Diets and feeding methods of captive seabirds in mixed enclosures (*Rissa tridactyla, Uria aalge, Fratercula arctica and Somateria mollissima*)

Graduation thesis about the nutrition of captive seabirds in mixed enclosures

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Photos first page: Pictures of bird species in Bass Rock, Rotterdam Zoo. Top left: common guillemot (*by Bryan Black)*, top right: common eider (*by Marco Valenti)*, bottom left: Atlantic puffin (*by Massimiliano Sticca)* and bottom right: black-legged kittiwake (*photographer unknown*).

Preface and acknowledgements

This report is written as a final thesis of the education 'Animal health and Management' at Dronten University of Applied Sciences: a research which has investigated the most optimal feed and foraging method of four seabird species of Rotterdam Zoo. The species are: black-legged kittiwakes (*Rissa tridactyla*), common guillemots (*Uria aalge*), Atlantic puffins (*Fratercula arctica*) and common eiders (*Somateria mollissima*). Research and writing of the thesis were done in Rotterdam Zoo (Diergaarde Blijdorp).

Rotterdam Zoo was officially opened on May 18, 1857 and is currently the most attractive zoo in the Netherlands; it has the highest number of visitors (1.4 million visitors a year). The zoo has also a large variety of animal species and is divided into continents of the world: North America, South America, Asia, Africa, and Arctica. Only Europe is not divided. The Oceanium is a part of Rotterdam Zoo and is opened in 2001. The number of visitors has almost doubled since the opening of the Oceanium. The seabirds of this study are located in the Bass Rock enclosure in the Oceanium. The feed of zoo animals was developed in the past years, but the feed and feeding method of the seabirds at Rotterdam Zoo has been the same for a long time. Unknown is whether the feed and feeding method in this enclosure is optimal, as well as in seabird enclosures in other zoos. This is not investigated. Besides that, fish, that are present in the housing of the seabirds, eat also from the feed of the birds, which causes loss of feed that is actually intended for the birds. Also was unknown whether the feeding method is as close as possible to the natural situation. Dionne Slagter, supervisor and Taxon Advisory Group chair, would have this to be investigated. This unknown part was investigated during a ten week study.

The objective of the study was to investigate the natural foraging needs of seabirds, compare it to the captive situation in Rotterdam zoo and other zoos, and investigate the alternative feedings methods to get the foraging situation of the seabirds as close as possible to the natural situation. The global objective was to optimise the feed and foraging behaviour of the seabirds and share the results with the European Association of Zoos and Aquaria (EAZA). Other Zoos that are affiliated to EAZA can make use of it.

I would like to express my thanks to the following people and organisations: First of all, Dionne Slagter and Harald Schmidt from Rotterdam Zoo, for supervising and helping me during this study. Next is Simon Bruslund, bird curator and head animal management in Heidelberg Zoo, for the opportunity to visit Heidelberg zoo, take some interviews and the accommodation for overnight. It was a great experience. Then, Melanie Oesterwind, veterinarian of Heidelberg zoo, for answering my questions. Joeke Nijboer, nutritionist in Rotterdam Zoo, for answering all questions during this study about nutrition and giving some tips and Linda van Sonsbeek, veterinarian in Rotterdam Zoo, for answering questions. I also want to thank Tinus Boomstra, sales leader and Erik Berenpas, nutritionist of Arie Blok nutrition, for answering all questions of nutrition of common eiders and related species. I also want to thank all participated zoos, which are: AG Zoologischer Garden Köln, Aquamarine Fukushima, Biodôme de Montréal, Bristol Zoo Gardens, Burger's Zoo, Cincinnati Zoo and Botanical Garden, Cotswold Wildlife Park, Exmoor Zoo, Fota Wildlife Park, Hannover Zoo, Heidelberg Zoo, Jurong Bird Park, Leipzig Zoo, Living Coasts, Loro Parque Tenerife, Lotherton Bird Garden, National Aquarium Denmark, Oceanário de Lisboa, Omaha's Henry Doorly Zoo, Parc des Oiseaux, Point Defiance Zoo & Aquarium, Riga Zoo SeaWorld California, SeaWorld San Antonio, Whipsnade Zoo, Woodland Park Zoo, Zoo Augsburg, Zoo Zürich, ZooParc de Beauval, Zoo Basel and WWT Martine Mere Wetland Centre. Finally, I would like to thank all employees in Rotterdam Zoo for helping me and ask some questions.

Enjoy reading!

Linda Vervloed
Rotterdam, May 28, 2015

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List of abbreviations and symbols

Abbreviation	Description
~	Approximate
<	Lesser than
>	Greater than
µg	Microgram
ANOVA	Analysis of Variance
Ca	Calcium
Cfat	Crude fat
CP	Crude protein
EAZA	European Association for Zoos and Aquaria
Fe	Iron
IU	International units
kg	Kilograms
m	Meter
Mg	Magnesium
mg	Milligram
P	Phosphorus
ZIMS	Zoological Information Management System
Zn	Zinc
α	Alpha

English summary

Bass Rock is the enclosure of four seabird species in Rotterdam Zoo: Black-legged kittiwakes (*Rissa tridactyla*), common guillemots (*Uria aalge*), Atlantic puffins (*Fratercula arctica*) and common eiders (*Somateria mollissima*), together with some fish species: sea perches, sea bream and crayfishes. The feed and feeding method is the same for several years, unknown is whether diets and feeding methods are sufficient for these types of birds. This study investigated on which way seabirds, in mixed enclosures, can be provided in nutritional needs in a way that is as close as possible to their natural situation. The main question of research is: "How should the seabirds at Rotterdam Zoo be provided in their nutritional needs in a way that is as close as possible to their natural situation?"

The aim of this study was to investigate the most optimal foraging situation for seabird species which are the same, or similar to, as species present in the Bass Rock enclosure in Rotterdam Zoo. The information of this study can be used as principle research in other zoos and other instances, and will also be shared with the European Organisation for Zoos and Aquaria (EAZA). Expected was that the current diet of birds in Rotterdam Zoo provides the birds in nutritional needs, but that there was a lack of scientific information.

Information was gathered by way of literature study, behavioural study and questionnaires to other zoos. Literature study was done to investigate nutritional needs and foraging behaviour in wild and captivity. Behavioural study was done within four weeks by way of scan-sampling per bird species. The recording rule was instantaneous sampling and questionnaires were answered by 31 zoos to investigate diets and methods in other zoos.

Natural diets and foraging behaviour were not always evidenced by scientific research. Evidenced is that the gastrointestinal tract differs a little bit from non-piscivorous birds: The gizzard is relatively small and less muscled. The salivary glands are less important, because seabirds eat mostly wet food items. Seabirds have also salt glands to filter salts of the body, other birds do not have these glands. Bigger kidneys are needed for filtering salt out of the body. The crop of seabirds has mostly no function, because seabirds have a very elastic oesophagus and stomachs. Fermentation of nutrients is the same as in other, non-piscivorous birds, but the caeca are less important. Seabirds are able to detect preys due to well-developed olfactory and visual senses, and are able to remember conditions and places to successfully catch preys. Skin and feathers are also important factors related to the condition of birds. Feathers showing fault bars can be signs of malnutrition. Malnutrition can also cause other problems with plumage of birds.

Nutrients that are considered as important nutrients for seabirds are: methionine and cysteine, which are limiting amino acids, the fatty acids: linoleic acid and α-linoleic acid, calcium and some vitamins. Vitamin requirements are based on experiences, but not scientific improved. Vitamin A (retinol and carotenoids), B_1 and E are considered as important vitamins, because these vitamins are broken down during freezing- and storage processes. Frozen fish lack a sufficient amount of these vitamins. These vitamins, and also carotene, vitamin D, vitamin C and folic acid can be influenced by light, heat and/or air or oxygen.

Literature study in diets and behaviour of individual bird species has shown that all four types of birds show different types of behaviour to catch preys. The Atlantic puffin is considered as most social bird, followed by common eiders. *Alcidae* and gulls can show aggressive behaviour and gulls can even kill other seabirds. The variety of food items and prey types also vary among the bird species.

Diets of captive seabirds also differs a lot. Common eiders are primarily fed on commercial diets and other birds on fish, including some additives. Additives are mainly multivitamins, including vitamin B_1, E and mostly also vitamin A. Calcium is already present in sufficient amounts in the viscera of fish. Chosen fish species are mainly capelin, lake smelt, krill and herring for Atlantic puffins, black-legged kittiwakes and common guillemots and smelt for common eiders besides commercial feed. Most zoos feed their animals twice or thrice a day. Preferences for Atlantic puffins, black-legged kittiwakes and common guillemots are mainly preferences for some fish species (capelin, herring, silversides and krill), but common eiders do not seem to have any preferences.

A behavioural study in Rotterdam zoo shows a significant preference for feeding bowl for the Atlantic puffin and kittiwakes. The left bowl was more attractive than the right one. There was no significant evidence for the preference of feeding time. The time spent on foraging compared to other behaviour seem also be way less than foraging behaviour in wild. Common eiders did not show even foraging behaviour, besides only eating from the feeding bowl and have showed some stereotype behaviour. The current diet of Atlantic puffins, black-legged kittiwakes and common guillemots in Rotterdam Zoo consists mostly of one type of feed per day, while other zoos feed different types of fish per day.

