndrome is similar to the exfoliative dermatitis and raw, tender feet syndrome observed in domestic and exotic canids with B-complex deficiencies.

Table 10 – Adjustments in the body of the brown bear during hibernation.

	Not in hibernation	**Hibernation**
Body temperature	37.7-38.3℃ [a]	above 31℃ [a]
Metabolic rate	100%	40-50% [b]
Respiration frequency	6-10 breaths/minute [c]	1 breath/45 seconds [c]
Heart rate	40-50 beats/minute Summer [c]	8-19 beats per minute [c]

[a] Bagget, 1984, [b] Craighead and Craighead, 1972; Rogers, 1981, [c] Biel and Gunther, 2006

3.1.1.4. Behaviour

Bears are solitary animals and have home ranges rather than territories. Kodiak Island has a large availability of food, and this accounts for the highest density of bears, with one bear per 0.7 km^2, the smallest home range present on the island [19].

Denning

Before Kodiak bears finally enter their dens, they make several excavations in adjacent locations, alternating with periods of rest (Daele et al., 1990, p.259). Triggers for bears to enter their dens depend on the location in which they live. Schoen et al. (1987) studied the hibernation ecology of brown bears on the Admiralty and Chichagof Islands, located on the east side of the Gulf of Alaska at the same latitude as Kodiak Island, and Miller (1990) studied the hibernation ecology of brown bears of south-central Alaska. Daele et al. (1990) compared these authors' hibernation data with information he collected from the population on the southwest side of Kodiak and in the Terror Lake area, on the northeast side of Kodiak, in the period 1982-1988 (see Table 11).

Table 11 – Mean den entrance dates in four study areas in Alaska (Daele et al., 1990, pp.259, 261).

		Reproduction status			
Study area	**Action**	**Males**	**Lone females**	**Females with young**	**Females pregnant/with coy** [d]
South-central Alaska[a]	Begin	16 Oct	14 Oct	15 Oct	13 Oct
	Emerge	23 Apr (188[d])	30 Apr (197)	4 May [c] (200)	15 May (213)
Southeastern Alaska[b]	Begin	5 Nov	5 Nov	27 Oct	22 Oct
	Emerge	19 Apr (169)	29 Apr (179)	16 May [c] (200)	11 May (200)
Terror Lake Kodiak	Begin	16 Nov	10 Nov	9 Nov	5 Nov
	Emerge	22 Apr (156)	2 may (172)	12 May [c] (183)	27 May (202)
Southwest Kodiak	Begin	12 Dec	26 Nov	3 Dec	19 Nov
	Emerge	8 Mar (87)	28 Apr (152)	27 Apr [c] (144)	31 May (190)

[a] Miller (1990): female with 2-year-olds included in the 'lone female' category, [b] Schoen et al. (1987), [c] Female with yearling or older offspring, [d] Females with cubs-of-the-year, [d] days in hibernation

Den-entering dates for Kodiak bears are later than in the two other areas, with bears on the southwest side of the island being the last to enter. The order in which bears enter their dens is almost the same in all areas; first the pregnant female enters her den, followed by the female with young, then the lone female and finally the male. Triggers for entering the dens are weather circumstances and food availability. In the event of a harsher climate, bears enter their dens earlier. This is also the case when the climate is milder but food is limited (Daele et al., 1990; Miller, 1990; Schoen et al., 1987; Johnson and Pelton, 1980). This is even noticeable on Kodiak, where food is scarce in southeast Kodiak but still available in southwest Kodiak in late autumn. Southeast Kodiak has the earliest mean den-entering dates and the southwest has the latest (Daele et al., 1990). It is important to remember that the data collected are from average bears in a period more than 15 years ago.

Emergence from the dens occurs in the reverse order, starting with the males. The dates of emergence are closer between the four habitats in comparison to the entering dates. Typical patterns of emergence from the den start with opening the den entrance followed by remaining near or in the den for several days, interspersed with short forays before a final abandonment of the den site (Daele et al. 1990, p.259). Another factor influencing the post-den period may be tender paws, as the foot pads were shed during hibernation and may not yet be totally keratinized (Rogers, 1974, pp.672-673).

3.1.1.5. Reproduction

Hensel et al. (1969) studied reproduction habits of the brown bear from Kodiak Island and the Alaska Peninsula, and determined that females attain sexual maturity at the age of three to six years and commonly when they are four years old. At this point, they are still not fully mature and continue to grow until their tenth or eleventh year.

The mating season starts in the last half of May and continues until mid-July (Hensel et al., 1969, p.357). After copulation, the fertilised eggs develop into blastocysts and a delayed implantation in the uterus occurs [7]. When the female enters her den in November (Daele et al., 1990), blastocysts become implanted and a gestation of six to eight weeks follows [7]. The total gestation period is estimated to be approximately 245 days, from copulation until parturition. Parturition of an average litter size of 2.23 cubs occurs in January or February (Hensel et al., 1969, p.357) and the cubs have a weight of 340 to 680g [7]. Mother and cubs emerge from the den early in May (Daele et al., 1990), but the cubs first leave the mother at the age of three to five years. Weaning of the cubs takes place prior to or during the second winter of hibernation. The lactation probably inhibits reproduction during the first and second summer after parturition; as a result, brown bears normally breed every third year (Hensel et al., 1969, p.357).

Placental scars display the number of embryos present during gestation. Comparing the mean placental scars of 2.37 to the litter size of 2.23 indicates a low postnatal mortality. Another 10% decrease in litter size occurs during the first year of the cubs' life. In Hensel's study, the sex ratio with regard to 81 live trapped cubs and yearling bears was essentially even: 41 females to 40 males.

3.1.2. Diet

Between the time that Kodiak bears emerge from their dens in May and until they enter the den in November, they can experience a weight gain of 20-30% [6]. This is due to their seasonal fluctuating diet, which is a result of the climate and the amount of food available. Food item availability changes each season and is discussed below in paragraph 3.1.2.1. Next, the food items are listed and a hypothetic in situ diet for Kodiak bears is displayed. The nutrient usage is also discussed as well as the resulting energy uptake.

3.1.2.1. Foraging

Winter

During the winter, bears generally hibernate and do not feed [21]. If they do feed at this time of year, they will search mainly on the beaches for food. Here they find seaweed, *Porphyra laciniata*, as well as carrion from cetaceans or other bears and from other sizable carcasses (Daele, 2007, p.15; Clark, 1957, p.147). Old carrion is more attractive than fresh, since older carrion has putrefied and softened and is easy for the bear to masticate (Clark, 1957, p.147).

Spring

In spring, after the hibernation period, the amount of food present is very low and the bears continue to lose weight (Nelson et al., 1980, p.285). This stage is called hypophagia and it is assumed that bears do not change their physiological hibernation condition (Wittenberg and Wenzelides, 2000, p.131; Hock, 1958). Normal food consumption starts 10 to 14 days after the bears emerge from the dens, when they begin to search for carrion, seaweed and herbaceous and fresh grass [21]. If the ground is still covered with snow, the bears find their first food – seaweed and carrion – on the snow-free beaches. In this period, the bears' scat is a formless pile wherein food items appear in small chunks (Clark, 1957, p.145). Later, when the snow has melted and the first vegetation has begun to sprout, the bears start to graze. The beaches are still visited regularly and other food such as conks, *Fomes applanatus*, which is an alder root parasite, and other types of vegetation are also consumed (Daele, 2007, p.15; Atwell et al., 1980, p.302; Clark, 1957). By this time, the scat piles have the appearance and odour of horse dung (Clark, 1957, p.146).

Summer

From the beginning of summer, when the vegetation is still new and rich in protein, the bears graze for another month. After the river ice has melted, the first salmon arrive: first, the sockeye salmon, *Oncorhynchus nerka,* and somewhat later the pink, *Oncorhynchus gorbuscha*, and chum salmon, *Oncorhynchus keta*. The bears switch to this high-quality food and the competition for the best fishing spot begins (Daele, 2007, p.15; Atwell et al., 1980, p.304; Clark, 1957). The manners of fishing include a wide range of hunting techniques, varying from standing above a waterfall to snatch the salmon out of the air to diving and trying to catch the fish underwater (Wittenberg and Wenzelides, 2000, p.131). Feeding on salmon results in scat like that of cattle, with a grey colour (Clark, 1957, p.146). As well as feeding on salmon at this time, bears graze on Bent-leaved angelica, *Angelica genuflexa*, of which the flower and the upper portion of the stem are eaten. The nests of bees, *Bombus* sp., and hornets, *Vespa* sp., are also visited from time to time. Tundra voles, *Microtus oeconomus kaniacensis*, are in abundance over the whole island but are seldom used by bears as a food source (Clark, 1957). In the second week of August, berries normally start to ripen and the bears begin to feed on them. During this time, plenty of fish are still available but the berries hold the bigger attraction; hence, bears are to be found in the brushy lower slopes. The main fruit-producing shrubs on the island are elderberry, *Sambucus racemosa pubens*, and Devil's club, *Oplopanax horridus*, close to Afognak Island. Most of the other kinds of berries are consumed as well when they are plentiful and ripe (Daele, 2007, p.15; Clark, 1957).

Autumn

Feasting time, or hyperphagia, occurs in late summer and early autumn (Nelson et al., 1980, p.286). The bears now consume large amounts of berries and salmon, and spend up to 20 hours a day searching out these food sources (Rode et al., 2006, p.73; Nelson et al., 1980, p.286). Besides the berries and salmon, the bears feed on terrestrial animals, grass, roots and other vegetation that is easy to obtain and of a high quality. A characteristic of scat in this period is the pile of berries that have passed through the alimentary system practically unscathed (Clark, 1957, p.147). With the arrival of the first frost and snow, the availability of food, especially berries, begins to drop. The activity of the bears slows down and they start a cleanup period. During this time, the bears feed on dead grass, old salmon carcasses or sometimes on late spawning salmon, carrion and whatever else they can find (Daele, 2007, p.15; Clark, 1957). With less food available and more snow present, the home ranges become smaller and after a while most bears disappear into their dens.
For an overview of the seasonal foraging schedule, see Table 12.

Table 12 – Seasonal food items on which Kodiak bears fed (Daele, 2007; Atwell et al., 1980; Clark, 1957).

Common name	**Scientific name**	**Apr - Jun Spring**	**Jun - Sep Summer**	**Sep - Nov Autumn**	**Nov - Apr Winter**
Sockeye	*Oncorhynchus nerka*		x	x	
Chum	*Oncorhynchus keta*		x	x	
Pink	*Oncorhynchus gorbuscha*		x	x	
Elderberry	*Sambucus racemosa pubens*		x	x	
Salmonberry	*Rubus spectabilis*		x	x	
High bush cranberry	*Viburnum edule*		x	x	
Crowberry	*Empetrum nigrum*		x	x	
Devil's club	*Oplopanax horridus*		x	x	
Sedges	*Carex macrochaeta*	x	x	x	
Horsetail	*Equisetum arvense*	x	x	x	
Nettle	*Urtica lyalli*	x	x	x	
Seacoast angelica	*Angelica lucida*	x	x	x	
Bent-leaved angelica	*Angelica genuflexa*		x	x	
Conk	*Fomes applanatus*	x			
Seaweed	*Porphyra laciniata*	x			x
Carrion		x			x
Tundra voles	*Microtus oeconomus kaniacensis*		x	x	
Bumblebees	*Bombus* sp.		x		
Yellowjackets	*Vespa* sp.		x		

3.1.2.2. Food items

Bears are highly opportunistic and use all kinds of food sources such as carrion, kills and seaweed, as well as grass and other vegetation. Food quality is important for the bears, and when given the choice they opt for high-quality food that is easy to obtain [19]. They walk hundreds of kilometres to reach an optimal feeding place, like a river with spawning salmon or an area of ground rich with berries. In the spawning peak, the bears eat only the fat spawn, skin and brains of the fish (Wittenberg and Wenzelides, 2000, p.131).

For an overview of the food items that Kodiak bears have on their annual menu, see Table 13 for the compiled list.

Table 13 – Important food items for Kodiak bears (Daele, 2007; Atwell et al., 1980; Clark, 1957).

- **Salmon**
  - Chinook (*Oncorhynchus tshawytscha*)
  - Chum (*Oncorhynchus keta*)
  - Coho (*Oncorhynchus kisutch*)
  - Pink (*Oncorhynchus gorbuscha*)
  - Sockeye (*Oncorhynchus nerka*)
- **Berries/shrubs**
  - Bearberry *(Arctostaphylos una-ursi, A. alpine)*
  - Blueberry *(Vaccinium ovalifolium, V. uliginosum)*
  - Cloud berry *(Rubus chamaemorus)*
  - Cranberry *(Vaccinium vitis-idaea)*
  - Crowberry *(Empetrum nigrum)*
  - Devil's club *(Oplopanax horridus)*
  - Elderberry *(Sambucus racemosa pubens)*
  - High bush cranberry *(Viburnum edule)*
  - Salmonberry *(Rubus spectabilis)*
  - Twisted stalk *(Streptopus amplexifolius)*
- **Carrion**
- **Voles**
  - Tundra voles *(Microtus oeconomus kaniacensis)*
- **Insects**
  - Bumblebees *(Bombus sp.)*
  - Yellowjackets *(Vespa sp.)*
- **Sedges**
  - *Carex lyngbei*
  - *Carex macrochaeta*
  - *Carex mertensii*
- **Grasses**
  - Beach rye *(Elymus arenarius mollis)*
  - Bluejoint *(Calamagrostis Canadensis logsdorffii)*
  - Meadow barly *(Hordeum brachyantherum)*
- **Equistum**
  - Horsetail *(Equisetum arvense)*
- **Nettle**
  - *Urtica lyalli*
- **Angelica**
  - Seacoast angelica *(Angelica lucida)*
  - Bent-leaved angelica *(Angelica genuflexa)*
- **Conk**
  - *Fomes applanatus*
  - Red Banded Polypore *(Fomes pinicola)*
- **Seaweed**
  - **Porphyra laciniata**
- **Plant parasite**
  - Red poque *(Boschniakia rossica)*
- **Roots**
- **Hogweed**
  - Cow parsnip *(Heracleum lanatum)*

The foraging behaviour and the food items used by Kodiak bears are discussed above. By using the sources listed in those paragraphs, a conceivable in situ diet was compiled (see Table 14). The mean hibernation time of a lone female of 400 kg was used (Daele et al., 1990, pp.259, 261). The diet was compiled to gain an idea about the in situ diet and to compare it to the ex situ diet.

Nutrient values of all products listed in Table 13 were not available, as a result of which some groups of food items are missing. To provide a clear overview of the diet, food items of the same group were put together. An overview of the used nutrient values and the group compilation is found in Appendix II.

Table 14 – Estimated in situ diet of the Kodiak bear derived from literature sources (Daele, 2007; Atwell et al., 1980; Nelson et al., 1980; Clark, 1957). The mean hibernation period of a lone female of 400 kg was used (Daele et al., 1990, pp.259, 261).

Food item [a]	**May 750 MJ**	**Jun 1120 MJ**	**Jul 1760 MJ**	**Aug 2420 MJ**	**Sep 2860 MJ**	**Oct 1920 MJ**	**Nov 540 MJ**
Berries high [b]				25%	35%	35%	
Berries low [c]				5%	15%	15%	
Carrion	30%	5%				5%	20%
Herbaceous	40%	80%	60%	10%	5%	5%	10%
Salmon, first [d]			40%	30%	25%		
Salmon, mean [e]				30%	20%	25%	10%
Seaweed	30%	15%				15%	60%
CP	**29%**	**14%**	**36%**	**50%**	**39%**	**31%**	**41%**

[a] *Most nutrient values are from the USDA for details see Appendix VI,* [b] *Consumed to high extent,* [d] *Salmon present first,* [c] *Consumed to low extent,* [e] *All salmon available*

3.1.2.3. Nutrients

Water

In hibernation, bears compensate for water loss through respiration or eventual lactation, as metabolic water is released by the combustion of fat. One gram of fat gives 1.06g of metabolic water (Veldhuis Kroeze and Vente, 2001, pp.29-30).

Fat

Fat is a highly attractive nutrient for bears, and for that reason they prefer fat-rich food items. For example, when the spawning of salmon is at its peak and plenty of fish is available, the bears eat only the fatty parts of the fish (Wittenberg and Wenzelides, 2000, p.131).

The importance of fat in the diet of bears is not yet known. What is known, however, is that fat has double the amount of energy per gram than do carbohydrates and proteins, and therefore it is an important energy source. Further, it is known that body fat is the source of energy needed for hibernation, and without this fat reserve a successful hibernation would not be possible.

Protein

The diet of Kodiak bears can contain more than 70% of crude protein in dry matter (DM), if the diet contains high amounts of fish (Rode and Robbins, 2000).

Carbohydrate

For bears, carbohydrates, specially the easily digestible ones that involve storage and transport, are an important energy source. However, it is not yet clear how much of the structural carbohydrates can be used by bears. From the point of view of physiology, the dog has a similar digestive tract (Wallach and Boever, 1983, p.561) and dogs very seldom use structural carbohydrates (Oppmann, 2001, pp.229-237). Prichard and Robbins (1990) showed the existence of a strong relation between total dietary fibre and dry matter digestibility, in which a higher percentage of dietary fibre results in a lower percentage of digestibility.

Minerals

The required ratio for calcium (Ca) and phosphate (P) is still unknown for the brown bear, but from other animals is it known that the ratio of Ca:P must be between 1:1-2:1. When the ratio is less than 1:1, calcium deficiency is likely to occur. Vitamin D is important for a better absorption of Ca from the intestinal tract; however, a high fat percentage and acid pH in the contents decreases the absorption of Ca (Pond et al., pp.173, 463-464).

3.1.2.4. Energy

The metabolic weight (MW) of a bear equals body weight (BW) in kg raised to the power of 0.75, hereinafter referred to as $BW^{0.75}$, and this is the same for most other mammals (Kleiber, 1961). The metabolic weight, also referred to as metabolic size, gives an indication of the basal metabolic rate (BMR) of the animal.

The BMR of an adult bear in hibernation is 213.53 kJ per day and per $BW^{0.75}$ (see formula and example in Formula 4) (Pond et al., 2005, p.155; Rode and Robbins, 2000, p.4). When the bear is awake, the daily maintenance costs are 444 kJ per $BW^{0.75}$ on a diet with 35% protein. A diet consisting of fruits only, with a much lower protein percentage, permits the maintenance cost to rise by more than a factor of 2 in comparison with the maintenance costs on a 35% protein diet (Rode and Robbins, 2000, p.4). It is not known whether bears feed on the basis of protein requirements or on taste.

Formula 4 – Calculation of hibernation cost and maintenance cost of bears.

1 kcal = 4.1868 kJ

Hibernation cost: 51 kcal of 213.53 kJ * $(BW^{0.75} * \text{day})^{-1}$

Example hibernation

A bear of 400 kg in the middle of its hibernation period has a metabolic weight of 89.443 kg and needs 19.098 kJ, which is approximately 20 MJ per day. During a hibernation of 120 days, this results in 2292 MJ for the total hibernation period. This energy needed is provided by approximately 60 kg fat (1g fat has 38 kJ).

Maintenance cost on a 35% protein diet: 106 kcal or 443.80 kJ * $(BW^{0.75} * \text{day})^{-1}$

Example maintenance

A bear weighing 400 kg needs 39.695 kJ or round 40 MJ per day to keep its body weight stable on a 35% protein diet.

To calculate the amount of food required by a bear, the metabolic energy (ME) for every food item must be known. To date, it is unclear how bears use most food items that originate in the wild. Hence, the digestible energy (DE) or gross energy (GE) of the food items should be used, although these are less accurate than ME to calculate the amount of food required.

When no bear data was available, the standard ME of the dog was used for crude fat (35.6 kJ/g), crude protein (14.7 kJ/g) and nitrogen-free extract (14.7 kJ/g). For the formula of GE, DE and ME, see Formula 5.

The GE is known for a couple of food items (see Table 15) (Kolter, 2007, p.5-7, 5-8; Pritchard and Robbins, 1990).

Formula 5 – Formulae for calculating gross energy, digestible energy and metabolic energy in bears (Pond et al., 2005, pp.147-148).

Formula
GE = Heat of combustion
DE = GE – faecal energy
ME = GE – faecal energy – urinary energy – gaseous products of digestion
GE = Gross energy, DE = Digestible energy, ME = Metabolic energy

Table 15 – Food items of which the gross energy is known (Pritchard and Robbins, 1990).

Food item	GE kJ/100g	DE kJ/100g	ME kJ/100g
Beef	1044.1	1001.3	947.3
Deer	798.9	743.0	691.7
Ground squirrel*	636.8	484.6	446.8
Trout	597.8	536.8	484.2
White clover	144.1	66.4	63.8
Wood berries	334.9	213.7	206.6
Fir cone*	2577.4	1061.9	1044.9

**From black bear*

In the feasting period, is it important for bears to gain weight and to lower energy costs. Robbins et al. (2007) studied weight increase in bears by feeding them diets with different percentages of proteins. The result of this research project was the observation that bears obtained the highest growth rates with a dietary protein of 19 ± 3% in dry matter. A higher percentage of dietary protein slows down the increase in weight and a lower percentage of dietary protein causes even more extreme decreases. The relation between the increase in weight and percentage of dietary protein in dry matter is illustrated in Figure 4.

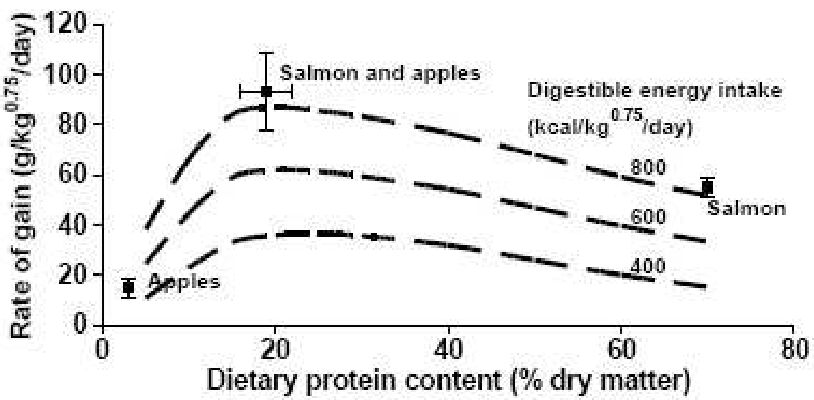

Figure 4 – Optimising the protein intake as a foraging strategy to maximise increase in the weight of a bear.

Robbins et al. (2007) and Rode and Robbins (2000) concluded that the maintenance costs change dramatically in relation to the dietary protein percentage. Diets containing 25-35% protein have the lowest maintenance costs, while a lower or higher percentage of protein in the diet causes the maintenance cost to increase (see Figures 5 and 6).

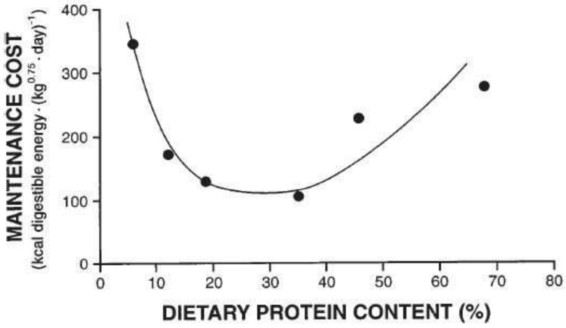

Figure 5 – Relation between dietary protein and maintenance cost (Robbins et al. 2007).

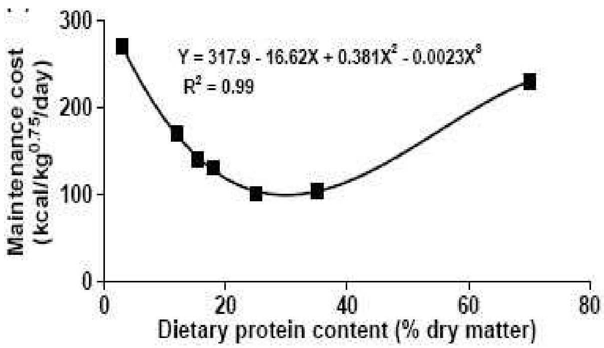

Figure 6 – Relation between dietary protein and maintenance cost (Rode and Robbins 2000).

To calculate the maintenance cost of different protein-rich diets, see Formula 6 below for a 35% diet and a diet with 2.3-5.6% protein.

Formula 6 – Calculating maintenance cost with a 35% protein diet and a 2.3-5.6% protein diet.

35% protein diet	2.3-5.6% protein diet
The maintenance cost of the bear is 24g $(kg^{0.75}\cdot day)^{-1}$ or 502 kJ DE $(kg^{0.75}\cdot day)^{-1}$.	The maintenance cost of the bear is 80g $(kg^{0.75}\cdot day)^{-1}$ or 1424 kJ DE $(kg^{0.75}\cdot day)^{-1}$.

3.1.3. Relation between body weight, diet and reproduction

Hilderbrand et al. (1999c) showed in his research that a relation exists between food resources and the mean body weight and the litter size of North American brown bears.

This relation between food resources and mean body weight is stronger when more food, and of a higher quality, is available in autumn during the feasting time than in spring after hibernation. Salmon seems to play an important role in the connection between availability of high-quality food and mean body weight (see Figure 7). Though it is not clear whether a diet with a high amount of salmon is better than one with a high amount of terrestrial meat, or whether foraging on salmon is more efficient than foraging on terrestrial meat.

A similar relation is found between diet quality and mean litter size. Females with access to high amounts of high-quality meat in their diet, such as spawning salmon, give birth to more cubs than do bears without access to these sources or who have no meat at all in their diet (see Figure 8).

This relation is also found between weight and litter size. Heavier females produce bigger litter sizes than do lighter females (Hilderbrand et al., 1999c) (see Figure 9).

Bear populations that have access to high amounts of high-quality meat in autumn have a greater density than a population without this access. With an increase in meat availability in a habitat, the quality of the habitat for the bears increases and allows a higher density of the animals.

Although a conclusion has not yet been reached, it appears that the high amount of high quality meat in autumn – in the case of Kodiak bears, the spawning salmon – has a tremendous influence on the body size and the reproduction rate of bears, as well as on the density of bears on the Kodiak Archipelago.

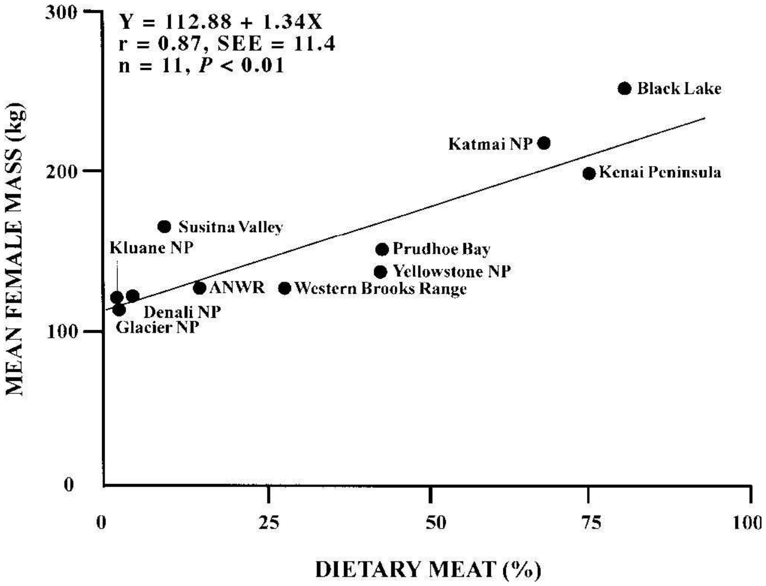

Figure 7 – The relation between meat in the diet and mean female body mass from 11 North American brown bear populations (Hilderbrand, 1999c, p.135).

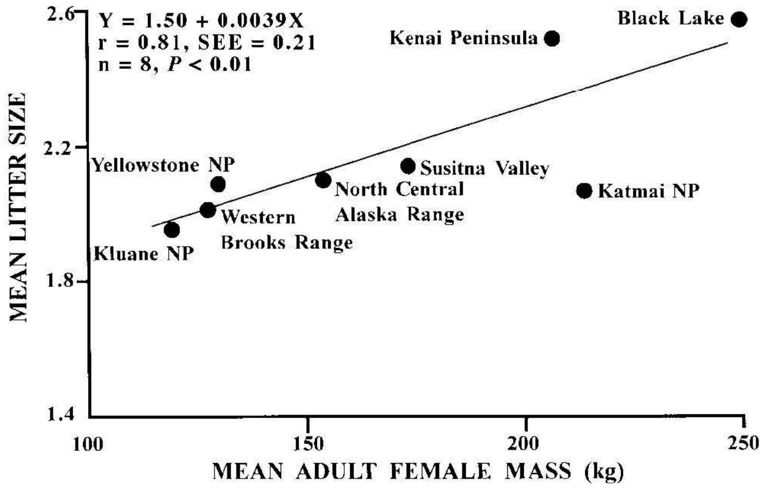

Figure 8 – Relation between meat in the diet and mean litter size from eight North American brown bear populations (Hilderbrand, 1999c, p.135).

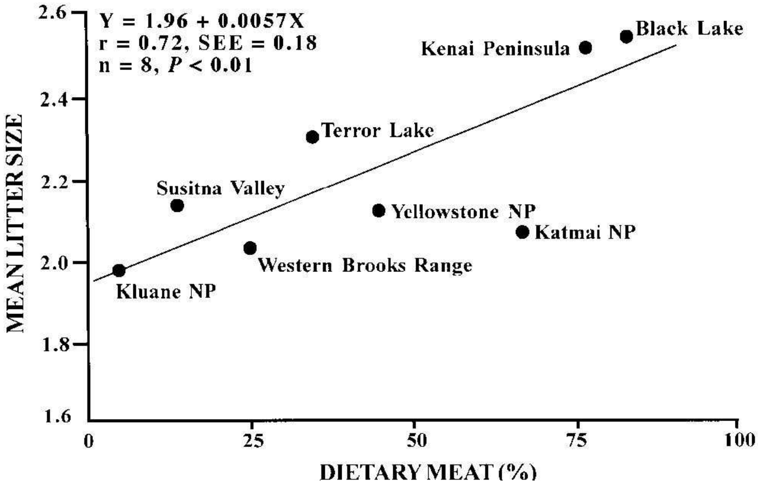

Figure 9 – Relation between mean female mass and mean litter size from eight North American brown bear populations (Hilderbrand, 1999c, p.135).

3.2. Ex situ

The description of the in situ situation can be used to a large extent for the ex situ situation as well. In this section, only the divergent subjects will be described, as well as those related to the ex situ situation, such as diet-related diseases.

3.2.1. Captive situation

The biology of Kodiak bears in ex situ situations is similar to that in in situ situations. However, the habitat differs and therefore the behaviour of the bears may change as well. Stereotypic behaviour is expressed in an ex situ environment and less space is available for movement. Kodiak bears are kept with more individuals in one enclosure; this is unnatural, but it is known that Kodiak bears live in high densities of one bear per 0.7 km^2 [19] if food resources are readily available.

Bears in situ are opportunistic animals; they eat what they find and move as little as possible, but when food is scarce they will walk for long periods in search of it. This indicates that bears are inherently lazy and, in the ex situ situation, keepers need to make it hard for them to find their food and thus force them to have some exercise. Because bears ex situ are given complete dry dog food, which is a complete feeder and includes a number of minerals and vitamins, food deficiencies are not common. It is expected that obesity is a more common problem for bears ex situ. Bears in situ have a seasonal fluctuating diet and body weight. Because of the climate on the Kodiak Archipelago, there is almost no food available during the winter and therefore bears hibernate. However, the climate in ex situ situations is often not challenging and food is readily available, resulting in bears that do not have to hibernate (Schoen et al., 1987, p.296) and a weight that stays the same throughout the year.

3.2.2. Diet-related diseases in captivity

Infectious or non-infectious disorders are rarely seen in brown bears. This may be due to an exclusive resistance against different kinds of diseases or because of the ability to disguise any symptoms of sickness or pain (Rietschel, 1994). The known diseases that may occur in bears with regard to diet will be discussed here. The only known product forbidden to feed to bears is uncooked pork meat (Moresco et al., 1997; Zanin et al., 1997, as pigs are susceptible to Aujeszky's disease, which is fatal for bears.

Although it is also reported for in situ situations, endoparasites are characteristic for bears in an ex situ environment (Kuntze, 1995). It is hard to remove all phases of worm cycles in the outdoor enclosure, and the presence of more than one bear in an enclosure also makes it more difficult to get rid of the parasites (Veldhuis Kroeze and Vente, 2000, p.46; Claro-Hergueta et al., 1998). Bears are most sensitive to the roundworm, *Baylisascaris transfuga* (Morán et al., 1994; Frechette and Rau, 1977; Clark et al., 1969; Wallach and Williamson, 1968), and the hookworms, *Ancylostoma malayum* and *Uncinaria yukonesis* (Kuntze, 1995; Rausch et al., 1979; Frechette et al., 1977).

Dental problems related to diet are trauma and caries. Trauma is named because a fractured element can contribute to the occurrence of caries. Caries may be a result of a diet consisting of identical, soft and low-fibre food items that do not stimulate the mechanical cleaning of the dental elements during feed intake and that accelerate the realisation of plaque and calculus. Periodontal damage and inflammation may result. Branches and other fibre-rich food items should be included in the diet (Kaya and Dorresstein, 1994; Wenker et al., 1996).

Neoplasia has been reported in brown bears, but it occurs less often than the problems mentioned above. Moulton (1961) and Wadsworth and Williamson (1960) reported hepatomas, cancer originating in the liver, and bile-duct carcinomas in the Kodiak bear, grizzly bear, black bear and sloth bear over the age of 17 years old. Veldhuis Kroeze and Vente (2000, p.51) reported that according to the literature brown bear species are not sensitive to a particular kind of neoplasia, although the malign version is reported in most cases. Feeding of old bread containing the mould *Aspergillus flavus* is speculated to contribute to producing neoplasias (Wallach and Boever, 1983, pp.564-565). *Aspergillus flavus* is an aflatoxin and is known to cause similar tumours in different kinds of laboratory animals (Wogan, 1966). Furthermore, Hage and Dorresstein (1994, p.129) mentioned the high life expectancy of bears ex situ, which may be related to the occurrence of neoplasias, as neoplasias occurs more often in older individuals.

To a much lesser extent, deficiencies occur in ex situ situations, because bears are fed complete dry dog food that includes minerals and vitamins. If no commercial diets are fed, the most frequently occurring deficiencies are B-complex and calcium deficiencies, along with hypothyroidism (Wallach and Boever, 1983, pp.554-555).

Gastritis and gastric diseases are frequently observed in bears, due to their tendency to eat almost anything and in large amounts. Symptoms may include emesis, salivating, diarrhoea and abdominal distension with colic and constipation. Gastritis is often the result of eating garbage or foreign objects. Acute gastritis dilatation has been observed in bears after they have eaten large amounts of dry dog food followed by large volumes of water. In this case, death may result in undiagnosed cases. The therapy used is the same as for dogs (Wallach and Boever, 1983, pp.562-563).

It is expected that the main problem confronting bears in captivity is obesity. Unfortunately, no literature was found with regard to this assumed problem.