A wide variety of feeding methods are used in other zoos. Atlantic puffins, black-legged kittiwakes and common guillemots are mainly fed by using bowls in combination with food scattered in the water, some zoos feed their birds by hand. Only three zoos use only bowls as feeding method. Hand feeding is the most time-consuming method, but ensures the individual food intake. Bowls are less time consuming and makes food available during the whole day, but there is no individual control and other wild birds can steal food. Scattering in the water stimulates diving and hunting behaviour and the individual intake of birds can be controlled more easily, compared to feeding in bowls. A disadvantage is that food scattered in the water can influence the water quality negatively, which can influence the plumage of birds. Common eiders are mainly fed with feed scattered in the water or a combination of bowls and scatter feed in the water. On zoos uses a cage over the water to prevent wild birds eating from the pellets.

Recommended is to vary given fish species per day and add some carotenoids in the diet of Atlantic puffins, black-legged kittiwakes and common guillemots to fill up the shortage of vitamin A. The bowls should be placed on more different places in the enclosure. This method of feeding can be varied by giving some low-fat fish in water as enrichment, but there must be ensured that fish species in the enclosure do not eat too much of this fish. Common eiders should be given more enrichment to reduce stereotype behaviour by giving bowls of grain in different places in the water and giving some blue mussels as enrichment. The current diet can be used, but scatter this food in the water can improve the foraging behaviour. Unknown is whether other birds and fish eat from the pellets.

Recommended for further research is to investigate requirements of different species, or at least for seabirds and sea ducks in general. Behavioural research in Rotterdam zoo can be extended and compared to behavioural studies in other zoos. Behaviour of common eiders should also be investigated to improve health and welfare of the birds. Rotterdam Zoo should consider whether the composition of the birds in Bass Rock should be changed. The last recommendation is to investigate the effects of fish fed in the water to the water quality and bird's plumage.

Dutch summary – Nederlandse samenvatting

Het zeevogelverblijf in Diergaarde Blijdorp, genaamd Bass Rock, bevat de volgende zeevogels: drieteenmeeuwen (*Rissa tridactyla)*, papegaaiduikers (*Fratercula arctica)*, zeekoeten (*Uria aalge)* en eidereenden (*Somateria mollissima)*. In het water leven nog een aantal diersoorten, namelijk de zeebaars, zeebrasem en Noordzeekreeft. De voeding en voedingsmethode in dit verblijf is al jaren hetzelfde en het is onbekend of de diëten en methoden voldoen aan de behoeften van de vogels. Dit onderzoek betreft een onderzoek naar de voeding en voedingsmethoden in gemengde zeevogelverblijven. De hoofdvraag van het onderzoek was: ”Op welke manier zouden de zeevogels in Diergaarde Blijdorp moeten worden voorzien in nutritionele behoeften die zo dicht mogelijk ligt bij hun natuurlijke situatie”.

Het doel van dit onderzoek is het onderzoeken van het meest optimale dieet en voedingsmethode voor de zeevogelsoorten in het Bass Rock verblijf, of vergelijkbare zeevogels. De resultaten en informatie van dit onderzoek kunnen door anderen dierentuinen en organisaties worden gebruikt als uitgangspunt en worden tevens gedeeld met de European Organisation for Zoos and Aquaria (EAZA), zodat andere dierentuinen er gebruik van kunnen maken. De verwachting was dat het huidige dieet van de zeevogels voldoet aan de nutritionele behoeften, maar dat er een gebrek was aan wetenschappelijke informatie.

Informatie is verkregen via literatuuronderzoek, gedragsonderzoek en questionnaires naar andere dierentuinen. Literatuuronderzoek is gedaan om de nutritionele behoeften en foerageergedrag duidelijk te krijgen voor zeevogels in het wild en in de natuur. Een vierweeks gedragsonderzoek is gedaan om gedrag van zeevogels in gevangenschap duidelijk te krijgen. De sampling rule was scan-sampling en de recording rule was instantaneous sampling. De questionnaires naar andere dierentuinen onderzocht de diëten en methoden in andere dierentuinen.

Natuurlijk gedrag en voeding was vaak beschreven op basis van ervaringen en niet altijd op basis van wetenschappelijk onderzoek. Bewezen is dat het maagdarmkanaal van zeevogels enigszins afwijkt van dat van niet-visetende vogels. De spiermaag is bijvoorbeeld relatief klein en minder gespierd. Speekselklieren in de bek van de vogel zijn minder belangrijk, omdat zeevogels voedsel eten dat al vochtig is. Zeevogels hebben ook zoutklieren om zout uit het lichaam te filteren, ander vogels hebben deze niet. Om dit zout uit het bloed te filteren zijn grotere nieren nodig. De krop van zeevogels daarentegen heeft nauwelijks functie, omdat zeevogels een flexibele slokdarm en magen hebben. De fermentatie van nutriënten is hetzelfde als niet-visetende vogels, maar de functie van de blinde darm is minder belangrijk. Zeevogels zijn door hun goed ontwikkelde reuk- en zichtvermogen in staat om prooien te ontdekken en tevens succesvolle plaatsen en condities te onthouden om prooien te vangen. Huid en veren zijn belangrijke factoren die gerelateerd zijn aan de conditie van een vogel. Foutstrepen (fault bars) die zichtbaar worden in de veren zijn een indicator voor slechte of verkeerde voeding. Verkeerde voeding kan ook problemen met de waterdichtheid van het verenkleed veroorzaken.

Een aantal nutriënten worden gezien als belangrijke nutriënten voor zeevogels. Dit zijn: de aminozuren methionine and cystine, de vetzuren linolzuur en α-linoleenzuur, calcium en enkele vitaminen. De aanbevolen hoeveelheid vitaminen zijn gebaseerd op ervaringen en niet op wetenschappelijk onderzoek. Vitamine A (als retinol en caroteen), B_1 en E zijn aangemerkt als belangrijke vitaminen, omdat deze vitaminen worden afgebroken tijdens vries- en bewaarprocessen. Deze vitaminen, maar ook caroteen, vitamine C en D en foliumzuur worden negatief beïnvloed bij het in contact komen met licht, hitte en/of lucht of zuurstof.

Literatuuronderzoek naar diëten en gedragingen van individuele vogelsoorten wijst uit dat alle vier de soorten verschillende gedragingen vertonen bij het vangen van prooien. Van de vier soorten in de papegaaiduiker de meest sociale vogel, gevolgd door de eidereend. Alken en meeuwen kunnen agressief gedrag vertonen. Meeuwen kunnen zelfs andere vogels doden. De variëteit in voedselitems en prooitypen varieert ook tussen de vogelsoorten.

De diëten van zeevogels in gevangenschap verschilt ook een hoop. Eidereenden krijgen voornamelijk commerciële voeders gevoerd en de andere vogels hoofdzakelijk vis met additieven. De additieven bestaand voornamelijk uit multivitaminen, inclusief vitamine B en E en meestal ook vitamine A. Calcium is al voldoende aanwezig in de visgraten. De gekozen vissoorten zijn voornamelijk lodde, zandspiering, kreeftjes en haring voor de papegaaiduikers, drieteenmeeuwen en zeekoeten. Spiering wordt ook gegeven aan eidereenden, naast commerciële pellets. De meeste dierentuinen voeren hun dieren twee- of driemaal per dag. De papegaaiduikers, drieteenmeeuwen en zeekoeten hebben de meeste voorkeur voor vissoorten (lodde, haring, koornaarvis en kreeftjes), terwijl de eidereenden geen voorkeur voor voeding lijken te hebben.

Gedragsonderzoek in Diergaarde Blijdorp wijst uit dat er een significante voorkeur is voor voerbak voor de papegaaiduiker en de drieteenmeeuwen. Er was geen significante voorkeur voor tijdstip van voeren. De tijdsbesteding aan foerageren, vergeleken met overige gedragingen, lijken veel minder dan foerageergedrag in het wild. Eidereenden vertoonden zelfs geen foerageergedrag, behalve het eten uit de voerbak. De eenden vertoonden ook voor 40% van hun tijd stereotiep gedrag. Het huidige dieet van de papegaaiduikers, drieteenmeeuwen en zeekoeten in Blijdorp bestaat meestal maar uit een enkel type vis, terwijl andere dierentuinen een mix van vissoorten aanbieden.

Dierentuinen gebruiken verschillende voedingsmethoden. De papegaaiduikers, drieteenmeeuwen en zeekoeten worden hoofdzakelijk gevoerd in bakken, in combinatie met het voeren van vis verspreid in het water. Sommige dierentuinen voeren de vogels met de hand. Slechts drie dierentuinen gebruiken alleen een voerbak als voedingsmethode. Voeren met de hand kost het meeste tijd, maar geeft een goed beeld van de individuele voedselopname. Het voeren in bakken kost minder tijd, maar geeft geen goed beeld van de voedselopname en andere, wilde vogels kunnen makkelijk voer stelen. Het strooien van voer in het water stimuleert het natuurlijke duik- en jaaggedrag en de individuele opname kan beter worden gecontroleerd wanneer dit wordt vergelijkt met het voeren in bakken. Een nadeel is dat de waterkwaliteit achteruitgaat en dit het verenkleed van de vogels kan beïnvloeden. Anseriformes worden hoofdzakelijk gevoerd door middel van het voeren in het water of een combinatie van voeren in bakken en in het water. Een dierentuin gebruikt een kooi, geplaatst over het water, om wilde vogels te weren.

De aanbeveling is om verschillende vissoorten per dag te geven, in plaats van één soort. Dit dieet kan worden aangevuld met caroteen om het tekort aan vitamine A op te vullen. De voerbakken zouden moeten worden geplaatst op meerdere plaatsen in het verblijf. Deze methode kan worden aangevuld met het voeren van vis, laag in vetpercentage, in het water als verrijking. Er moet hierbij worden gekeken of de vissen in het verblijf niet teveel mee eten en daarnaast de waterkwaliteit. De eidereenden zouden moeten voorzien van meer verrijkingsmateriaal door bakjes met eendengraan op verschillende plaatsen in het verblijf te plaatsen, net onder water. Het geven van enkele mossels kan ook een oplossing zijn. De huidige voeding kan worden gegeven in het water, in plaats van in een voerbak.

Aanbevelingen van verder onderzoek zijn: het onderzoeken van de nutritionele behoeften van de verschillende vogelsoorten, of minstens de behoeften van zeevogels en zee-eenden in het algemeen. Gedragsonderzoek in Diergaarde Blijdorp kan worden uitgebreid en vergeleken worden met gedragsonderzoeken in andere dierentuinen. Het stereotiep gedrag van de eidereenden zou ook moeten worden onderzocht om het welzijn en de gezondheid van de vogels te verbeteren. Diergaarde Blijdorp zou moeten overwegen of de samenstellingen van de vogels zou moeten worden veranderd. De laatste aanbeveling is om de effecten van het voeren van vis in het water te onderzoeken op de waterkwaliteit en de kwaliteit van het verenkleed van de vogels.

Chapter 1. Introduction

Animal welfare is an important term in the Netherlands and the EU (European Union). Consumers want animal friendly products (Botreau et al, 2007), governments have numerous of requirements for animal welfare (Botreau et al, 2007) and livestock farmers are balancing between consumer demands and governments' demand (Carporale, et al, 2005). Animal welfare is multidimensional and is not uniformly defined. The Dutch policy statement of animal welfare defines animal welfare as: "The quality of life of the animal, whereas the keeper of the animal respects the 'five freedoms' and do not exceed the boundaries of the adaptation abilities of the animal." (Ministry of Economics, Agriculture and Innovation, 2012). The Five freedoms formulated by Brambell (1965) and revised by FAWC (1993) are: freedom from thirst, hunger and malnutrition, freedom from discomfort, freedom from pain, freedom to express normal behaviour and freedom from fear and distress.

All keepers of animals are supposed to take care for animals and adapt the five freedoms (Veissier et al., 2008). It is sometimes difficult to accomplish all those requirements and create the best environment for captive animals. Zoos are good examples of it. Visitors of zoos want to see as much as possible of the kept animals and also want to watch animals from as close as possible. Enclosures for animals are adapted to their natural life and behaviour, but also to the visitors of the zoo. Safety, for instance, is a very important factor. Visitors of zoos must not be able to interrupt or importune animals and vice versa. Another example is the living environment of zoo animals which is very small, compared to their natural situation. This could be in contradiction with one of the five freedoms: freedom to express normal behaviour, because it is sometimes impossible to adapt the living environment in such a way that captive animals can express behaviour as they would in the wild.

Rotterdam Zoo has a visitor number of 1.4 million people a year and is one of the biggest attractions in the Netherlands (Diergaarde Blijdorp, 2015; Rabobank, 2011). A part of Rotterdam Zoo, Oceanium, has been opened since 2001. The opening of the Oceanium had almost doubled the amount of visitors (Diergaarde Blijdorp, 2015). In Bass Rock, a department of the Oceanium, are living some seabirds: Black-legged kittiwakes (*Rissa tridactyla*), common guillemots (*Uria aalge*), Atlantic puffins (*Fratercula arctica*) and common eiders (*Somateria mollissima*), together with fish species: sea perches, sea bream and crayfishes. Bass Rock has a basin of 200 m^2 and has an average depth of 1 meter. The side walls of the basin are cliffs, simulating the natural living space of seabirds. One side is accommodated with a glass wall for visitors. Figure 1.1 – 1.4 show the housing of the seabirds in Rotterdam zoo.

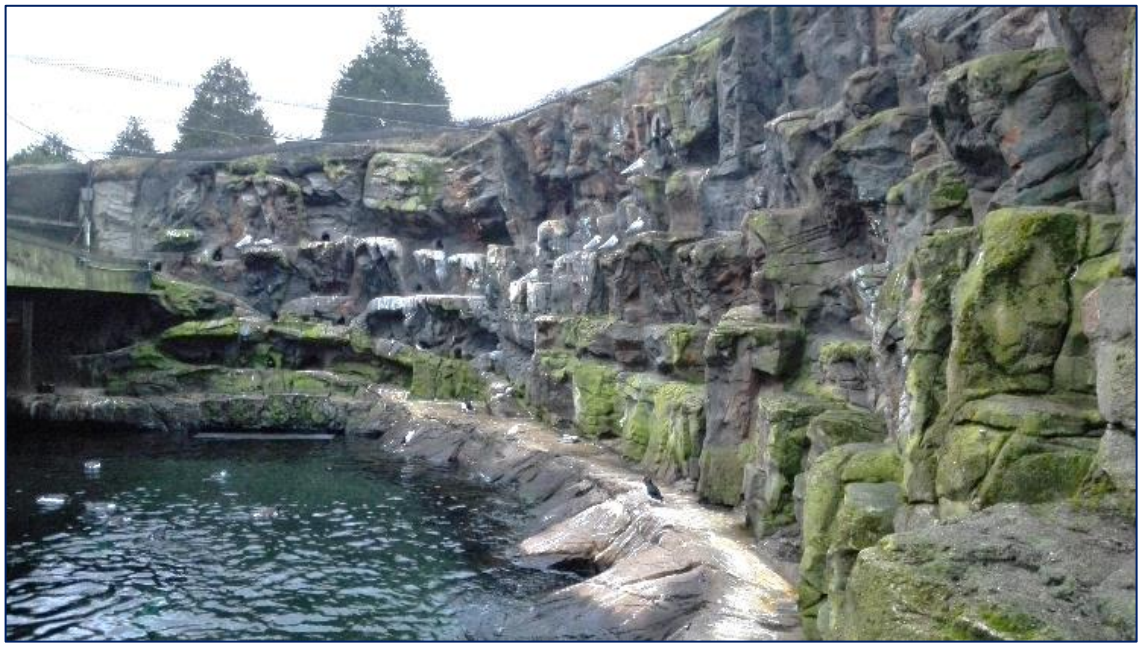


Figure 1.1 'Rocky side wall of Bass Rock'

Figure 1.2 'Metal feeding bins in Bass Rock'

Figure 1.3 Feeding bin of the common eider'

Figure 1.4 Visitors side of Bass Rock

All birds originally live in Northern regions of the world. The black-legged kittiwake (*Rissa tridactyla)* is a white-headed gull, lives in arctic and temperature waters (Hoyo, Elliott and Sargatal, 1996) and breeds on high, steep cliffs on coasts. The kittiwake eats fish and invertebrates, sometimes also planktonic invertebrates. The common guillemot (*Uria aalge)* is one of the most studied seabird species (U.S. Fish & Wildlife Service, 2006) and has a black and white colour. This bird can be found in the low-arctic and boreal waters of the North Pacific and North Atlantic. The common guillemot eats fish, crustaceans and mollusks and nestles on cliff ledges, bare rock (Hoyo, Elliott and Sargatal, 1996). Atlantic puffins (*Fratercula arctica*) live along rocky coasts and offshore islands (Rector, 2011). The Atlantic puffin eats mostly small fish, but sometimes also crustaceans, nereids and squid (Hoyo, Elliott and Sargatal, 1996; Rector 2011). The common eider (*Somateria mollissima*) lives in arctic and subarctic marine areas and often breeds in nests around other seabirds. This bird is the largest species of seabirds (Hoyo, Elliott and Sargatal, 1996; Rector 2011). Figure 1.5 shows pictures of the bird species in Bass Rock.

Figure 1.5 'Pictures of bird species in Bass Rock, Rotterdam Zoo. Top left: common guillemot, top right: common eider, bottom left: Atlantic puffin and bottom right: black-legged kittiwake'

The feed and feeding method of the seabirds of Rotterdam Zoo has been the same since 2010 or earlier (D. Slagter & S. Timmermans, personal communication, March 13, 2014). The feed industry of zoo animals is developed in the past years (Bruin et. al, 2005), but unknown is whether the feed and feeding method in Rotterdam Zoo is optimal adapted to the natural habitat, this is never investigated. Another problem is that there is no unambiguous way to feed the birds, employees have their own method of feeding. Fish species that are present in the housing of the seabirds eat also from the feed of the seabirds and inversely (D. Slagter, personal communication, February 9, 2014). The common eiders can eat pellets ad-libitum (*sea duck pellets*). The other birds are fed different fish species, including vitamin powder (*Mazuri Zoo Foods, Fish Eater Tablets*).

The Fish Eater Tablets contain vitamins, maltodextrin, yeast, silica, stearic acid, magnesium, stearate and cellulose. Vitamin powder is given, because frozen fish contains too little essential vitamins (thiamine for example) (McWilliams, 2008). The vitamin powder has the disadvantage that given fish cannot be scattered in the water, because the powder rinses off. Given fish species are: sprat, sand eels, capelin and smelt. The birds are fed three times a day in two flat, metal bins, because of the perishability of the given fish, especially during summers. The fish was removed every evening, otherwise, mice and rats will eat the fish and can form a pest.