4. Results

During this research project, a survey was sent to several institutions to gather information about different ex situ situations and the diet maintained. In addition, the current diet implemented at Emmen Zoo was analysed for its digestibility. Results obtained from the survey are discussed in the first part (4.1. Survey) of this chapter; results of the digestibility analyses are given in the second part (4.2. Nutrient analyses).

4.1. Survey

The survey was constructed with reference to different subjects and the results will be shown in this section of the chapter, moving through the different questions. First the response from institutions in different parts of the world will be shown, followed by general results with regard to the animals, enclosures, feeding, diet, hibernation and health problems.

4.1.1. Response

In total, 63 institutions, including Emmen Zoo, received the survey, and 20 institutions responded, of which 16 returned the completed survey: a total result of 25%. With five out of 16 surveys returned, Europe had the highest response at 31%, followed by North America with 11 out of 44 returned, which is a response of 25%. There was no response from the three other parts of the world (South-Africa, South America and Australia). An overview of the surveys sent and the responses can be found in Table 16. For the institutions that responded, see Table 17, and for a detailed list of the institutions that responded, see Appendix III. A detailed list of the researchers contacted can be found in this appendix as well.

Table 16 – Sent and received number and percentage of responses to the surveys in the period between March 2008 and May 2008.

Part of the world	Sent No.	Response No.	Response %
North America	44	11	25%
Europe	16	5	31%
Other	3	0	0%
Total	**63**	**16**	**25%**

Table 17 – Names and given numbers of the institutions that returned the surveys as well as Ouwehands Zoo (No. 104), from which data originated from Meetsma and Pfauth (2005).

No.	Name institution	No.	Name institution
6	Dierenpark Emmen	37	Great Plains Zoo
7	Indianapolis Zoological Society Inc.	44	Little Rock Zoo
12	Pittsburgh Zoo & PPG Aquarium	46	Moscow Zoo
15	Silver Springs Natures Theme Park	47	Nikolaev Zoo
18	Tierpark Hagenbeck GmbH	48	North Carolina Zoological Park
21	Zoo Duisburg AG	49	Northwest Trek Wildlife Park
25	Assiniboine Park Zoo	56	Saint Louis Zoo
33	Columbus Zoo and Aquarium	104	Ouwehands Zoo
34	Dakota Zoo		

4.1.2. General animal information

In total, the 16 institutions keep 40 *Ursus arctos* species: hence, an average of 2.5 bears per institution. The different subspecies are listed below in Table 18. Of the 40 bears, 26 were males and nine of these had been castrated. The average age of the bears was 17.7 years, with the oldest female being 34 and the youngest bears one year old. The age range of the 40 bears is displayed in Figure 10.

Table 18 – Different Ursus arctos subspecies kept by the institutions.

Animals	No.
Ursus arctos middendorffi	12
Ursus arctos horribilis	13
Ursus arctos beringianus	10
Ursus arctos	3
Hybrid *Ursus arctos middendorffi/horribilis*	2
Total	**40**

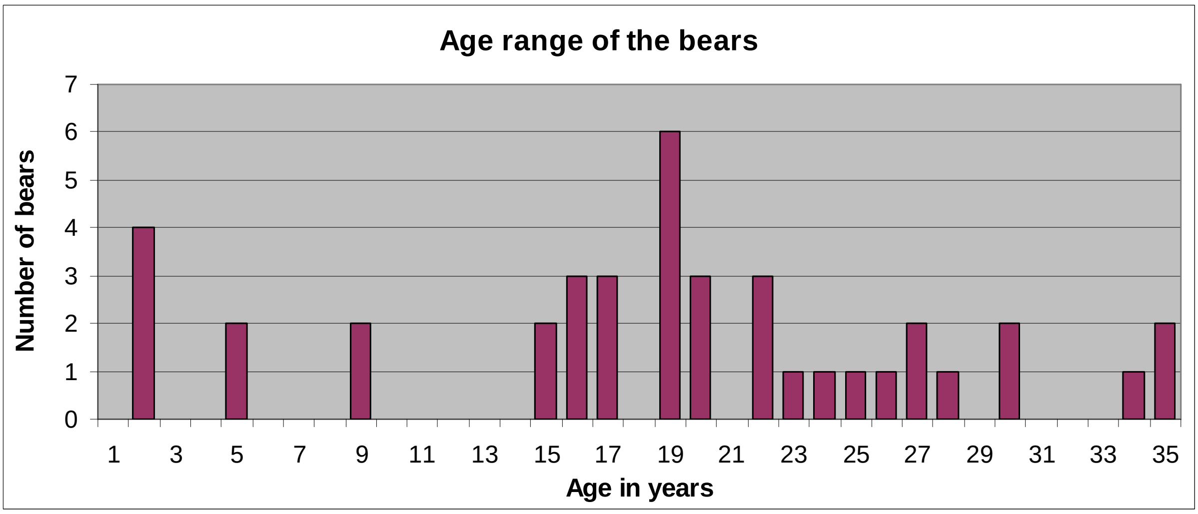

Figure 10 – The age range of the survey population, including 40 bears.

4.1.3. General enclosure information

The 16 institutions reported a total of 31 indoor and 21 outdoor enclosures, the sizes of which varied considerably. For more information about enclosure sizes, see Table 19 below.

Table 19 – Surface dimensions of the 31 indoor and 21 outdoor enclosures, with the average and median in square metres.

Surface indoor m²		Surface outdoor m²	
200	Biggest	4500	Biggest
5	Smallest	70	Smallest
22.9	Average	796	Average
11.5	Median	502	Median

The floor in all indoor enclosures was made of concrete. In the outdoor enclosures, nine out of 21 were made of concrete, three were made of a mix of concrete and dirt and the other nine were compiled of natural materials like dirt, grass or rock.
The group size of bears kept in indoor enclosures was as follows: twelve bears were alone, 14 bears were in groups of two and two groups of four bears were kept together. In the outdoor enclosures,

eight bears were kept alone, 20 bears were in groups of two, one group contained three bears and in two instances a group of four bears were kept together (see Table 20).

Table 20 – Group sizes of the indoor and outdoor enclosures.

Group size	Enclosures Indoor	Enclosures Outdoor
1	12	8
2	7	10
3	0	1
4	2	2

In each institution, the accessibility of the enclosures is arranged differently. In some, the bears have access to the indoor enclosure during the cleaning period only, but in others the whole day long. The accessibility may also differ per individual and this may result in different access arrangements for each institution. Most bears have daily access to the outdoor enclosures throughout the whole year, although sometimes only in the daytime (see Table 21).

Table 21 – Access arrangements for bears to enter the enclosures.

Access indoor		Access outdoor	
10	Daily	13	Daily
7	At night	5	During the day
3	Only for cleaning	1	Every second day
1	Every second day		
1	Bad weather conditions		

Most institutions have non-food enrichment for bears in the indoor as well as in the outdoor enclosures. A complete list of all used non-food enrichments is given in Table 22. Because some institutions use more than one enrichment item, the total number is higher than the number of institutions.

Table 22 – Non-food enrichment items used indoors and outdoors.

Enrichment indoor		Enrichment outdoor	
3	Toys	17	Pool/stream/waterfall
2	Pool	12	Trees/bushes/forest
1	Barrel	9	Trunks
1	Den	5	Rocks
1	Hay	4	Dig pits
1	Plastic balls	2	Toys
1	PVC pipes	1	1,1 *Ursus thibetanus*
1	Rope	1	Tactile olfactory
1	Tactile olfactory	1	Trunks squat
1	Trash cans		
1	Trees		
1	Trunks squat		

4.1.4. Feeding information

In four institutions, bears received the same quantity of food throughout the whole year and in nine institutions the same food items. Of the 16 institutions, eleven weighed the food for the bears and in six the amounts were estimated.

The diets differed between the institutions with regard to energy, food items and quantity. The amount of energy per day and per bear varied among all institutions: for instance, in September between 25 MJ and above 100 MJ. For an overview of the average energy and median of all diets, see Figure 11. For more details see Figure 12, which shows the fed energy at institutions that provided a seasonal fluctuating diet during the year; see Figure 13 for the fed energy at institutions that fed the same quantity all year round.

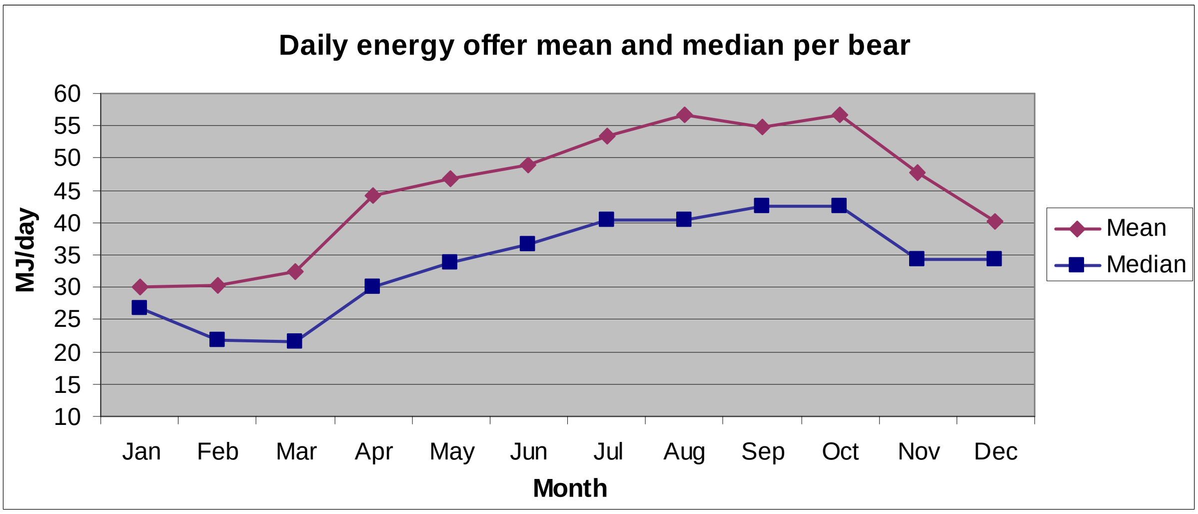

Figure 11 – The mean and median of the daily energy offered per bear for each month.
Data was used from all institutions except No. 7 and No. 34, and from institution No. 18 only data from February was used for the calculation. It was not possible to create an overview of the fed energy during a 12-month period at these institutions.

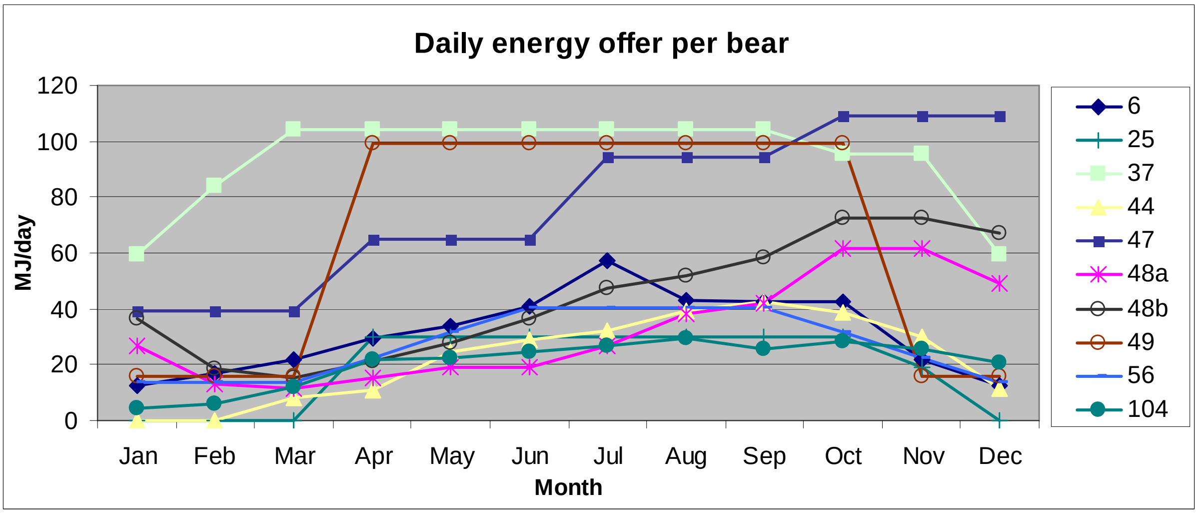

Figure 12 – Daily energy offered per bear for each month in institutions that fed a seasonal changing diet throughout the year.

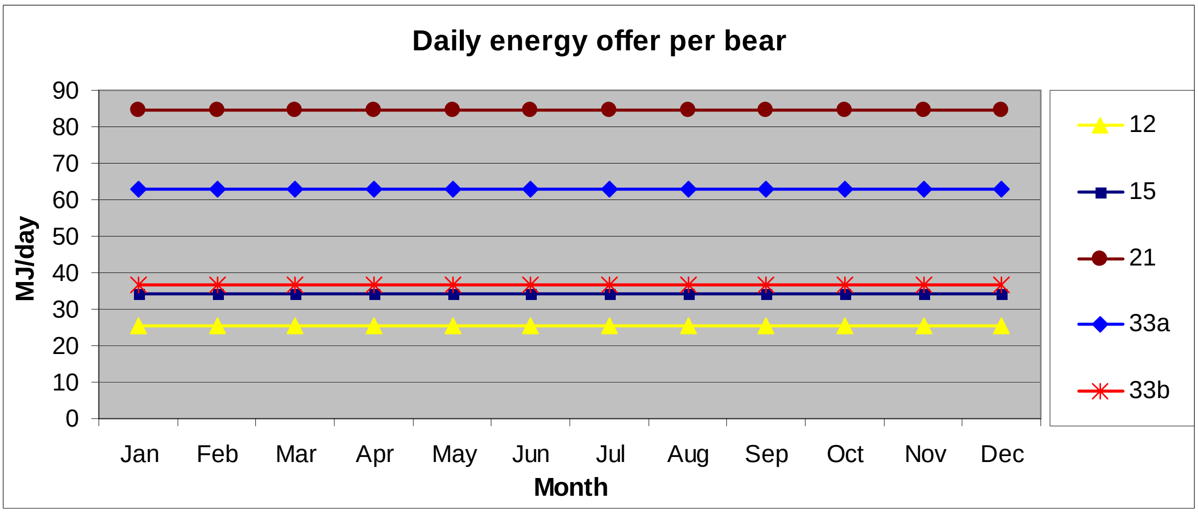

Figure 13 – Daily energy offered per bear for each month in an institution that fed the same quantity throughout the year.

Food items

More than 68 different food items were fed to the bears in the 16 institutions. Apples and complete dry dog food were the most frequently offered food items: 12 and 11 institutions, respectively, fed these, followed by carrots, fish and meat, which were provided in 10 institutions. For more details see Table 23, where the 15 most frequently fed food items are listed. Different fish, meat/bones and feeders are combined and a detailed list is found in Appendix VII.

Table 23 – The 15 most provided food items in the 16 institutions.

Food items	*6	7	12	15	18	21	25	33	34	37	44	47	48	49	56	104	N
Apples	X		X	X	X	X	X	X	X	X	X		X			X	12
Dry dog food	X		X	X	X	X	X		X	X	X	X	X				11
Carrots			X	X	X	X	X	X		X		X	X			X	10
Fish	X		X			X		X	X	X		X	X		X	X	10
Meat/Bones	X	X			X	X	X		X	X	X	X				X	10
Bread	X	X			X		X		X	X		X				X	8
Omnivore Diet		X	X					X					X	X	X		6
Sweet potatoes			X	X				X		X	X		X				6
Oranges			X	X	X						X		X				5
Carnivore diet		X									X		X		X		4
Grass	X	X				X					X						4
Pears								X	X							X	3
Corn on the cob											X	X				X	3
Diverse fruits	X	X										X					3
Lettuce				X					X							X	3

**Number of the institution*

The number of food items fed in institutions range from four to 21, and the average number of different food items used per institution is nine and ten (see Figure 14).

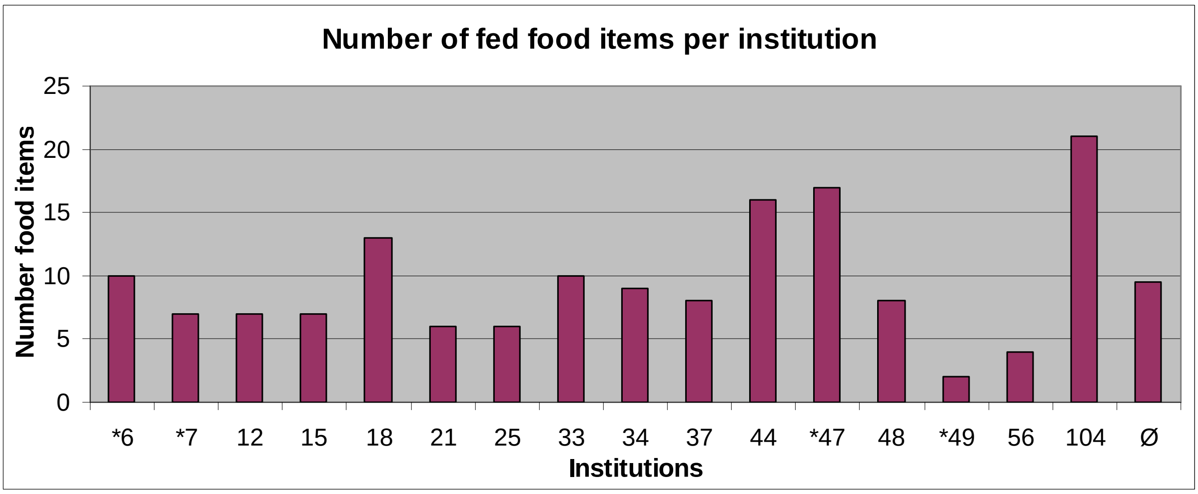

Figure 14 – Number of different food items fed in each institution.
**Institutions No. 6, 7, 47 and 49 are probably undercalculated. These institutions fed different fruits, different vegetables or a mix of fruit and vegetables counted as one food item in the figure, but these items are compiled of different foods.*

4.1.5. Enrichment

The use of food as enrichment is applied in 15 institutions in many diverse ways; no information was available from one of the institutions. An overview is given in Table 24; some institutions use different methods. Food items that were used for enrichment are listed in Appendix V.

Table 24 – Food enrichment used in 15 institutions.

Food enrichment	
14	Food scattered/spread/distributed
9	Food hidden
9	Ice blocks
6	Bones or meat with bones
4	Sweets (honey or syrup)
2	Food in toys
1	Fish whole
1	Food dispenser
1	Hand feed
1	Live fish
1	Smell

The spreading of feeding times over the day differed considerably between the institutions. Some fed once a day, whereas others fed up to six times a day. The places and times of feeding differed as well, ranging from fixed places and times to different places and times.

Most institutions mentioned experience as an important source for diet compilation. Zoos and the literature were often named as sources as well. The different sources are listed below in Table 25; some institution named more than one source.

Table 25 – Sources for the diet compilation used in 16 institutions.

Source	
11	Experience
7	Other zoos
6	Literature
2	Data from in situ diet
2	Nutritionist
1	Veterinarian

4.1.6. Weight of the bears

Half of the institutions saw a weight fluctuation over the year and the other half did not. Of the institutions that saw a fluctuation, the estimated changes were between 10-30%. The facility to weigh the bears was present in six institutions. For five bears in two of the institutions, the weight was measured regularly between January 2007 and February 2008. The weight fluctuations are displayed in Figures 15 and 16.

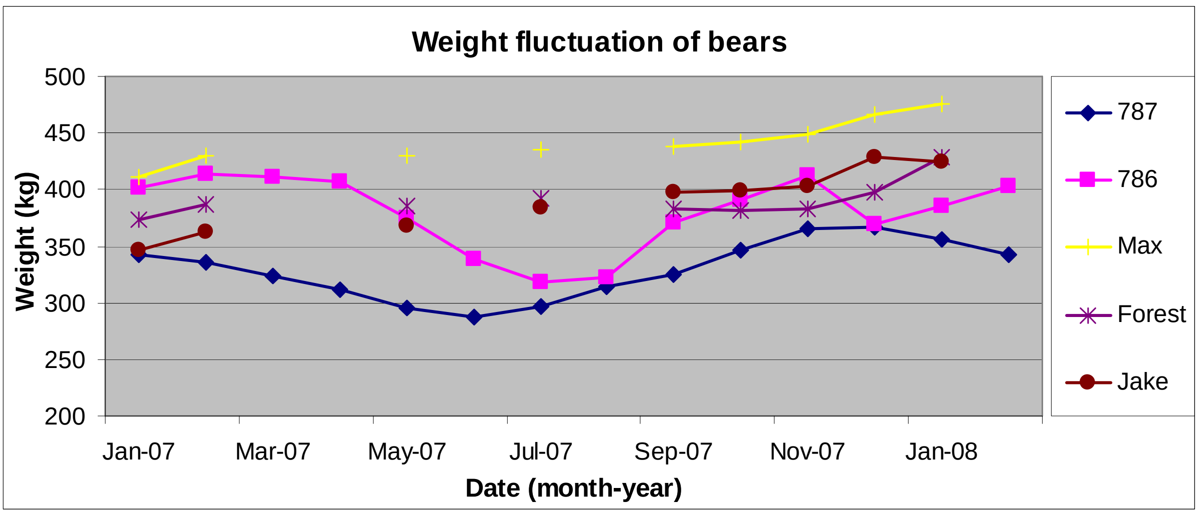

Figure 15 – Weight fluctuations of five bears from two institutions.

No. 787 and 786 are two hybrids Ursus arctos middendorffi/horribillis from institution No. 49 and they were born in 1990. Max, Forest and Jake are three Ursus arctos middendorffi from institution 15 and they were born in 1993. Measurements were performed in January 2007 and February 2008.

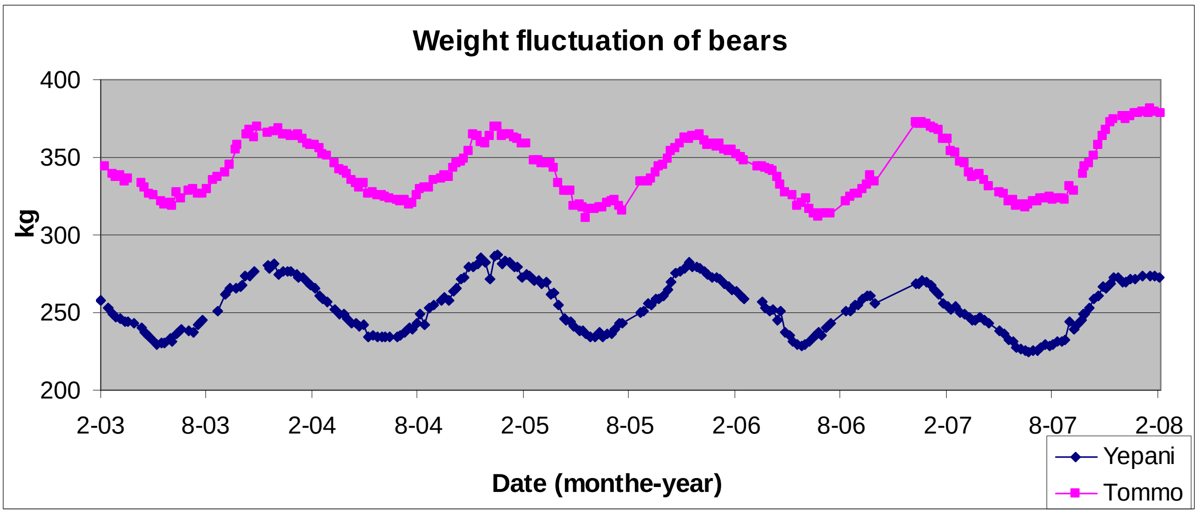

Figure 16 – Weight changes in two *Ursus arctos horribillis.*
Yepani and Tommo from institution No. 48 were born in 1990 and 1992, respectively. Measurements were performed in February 2003 and May 2008.

4.1.7. Reproduction

Only bears at Moscow Zoo have bred successfully in the past few years. Two reasons that bears in the other institutions did not breed were that often only one gender was kept or the males had been castrated. The reasons for non-breeding are listed in Table 26.

Table 26 – Reasons that no breeding took place at institutions.

	Reason for no reproduction
5	Only one gender at the institution
4	Males were castrated
2	No specific information
2	Siblings
1	Age of the bears
1	Do not breed in this institution

4.1.8. Hibernation

In 11 institutions, none of the bears hibernated. In the other five institutions, nine bears hibernate, for an average length of four to five months. In some institutions, only females were allowed to hibernate.

4.1.9. Health information

Four institutions indicated that their bears have health problems relating to their diet. For two institutions, these included diarrhoea and tooth issues like caries; for the third institution, the problem was arthritis aggravated by obesity; for the fourth institution, the problem was hair loss, which was probably related to Mazuri® Ominvore Zoo Feed "A".

4.2. Nutrient analyses of Kodiak bear diet from Emmen Zoo

4.2.1. Results analyses

The analyses of the food and faeces samples from Kodiak bears at Emmen Zoo are shown in Tables 27, 29, 31 and 33 and the calculation of energy in Table 33. For a comparison between analysed and calculated nutrients, nutrients were calculated and are shown in Table 28 and 30. All results were calculated on a DM basis; for a calculation of the NFC, see formula below.

Formula 7 – Calculating non-fibre carbohydrates (NFC).

NFC = 100% - CP% - CFat% - NDF% - ash – sand

CP = crude protein, CFat = crude fat, NDF = neutral detergent fibre

Table 27 – Analyses results for Kodiak bear diets at Emmen Zoo (DM basis).

Sample date	DM	CP	CFat	NFC	CFibre	ADF	NDF	Ash
25.03.2008	**35.6%**	27.6%	4.7%	39.6%	*2.8%	**3.5%**	*20.1%	8.0%
26.03.2008	**47.9%**	20.8%	**30.9%**	20.7%	***7.2%**	****/*8.8%**	*23.8%	**3.8%**
27.03.2008	37.3%	21.6%	15.4%	30.9%	*3.6%	**/*4.9%	*25.6%	6.5%
28.03.2008	40.2%	**15.6%**	***2.0%**	**58.3%**	*3.4%	**/*5.7%	*19.2%	5.0%
29.03.3008	36.5%	**35.7%**	7.1%	30.2%	***1.9%**	**/*3.9%	*17.3%	**9.7%**
30.03.2008	38.8%	31.4%	12.7%	**16.1%**	2.7%	**/*5.8%	**32.9%**	7.0%
31.03.2008	38.4%	29.9%	4.0%	44.6%	*2.1%	4.0%	**12.7%**	8.8%
Average	**39.2%**	**26.7%**	**12.5%**	**34.4%**	**3.6%**	**5.4%**	**21.9%**	**7.0%**

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates, CFibre = crude fibre, ADF = acid detergent fibre and NDF = neutral detergent fibre

**Bigger difference between the replicates than the permitted ± 3% of the mean*

***The mean of two or more analyses*

CFat, CP and NFC have high variations between the different samples ranging from 2% to 30.9%, 15.6% to 35.7 and 16.1% to 58.3 respectively. This reflects the sample compilation, whereas some samples contain more fatty animal products than others.

Table 28 – Calculation results for Kodiak bear diets at Emmen Zoo (DM basis).

Sample date	DM*	CP	CFat	NFC	CFibre	Ash
25.03.2008	36.8%	30.8%	7.2%	4.3%	26.3%	4.7%
26.03.2008	46.5%	22.2%	29.4%	3.5%	21.7%	3.5%
27.03.2008	36.8%	23.7%	13.3%	5.9%	33.4%	5.1%
28.03.2008	44.4%	15.2%	4.6%	6.0%	33.0%	4.6%
29.03.3008	37.1%	40.2%	9.5%	3.1%	21.8%	5.3%
30.03.2008	38.4%	34.6%	8.5%	3.8%	24.2%	5.1%
31.03.2008	41.0%	31.9%	8.0%	3.9%	25.9%	5.1%
Average	**39.9%**	**29.2%**	**12.5%**	**4.2%**	**25.8%**	**4.7%**

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates and CFibre = crude fibre

**Data used for the calculation were from the USDA and other sources; for details, see Appendix VI and XIII*

The calculated and chemically analysed nutrient values in food items have a highly similar average for DM, CP, CFat, CFibre and ash. The biggest difference is 8.6% between the NFCs. The differences are often bigger between the different samples.

Table 29 – Mineral analyses of the diet including the Ca:P ratio (DM basis).

Sample date	**Na**	**K**	**Mg**	**Ca**	**P**	**Ratio Ca : P**
25.03.2008	0.09%	0.64%	**1.43%**	*0.91%	*0.93%	0.98 : 1
26.03.2008	**0.06%**	**0.62%**	*0.84%	**0.28%**	**0.44%**	0.64 : 1
27.03.2008	0.09%	**0.90%**	*0.95%	0.54%	0.65%	0.82 : 1
28.03.2008	0.08%	0.70%	***0.84%**	0.35%	*0.52%	0.67 : 1
29.03.3008	0.10%	**/*0.76%	1.21%	***1.20%**	***1.18%**	1.02 : 1
30.03.2008	0.10%	0.82%	1.08%	0.57%	0.80%	0.72 : 1
31.03.2008	**0.10%**	0.67%	0.93%	1.07%	*1.06%	1.01 : 1
Average	**0.09%**	**0.73%**	**1.04%**	**0.71%**	**0.80%**	**0.88 : 1**

**Bigger difference between the replicates than the permitted ± 3% of the mean*

***The mean of two or more analyses*

The ratio from Ca and P are on average 0.88:1 (Table 29); only in two food samples were the Ca values higher than the P values. The difference between samples is highest with Ca, with a factor of 4.3 between the lowest and highest percentage.

Table 30 – Calculated mineral content including the Ca:P ratio (DM basis).

Sample date	**Na**	**K**	**Mg**	**Ca***	**P**	**Ratio Ca : P**
25.03.2008	0.45%	0.53%	0.11%	0.43%	0.54%	0.80:1
26.03.2008	0.36%	0.39%	0.08%	0.36%	0.42%	0.85:1
27.03.2008	0.39%	0.62%	0.15%	0.52%	0.58%	0.89:1
28.03.2008	0.55%	0.31%	0.11%	0.48%	0.45%	1.06:1
29.03.3008	0.42%	0.73%	0.12%	0.49%	0.64%	0.76:1
30.03.2008	0,45%	0.65%	0.12%	0.49%	0.60%	0.81:1
31.03.2008	0.46%	0.57%	0.12%	0.50%	0.59%	0.85:1
Average	**0.43%**	**0.55%**	**0,.11%**	**0.46%**	**0.55%**	**0.84:1**

**Data used for the calculation were from the USDA and other sources; for details, see Appendix VI and XIII*

The average amount of Mg present in the food samples was 0.11% in the calculated results, which is much lower than in the chemically analysed food samples, which resulted in an amount of 1.04% Mg. For the amount of Na, it was the opposite, and the chemically analysed food samples had much lower outcomes, with an average amount of 0.09%; the calculated food samples resulted in an average amount of 0.55% Na.

Table 31 – Analysis results for Kodiak bear faeces at Emmen Zoo (DM basis).

Sample date	DM	CP	CFat	NFC	CFibre	ADF	NDF	Ash	Sand
26.03.2008	19.2%	17.4%	*2.4%	9.2%	16.0%	*25.2%	40.1%	26.5%	*4.5%
27.03.2008	16.0%	20,9%	2.7%	7.7%	13.7%	*24,8%	41.3%	*22.1%	5.3%
28.03.2008	19.3%	18.8%	6.8%	16.0%	13.3%	23.1%	37.2%	18.4%	2.9%
29.03.2008	18.3%	16,9%	*1.8%	17.8%	13.9%	15.5%	31.0%	30.9%	*1.6%
30.03.2008	18.9%	*20.0%	1.8%	15.9%	*9.2%	14.8%	*27.1%	34.2%	*1.1%
31.03.2008	18.1%	17.8%	*1.6%	17.1%	*13.2%	18.0%	30.6%	31.0%	1.9%
01.04.2008	18.2%	16.2%	1.4%	10.0%	11.2%	20.2%	37.7%	29.9%	*4.8%
Average	**18.3%**	**18.2%**	**2.7%**	**13.4%**	**13.0%**	**20.3%**	**35.0%**	**27.5%**	**3.1%**

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates, CFibre = crude fibre, ADF = acid detergent fibre and NDF = neutral detergent fibre

**Bigger difference between the replicates than the permitted ± 3% of the mean*

Table 32 – Mineral analysis of the faeces (DM basis).

Sample date	Na	K	Mg	Ca	P
26.03.2008	**/*0.15%	1.28%	2.77%	3.60%	2.77%
27.03.2008	0.18%	1.07%	*3.64%	2.46%	1.85%
28.03.2008	**/*0.12%	0.87%	3.64%	2.40%	1.64%
29.03.2008	0.19%	1.49%	*3.49%	4.80%	3.59%
30.03.2008	**/*0.22%	1.65%	4.96%	5.58%	4.42%
31.03.2008	**/*0.17%	1.49%	4.18%	*4.93%	3.65%
01.04.2008	**/*0.16%	1.44%	3.19%	4.55%	*2.70%
Average	**0.17%**	**1.32%**	**3.67%**	**4.04%**	**2.94%**

**Bigger difference between the replicates than the permitted ± 3% of the mean*

***The mean of two or more analyses*

The faeces samples contained an average of 18.3% CP in DM, which is a high amount of CP in comparison to the results of the food samples, where the average amount of CP was 26.1%. CFat was much lower in the faeces samples, with an average amount of 2.6%, than in the food sample, with an average amount of 11%. The fibres and NFC were higher compared to the food samples. All minerals were also higher compared to the food samples.

Table 33 – Calculation of energy in food and faeces samples (DM basis).

Sample data	Chemically analysed kJ/100g food	Calculated kJ /100g food	Chemically analysed KJ/100g faeces
25.03.2008	*1148.4	1680	
26.03.2008	1705.8	2163	710.2
27.03.2009	1315.7	1736	861.0
28.03.2009	1150.4	1583	1035.1
29.03.2010	1215.3	1733	839.8
30.03.2010	1144.6	1701	925.0
31.03.2011	1231.0	1684	819.5
01.04.2008			762.2
Average	**1273.0**	**1780**	**850.4**

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates, ME = metabolic energy

**kJ ME = CP * 14.6 + CFat * 35.6 + NFC * 14.6*

***Difference = Food kJ - Faeces kJ day after*

Formula 8 – Calculation of energy in food and faeces samples.

Energy Energy = CP * 14.6 kJ/g + CFat * 35.6 kJ/g + NFC * 14.6 kJ/g CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates

Results of the chemical and calculated analysis of the samples to detect the amount of energy (kJ) present were quite different. The calculated energy was always higher than the chemically analysed energy. Furthermore, the amount of energy resulting from chemically analysed faeces was approximately one-third lower than that resulting from chemically analysed food samples. For an example of the calculation of energy from food and faeces samples, see Formula 8.