Rotterdam Zoo is not the only zoo, which diets in mixed seabird enclosures are quite unknown. This research investigated whether the current feed and feeding method in Rotterdam Zoo is optimal for these birds and if not, which feed and feeding method provide the birds in their nutritional needs in a way that is as close as possible to the natural situation. The results of this research, with Rotterdam Zoo as principle, can be used by other zoos. The results will be shared with all participants of this research and also with EAZA (European Organisation for Zoos and Aquaria) who uses the information for advice to other zoos which have similar mixed enclosures.

Main question

The main question of this research was: "How should seabirds at Rotterdam Zoo be provided in their nutritional needs in a way that is as close as possible to their natural situation?"

The following sub-questions were investigated to answer the main question:

1. What are the nutritional needs of the *Rissa tridactyla*, *Uria aalge*, *Fratercula arctica* and *Somateria mollissima*?
2. What is the current diet of the seabirds in Rotterdam Zoo?
3. What method is used to provide the birds of food in Rotterdam Zoo?
4. In which way could the natural foraging behaviour of the birds be stimulated?
5. What kind of feed and feeding method do other zoos, which have seabirds, use?
6. Is there an alternative feed or feeding method for the seabirds, which can be applied in Rotterdam Zoo?
7. If there are any alternative method(s), which method provides the birds in their nutritional needs and is as close as possible to their natural situation?

The second chapter describes how and why these sub-questions were researched.

Hypothesis

It was unknown whether the current feeding method is good enough to continue. The hypothesis below was investigated during this study:

- H_0-hypothesis = There is *no improvement* possible to provide the seabirds of Rotterdam zoo in nutritional needs in a way that is as close as possible to their natural situation
- H_1-hypothesis = There is *one or more improvement* possible to provide the seabirds of Rotterdam zoo in nutritional needs in a way that is as close as possible to their natural situation

Objective

The aim of this study was to investigate the most optimal foraging situation for seabird species which are the same, or similar to, as species present in the Bass Rock enclosure in Rotterdam Zoo (*Rissa tridactyla*, *Uria aalge*, *Fratercula arctica* and *Somateria mollissima*). This whole research is done for all zoos which have seabirds or would like to have seabirds. This study was done in Rotterdam Zoo, but the results become available for all participants and members of EAZA. Rotterdam Zoo uses the information and recommendations for protocols and working methods of the seabirds. These results will be shared with all participants of this research and the European Association of Zoos and Aquaria (EAZA). EAZA will make the information available for other affiliated zoos. Other zoos can have profit of the results of this study and compare these results to their own zoo.

Duration and feasibility of the study

This study was completed within eleven weeks. The amount of ECT's for the final thesis is 15 points, which is similar to 420 working hours. This study was demarcated to a feasible study with enough depth to finish the thesis.

Expectations

Expected was that the current feed of the seabirds is enough to meet the nutritional needs of the birds, but that the way of feeding can be optimized. This expectation was based on the fact that as long as employees of Rotterdam Zoo know the method of feeding is unchanged. And the birds do reproduce and seems to be healthy (D. Slagter, personal communication, February 9, 2014). Active and healthy birds are also more attractive for visitors of the zoo. Also was expected that there is a lack of animal specific information; the lack of information should possibly be attained from other zoos and instances that have seabirds.

Relevance

Diets and feeding methods of captive animals are sometimes insufficient, although zoo nutrition is more developed for the past few years (Tully, Dorrestein and Jones, 2009). Especially diets of not well-known or less popular zoo animals lack specific information about diets and feeding methods. This report contributes to the development of diets and feeding methods of captive seabirds and sea-ducks, because it analyses different diets, methods and some requirements. Besides that, the interest in animal welfare become higher (Amos and Sullivan, 2014; American Humane Association, 2014).

This study can be used as principle for other, future research. Zoos can use this document to compare the results to their own zoo and adapt the diet and feeding methods to their own seabirds. This study can show a different perspective than zoos already have, which can improve the welfare of animals.

Chapter 2. Materials and methods

This study consists of different parts: literature study, behavioural studies and questionnaires to other zoos. This chapter describes the materials and methods used during these different parts of the study. All appendices are placed in a different document: "Diets and feeding methods of captive seabirds in mixed enclosures (*Rissa tridactyla*, *Uria aalge*, *Fratercula arctica* and *Somateria mollissima*) – Bundle of appendices". This bundle of appendices can be viewed on demand.

2.1 Research method

Research was partly done by qualitative research and partly by quantitative research. The qualitative part of this study consisted of literature study and contact with other zoos which have seabirds. The quantitative part was an observational study. The experiments were done from March 2015 to the end of April 2015. Analysis and writing was done in May 2015. This study was completed within eleven weeks. The amount of ECT's for the final thesis was 15 points, which is similar to 420 working hours.

2.2 Literature study

Literature study was done to investigate the nutritional needs and foraging behaviour of all seabird species that are present in the Bass Rock enclosure in Rotterdam zoo. The investigated species were: Atlantic puffins (*Fratercula arctica)*, black-legged kittiwakes (*Rissa tridactyla*), common guillemots *(Uria aalge*) and common eiders (*Somateria mollissima*). The information about nutritional needs and foraging behaviour in the wild, as far as this was known in literature, was needed to compare the natural situation of the birds with birds in captivity and also to compare the results of literature to the results of the questionnaires. Diets cannot be composed without any knowledge and information on nutritional needs and natural behaviours.

Scientific information was retrieved from different (scientific databases), like:

- Wageningen Library
  - This library gives access to almost all scientific articles worldwide. The library of CAH Vilentum is also possible, but is more limited in access. Examples of databases that become available are: Science Direct, Springer Link, Edepot, Wiley Online Library, PubMed and Oxford journals.
- Library of Rotterdam Zoo
  - Gives access to some specific information of animals in zoos, mainly books and articles.
- EAZA database
  - Gives also animal specific information about animals in zoos and gives access to the (nutritional) requirements of the most animal species.
- ZIMS (Zoological Information Management System)
  - Database that gives access to the population of animals in zoos and aquaria which have this programme also

Expected was that there was a lack of bird specific information about nutritional needs and values and also about captive seabirds in general. Many articles were combined to get a reliable result. When there was no bird specific information, there was focussed on the scientific order of the birds, which are Charadriiformes (*Laridae and Alcidae)* for the Atlantic puffin, black-legged kittiwake and common guillemots and Anseriformes (*Anatidae)* for common eiders.

The results of literature study are incorporated in the whole report, but mainly in chapter three: 'Natural diet and foraging behaviour'. All used literature is referred in the text using the APA norms. The results are divided in general results, results of Charadriiformes and results of Anseriformes. The results of literature study should give an answer on sub-question one and two.

Materials

Materials used for literature study are:

- (Scientific) literature studies
- Databases
- (Scientific published) books

2.3 Behavioural studies

Behavioural studies were done to investigate the feeding behaviour of seabirds in captivity, because the feed is only given in metal bowls. Normally, seabirds hunt and dive for fish. It is unknown whether the birds can behave like in wild and whether the birds have any preference for the left or right bowl. Observations were done three times a day for one hour: during and after feeding moments. The moments of observation were at 7.45 AM, 12.00 PM and 03.00 PM.

All types of behaviour were noted during a period of four weeks, one week of observations per bird species. This means that there were done fifteen observation per bird species. It was unfortunately not possible to observe every individual bird, because of the amount of birds in Bass Rock, the speed of the birds and their similarity. The sampling method was scan-sampling per 2.5 minutes. Only frequencies of behaviour per bird species, were noted, because it was not possible to measure individual times and frequencies. The recording rule was instantaneous sampling. Frequencies of foraging behaviour were used to compare those frequencies to the other types of behaviour.

Data was going was collected by using a protocol. All protocols are placed in appendix 2. The protocols were printed, filled in with a pen, and retyped in Microsoft office program Excel used for every observation. The ethogram, used for observations, can be found in appendix 1. The results of behavioural studies should give an answer on sub-question three.

Sub-question two was also investigated during this part of the study, which is the current diet of seabirds in Rotterdam Zoo. During the period of behavioural studies was noted what amounts of feed and vitamins are given and what method was used. This was needed to compare diets and methods in Rotterdam Zoo to diets and methods in other zoos.

Materials

The used materials for the behavioural studies are:

- Ethogram (placed in appendix 1)
- Protocols (placed in appendix 2)
- Stopwatch
- Pencils
- SPSS program for statistical tests
- Calculator for calculations and statistical tests

2.4 Diets and methods in other zoos

To investigate the most optimal way of feed and feeding methods, there was made use of information of others zoos and instances, by way of questionnaires. Not only zoos in the Netherlands, but also zoos in Europe, America and Asia. ZIMS, an International Species Information System, was used as database for captive seabirds. Via ZIMS was investigated which zoos have any Atlantic puffins, black-legged kittiwakes, common guillemots or common eiders. 56 Institutions have common eiders, 13 zoos which have common guillemots, 12 zoos which have Atlantic puffins and only 1 zoo which have kittiwakes. Some had a combination of more species.

64 zoos were approached to fill in the questionnaire. Five zoos had responded that there were no seabirds present in their zoo anymore. 31 zoos have filled in the questionnaire. The remaining zoos did not respond within the right time.

The 31 zoos that have filled in the questionnaire were questioned about their seabirds, nutrition, feeding method and housing. The questions were the same for all zoos. The used questionnaire is showed in appendix 3. The results of the questionnaires are described in chapter 4.2 and chapter 5.2. The results are divided in results of Charadriiformes and results of Anseriformes and should give an answer on sub-question five. The results of the questionnaires are viewed in appendix 10 of the bundle of appendices.