4.2.2. Digestion coefficient (DCFI)

The bears at Emmen Zoo used 82% and 95%, respectively, of the CP and CFat present in the fed food items. CFibre and ADF present in the fed food items were poorly used: in total 7% and 3%, respectively. NDF, however, was digested for more than 50% and NFC for 88%. Eighteen percent of the energy was found back in the faeces. An example of the calculation of the DCFI of CP is shown in Formula 9.

Formula 9 – Calculation example of the digestion coefficient (DCFI) of crude protein (CP)

DCFI CP = (kg fed CP – kg faeces CP) / kg fed CP Fed CP = The amount of CP of the total fed diet present on a dry matter basis. Faeces CP = The CP from the total estimated amount of faeces on a dry matter basis.

Table 34 – Digestion coefficient (DCFI) of the analysed food and faeces samples. The energy composition is the average of the total sampling period of seven days.

	CP	CFat	CFibre	ADF	NDF	NFC	Ash	Energy
Average DCFI	82%	95%	7%	3%	58%	88%	4%	82%

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non-fibre carbohydrates CFibre = crude fibre, ADF = acid detergent fibre and NDF = neutral detergent fibre
For the calculation, an average of 7.67 kg faeces per day was used.

In the faeces samples, 55% more Ca was present than in the food samples. A possible reason for this result is discussed in the next chapter. Na and K were used for approximately 50% and Mg and P were used very poorly, at only 5% and 0%, respectively.

Table 35 – Digestion coefficient (DCFI) of the analysed food and faeces samples. The mineral composition is the average of the total sampling period of seven days.

	Na	K	Mg	Ca	P
Average DCFI	47%	51%	5%	-55%	0%

For the calculation, an average of 7.67 kg faeces per day is used.

5. Discussion

To optimise the diet for Kodiak bears at Emmen Zoo, a comparison was made between the in situ and ex situ diets provided in several institutions. Based on the animal's known seasonal foraging behaviour and the known nutrient values of the food items, a conceivable in situ diet was compiled for an average bear. In this chapter, general observations will be discussed first, followed by the general points of interest concerning the method and then the results of this research project.

5.1. General observations

An obvious feature was the level of communication at Emmen Zoo. Several animal caretakers were approached at the start of this project, and each had his or her own differing point of view with regard to the health of the bears and the compilation of their diet.

Another feature was the bears' outside enclosure. When the bears move from one side of the enclosure to the other it is difficult for them to avoid each other and this may cause tension. Furthermore, it is not possible to keep the bears separated in the outdoor enclosure. Thus, if the three bears are not able to be kept together, they are separated by placing one or two of them in the indoor enclosure.

5.2. Method

5.2.1. Survey

The survey results from the different institutions were sometimes difficult to compare. For example, the question about diet was answered in a number of ways. One institution reported the exact weight of each food item fed, whereas another entered the amount as being one bucket of carrots or five fishes. Some institutions reported only the diet for a period of one month, whereas others reported a diet for each month over the whole year.

Another aspect concerned questions that were simply answered with a 'yes' or a 'no', though they required a more detailed response. Queries concerning weight, reproduction, hibernation and health were often answered negatively and did not provide any further information. As a result, almost no data from the institutions could be used to identify a possible relationship between the bears' diet and hibernation, reproduction and health in an ex situ situation.

It was reported how much of which food items was offered to the bears in the institutions, but it is not known whether all the food offered was consumed. As a consequence, the actual energy intake may be lower than reported.

Nutrient values of the food items present in the in situ and ex situ diets used in this research project may deviate from the actual values. Most sources providing nutrient values of food items use the edible products for humans, and these exclude the skin, seeds, bones and intestines, which may be consumed by bears. Overall, the products that bears consume probably contain more fibre and have a lower digestibility.

5.2.2. Digestibility analyses

For the digestibility analyses, food and faeces samples were collected at Emmen Zoo. Because their Kodiak bears also defecate in the water, the faeces samples collected from the ground constituted most of the total mass. An estimation of the collected faeces from the total faeces mass was made by the keepers. On some days this estimation was not given and therefore the correct total amount of faeces is not known. This may have influenced the outcome of the diet digestibility analysis. If the amount of faeces collected was estimated too high, the digestibility coefficient was underestimated; in

the event that the amount of collected faeces was estimated too low, the digestibility coefficient was overestimated.
Another aspect influencing the digestibility coefficient is the sample taking of several bears and using this as one sample, n = 1. Each bear has a different digestive capacity. In the event that the collected faeces were not mixed equally or one bear produced more faeces than the others, the average digestibility factor may be biased.
Unfortunately, there were problems involving the accuracy of the results. In the NDF, ADF and CFibre analyses, small amounts of the sample were released as a result of soaking in acetone or ether. This may have influenced the precision of the replicates. Another aspect was the homogeneity of the samples. Different kinds of food items were mixed and kept in closed glass jars; the heavier items may have sunk faster than the lighter ones, which could have affected the homogeneity.

5.3. Results

5.3.1. Ex situ weight and energy intake

The amount of energy offered to bears was extremely diverse, and the weight of the bears varied as well. An overview of the daily amount of energy offered each month to bears of different weights in the different institutions is given in Figure 17.

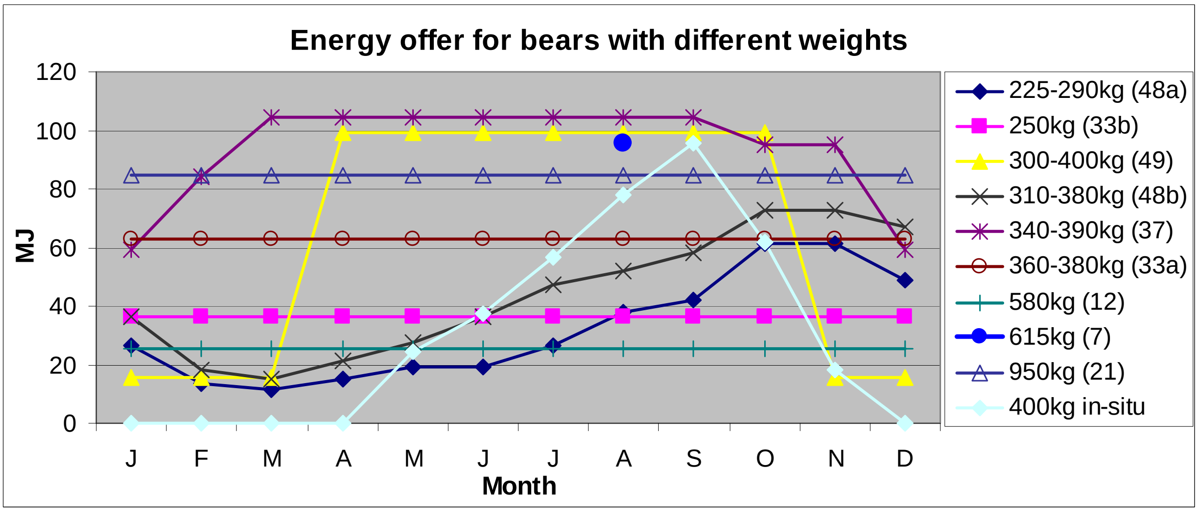

Figure 17 – Amount of energy (MJ/day) offered each month to bears of different weights.

To compare the offered amount of energy between the bears, the average annual offered energy $BW^{0.75}$ is shown in Table 36. The amount ranges between 0.21 and 1.18 MJ/day $BW^{0.75}$ and 0.35 MJ/day $BW^{0.75}$ for the ex situ and in situ situation, respectively. It should be noted that in the in situ situation a hibernation period of five months occurs, while in the ex situ situation no hibernation or a shorter hibernation period takes place. Furthermore, the expected amount of consumed energy is used for the in situ situation and not the offered amount of energy. In the ex situ situation, it is assumed that the amount of energy offered is equal to the consumption of energy. The average annual amount of offered energy in all institutions is 0.64 MJ/day $BW^{0.75}$; this is three times higher than the lowest amount of energy offered and nearly half of the highest amount.

Table 36 – Average amount of energy (MJ/day) BW$^{0.75}$ offered to several bears of different weights.

	Ø Energy (MJ/day) BW$^{0.75}$		
Weight bears (inst.)	**Lowest weight**	**Highest weight**	**Average weight**
225-290 kg (48a*)	0.55 MJ/day	0.46 MJ/day	0.50 MJ/day
250 kg (33b)		0.58 MJ/day	0.58 MJ/day
300-400 kg (49)	0.90 MJ/day	0.72 MJ/day	0.81 MJ/day
310-380 kg (48b)	0.60 MJ/day	0.51 MJ/day	0.55 MJ/day
340-390 kg (37)	**1.18 MJ/day**	1.07 MJ/day	1.12 MJ/day
360-380 kg (33a)	0.76 MJ/day	0.73 MJ/day	0.75 MJ/day
580 kg (12)		**0.21 MJ/day**	0.21 MJ/day
615 kg (7)**		0.77 MJ/day	0.77 MJ/day
950 kg (21)		0.49 MJ/day	0.49 MJ/day
400 kg in situ		**0.35 MJ/day**	
Average institutions			**0.64 MJ/day**

**Number institution, **Only data from August are included in the calculation*
Calculation: annual average offer per BW$^{0.75}$ / day

The diets of bears are often rich in energy, and the chance is high that bears also consume this high amount of energy and then fall victim to gastric diseases and obesity. In comparison to dogs, bears have a large body size and should actually need less energy per BW$^{0.75}$ than dogs, since larger animals need relatively less energy than smaller animals (Kleiber, 1961). The opposite can be seen in the results of this research project; the average energy of 0.64 MJ/day BW$^{0.75}$ offered to bears is much higher compared to the average needs of normal active dogs, which is 0.40-0.55 MJ / BW$^{0.75}$ (NRC, 2006). In addition to this, it is also known that an animal containing a high amount of fat needs relatively less energy to maintain the BMR than do slender animals, because considerably less energy is needed to maintain a kg of fat tissue than a kg of other tissue. Hence, it can be expected that many bears are too heavy and have similar problems as dogs with regard to obesity.

5.3.2. Hibernation and energy intake in ex situ situations

Comprehensive diet information is needed to compare the energy intake of bears that hibernate. Bears kept in institutions No. 25 and 44 hibernate, and a complete record of their diet was available as well. The diet offered in institution No. 44 has a fluctuation over the year similar to the in situ diet but with softer peaks and less fluctuation. The diet offered in Institution No. 25 has few similarities to the in situ diet, apart from the occurrence of hibernation. The energy intake of the in situ diet and diets of institutions No. 25 and 44 are shown in Figure 18 in paragraph 5.3.5.

5.3.3. Reproduction

Kodiak bear reproduction has not been successful at Emmen Zoo over the past few years, although copulation does occur. Most of the institutions that participated in the survey do not breed the bears, and therefore the survey results did not yield the desired information.
Most institutions prefer not to breed; they keep only one gender, or castrate the males or keep siblings. Successful reproduction did take place at one zoo in the past, but the bears are now too old. The age of the bears may also be the reason for unsuccessful reproduction at Emmen Zoo. The only institution that still breeds Kodiak bears successfully is Moscow Zoo, although no information about the diet was provided and no other obvious or pertinent results emerged from their response to the survey.

Information from in situ research executed by Hilderbrand et al. (1999c) showed the existence of a relation between diet quality and mean litter size and weight and mean litter size. Females with access to high-quality meat in large amounts give birth to more cubs than do bears without this access. Females also produce bigger litter sizes when they have a higher weight than do females with a lower weight.

5.3.4. Health status of bears ex situ

The only known health problem in relation to diet in situ is the shedding of foot pads during hibernation, which might occur as a result of a B-complex deficiency (Wallach and Boever, 1983, p.555). It is not known to occur in ex situ situations, and this may be related to the complete dry dog food that is fed as well as to the shorter hibernation period.

Endoparasites are known to be present in bears in situ, but are more characteristically present in bears ex situ (Kuntze, 1995). Local guides on Kodiak Island as well as native people state that the acid produced by berries helps to dislodge tapeworms, *Diphyllibothrium*, that are present in red salmon (Clark, 1957, p.147). In ex situ situations, veterinarian products are applied and can control the problem by intensive use.

Another difficulty for bears ex situ is neoplasia, although it occurs less often. It is expected to be related to the mould *Aspergillus flavus*, which is present for example on old bread. This is an aflatoxin and is known to cause similar tumours in different kinds of laboratory animals (Wogan, 1966).

Caries is also a more common problem and can be the result of a diet consisting of identical, soft and low-fibre food items. To prevent caries, branches and other fibre-rich food items should be included in the bears' diet (Kaya and Dorresstein, 1994; Wenker et al., 1996).

No other health problems have been reported to occur on a regular basis in bears in situ or ex situ. It was, however, no surprise that problems were observed in the locomotion of the bears, such as osteoarthritis or the occurrence of aberrations in glucose metabolism and homeostasis, since these are indicators of obesity in dogs (Case, 2005, p.63; Henegar et al., 2001; Impellizeri et al., 2000; Hess et al., 1999; Rocchini et al., 1999; Perez et al., 1998; Chikamune et al., 1995; West et al., 1992; Mattheeuws et al., 1984). One institution reported the occurrence of arthritis aggravated by obesity. Obesity was expected to occur in ex situ situations, because it is a known problem in zoos and bears are susceptible to obesity. The results of the survey also indicate possibly obese animals.

5.3.5. Comparison of in situ and ex situ diets

Energy is an important factor in the diet offered to Kodiak bears, and in this research project large differences are reported between the in situ and ex situ diet results. In many ex situ situations, bears do not hibernate and are fed throughout the year. Institutions No. 25 and 44 allowed the bears hibernate, but for a shorter period than would have been normal in situ. In the in situ situation, the differences in energy intake between the months are much higher than in the ex situations (see Figure 18 for more information).

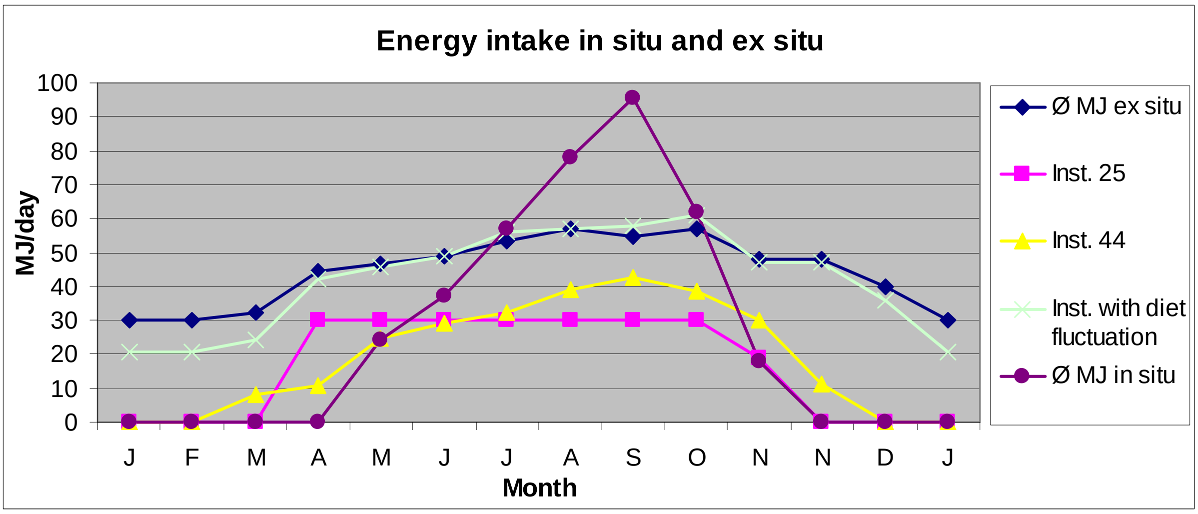

Figure 18 – Daily amount of energy intake expressed for each month for the ex situ and in situ situations.
The average amount of energy in the ex situ diet is based on 17 diets offered in 15 institutions. Institutions with diet fluctuations include ten diets from nine institutions. Average energy (MJ) in situ is in the diet in Table 14.

5.3.6. Nutrients

The amount of nutrients available in the in situ diet differs considerably from the ex situ diet. The percentage of protein present in the ex situ diet shows only a very small fluctuation between the months, whereas the protein percentage in the in situ diet has a strong fluctuation (see Figure 19).