Materials

The used materials for this part are:

- ZIMS (Zoological Information Management System) for an inventory of birds in zoos
- Contact persons of zoos
- Questionnaires (placed in appendix 3)

2.5 Interviews

Because of a lack of scientific information about the bird species in Rotterdam Zoo or similar bird species, there are held some personal interviews. The first interview was at Heidelberg Zoo, Germany, with Simon Bruslund and Melanie Oesterwind. Simon Bruslund is bird curator and head of animal management at Heidelberg Zoo and had also worked at Loro Parque, Tenerife. Melanie Oesterwind is a veterinarian at Heidelberg Zoo and had also worked at Loro Parque. Both told their experiences with seabirds, especially common eiders and Atlantic puffins. The second interview was at Arie Blok Animal Nutrition, a Dutch grain processing company, which produces different types of animal nutrition for the professional and private sector. The feed of the common eiders in Rotterdam Zoo is produced by Arie Blok. The interview was done with Tinus Boomstra, sales manager at Arie Blok, and Erik Berenpas, nutritionist. Both had answered questions about common eiders and their nutrition, related to the results of literature and questionnaires.

2.6 Alternative feeds and feeding methods

Alternative methods, which probably can stimulate natural behaviour, were investigated when literature study and observational studies about foraging behaviour were finished. Methods that are used in other zoos were investigated first by looking for the advantages and disadvantages. Alternative diets, used in other zoos, were also analysed. These feeds and feeding methods were investigated by literature study and the results of questionnaires. These results are described in chapter 5.3.

Sub-question four, six and seven were answered by a combination of the above mentioned studies.

2.7 Competences

Competences that have been practiced during this study are described below. The CAH-competences were reviewed by Dionne Slagter in appendix 4. Reviewing was done by giving grades from 4-10. 4 is the lowest grade and 10 is the highest.

1. Globalising

A part of this study was done by questionnaires to other zoos. These zoos are mainly outside the Netherlands. Professional skills were required to get the right contacts and information of the zoos.
Grade: 8

2. Leading

The project was done individually, but also in corporation with other people. Leading of the own project is very important. Other people and organisations were needed to accomplish the final thesis, which means that effective leadership was needed to get the best result, also in complex situations.
Grade: 8

3. Entrepreneurship
Initiative, corporation and flexibility is needed for every project, especially as a manager or leading person. An entrepreneurial person must be able to react correctly during different circumstances and be problem solving. During this project different problems were occurring that are solved now.
Grade: 8

4. Presenting
The final results will be presented to employees of Rotterdam zoo and supervisor(s) of Dronten University of Applied Sciences. The final presentation requires the right skills to present at the right way. Besides the final presentation, I had to present myself continuously to other zoos, (unknown) employees and visitors.
Grade: 8

5. Investigating
The biggest part of this thesis was investigating. Literature studies, behavioural studies and questionnaires are all part of investigating.
Grade: 7

Average grade: 7.8

Chapter 3. Natural diet and foraging behaviour

Diets of captive birds should meet the nutritional needs, but should also be adapted to their feeding ecology and natural behaviour (AZA Charadriiformes Taxon Advisory Group, 2014). Unfortunately, are diets in zoos mainly diets which are composed on experiences of zookeepers and local traditions (Tully, Dorrestein and Jones, 2009). These diets are not always suitable. Avian nutrition can be determined by learning the diets of the family of birds (Tully, Dorrestein and Jones, 2009) and subsequently adapt these diets to the anatomy and physiology of the bird species (Harrison and Lightfoot, 2006). The Atlantic puffins, common guillemots and black-legged kittiwakes belong to Charadriiformes and common eiders belong to Anseriformes. Charadriiformes have three suborders: *Alcidae*, Charadrii and *Laridae*. The Atlantic puffin and common guillemots are sub-ordered as *Alcidae* and the black-legged kittiwake is sub-ordered as *Laridae* (Mc Cain, 2015). Diets of abovementioned seabirds consist mainly of small fishes and invertebrates (Klasing, 1998). Table 3.1 gives a short overview of general information about the birds in Rotterdam Zoo. All birds originally live in the Northern regions of the world and, of course, in Bass Rock, Scotland. And are mainly fish-eaters (piscivorous birds) or eating other marine materials.

Table 3.1 'General information about the birds in Bass Rock (Del Hoyo, Elliott and Sargatal, 1996 [1]; Del Hoyo et al, 1992)

	Atlantic puffin	Black-legged kittiwake	Common guillemot	Common eider
Family	*Alcidae*	*Laridae*	*Alcidae*	*Anatidae*
Heights	26-36 cm	38-40 cm	38-43 cm	50-71 cm
Weight	460 g	305-512 g	945-1044 g	810-3040 g
Habitat	Rocky coasts and offshore islands.	Arctic and temperate waters, preference for high, steep cliffs, up to 20 km inland	Sea coasts, along rocky cliffs and offshore islands	Northern coasts of Europe, North America and Eastern Siberia. Breeding along rocky coasts
Food	Small crustaceans, nereids and squid. Fish: sand eels, capelin, herring, sprat, Atlantic mackerel and gadids.	Marine invertebrates and fish: sand eels, capelin, herring and gadids. Other food items are garbage and human food	Crustaceans, molluscs, polychaetes and fish eggs. Fish: capelin, herring, sprat and sand eels.	Crustaceans, molluscs, mussels and other invertebrates
Recommended food intake	15-20% of mature body weight.	20-25% of mature body weight	25-33% of mature body weight	20-25% of mature body weight
Breeding season	Late-May to early June	Mid-May to mid-June	Mid-May to Early June	April-May

3.1 Anatomical characteristics, related to foraging

Alcidae (Atlantic puffins and common guillemots) are small to medium sized birds, have short wings, short tails and often stocky bodies. *Laridae* have longer wings and more slender bodies (McCain, 2015). *Anatidae* have relatively short legs, webbed feet, soft and sensitive bills, and strong wings (Backues, 2015). These differences in body anatomy influence hunting behaviour, which are per bird species described in sub-chapter 3.3. This sub-chapter describes the anatomy when different than non-piscivorous birds, nutrients and related diseases and natural diets and behaviour of species in Rotterdam Zoo.

3.1.1 Gastrointestinal tract of seabirds in general

The digestive tract of piscivorous birds is not comparable to poultry (granivorous birds), but is closely related to the dietary components and habits of bird species (Kwakkel and Pellikaan, 2015). The gastrointestinal tract of Charadriiformes is flexible and is adaptable to the diet (McWilliams, 2008). The proventriculus, for example, is larger for the breakdown of protein and the gizzard is relatively small, because it is less muscled when diet consist only of fish. When the diet contains a higher ratio of shells to crush, the gizzard will be more muscled. The diet of Charadriiformes and Anseriformes consist mostly of fish, which is fermented in the proventriculus and less in the gizzard (Miller and Fowler, 2012).

Head, beak and mouth

The gastrointestinal tract starts at the beak of the bird. The beak has the function to catch preys, obtain feed and swallow preys into the stomach. Salivary glands in the mouth of birds wet the feed to make it easier to swallow feed in the stomach. Salivary glands in the mouth of seabirds are less important than glands in granivorous birds, but birds who lubricate their prey in the water or eat dry food show also more development (Samar et al., 1995).

Seabirds have salt glands to filter salt out of the vascular system (Schreiber and Burger, 2002). The small intestine and kidneys absorb the biggest part of the salts. This is the reason why birds which have salt glands have bigger kidneys (>1% of body mass) for filtering. Birds without salt glands have kidneys less than 1% of body mass (Scanes, 2014).

Stomachs

When feed is swallowed through the oesophagus into the stomach, it passes the crop. The crop is located on the right side of the neck. Crops are less developed in duck species and gulls even lacking crops, because gulls have a very elastic oesophagus (Gelis, 2006).

The first stomach of birds is the called the proventriculus or glandular stomach and the second is the ventriculus, the gizzard or muscular stomach. The size and development of both stomachs depends on the diet of birds. Piscivorous birds, which eat mainly fish or other soft food items, have very elastic stomachs to compensate the lack of sufficient crop function. The space between the proventriculus and ventriculus lacks glands and folds.

Proventriculus

The proventriculus of piscivorous birds have ridges and two types of glands: tubular and gastric glands. Tubular glands secrete mucus for protection of epithelial walls of the intestinal tract from digestive juices and damage. Gastric glands secrete hydrochloric acid and pepsin. Hydrochloric acids and pepsin in the proventriculus coat food and start to enzymatically break down food items. Pepsin breaks down proteins into peptides and finally in amino acids. Hydrochloric acids protects the body from bacteria and other pathogens.

The gizzard (ventriculus)

The gizzard has the function to mechanically breakdown feed, by pepsin and hydrochloric acid. Muscles into the gizzard grind and mix feed during contractions to smaller particle sizes. The opening (pylorus) between the gizzard and small intestine allows ingesta (food mass) to pass by way of contractions. The isthmus, which separates the proventriculus from the ventriculus, opens to allow ingesta go back into the proventriculus when food particles are too big.

Intestines and pancreas

Enzymatic digestion and absorption of nutrients occurs in the small intestine of birds. The first part of the small intestine is called the duodenum. The ingesta passes the duodenum by way of peristaltic contractions. The duodenum forms a loop and surrounds the pancreas. The pancreas is a small gland, closely situated to the duodenum. The pancreas has exocrine and endocrine functions. The exocrine part is the largest part and produces digestive juice, bicarbonate and enzymes (amylase, trypsin and lipase). The endocrine part produces insulin and glucagon for the metabolism of carbohydrates and transport (Gelis, 2006). After the duodenal loop begins the jejunum and follows the ileum, but duodenum, jejunum and ileum cannot be differentiated easily.

Ingesta is fermented further and nutrients are absorbed. The ceca are important to ferment vegetable parts of food, which means that the ceca are less developed in seabird species (Gelis, 2006).

3.1.2 Senses

The detection of preys is very important in wild-living seabirds as well as in captive seabirds. Seabirds have well developed olfactory and visual senses (Ainley et al., 2003). Seabirds can also remember places where fish is caught successfully and also under which conditions (Whanless, Harris and Morris, 1990). Seabirds concentrate on specific places where to catch preys and then use visual senses to specify their feeding behaviour. For example, seabirds can see where other birds (or other marine mammals) actively catch preys and can even see whether changing circumstances can lead to more successful foraging. Changes or signals of foraging successful can be: changes in colour of water, breaking school preys, odours or turbulence (Ainley et al., 2003). However, olfactory senses are less developed in gulls and *Alcidae* (Bang, 1966).

3.1.3 Skin and feathers

Birds have a thinner skin than human and mammals. Feathers are important for all types of birds for thermoregulation and floating on water. Feathers contain a different type of keratin (90% beta-keratin) whereby nutritional deficiencies can influence feather growth (Prum and Brush, 2014). This means that the feather quality is part of the birds' health, related to their nutrition. The development of new feathers is a sensitive process (Macwhirter, 2009). Malnutrition can cause forming of horizontal fault bars on growing feathers. Figure 3.1 shows an example of fault bars.

Figure 3.1 "Fault bars on the wing of a bird"

3.2 Nutrients and related diseases

Exact nutritional requirements of the four species in Rotterdam Zoo are unknown. There is insufficient information available to set requirements with certainty (Brue, 1994). General information and comparable seabird species are used to determine the required nutrients and nutrient-related diseases of those birds.

3.2.1 Water

The body of a bird consist around 65% water (Ellis and Jehl, 1991; Schreiber and Burger, 2002). Water is an essential nutrient for birds, it is important in the metabolism of the body and control of body temperature. Fresh drinking water should always be available. Fish contains for 70-80% of water, but sea duck pellets only 40-50% of water. Seabirds which eat fish can obtain more water from the fed fish, while common eiders, which eat mainly pellets, should drink more fresh water (Northern territory, n.d.).

3.2.2 Protein

Protein may be considered as the most important nutrient (Stevens, 1996) and is used for different processes in the body. Requirements of amino acids change during moulting; the quality of dietary protein increases. The requirement for dietary protein is the highest for hatchlings and the lowest for adult birds at maintenance (McDonald, 2006). Digestibility and the balance of amino acids and quantity of proteins are considered as very important during moults. The reason for this is a loss of 25% of protein mass in the body during moult season (McWilliams, 2008). Important amino acids for the feathers are: methionine and cysteine, which are considered as limiting amino acids in marine fish (Crissey and McGill, 2003). Excess of proteins can cause overgrowth of beak and nails (McDonald, 2006). However, exact protein intake remains unknown.

3.2.3 Fat

Fats are needed as a source of energy. Birds have no requirements for fat, but requirements for fatty acids which make up fats (Brue, 1994). Essential fatty acids for seabirds are: linoleic acid and α-linolic acid, and probably also arachidonic acid (McWilliams, 2008; Brue, 1994). Excess of fats can cause obesity, oily feather textures, lipidosis of the liver and problems with mineral absorption, like calcium. Deficiency of fat can cause loss of weight, stagnation of growth, less immunity, poor reproduction and poor hatchability. Linolic acid will be destroyed when fatty acids become rancid and the need for vitamin E will be higher. Around 2% of dietary fat is needed for the absorption of carotenoids and fat-soluble vitamins (McWilliams, 2008). The content of fat in fish can vary from 1%-20%.

3.2.4 Carbohydrates

Carbohydrates are important sources of energy and are the only source of utilisable energy of the nervous system of birds. Deficiency of carbohydrates can cause neurological problems. Seabirds which have neurological signs should be fed glucose, vitamin A, B and calcium, because all-meat diets are low in those nutrients (Tully, Dorrestein and Jones, 2009).

3.2.5 Vitamins and minerals

Vitamin A, B_1 and E are considered as important vitamins to add to feed of piscivorous birds, because of vitamin loss during freeze and storage processes of fish (Nijboer, 2015). The exact vitamin requirement for most piscivorous birds is unfortunately unknown (Dierenfeld, 1997). Nutritionist Joeke Nijboer advises 10,000 IU vitamin A, 150-160 mg vitamin E and 50 mg vitamin B_1 for captive seabirds (Nijboer, 2015). For the intake of minerals and vitamins for captive seabirds is recommended to feed whole fish, including abovementioned vitamins (McWilliams, 2008).

Problems with vitamins are caused by deficiency (hypovitaminose) or excess (hypervitaminosis). Hypervitaminosis is an increased problem since zoos often over-supplementing vitamins rather than supplement the advised amounts. Mostly because of a lack of nutritional information. Lots of clinical signs of vitamin deficiency are similar to the signs of vitamin excess (Tully, Dorrestein and Jones, 2009). Excess of water-soluble vitamins (B and C) are less dangerous than fat-soluble vitamins (A, D, E and K), but both should be added in sufficient amount.

Vitamin A

Vitamin A (retinol) is formed in the liver (Harrison, 1993). It is related to the health of eyes, and is an important vitamin for growth, development of the vascular system, production of hormones and immunity (Tully, Dorrestein and Jones, 2009) and is also called the immunity-vitamin (Prum and Brush, 2014; Davison, Kapsers and Schat, 2008). Clinical signs of Vitamin A deficiency can be: Pustules on the mouth, oesophagus, crop and nose, less immunity, ataxia, paralyse, reduced egg and sperm production, insufficient coloration of the feathers, and polyuria/polydipsia (Backues, 2015) and mucosal membrames can become hornified (L. van Sonsbeek, personal communication, May 27, 2015). Symptoms of hypervitaminosis A are often the same as symptoms of hypovitaminose A. Symptoms can be: loss of weight, dermatitis, hepatopathy, decreased strength of the bones, infections of the nares and mouth (Tully, Dorrestein and Jones, 2009). The required vitamin intake for captive seabirds should be between 10,000 and 15,000 IU per kg of fish. Deficiency of vitamin A can also be related to aspergillosis (*Aspergillus fumigatus)*, a disease that is caused by a fungus and can lead to death. A lot of birds in Rotterdam Zoo died due to this disease (Nijboer, 2015).

The colour of the beak and gapes of black-legged kittiwakes and Atlantic puffins, and probably more seabird species (Hill and McGraw, 2006), are related to the body condition of the birds (Doutrelant et. al, 2013). Beaks and gapes consist of carotenoids (pigments), which colours it more brighter when the birds are in better condition. The relation between the condition of the bird and the colouration of the gape is in female puffins is stronger than male puffins (Doutrelant et. al, 2013). Carotenoids are fat-soluble pigments that are often considered as limiting. Carotenoids can only be acquired by food intake (Olson and Owens, 1998). Carotenoids are also a type of antioxidants, and regulate and stimulate the immune system of the bird (Møller et. al, 2000).

Vitamin B_1 (Thiamine)

Frozen fish contains thiaminase, which is a thiamine-splitting enzyme and metabolites thiamine. Thiamine is a water soluble vitamin and is used for energy production and carbohydrate metabolism. Excess of thiamine have never been reported. Thawing fish in running water can cause loss of thiamine. Deficiency of vitamin B_1 can cause stargazing and loss of weight in ducks (Backues, 2015). The required vitamin B_1 intake should be 50 mg per kg fish. Most of other vitamin B is already present in (frozen).

Vitamin D

Ingested vitamin D is synthesised in the body by sunlight (UV B-light) into the active form of vitamin D, which is vitamin D_3 (Tully, Dorrestein and Jones, 2009). Ultraviolet light is absorbed by the non-feathered part of the bird's body. Vitamin D_3 is used for the absorption of calcium (Nijboer, 2015). Vitamin D is also considered as an important vitamin for captive seabirds, because these birds are often fed human-prepared fish. This type of fish does not contain any viscera by birds in captivity (McWilliams, 2008). Sunlight or artificial light is needed to synthesise vitamin D. 12 hours of sunlight are considered as most optimal time (AZA Charadriiformes Taxon Advisory Group, 2014), UV B-light is only present for a few hours per day.

Vitamin E

Vitamin E is an anti-oxidant. Deficiency of vitamin E can cause problems like instability, hanging wings and weakness of the bird. A shortage of vitamin E can also enhance lipid peroxidation during storage, which lead to damage of cells (McDonald, 2006). Just as vitamin A and B_1 is vitamin E not stable during storage and freezing processes and should be fed as a supplement (McWilliams, 2008). The required intake for vitamin E should be 150 mg per kg of fish extra (besides the value of the fish (Nijboer, 2015).

Vitamin K
This vitamin is needed for haemostasis. Deficiencies or excess of vitamin K are unknown, even as requirements or advises (Crissey et al, 2002). But there are some cases known whereby animals have eaten rat poison (warfarine and coumarin), these animals have a deficiency of vitamin K (L. van Sonsbeek, personal communication, May 27, 2015).

Calcium and phosphorous
Calcium and phosphorus are needed for bone and eggshell formation, the ratio is 2:1. Deficiency of these minerals can lead to weak bones, in combination with vitamin A and D. Exposure to sunlight for at least a period of the day is needed for the use of calcium, phosphorous and vitamin D. UV B-light is almost not present from March-October, in the Netherlands, which means that vitamin D cannot be synthesised. These components should be supplemented into the diet (Northern Territory, n.d.) as cholecalciferol (L. van Sonsbeek, personal communication, May 27, 2015).