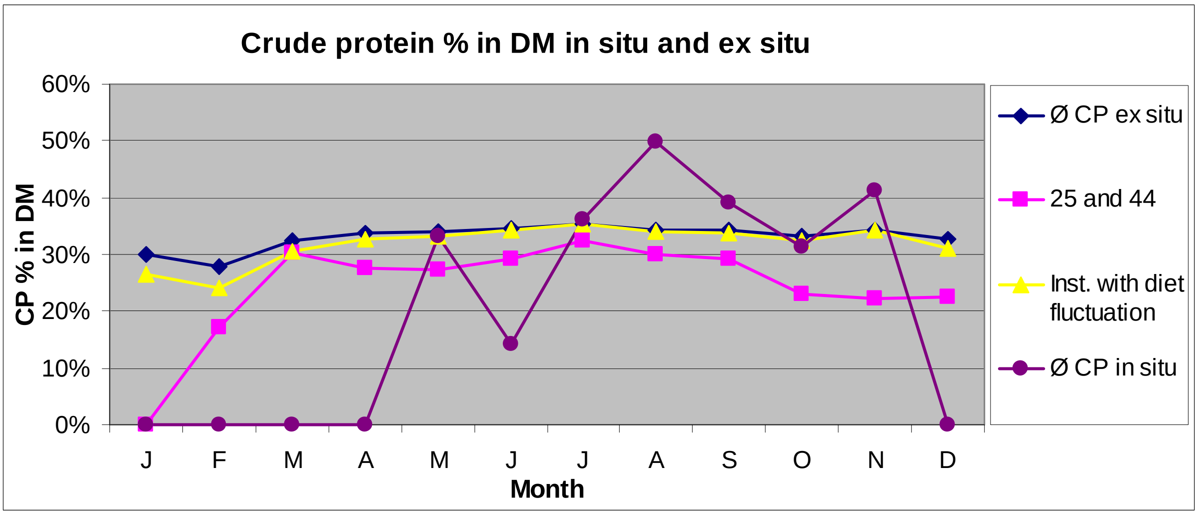

Figure 19 – Monthly protein percentages in, in situ and ex situ diets.
Average amount of energy (MJ) ex situ is based on 16 diets offered at 14 institutions. Institutions with diet fluctuation include ten diets from nine institutions. Average amount of energy (MJ) in situ is in the diet in Table 14. CP = crude protein, DM = dry matter

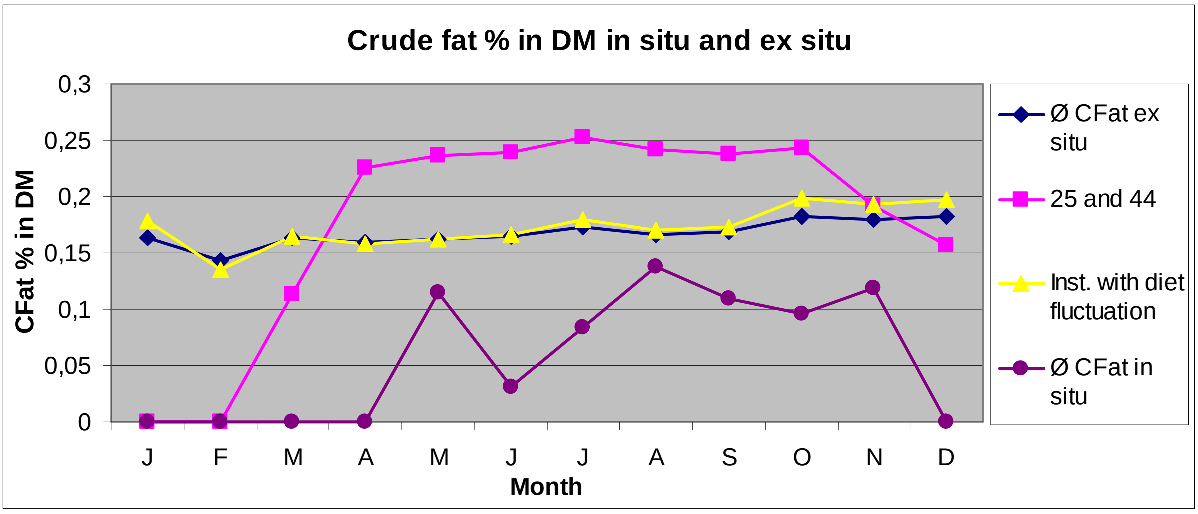

Figure 20 – Monthly fat percentages in, in situ and ex situ diets.

Average MJ ex situ are 16 diets offered at 14 institutions. Institutions with diet fluctuation are ten diets from nine institutions, average MJ in situ is in the diet in Table 14. CFat = crude fat, DM = dry matter

Fat percentages in the diets are similar to the protein percentages (see Figures 19 and 20 for the comparison). In the ex situ diet, small fluctuations occur in comparison to the in situ diet, and in the in situ diet the percentages are much lower than in those ex situ. The first peak of the in situ diet is not always present, depending upon the type of animal carrion. If it is deer carrion, the peak will be much lower, as most of the time deer die of starvation during the winter period, but in the case of a cetacean it might be a higher peak than in the figure. Substantial differences are also reported within the ex situ diets; institutions No. 25 and 44 had a much higher average than that in the other institutions.

5.3.7. Digestibility of the ex situ diet at Emmen Zoo

The main problem with calculating the DCFI for Kodiak bears at Emmen Zoo is that it is not precisely known how much faeces the bears produce per day, and this has a strong influence on the DCFI. Another factor that may have influenced the results is that it is unknown whether the bears consumed other food items, such as vegetation in the outdoor enclosure, although it has sparse vegetation, or whether they grazed the straw/hay that forms the cover of the indoor enclosure. In addition, it is not clear whether the bears were given supplements with the meat. These points might explain why the faeces samples contained more Ca (DCFI of -55%) than was found in the diet samples.
The DCFI of the analysed diet at Emmen Zoo is shown in Table 37 and the DCFI of polar, grizzly and black bears (Best, 1985; Ramsay, 1993; Meyer, 1998) in Table 38.

Table 37 – Digestion coefficient (DCFI) of the diet with the average values of the total sampling period of seven days.

DCFI	CP	CFat	CFibre	ADF	NDF	NFC	Ash
Average	82%	95%	7%	3%	58%	88%	4%

DCFI	Na	K	Mg	Ca	P	KJ
Average	47%	51%	5%	-55%	0%	82%

DM = dry matter, CP = crude protein, CFat = crude fat, NFC = non fibre carbohydrates, CFibre = crude fibre, ADF = acid detergent fibre and NDF = neutral detergent fibre

For the calculation an average of 7.67 kg faeces per day was used.

Table 38 – Digestibility (% of nutrients in diet) of different diets in bears (Best, 1985; Ramsay, 1993).

Diet	Polar bear			Grizzly bear			American black bear		
	DM	CP	GE	DM	CP	GE	DM	CP	GE
Herring, head removed	94	95	96						
Seal muscle + viscera	87	93	92						
Seal muscle, viscera, skeleton	54	75	82						
Seal muscle, viscera, skeleton, skin, blubber	82	83	92						
Seal skin + blubber	93	72	96						
Deer (meat, fat, skin, hair)				93	89	95	92	89	93
Beef (meat, fat, skin, hair)				96	96	97	93	93	93
Cutthroat trout (heads + tails removed)				90	95	94	87	94	92
Ground squirrel (whole)							76	85	84
Blueberries				64	19	63	65	17	64
White clover				46	77	51	45	76	51
Pinyon pine nuts							41	57	50
Yams + carrots							58	53	58
Alfalfa-grain pellets				48	63	48	56	69	44
Steelhead, alfalfa, pine nuts				58	85	65	60	88	66
Beef, clover, blueberries				67	79	70	67	79	70

DM = dry matter; CP = crude protein; GE = gross energy.

Deer = Odocoileus hemionus; Cutthroat trout = Salmo clarkii; Ground squirrel = Spermophilus columbianus; Blueberries = Vaccinium corymbosum; White clover = Trifolium repens; Pinyon pine nuts = Pinus edulis; Yams = Diocorea spp.; Carrot = Daucus carota; Alfalfa = Medicago sativa; Steelhead = Salmo gaidnerii; alfalfa-grain pellets = 50% alfalfa, 15% barley, 15% wheat, 10% corn, 6% molasses, 4% mineral and vitamin supplements

If the DCFI of CP is compared in those two tables, the 82% DCFI for CP of the Emmen Zoo diet is within the range of the other studies. The CDFI for CFat of 95% in the Emmen Zoo diet is very high in comparison to the other studies, but this was expected and can be compared to the CFat DCFI of cats (Kane et al., 1981) and dogs (Meyer, 1998). The DCFI for fibre is also similar for bears and dogs (Meyer, 1998).

6. Conclusion

The objective of this research was ‘To formulate the nutritional needs of Kodiak bears to design a new feeding protocol’. With the help of this new feeding protocol, Emmen Zoo hopes to accomplish its own goal: improvement in the seasonal weight fluctuation, reproduction successes and the wellbeing of the bears. First the sub questions will be answered, and with the help of these answers the project’s research question will be answered.

6.1. What comprises the in situ diet of Kodiak bears?

The estimated diet of a 400 kg bear with a hibernation period lasting from 18 November until 30 April is used as a starting point to answer this sub question. In the spring, bears emerge from their dens and slowly begin to feed on carrion and seaweed. Next, they feed on herbaceous food plants and have an energy intake of approximately 40 MJ/day, which helps them maintain their basal metabolic rate. At the start of the summer, grazing is continuous but it is replaced by salmon consumption in July and berries are added in August. In late summer and at the beginning of autumn, the foraging peak takes place and an energy intake of up to 100 MJ/day occurs. In autumn, the availability of food items decreases along with the amount of energy intake. At the end of autumn, bears feed on dead grasses, late spawning salmon and salmon carcasses. By November, the amount of energy is reduced to 20 MJ/day and a cleanup period starts and continues until the bears enter their dens.

6.2. What comprises the ex situ diets of Kodiak bears?

Eighteen diets provided at 16 institutions were analysed. Most of these institutions fed their bears different quantities and also different food items over the year.
The variation in food items used in the institutions is considerable, with more than 70 types of food being provided to the bears. With regard to the variation between items, there is also a wide diversity, ranging from different fruits and vegetables to browse products such as grass, bamboo or willow, and from honey and other sweets to meat and fish products and animal feeders, since complete dry dog or omnivore food is used in every institution as well.
The differences in nutrient and energy values between the diets are large but not surprising when one looks at quantity and the food items used. The amount of energy present in a diet demonstrated the differences between the diets very well when they were calculated for the metabolic weight of the different bears. The average offered energy per $kg^{0.75}$ bear/day over the year in all institutions is 0.64 MJ. This value is much higher than the needs of a normal active dog at 0.40-0.55 MJ $kg^{0.75}$.
The amount of protein and fat present in the ex situ diet are stable over the year and have a value of around 30% and 17%, respectively. Nutrient deficiency is not expected to occur, because most diets include a complete dry dog food.

6.3. How can diet influence hibernation, health and reproduction?

6.3.1. Diet-hibernation relation

When bears are fed the same amount of food throughout the year, they do not hibernate. It can be said that fluctuations in the diet with a peak in late summer/ beginning of autumn and a decrease in autumn stimulate the occurrence of hibernation.

6.3.2. Diet-health relation

According to the in situ literature, the only known health problem that relates to diet is the shedding of food pads, which is maybe caused by a B-complex deficiency. Several ex situ-related problems are known, including endoparasites, caries, neoplasias and gastric diseases. Food deficiencies are rarely seen and the occurrence of obesity was reported only once. Finally, it should be mentioned that uncooked pork should not be fed to bears because of the risk of them contracting Aujeszky's disease, which is fatal for them.

6.3.3. Diet-reproduction relation

On the basis of the survey, nothing can be said specifically about the influence of diet on Kodiak bear reproduction. In the last few years, only one institution has successfully bred Kodiak bears, and the diet applied in this institution is unknown.
Of the in situ situation, it is known that heavier females produce bigger litter sizes than do females that weigh less (Hilderbrand et al., 1999).

6.4. How do Kodiak bears use the different nutrients?

Little is known about the ability of bears to utilise the different nutrients. Kodiak bears have a shorter gut than ungulates and lack a fermentation chamber (Ramsay, 1993). In addition to these features, brown bear species have no caecum and their stomach is too acidic to encourage microflora (Rogers, 1976, p.183). It is possible that bears can digest cell wall constituents in the colon, but this is not yet clearly known. Furthermore, bears cannot move their jaws on the horizontal plane (Kolter, 1998, p.5-5; Ramsay, 1993). Kodiak bears have smaller premolars than those of other carnivores and the fourth upper premolar is more broadened and flattened (Kolter, 1998, p.1-8). These features make it possible for Kodiak bears to utilise herbaceous food items more efficiently than other carnivores but not as well as ungulates.
Bear scat demonstrates the varied digestibility of the food items, and the scat most characteristic of a period is mentioned below. After bears emerge from their dens and activate the body processes, they feed on carrion and seaweed. In this period, the scat consists of formless piles wherein food items appear in small chunks. Later in spring, when the bears also feed on herbaceous growth and conks, the scat piles have the appearance and odour of horse dung. At the start of the summer period, when the bears feed on salmon, the excrement is grey in colour and resembles that of cattle. In autumn, when berries are still eaten in abundance, characteristic scat contains piles of berries that have passed practically unscathed through the bears' alimentary system (Clark, 1957).
The digestibility coefficient (DCFI) of the diet resulting in 82% for CP and 95% for CFat is very similar to what is found in the literature for dogs and cats. For fibre, the difference is also small between the CDFI of fibre for dogs and the results from the analyses in this research project. The CDFI of minerals can be expected to be almost the same for bears as for dogs.

6.5. What is a good diet for Kodiak bears in ex situ situations?

A good diet contains aspects of seasonal fluctuation in quantity and quality, stimulating the bears' natural behaviour and supporting their physical and mental health.

6.5.1. Seasonal fluctuation

In the first one to two weeks after hibernation, bears have enough browse products to feed on. A slow start is then made with feeding on meat, grass, vegetables and complete feeders. During this time, the bears are still losing weight. After one to one and a half months, the amount of energy fed must be so high that the bears' weight stabilises. Next, the feasting period starts and the bears gain weight. At this time, fish is an important part of the diet in combination with fruits. In late summer and at the beginning of autumn, the energy intake peak occurs and the diet is rich in fruits, vegetables and animals products. After the peak, the amount of food decreases rapidly and more browse products are included in the diet. One week to ten days before hibernation, no fresh products are fed and the bears feed only on browse products during the cleanup period.

6.5.2. Stimulation

The diet must trigger the bears to activate their locomotion and have them active as long as possible. Different feeding times are a good way to break up the typical daily schedules. Furthermore, the food items should be offered in diverse ways, such as scattered, spread or hidden in the enclosures and also in different places. When food is provided inside the enclosures, using whole carcasses, live fish or food toys such as ice blocks containing pieces of apple and fish can also encourage the bears to be active.

6.5.3. Health

When providing bulk food, it is healthier for bears if the feeding regime is spread over the day to minimise the chance of gastric diseases; it also keeps them active. Branches and other fibre-rich structured items should also be included in the diet to prevent caries. To prevent nutritional deficiencies and to increase foraging time, complete dry dog food can be included in the diet. It may, however, be better to use another product with the same features but which is less energy dense in energy. Uncooked pork or old, mouldy bread should never be fed to the bears.

7. Recommendations

In conclusion, the research question 'What is a good diet for Kodiak bears in ex situ situations?' was answered. The diet compilation itself is referred to the Conclusion. In this chapter, recommendations are given to the nutritionists at Emmen Zoo for the improvement of the diet protocol. In the last paragraph, recommendations for subsequent research projects are made.

To motivate the bears to be more active, an increase in the use of enrichment items is suggested. Odour can be an effective means by using for example the faeces of other animals or tactile olfactory means. Further toys can be used, including tree trunks containing attractive food items or ice cubes containing fish or apples. To stimulate the bears to demonstrate their natural behaviour whole carcasses can be fed.

It is important to motivate the bears to be more active and to spread the provision of bulk food items over the course of a day. To lure bears into the inside enclosure, appealing food items can be used that have a high attraction but form only a small part of the animals' diet.

To actually monitor the seasonal fluctuation rendered in the weight of the bears, it is necessary to know whether the diet is successful or should be adapted. For this purpose, the availability of a weighing facility is a prerequisite. A good example is given by institution No. 48 (North Carolina Zoological Park), which weighs its bears on a weekly basis and has a diet that is structured on different levels in direct relation to the weight of the bears. The reported weight is also a useful tool to indicate to the caretakers why a diet is compiled the way it is and what influence it has on the bears.

To carry out the feeding protocol, good communication between animal caretakers, veterinarians and nutritionists is important, so that all persons working with the Kodiak bears or their diet have the same intention and level of knowledge. The feeding protocol should be followed, and in the event that someone has a suggestion for improvement or the situation of a bear changes, this should be communicated to the nutritionist who compiled the diet. If all of the above is not implemented, the diet of the bears becomes unbalanced and probably has a negative influence on their wellbeing.

To learn more about the way bears use the different nutrients, a sequel study needs to be performed with its focus on the digestibility of different food items. In addition, a larger research population should be used.

A comparison between the diet analysed during this research project and a new diet should also be performed.

Little is known about the reproduction of bears ex situ, and it is recommended to conduct a sequel study in this regard. In such a study, the relation between the success of reproduction and a seasonal fluctuating diet and a stable one should be explored.

Also little is known about the occurrence of obesity in ex situ although the survey results indicate that this may be a common problem. A sequel study is therefore highly recommended and should explore the consequences of obesity in bears.