Sodium and chloride
The function of Sodium and Chloride balance and maintain conditions for metabolic reactions. Seabirds ingest lots of salts when foraging. Abundance of salt in the body of the bird can lead to dead. Seabirds have one pair of nasal salt glands to filter salt out of the blood of the bird. The salt glands can excrete a high concentration of NaCl (Natrium Chloride) with a low loss of water in the body (Schreiber and Burger, 2002).

3.3 Natural diets and behaviour
Diets of Charadriiformes consist generally of fish and invertebrates. The diets of captive Charadriiformes consist of these items, but also commercial diets are fed in some zoos, in combination with fish and crustaceans. Sprat, eels, herring and sardines are often suitable for most seabirds in captivity, chopped or small fishes (Stocker, 2005). This subchapter describes the natural diet and foraging behaviour of Charadriiformes and Anseriformes species that are present in the Bass Rock enclosure in Rotterdam Zoo. Only bird specific diets and behaviour are described. All general information about diets is already described in the previous subchapters.

3.3.1 Diet and foraging behaviour of Atlantic puffins (*Fratercula arctica)*

Foraging behaviour
The Atlantic puffins are considered as limiting to catch preys, due to their body anatomy: small wings and stocky bodies (Balance et al., 2001). The Atlantic puffin catches preys by diving, with a mean depth of 10 metres and average time of 115 seconds. Maximum depths of 68 metres were measured in different researches (Burger and Simpson, 1986; Piatt and Nettleship, 1985) Puffins normally catch preys within an average distance of thirty one kilometre away from the colony. These birds prefer to catch preys in mornings and afternoons (Spencer, 2012). Atlantic puffins mostly hunt in small groups of two or three puffins. The puffin swallows preys in the water.

Interaction
The Atlantic puffins are the most social seabird species (Harris, 1984). These birds live and nests in colonies. It is evidenced that puffins avoid areas where some gull species are present, because gulls often try to steal preys from puffins and show often aggressive behaviour (Pierotti, 1983).

Food items
Atlantic puffins eat mainly fish. The fish is supplemented by crustacean, nereids and squid during the end of summer. Eaten fish species are: sand eels (*Ammodytes* and *Hyperoplus*), Atlantic herring (*Clupea harengus)*, Atlantic Mackerel (*Scomber scombus)*, gadids and sprat (*Sprattus sprattus)* (Rose, 1996). The bill of the puffin is formed to carry larger amounts of fish to feed hatched chicks.

Breeding season
The chicks of Atlantic puffins are fed by both parents. The average amount of given fish for chicks is 43-62 grams, divided into 3-9 meals a day (Rose, 1996). The Atlantic puffins incubate the eggs under the wings, other birds incubate the eggs while sitting on the eggs.

3.3.2 Diet and foraging behaviour of black-legged kittiwakes (*Rissa tridactyla)*

Foraging behaviour
Kittiwakes do not dive deep into the water, but on water surface. The main foraging methods of the black-legged kittiwake are plunge-diving and surface dipping (Coulson, 2011; Burger and Gochfeld, 1996). Black-legged kittiwakes hunt up to 70 km away from the colony (Daunt et al, 2002).

Interaction
Gulls, in general, can kill and even eat other adult seabirds. Larger chicks try sometimes to pirate food from other chicks. Piracy occurs not only by chicks, but adult gulls pirate also food from other birds. Adult gulls pirate even more than younger birds, because it requires skills to select and pursue victims. Black-legged kittiwakes forage often together with humpback whales (Burger and Gochfeld, 1996) and returns back in one direct flight (Ford et al, 2007).

Food items
Gulls have a wide variety of food items and foraging behaviour (Del Hoyo, Elliott and Sargatal, 1996 [1]). Black-legged kittiwakes eat mainly fish and invertebrates. Many fish species are part of the diet: sand eels (*Ammodytes*), capelin (*Mallotus villosus*), herring *(Clupea harengus*) and gagidae (*Pollachius virens*). The black-legged kittiwakes takes rarely some eggs and sometimes molluscs, crustaceans, earthworms, small mammals and vegetation (Burger and Gochfeld, 1996). Gulls often forage other items, like garbage and human food. (Daunt et al, 2002).

Breeding season
The breeding season starts in January for some colonies of kittiwakes, but most kittiwakes start to breed in February. The black-legged kittiwake lays eggs from mid-May to Mid-June and breeds in big colonies. The incubation time of these birds is 24-28 days (Del Hoyo, Elliott and Sargatal, 1996).

3.3.3 Diet and foraging behaviour of common guillemots *(Uria aalge)*

Foraging behaviour
Common guillemots forage on continental shelfs, which are the coastal waters of oceans. The average foraging time of common guillemots is between 5 and 5.5 hours per day (Davoren and Montevecchi, 2003), while these birds spend only 13% of their time on resting (Tremblay et al, 2003). Common guillemots dives mostly less than sixty seconds under water, but can dive to depths till 150 metres (Hedd et al, 2009).

Interaction
Common guillemots are less social than Atlantic puffins, but more social than gulls. Common guillemots turn back every year to the same mate and nest site (Moody et al, 2004) and breed in larger and in higher densities than other seabirds ('called a loomery'). This high density can influence the social behaviour of the common guillemots; there are sometimes aggressive interactions (Mahoney and Threlfall, 1982). Most of the failures of egg incubation is because of mishandling of the parents or attacks by gulls (Del Hoyo, Elliott and Sargatal, 1996 [1]).

Food items
The diet of common guillemots consists of 80% of fish; mainly sand eels (*Ammodytes*), capelin (*Mallotus villosus*), herring *(Clupea harengus*) and sprat (S*prattus sprattus),* but also squid and anchovies (Ainley et al, 1996; McWilliams, 2008). Common guillemots have a preference for small fish and catch mostly capelin, because this type of fish is the most available fish in the living area of common guillemots (Ainley et al, 1996; Hedd et al, 2009).

Breeding season
The birds spent most of the time of breeding seasons on rocky coasts, in high dense colonies, as earlier mentioned. Chicks are fed fish in high energy, around 20-32 grams a day (Del Hoyo, Elliott and Sargatal, 1996 [1]). The chicks are mainly fed capelins (*Mallotus villosus*) (Birkhead and Nettleship, 1987).

3.3.4 Diet and foraging behaviour of common eiders (*Somateria mollissima)*

Requirements for diets of waterfowl are well established in the National Research Council (NRC), but energy levels and proteins are calculated for maximum growth of the birds. The energy level of the diet should be adapted to accomplish the needs of non-productive birds (Backues, 2015). It is unfortunately unknown on what species these requirements are based on.

Foraging behaviour

The diet of the common eider is based on fish or specific marine ingredients (Backues, 2015). Common eiders diving down to catch preys, by head-dipping and upending in surface water (Del Hoyo, Elliott and Sargatal, 1996 [2]). Common eiders do not dive in deep waters. The ducks mainly eat submerged preys and swallow it completely into the stomach (Brinkman et al, 2003).

Interaction with other birds

Most birds interact with other birds during feeding times. Common eiders can be attacked by other birds or attack birds who have an interest in the same prey. Compared to other seabird species have the common eider much less interaction with other birds (Brinkman et al, 2003). Evidenced in a study on Texel is that none of the common eiders have tried to catch a prey of another bird (Brinkman et al, 2003).

Feed items

60% of the common eiders choose blue mussels (*Mytilis edulis*) as main food item for eiders according to several researches which are crushed and swallowed into the stomach (Bustnesj and Erikstad, 1990; Larsen and Guillemette, 2000; Del Hoyo, Elliott and Sargatal, 1996 [2]). Other bottom-lying molluscs, like periwinkles (*Littorina littorea*) are also main items of feed. Crustaceans, enichoderms and other invertebrates are also items of feed. Common eiders eat only occasionally some fish. These food items are complemented with vegetable matters, like algae, grasses and herbs.

Breeding season

Female ducks eat algae, berries, seeds and leaves of surrounding plants during incubation of eggs. The requirements for protein and energy intake become higher (Del Hoyo, Elliott and Sargatal, 1996 [2]).

Chapter 4. Diets of captive seabirds

This chapter describes an analysis of the current diet of seabird species that are present in the Bass Rock enclosure of Rotterdam Zoo, including the vitamin content. The second part of the chapter describes an analysis of different diets in other zoos which are contacted via questionnaires.

4.1 Diets in Rotterdam Zoo

All birds in Bass Rock are fed human quality fish, including viscera, with exception of the common eiders, which eat Anseres Sea-duck pellets expanded of Kasper's Faunafood. Appendix 5 shows the nutritional analysis of these pellets. The diet of common eiders is described in subchapter 4.1.2. Subchapter 4.1.1 describes the diet of the Atlantic puffin, kittiwakes and common guillemots, and subchapter 4.1.3 describes the current storage of feed and the influence of storage processes on the quality of feed.

4.1.1 The diet of seabirds in Rotterdam Zoo

The last diet for the Atlantic puffins, black-legged kittiwakes and common guillemots in Bass Rock was composed on February, 25, 2011 by Joeke Nijboer, nutritionist of Rotterdam Zoo, but is not up-to-date anymore. According to the diet sheet should be given 5-16 kilograms of capelin each day, including 2 grams of Twilmij vitamin powder per kg of fish. The birds should be fed three times a day and should get more fish when everything is eaten and less on the next feeding moment, when there is too much left of the previous feeding moment. When the birds have chicks, there should be given some extra smelts, including some vitamins also. Table 4.1 "Overview diet sheet of February 25, 2011" presents the official diet for the birds in Bass Rock.