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16 **Ankom Technology** (2005), Procedures, Available from: http://www.ankom.com/09_procedures/Crude%20Fiber%20Method%20A200.pdf (accessed: March, 2008)

17 **Ankom Technology** (2005), Procedures, Available from: http://www.ankom.com/09_procedures/NDF%20Method%20A200.pdf (accessed: March, 2008)

18 **Ankom Technology** (2005), Procedures, Available from: http://www.ankom.com/09_procedures/ADF%20Method%20A200.pdf (accessed: March 2008)

19 **Daele, L.J.** (March 2008), Kodiak Bear Fact Sheet, Available from: http://www.wc.adfg.state.ak.us/index.cfm?adfg=bears.trivia (accessed: March 2008)

20 **US National Parks & Monuments Travel Guide**, Yellowstone National Park - Bear Characteristics, Available from: http://www.us-parks.com/yellowstone/bear_characteristics.html (accessed May 2008)

21 **Kodiak National Wildlife Refuge**, Preferred Foods, Available from: http://www.kodiak.org/bears.html (accessed March 2008)

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Appendix I – Glossary and abbreviations

AD	Air-dry matter
ADF	Acid detergent fibre
ADL	Acid detergent lignin
Barrenground grizzly bear	*Ursus arctos richardsoni*
Brown bear	*Ursus arctos*
Brown bear hybrid	*Ursus arctos Hybrid*
Ca	Calcium
CFat	Crude fat
CFibre	Crude fibre
CH	Carbohydrates
CP	Crude protein
DM	Dry mater
European brown bear	*Ursus arctos arctos*
Grizzly bear	*Ursus arctos horribillis*
ISIS	International Species Information System
K	Potassium
Kamchatka brown bear	*Ursus arctos berungianus*
Kodiak bear	*Ursus arctos middendorffi*
LBE	Large bear enclosure
Mg	Magnesium
Na	Sodium
NDF	Neutral detergent fibre
NFC	Non fibre carbohydrates
NFE	Nitrogen free extract
OC	Organic compound
P	Phosphorus
U. a.	*Ursus arctos*
Ursus arctos gyas	Brown bear from western tip of Alaskan Peninsula
Ursus arctos isabellinus	Brown bear from Pamir, Kashmir and Punjab (Indian)
USDA	United States Department of Agriculture

Appendix II – Aspects on which the in situ diet is based

Hibernation

Hibernation period: mean hibernation of lone female 18 Nov - 30 April (163 days)

Spring:	Late April	–	Mid June
Summer:	Mid June	–	Mid September
Fall:	Mid September	–	Mid November
Winter:	Mid November	–	April

Diet and energy

Winter/ early spring:	Carrion, seaweed
Spring/ early summer:	Greens
Midsummer:	Greens and fish
Late summer/ mid fall:	Berries
Late fall/ winter:	Clean-up

40 MJ no gain no loss of body mass
Bears loose weight till summer
As nutrient value of carrion, the values for an adult white tailed deer were used, see Table II.2a and II.2b
As nutrient value of dead herbaceous products, the same nutrient values were used as the fresh products but a lesser amount was taken

Activity

April:	Emerge from den
May:	First two weeks not much activity; feeding at beaches on seaweed and carrion. Last two weeks feeding on herbaceous products bluejoint, sedges and nettle.
June:	First two weeks feeding on herbaceous products bluejoint, sedges and nettle. Last two weeks feeding on herbaceous products bluejoint, sedges, nettle and horsetail.
July:	First two weeks grazing continuous. Last two weeks in July salmons (sockeye (red), pink and chum).
August:	First week salmons (sockeye (red), pink, chum and other salmons). From second week berries, berries have a bigger attraction than salmons for the bears. Berries with a high consumption are elderberry, salmon berry and high bush cranberry and berries with a low consumption are cranberry, blueberry and cloudberry.
September:	Salmons and berries (peak feasting period).
October:	First two weeks salmons and berries. Last two weeks in October dead grass, salmon carcasses and late spawning salmons.
November:	First three weeks dead grass and salmon carcasses (lean-up period) Enter den, start hibernation.

Table II.1 – Data resource food items.

Food items	**Source**	**Name**
Sockeye salmon	USDA*	Fish, salmon, sockeye, raw
Chum salmon	USDA*	Fish, salmon, chum, raw
Pink salmon	USDA*	Fish, salmon, pink, raw
Chinook salmon	USDA*	Fish, salmon, chinook, raw
Coho salmon	USDA*	Fish, salmon, coho, wild, raw
Elderberry	USDA*	Elderberries, raw
Salmonberry	USDA*	Salmonberries, raw (Alaska Native)
High bush cranberry	USDA*	Cranberries, wild, bush, raw (Alaska Native)
Cranberry	USDA*	Cranberry, low bush or lingenberry, raw (Alaska Native)
Blueberry	USDA*	Blueberries, raw
Cloud berry	USDA*	Cloudberries, raw (Alaska Native)

Carex macrochaeta	Fox, 1991	-
Bluejoint	Oldemeyer et al.,1977	-
Urtica lyalli	Wild edible plants**	Nettle, Stinging
Horsetail	Wild edible plants**	Horsetail, Common
Carrion	Powers et al., 1989; Weiner et al., 1975	Deer, white tailed, adult ingesta-free
Seaweed	USDA*	Seaweed, laver, raw

** Agricultural Research Service - Nutrient Data Laboratory, USDA National Nutrient Database for Standard Reference, Available from: http://www.nal.usda.gov/fnic/foodcomp/search/ (accessed: April 2008)*
***Darnall-Kramer, M., Goude, J., Wild Edible Plant Nutrition, Available from: http://www.edibleplants.com/wepnut_frames.htm (accessed: May 2008)*

Table II.2a – Nutrient values of food items.

	Nutrient values in % of DM								
Food items	**MJ / kg DM**	**DM**	**CP**	**CFat**	**CBD**	**CFibre**	**NFC**	**Ash**	**Total %**
Berries, high [a]	16.1	15.3%	6.1%	2.2%	88.1%	32.9%	31.0%	3.6%	100.0%
Elderberry	15.1	20.2%	3.3%	2.5%	91.1%	34.7%	-	3.2%	100.0%
High bush cranberry	16.6	14.0%	7.9%	1.4%	87.9%	47.9%	-	2.9%	100.0%
Salmonberry	16.5	11.8%	7.2%	2.8%	85.2%	16.1%	31.0%	4.7%	100.0%
Berries, low [b]	16.3	14.0%	8.7%	4.0%	83.2%	15.2%	63.1%	4.1%	100.0%
Blueberry	15.2	15.8%	4.7%	2.1%	91.8%	15.2%	63.1%	1.5%	100.1%
Cloud berry	16.5	13.0%	18.5%	6.2%	66.2%	-	-	9.2%	100.0%
Cranberry	17.3	13.3%	3.0%	3.8%	91.7%	-	-	1.5%	100.0%
Carrion	26.5	41.1%	47.4%	41.4%	-	-	-	11.4%	100.2%
Herbaceous [c]	6.5	52.0%	7.4%	0.9%	-	60.1%	-	-	68.4%
Bluejoint [d]	11.6	52.0%	9.8%	-	-	69.8%	-	-	80.6%
Carex macrochaeta [d]	7.4	-	-	-		50.4%	-	0.2%	50.4%
Horsetail [e]	1.6	52.0%	1.9%	0.4%	-	-	-	-	2.3%
Urtica lyalli [e]	5.2	52.0%	10.6%	1.3%	-	-	-	-	11.9%
Salmon, first [f]	21.5	26.0%	79.2%	19.6%	0.0%	0.0%	0.0%	4.6%	103.4%
Salmon, mean [g]	22.7	26.7%	77.4%	23.4%	0.0%	0.0%	0.0%	4.6%	105.4%
Chinook salmon	26.4	28.4%	70.3%	36.8%	0.0%	0.0%	0.0%	4.7%	111.7%
Chum salmon	20.4	24.6%	81.8%	15.3%	0.0%	0.0%	-	4.8%	101.9%
Coho salmon	22.3	27.3%	79.1%	21.7%	0.0%	0.0%	0.0%	4.4%	105.2%
Pink salmon	20.5	23.7%	84.3%	14.6%	0.0%	0.0%	0.0%	5.2%	104.1%
Sockeye salmon	23.7	29.8%	71.6%	28.8%	0.0%	0.0%	0.0%	4.0%	104.3%
Seaweed	9.8	15.0%	38.8%	1.9%	34.1%	2.0%	3.3%	25.2%	100.0%

[a] *Berries, high include Elderberry, Salmonberry and High bush cranberry; these species are eaten in high extent*
[b] *Berries, low include Cranberry, Blueberry and Cloudberry; these species are eaten in low extent*
[c] *Herbaceous include the species Bluejoint, Carex macrochaeta, Urtica lyalli and Horsetail*
[d] *The MJ of Bluejoint and Carex macrochaeta are self calculated by multiplying fibre and protein with 14,6 kJ*
[e] *The same DM is used for Urtica lyalli and Horsetail as is the DM of Bluejoint*
[f] *Salmon, first includes Sockeye, Chum and Pink; these are the first salmon species present*
[g] *Salmon, mean includes Sockeye, Chum, Pink, Chinook and Coho; now all salmon species are present*
DM = dry matter, CP = crude protein, CFat = crude fat, CBD = carbohydrates by different, NFC = non fibre carbohydrates, CFibre = crude fibre

Table II.2b – Nutrient values of food items.

Food items	Mg / kg						IU / kg
	Ca	P	Na	K	Mg	Fe	A
Berries, high [a]	147.1	176.4	111.4	1106.4	76.0	6.2	4916.2
Elderberry	188.1	193.1	29.7	1386.1	24.8	7.9	2970.3
High bush cranberry	142.9	107.1	185.7	1000.0	-	7.1	7571.4
Salmonberry	110.3	229.0	118.7	933.0	127.2	3.4	4207.0
Berries, low [b]	124.0	167.7	6.3	487.7	38.0	3.4	878.0
Blueberry	38.0	76.0	6.3	487.7	38.0	1.8	342.0
Cloud berry	138.5	269.2	-	-	-	5.4	1615.4
Cranberry	195.5	157.9	-	-	-	3.0	676.7
Carrion	3.1	2.3	0.4	1.0	0.2	164.5	-
Herbaceous [c]	57.8	59.8	0.3	34.0	5.0	4.5	6423.1
Bluejoint	61.7	0.0	0.7	98.0	14.8	0.6	-
Carex macrochaeta	0.0	0.5	0.3	4.1	0.1	-	-
Horsetail [d]	111.5	178.8	0.0	0.0	0.0	8.5	346.2
Urtica lyalli [d]	-	-	-	-	-	-	12500.0
Salmon, first [e]	39.9	948.1	214.8	1474.0	93.3	2.4	515.1
Salmon, mean [f]	68.6	964.4	195.7	1471.7	145.7	2.0	701.7
Chinook salmon	91.7	1019.0	165.7	1389.3	335.0	0.9	1597.3
Chum salmon	44.7	1149.5	203.1	1742.5	89.4	2.2	402.1
Coho salmon	131.7	958.3	168.3	1547.2	113.4	2.0	365.8
Pink salmon	55.0	972.5	283.3	1365.8	109.9	3.3	494.7
Sockeye salmon	20.2	722.4	157.9	1313.8	80.6	1.6	648.5
Seaweed	467.6	387.4	320.6	2378.1	13.4	12.0	34749.5

[a] *Berries, high include Elderberry, Salmonberry and High bush cranberry; these species are eaten in high extent*
[b] *Berries, low include Cranberry, Blueberry and Cloudberry; these species are eaten in low extent*
[c] *Herbaceous include the species Bluejoint, Carex macrochaeta, Urtica lyalli and Horsetail*
[d] *The same DM is used for Urtica lyalli and Horsetail as is the DM of Bluejoint*
[e] *Salmon, first includes Sockeye, Chum and Pink; these are the first salmon species present*
[f] *Salmon, mean includes Sockeye, Chum, Pink, Chinook and Coho; now all salmon species are present*

Ca = calcium, P = phosphorus, Na = sodium, K = potassium, Mg = magnesium, Fe = iron, A = vitamin A

Appendix III – Institutions who responded to the survey and questions

Table III.1a – Institutions who responded to the survey (for more information see file contactlist.xls on the CD).

No.	Name institution	Zip code and city	Country	Contact person	Function	Homepage
6	Dierenpark Emmen	7811 EP Emmen	Netherlands	Cora Berndt	Nutritionist	http://www.dierenpark-emmen.nl
7	Indianapolis Zoological Society Inc.	Ale222, Indianapolis	USA	Dr. Jason Williams	Nutritionist	http://www.indianapoliszoo.com
12	Pittsburgh Zoo & PPG Aquarium	Pittsburgh Pa. 15206	USA	Mo Brown	Animal Keeper	http://www.pittsburghzoo.org
15	Silver Springs Natures Theme Park	Silver Springs FL 34488	USA	Logan Wilkinson	Animal Keeper	http://www.silversprings.com
18	Tierpark Hagenbeck GmbH	22527 Hamburg	Germany	Adriane Prahl	Veterinarian	http://www.hagenbeck.de
21	Zoo Duisburg AG	47058 Duisburg	Germany	Dr. Jochen Reiter	Curator	http://www.zoo-duisburg.de
22	Zoologicka zahrada Olomouc*	779 00 Olomouc-Svaty Kopecek Severomoravsky	Czech Republic	Dipl.Ing. Jitka Vokurková	Zoologist	http://www.zoo.olomouc.com/
25	Assiniboine Park Zoo	Winnipeg, Manitoba, R3P 2N7	Canada	Dr. Chris Enright	Veterinarian	http://www.zoosociety.com
26	BREC's Baton Rouge Zoo*	Baker LA 70704-0060	USA	Sam Winslow	Asst. Director/General Curator	http://www.brzoo.org/
32	Cologne Zoo**	50735 Cologne N Rhine-Westph	Germany	Dr. Lydia Kolter	Curator of Ursids & Felids	http://www.zoo-koeln.de/
33	Columbus Zoo and Aquarium	Powell, Ohio 43065	USA	Shelly Roach	Registrar	http://www.columbuszoo.org
34	Dakota Zoo	Bismarck ND 58502	USA	Terry Lincoln	Zoo Director	http://www.dakotazoo.org
37	Great Plains Zoo	Sioux Falls SD 57104	USA	Jay Tetzloff	Director of Animal Programs	http://www.gpzoo.org
44	Little Rock Zoo	Little Rock, AR 72205	USA	Debbie Thompson	Curator, Carnivores	http://www.littlerockzoo.com
46	Moscow Zoo	Moscow 123242	Russian Fed	Lubov Kurilovich	Curator, Animal Collection	http://www.zoo.ru/moscow/defengl.htm

47	Nikolaev Zoo	Nikolaev 54003	Ukraine	Tatiana Bordarenko	Curator, Carnivores	http://www.zoo.nikolaev.ua
48	North Carolina Zoological Park	Asheboro NC 27205	USA	Chris Lasher	-	http://www.nczoo.org/contactus
49	Northwest Trek Wildlife Park	Eatonville WA 98328	USA	Wendi Mello	Animal Keeper	http://www.nwtrek.org
52	Oregon Zoo*	Portland OR 97221-2799	USA	Mike Keele	Deputy Director	http://www.oregonzoo.org/
56	Saint Louis Zoo	St. Louis, MO 63110	USA	Steve Bircher	Curator, Carnivores	http://www.stlzoo.org

** This institution replay but had no bears at this moment.*

*** Replay tot the letter but no survey receive*

Table III.1b – Research institutions who responded to questions.

No.	Name institution	Zip code and city	Country	Contact person	Function	Homepage
1	Kodiak National Wildlife Refuge	Kodiak, AK 99615	USA	William B. Leacock	Wildlife Biologist	http://kodiak.fws.gov/
2	Washington State University Bear Center	Pullman WA 99164-4236, 509-335-1119	USA	Dr. Charles Robbins	Director	http://www.natural-resources.wsu.edu/research/Bear-Center/index.html

Appendix IV – Survey

Diet survey

Institution information

Name of institution	
Type of Institution	
Street	
Zip code, City	
Country	
Contact person	
Function	
E-mail	
Homepage	

General animal information

Question 1
How many brown bears of the different (sub)species are present in your institution? Please fill in the table.
If you have an ARKS Taxon Report, please fill in the missing information in the table and add the report to the survey.

Bear	Name	*(Sub) species	Sex	Date of birth	In your institution since	History of the bear and place of acquisition (e.g. zoo, circus, wild, confiscated, etc.)
e.g.	Mato	A☒B☐C ☐D☐	♂☒♀☐ Castrated	1986	1994	Born in Limburgse Zoo
1		A☐B☐C ☐D☐	♂☐♀☐			
2		A☐B☐C ☐D☐	♂☐♀☐			
3		A☐B☐C ☐D☐	♂☐♀☐			
4		A☐B☐C ☐D☐	♂☐♀☐			
5		A☐B☐C ☐D☐	♂☐♀☐			
6		A☐B☐C ☐D☐	♂☐♀☐			
7		A☐B☐C ☐D☐	♂☐♀☐			
8		A☐B☐C ☐D☐	♂☐♀☐			
9		A☐B☐C ☐D☐	♂☐♀☐			
10		A☐B☐C ☐D☐	♂☐♀☐			
11		A☐B☐C ☐D☐	♂☐♀☐			
12		A☐B☐C ☐D☐	♂☐♀☐			

*(Sub)species: A *Ursus arctos middendorffi* (Kodiak bear) B *Ursus arctos horribilis* (Grizzly bear)
C *Ursus arctos beringianus* (Kamchatka brown bear) D Other *Ursus arctos*

General enclosure information

Question 2
Please fill in the general information about the enclosure(s).

	Surface in m^2	Indoor (In) Outdoor (out)	Ground type	*Enrichment / other animals
1		In ☐ Out☐		
2		In ☐ Out☐		
3		In ☐ Out☐		
4		In ☐ Out☐		
5		In ☐ Out☐		
6		In ☐ Out☐		

**Like tree trunk, ponds, trees, etc.*

Question 3
When do bears have access to the enclosure during the year?

Indoor	
Outdoor	

Question 4
How is the composition of bears per enclosure?

Indoor	
Outdoor	

Feeding information

Question 5
Do bears receive the same quantity of diet year round?

Yes ☐ No ☐

Do bears receive the same food items year round?

Yes ☐ No ☐

Question 6
To compare the different diets we ask you to add your own diet sheet to the survey together with the labels of concentrated feed and supplements. If you do not have a diet sheet or information is missing on the sheet, please fill in the tables attached to this survey on page **7** and **8**.

Please add the diet sheets you use over the year and make clear if it is fed per day or week, in which unit of weight and to how many bears.

Please add your comments

Question 7
Is the total food amount estimated or weighed?

Estimated ☐ Weighed ☐

Question 8
How do you use food for enrichment?

Food items	Please describe

Question 9
How is the feeding spread over the day?

Question 10
On which information* is your diet based?

**e.g. literature, experience, other zoos, etc.*

Question 11
Have you changed food items recently?

Yes ☐ No ☐

If yes, please fill in the most important changes.

Food items		*Describe the reason for change
	New ☐ Removed ☐	
	New ☐ Removed ☐	
	New ☐ Removed ☐	
	New ☐ Removed ☐	
	New ☐ Removed ☐	
	New ☐ Removed ☐	

**e.g. ethics, diarrhoea, stereotypic behaviour, weight problems, etc.*

Weight fluctuation over the year

Question 12
Do you observe fluctuations in body weight during the different seasons?

Yes ☐ No ☐

If yes, please estimate how much the bears change in body weight over the season in %.

_____ %

Question 13
Do you have the facility to weight the bears?

Yes ☐ No ☐

If you have weighed the bears, please fill in the table.
If you use your own weight sheet, please add it to the survey.

Name bear	Date	Weight (Kg)		Name bear	Date	Weight (Kg)

Reproducing information

Question 14
Which bears have reproduced in your institution in the last 5 years, please list.

Name male/female	Number of litters	Mean litter size	*Place of parturition

**e.g. den, litter box, outside, etc.*

Question 15
Please describe the problems with reproduction, breeding and rearing cups in your institution?
e.g. infanticide, disease, abortion, stress, etc.

Hibernation

Question 16
Do the bears hibernate in your institution?

Yes ☐ No ☐

If yes, please fill in the table.

Name bear	No. of Months	*Where	Sleep solidly or awake often		Every year
			Sleep solidly Wake up regularly Wake up often	☐ ☐ ☐	Yes ☐ No ☐
			Sleep solidly Wake up regularly Wake up often	☐ ☐ ☐	Yes ☐ No ☐
			Sleep solidly Wake up regularly Wake up often	☐ ☐ ☐	Yes ☐ No ☐

*******e.g. den, litter box, outside, etc.*

Health information

Question 17
Have you observed any disease that can be associated with the diet?

Yes ☐ No ☐

If yes, which disease and how was the diet involved?

Additional information

Question 18
Please fill in your opinion about feeding bears, interesting sources or any other information.

Question 19
Can we contact you if we have further questions by e-mail or phone?

Name	____________	E-mail	____________	E-mail	Yes ☐	No ☐
		Phone No.	____________	Phone	Yes ☐	No ☐

Thank you very much for time and effort.
Jolanda Polet
Timo Weber

Attachments
☐ ARKS Taxon Report (question 1)
☐ Diet sheet (question 6)
☐ Indication of ingredients from supplements (question 6)
☐ Indication of ingredients from concentrated feed (question 6)
☐ Weight sheet (question 13)

When finished, please send this survey to the following address, fax number or e-mail address before Tuesday the 18th of March 2008 enabling us to finish the complete our project:

Mail: Attn T.R. Huisman, Van Hall Larenstein, Agora 1, Postbus 1528, 8901 BV Leeuwarden, the Netherlands
Fax: Attn T.R. Huisman, 0031 (0) 582846423
E-mail: c.berndt@zoo-emmen.nl

Food items sheet for question 6

Food items and enrichment food	Per day or week	*What is the amount in kg of food and in which month are the food items given		No. of bears	Comments about special offering of food
e.g. Apple	Day ☒ Week ☐	J kg F 0,25kg M 1,5kg A 3kg M 3kg J 6kg	J 6kg A 6kg S kg O kg N kg D kg	3	Pieces of apple are hidden in tree trunks in the outdoor enclosure
	Day ☐ Week ☐	J kg F kg M kg A kg M kg J kg kg	J kg A kg S kg O kg N kg D kg kg		
	Day ☐ Week ☐	J kg F kg M kg A kg M kg J kg kg	J kg A kg S kg O kg N kg D kg kg		
	Day ☐ Week ☐	J kg F kg M kg A kg M kg J kg kg	J kg A kg S kg O kg N kg D kg kg		

**J=January F=February M=March …………to D=December*

Supplement sheet for question 6

Supplements and brand	Per day or week	*What is the amount in g of supplement and in which month are they given		No. of bears	How is the supplement offered
	Day ☐ Week ☐	J g F g M g A g M g J g g	J g A g S g O g N g D g g		
	Day ☐ Week ☐	J g F g M g A g M g J g g	J g A g S g O g N g D g g		
	Day ☐ Week ☐	J g F g M g A g M g J g g	J g A g S g O g N g D g g		

**J=January F=February M=March …………to D=December*

Appendix V – Used food items for enrichment

Table V.1 – Used food items for enrichment in the institutions.

Food items			
Apples	Deer	Honey	Romaine
Alfa alfa pellets	Dog biscuits	Insects	Seeds
Beef knuckle	Dog Chow	Jell-o	Smelts
Berries	Dried fruits	Live fish trout	Sugar cubes
Bones	Eggs	Meat with bone	Syrup
Bread	Fish	Melon	Vegetable
Butter	Frozen Juice	Nuts	Watermelon
Cantaloupe melons	Fruits	Peanuts	Willow browse
Carrots	Grapefruit	Pears	Yams
Cereal	Grapes	Produce	
Cray fish	Grass clippings	Raisins	

Appendix VI – Used food items for diet calculation and sources

In the following Table VI.1a all the used food items for the diet calculations are listed with the source of it. Furthermore the refuse percentage is stated named with the excluded part of the food items (more information see appendix XIII).

Table VI.1a – Food items and sources.

No.	Food items	Source	Name	Without	Refuse %
1	Apple	USDA	Apples, raw, with skin	Core and stem	10.00%
2	Bamboo	USDA [aa]	Bamboo shoots, raw [ab]	[ac]	0.00%
3	Banana	USDA	Bananas, raw	Skin	36.00%
75	Blueberries	USDA	Blueberries, raw	Stems and green or spoiled berries	0.05%
4	Bone	See Table VI.1b	-	-	0.00%
73	Bone marrow	USDA	Caribou, bone marrow, raw (Alaska Native)		0.00%
74	Bone matrix	-	-	-	0.00%
5	Bran oat	USDA	Oat bran, raw	-	0.00%
6	Bran wheat	USDA	Wheat bran, crude	-	0.00%
7	Bread	USDA	Bread, French or Vienna (includes sourdough)	-	0.00%
8	Broccoli	USDA	Broccoli, raw	-	0.00%
9	Cabbage	USDA	Cabbage, raw	Outer leaves and core	20.00%
76	Cantaloupe	USDA	Melons, cantaloupe, raw	Cavity contents, cutting loss rind	0.49%
10	Carnivore meat	[b]	Tripe A Brand Meat Company Feline Complete Diet	-	0.00%
11	Carrot	USDA	Carrots, raw	Crown, tops and scrapings	11.00%
12	Cat diet	c	Premium Beef Feline Diet	-	0.00%
13	Celeriac	USDA	Celeriac, raw	Parings	14.00%
14	Cereals	USDA	Cereals ready-to-eat, KELLOGG, KELLOGG'S ALL-BRAN Original	-	0.00%
15	Cherries	USDA	Cherries, sweet, raw	Pits and stems	8.00%
16	Chicken	[d]	Chicken adult p 10	-	0.00%
17	Clover	CVB 2007	Klaver rode, vers p104	-	0.00%
18	Corn on the cob	CVB 2007	Snijmais, vers, DS<240g/kg p106	-	0.00%
21	Dog chow	See Table VI.1c	-	-	0.00%
28	Dog chow Hills	[f]	Adult Large Breed	-	0.00%
20	Dog chow inst. 37	[e]	Purina Exclusive Chicken & Rice Performance	-	0.00%
19	Dog chow inst. 15	Survey inst. 15	-	-	0.00%

64	Dog chow inst. 6	Zoo Emmen	Konacorn, Croc senior menu	-	0.00%
23	Egg cooked	USDA	Egg, whole, cooked, hard-boiled	Shell	12.00%
22	Egg raw	USDA	Egg, whole, raw, fresh	Shell	12.00%
24	Endive	USDA	Endive, raw	Outer leaves and core	14.00%
25	Fish	See Table VI.1d	-	-	0.00%
26	Fish freshwater	USDA	Fish, bass, fresh water, mixed species, raw	-	0.00%
27	Fish oil	USDA and survey inst. 15	Fish oil, cod liver	-	0.00%
29	Fruit diverse	See Table VI.1e	-	-	17.86%
30	Grapefruit	USDA	Grapefruit, raw, white, all areas	Peel, seeds, core, membrane	51.00%
31	Grapes	USDA	Grapes, red or green (European type, such as Thompson seedless), raw	Stems	4.00%
32	Gras	CVB 2007	Gras, vers, jaargemiddelde p102	-	0.00%
33	Herring	USDA	Fish, herring, Pacific, raw	-	0.00%
34	Honey	USDA	Honey	-	0.00%
35	Kohlrabi	USDA	Kohlrabi, raw	Leaves, stems and parings	54.00%
36	Lettuce	USDA	Lettuce, green leaf, raw	Outer leaves, core and trimmings	36.00%
37	Liver	USDA	Beef, variety meats and by-products, liver, raw	-	0.00%
38	Mackerel	USDA	Fish, mackerel, Atlantic, raw	-	0.00%
39	Mealworms	[g]	Mealworm (larvae) Tenobrio molitor	-	0.00%
41	Meat 15% fat	USDA	Beef, ground, 85% lean meat / 15% fat, raw	-	0.00%
42	Meat 30% fat	USDA	Beef, ground, 70% lean meat / 30% fat, raw	-	0.00%
40	Meat 5% fat	USDA	Beef, ground, 95% lean meat / 5% fat, raw	-	0.00%
43	Mulberry	USDA	Mulberries, raw	-	0.00%
44	Natural Balance	h	-	-	0.00%
45	Nuts	USDA	Nuts, hazelnuts or filberts (1)	Shell	54.00%
46	Okra (soy pulp)	USDA	Tofu, okara	-	0.00%
47	Omnivore	[i]	Omnivore Diet	-	0.00%
48	Omnivore Mazuri	Survey	Mazuri Ominvore Zoo Feed "A"	-	0.00%
49	Onions	USDA	Onions, raw	Stem ends, sprouts and defects	10.00%
50	Orange	USDA	Oranges, raw with peel	Seeds	1.00%
51	Ox heart	USDA	Beef, variety meats and by-products, heart, raw	Fat, veins and connective tissue	29.00%
52	Pears	USDA	Pears, raw	Stem, core and seeds	10.00%
53	Potatoes	USDA	Potatoes, white, flesh and skin, raw	-	0.00%
54	Produce	See Table VI.1f	-	-	20.23%

55	Prunes	USDA	Plums, dried (prunes), uncooked	Pits	13.00%
56	Pumpkin	USDA	Pumpkin, raw	Seeds, rind and stem	30.00%
57	Raisins	USDA	Raisins, seeded	-	0.00%
58	Red beets	USDA	Beets; raw	Parings and part tops	33.00%
59	Rice	USDA	Rice, white, medium-grain, cooked	-	0.00%
60	Salmon filet with skin	USDA	Fish, salmon, pink, raw	-	0.00%
61	Salt	USDA	Salt, table	-	0.00%
77	Strawberries	USDA	Strawberries, raw	Caps and stems	0.06%
62	Sugar beets	CVB 2007	Suikerbieten, vers p108	-	0.00%
63	Supplements	Zoo Emmen	Carnizoo	-	0.00%
65	Sweet potatoes (Yam)	USDA	Yam, raw	Skin	14.00%
66	Tomato	USDA	Tomatoes, red, ripe, raw, year round average	Core and stem ends	9.00%
67	Trout whole	USDA	Fish, trout, mixed species, raw	-	0.00%
68	Vegetable diverse	See Table VI.1g	-	-	19.92%
69	Vetch	[j]	-	-	0.00%
70	Watermelon	USDA	Watermelon, raw	Rind, seeds and cutting loss	48.00%
71	Wieners	USDA	OSCAR MAYER, Wieners (beef franks)	-	0.00%
72	Willow	[k]	Leaf and green steam	-	0.00%

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[j] *Agronomy Journa,l Available from: http://agron.scijournals.org/cgi/content/full/93/5/1006/TBL1 (accessed: May 2008)*

Table VI.1b – Bone calculation.

No.	Bone	% in the product
41	Meat 15% fat	25%
73	Bone marrow	15%
74	Bone matrix	60%
4	**Bone**	**100%**

Table VI.1c – Dog chow calculation.

No.	Dog chow	% in the product
19	Dog chow 15	25%
20	Dog chow 37	25%
28	Dog chow Hills	25%
64	Dog chow 6	25%
21	**Dog chow**	**100%**

Table VI.1d – Fish calculation.

No.	Fish	% in the product
26	Fish freshwater	50%
33	Herring	25%
38	Mackerel	25%
25	**Fish**	**100%**

Table VI.1e – Fruit diverse calculation.

No.	Fruit diverse	% in the product
1	Apple	14.29%
3	Banana	14.29%
30	Grapefruit	14.29%
31	Grapes	14.29%
50	Orange	14.29%
52	Pears	14.29%
55	Prunes	14.29%
29	**Fruit diverse**	**100.00%**

Table VI.1f – Produce calculation.

No.	Produce	% in the product
75	Blueberries	3%
76	Cantaloupe	10%
29	Fruit diverse	36%
34	Honey	2%
77	Strawberries	3%
65	Sweet potatoes	10%
68	Vegetable div.	36%
54	**Produce**	**100%**

Table VI.1g – Vegetable diverse calculation.

No.	Vegetable diverse	% in the product
8	Broccoli	7.69%
11	Carrot	7.69%
13	Celeriac	7,69%
24	Endive	7.69%
35	Kohlrabi	7.69%
36	Lettuce	7.69%
49	Onions	7.69%
53	Potatoes	7.69%
56	Pumpkin	7.69%
58	Red beets	7,69%
62	Sugar beets	7.69%
66	Tomato	7.69%
70	Watermelon	7.69%
68	**Vegetable diverse**	**100.00%**

No. = Number of food item registered as in Table VI.1a

Appendix VII – Food items that the institutions used in their diets

Table VII.1 – All used food items for the different diets sorted after frequency use.

Food items	No.	*6	7	12	15	18	21	25	33	34	37	44	47	48	49	56	104	N	Percentages
Apple	1	■		■	■	■	■	■	■	■	■	■		■			■	12	75.00%
Carrot	11			■	■	■	■	■	■		■		■	■			■	10	62.50%
Bread	7	■	■			■		■		■	■		■				■	8	50.00%
Dog chow	21	■		■		■	■	■		■		■		■				8	50.00%
Omnivore Mazuri	48		■	■					■					■	■	■		6	37.50%
Sweet potatoes (Yam)	65			■	■				■		■	■		■				6	37.50%
Meat 15% fat	41	■				■	■			■			■				■	6	37.50%
Fish	25									■	■		■			■	■	5	31.25%
Orange	50			■	■	■						■		■				5	31.25%
Gras	32	■	■				■					■						4	25.00%
Pears	52								■	■							■	3	18.75%
Cat diet	12											■		■		■		3	18.75%
Corn on the cob	18											■	■				■	3	18.75%
Fruit diverse	29	■	■										■					3	18.75%
Lettuce	36				■					■							■	3	18.75%
Natural Balance carnivore diet	44		■						■									2	12.50%
Trout whole	67						■		■									2	12.50%
Banana	3					■			■									2	12.50%
Bone	4		■									■						2	12.50%
Cereals	14		■										■					2	12.50%
Egg cooked	23					■						■						2	12.50%
Herring	33			■										■				2	12.50%
Mackerel	38	■															■	2	12.50%
Potatoes	53					■											■	2	12.50%
Red beets	58					■											■	2	12.50%
Sugar beets	62												■				■	2	12.50%
Tomato	66								■				■					2	12.50%
Watermelon	70												■				■	2	12.50%
Omnivore diet	47															■		1	6.25%
Salmon filet with skin	60								■									1	6.25%
Bamboo	2											■						1	6.25%
Bran wheat	6												■					1	6.25%

Broccoli	**8**										■							**1**	6.25%
Cabbage	**9**												■					**1**	6.25%
Carnivore meat	**10**										■							**1**	6.25%
Celeriac	**13**																■	**1**	6.25%
Cherries	**15**									■								**1**	6.25%
Chicken	**16**					■												**1**	6.25%
Clover	**17**											■						**1**	6.25%
Dog chow (15 Silver Spring)	**19**				■													**1**	6.25%
Dog chow (37 Great Plains Zoo)	**20**										■							**1**	6.25%
Endive	**24**																■	**1**	6.25%
Fish freshwater	**26**	■																**1**	6.25%
Fish oil	**27**				■													**1**	6.25%
Fodder's yeasts	**28**												■					**1**	6.25%
Grapefruit	**30**											■						**1**	6.25%
Grapes	**31**									■								**1**	6.25%
Honey	**34**																■	**1**	6.25%
Kohlrabi	**35**																■	**1**	6.25%
Liver	**37**							■										**1**	6.25%
Mealworms	**39**											■						**1**	6.25%
Mulberry	**43**											■						**1**	6.25%
Nuts	**45**																■	**1**	6.25%
Okra (soy pulp)	**46**												■					**1**	6.25%
Onions	**49**					■												**1**	6.25%
Ox heart	**51**																■	**1**	6.25%
Produce	**54**														■			**1**	6.25%
Prunes	**55**																■	**1**	6.25%
Pumpkin	**56**												■					**1**	6.25%
Raisins	**57**																■	**1**	6.25%
Rice	**59**					■												**1**	6.25%
Salt	**61**												■					**1**	6.25%
Supplements	**63**	■																**1**	6.25%
Vegetable div.	**68**												■					**1**	6.25%
Vetch	**69**											■						**1**	6.25%
Wieners	**71**							■										**1**	6.25%
Willow	**72**											■						**1**	6.25%
Used food items per institution		**9**	**7**	**7**	**7**	**13**	**6**	**6**	**10**	**9**	**8**	**16**	**17**	**8**	**2**	**4**	**21**	**150**	**13.99%**

**Number institute, No. = number food item*