Table 4.1 "Overview diet sheet of February 25, 2011"

Department	Bass Rock
Species	Atlantic Puffins (*Fratercula arctica*) Black-legged kittiwakes (*Rissa tridactyla*) Common guillemots (*Uria aalge*) Common eiders (*Somateria mollissima*)
Date of diet sheet	February 25th 2011
Feed seabirds	Capelin
Amount of feed	5-16 kg per day
Additives	2 grams vitamin powder of Twilmij per kg fish
Method	Divided in two metal bowls Feed moments are three times a day
Feed common eiders	Kasper's Faunafood - Anseres Sea-duck pellets
Amount of feed	Ad libitum
Additives	None
Method	Feed placed in one plastic bowl

Current diet
The fed fish is mainly sprat (*Sprattus sprattus)*, sometimes capelin (*Mallotus villotus)* and sand eels (*Hyperoplus lanceolatus*). During observations and weight moments was calculated which amount of fish and vitamins is given to the birds. This is described in appendix 6 'Average feed intake per bird species'. Table 4.2 gives an overview of the current diet.

Table 4.2 "Overview diet on April 14, 2015"	
Department	Bass Rock
Species	Atlantic Puffins (*Fratercula arctica*) – 6 birds Black-legged kittiwakes (*Rissa tridactyla*) – 17 birds Common guillemots (*Uria aalge*) – 21 birds Common eiders (*Somateria mollissima*) – 2 birds
Date of diet sheet	April 14, 2015
Feed seabirds	Sprat, capelin and sand eels
Amount of feed	4.2 kg a day
Additives	6.5 grams of vitamin powder (Mazuri fish eater tablets) per 3 kg of fish
Method	Divided in two metal bowls Feed moments are three times a day
Feed common eiders	Kasper's Faunafood - Anseres Sea-duck pellets
Amount of feed	Ad libitum (around 200 grams a day for 2 birds)
Additives	None
Method	Feed placed in one plastic bowl

The diet of the birds in Bass Rock is currently enriched with 6.5 grams of vitamin powder (Mazuri Fish eater tablets 852000) per 3 kilograms of fish, which is almost equal to 6.5 tablets (1 tablet is similar to 1.015 grams of powder).

Appendix 7 describes the eaten amount of fish during observations. The birds eat an average amount of 4.2 kg a day, as seen in appendix 7. The vitamin content is around 9.1 grams a day for 4.2 kg of fish. A loss of 20% vitamin powder during storage means that the birds get around 7.28 grams of vitamin powder on average a day. This 20% loss is calculated because of vitamin loss during storage (Nijboer, 2015; Bruslund, 2015), which is explained in subchapter 4.1.3.

Table 4.3 presents the requirements of vitamins per kilograms of fish. These requirements are calculated as extra vitamins per kilograms of fish, because the fish contain also some vitamins. These amounts are calculated including 20% vitamin loss during storage.

Table 4.3 "Requirements of essential vitamins per kg fish (Nijboer, 2015) and vitamin content per tablet of Mazuri Fish Eater Tablets (Mazuri, 2015)"		
	Advice nutritionist per kg fish	**Mazuri content per 1g tablet**
Vitamin A (as retinyl Acetate)	15,000 IU	10,000 IU
Vitamin B_1 (as thiamine)	50 mg	50 mg
Vitamin E (as dl-α-tocopherol acetate)	150 IU	160 IU

Mazuri fish eater tablets contain 10,000 IU of vitamin A, 160 IU of vitamin E and 50 mg of vitamin B1 per tablet (Mazuri Zoo Food, 2015). If this content is compared to the advice of Nijboer, 2015, as seen in table 4.4, there is a tiny shortage of vitamin A (0.06 tablet) and an excess of vitamin B_1 (2.04 tablets) and E (2.30 tablets).

Table 4.4 "Eaten vitamins per day"					
	Advice per 4.2 kg	**Current given amount per 4.2**	**Current amount per 4.2 kg, including 20% loss**	**Too much/less in units**	**Too much/less in tablets**
Vitamin A	63,000 IU	78,000 IU	62,400 IU	- 600 IU	0.06 too less
Vitamin B_1	210 mg	390 mg	312 mg	+ 102 mg	2.04 too much
Vitamin E	630 IU	1248 IU	998.40 IU	+ 368.40 IU	2.30 too much

4.1.2 Diet of Anseriformes in Bass Rock

The nutritional value of the sea duck pellets is shown in appendix 5. 'Anseres sea-duck pellets'. The common eiders have the ability to eat these pellets ad libitum, according to the diet sheet of February 2011. This diet is still the same. The common eiders are not fed any additives or enrichment fish.

4.1.3 Storage and quality of feed

Processes of preparation and storage of fish and pellets can influence feed quality, especially the quality of some vitamins. Fish is delivered to Rotterdam Zoo as frozen packages. Unknown is what happened before delivering of the fish. The influences of handling and storages process, after delivering, are described below.

Current feed storage

Frozen fish is stored in freezers of at least -18 degrees Celsius and thawed in a 4 degree Celsius refrigerator. The fish is thawed within one day and is stored for maximum two days in the refrigerator, including the day of thawing,. There is not made use of running water, because this can influence the vitamin quality within the fish.

Fish is stored in the enclosure in two metal bowls and refreshed at 8:00 AM, 00:00 PM and 03:00 PM, and sometimes two times a day: during winters and when nothing is eaten in the mornings and/or afternoons. The food for common eiders is stored in one, round, plastic bowl and refreshed when the bowl is empty or in the mornings.

Freezing and defrosting processes

During the process of freezing and storage reduces the vitamin content of fish. This means that there is a difference in vitamin intake of birds in captivity compared to the vitamin intake of wild birds. Vitamins should be added to the diet when feeding frozen fish. This loss of vitamins is partly caused by freezing and defrosting processes. Other losses are: loss in protein quality, decrease of weights, less or strange colouration and textures and oxidation of lipids (Ersoy, Aksan and Özeren, 2008).

Freezing

Fish should be frozen as soon as possible after catching. The supplier of fish should work according hygiene rules and appropriate handling and storage processes. Even when the fish is properly caught and packed, it still is only a few months tenable as a frozen product. If something went wrong in one of those first processes, the quality of the fish will be poor (Crissey et al, 2002). Storage should be done between -18 to -30 degrees Celsius (Crissey et al, 2002)

Frozen food can be dehydrated, which can lead to problems when animals ingest water or food and not of drinking water. During freezing reduces also the vitamin content of vitamin B_1 and E. Thiaminase can occur in herring, smelt and clams when frozen, but it probably can occur in more fish species (Crissey et al, 2002). Vitamin E can be destroyed after only a week of frozen storage (Bernard and Allen, 2002). Vitamin E content reduces during the breakdown of fats, which is called oxidation, and depend on the content of fat that is present in fish (Crissey, 1998).

The recommended temperature ranges between 2 and 3.5 degrees Celsius (Crissey et al, 2002). When fish is stored at higher temperatures than 7 degrees Celsius there are minor changes in microbiological activity, and larger changes in microbiological activity when stored at temperatures higher than 10 degrees Celsius. Fish, in general, can be stored for 5-6 days when stored at maximum 4 degrees Celsius, vacuum packed (Huss, 1995).

Thawing

Frozen fish should be thawed in air under refrigeration, and not in running water, to maintain the most optimal vitamin content and also reduce the loss of moisture. Thawing in running water rinses away water-soluble vitamins. When thawing at higher temperatures than 10 degrees Celsius or room temperature, there is more bacterial growth and fish will spoil (Stoskopf, 2012; Ersoy, Aksan and Özeren, 2008).

Weight loss

Weight loss of fish can be reduced by thawing at higher relative humidity (Ersoy, Aksan and Özeren, 2008). Loss of vitamins can caused by preparation, rain, heat and remaining vitamins in the feeding bowl.

Sea-duck pellets

Sea duck pellets of the common eiders are sometimes refreshed once a day. The food quality will remain the same when feed is consumed within one day, even when the feed becomes wet (Boomstra, 2015). Sea duck pellets are stored in packages of the supplier before opening and stored in plastic, closed bins. Unknown is the influence of this method on feed quality.

Storage after placing feeding bowls

Light, heat and air (or oxygen) can influence the quality of food also. Recommended is to store fish, after thawing, refrigerated or in ice and should be never refrozen again (Crissey, 1998). Ice can be placed into the feeding bowls, so that fish can be fed under cool conditions.

Table 4.5 gives an overview of unstable nutrients when exposed to light, heat and air or oxygen (Newberne and Fox, 1980). As seen in this table, a lot of nutrients are unstable when exposed to some factors. Methionine, considered as limiting amino acid, remains stable. It is important that feeding bowls are placed on dry, cool places and also as long as possible vacuum packed.

Table 4.5 'Nutrient stability when exposed to light, heat or air'.

	Light	Heat	Air or oxygen
Vitamin A	U	U	U
Vitamin C (Ascorbic acid)	U	U	U
Carotene	U	U	U
Vitamin D_3	U	U	U
Folic acid (vitamin B_{11})	U	U	U
Vitamin E (tocopherol)	U	U	U
Thiamine	U	S	U
Methionine	S	S	S

S = stable, there is no significant destruction measured
U = unstable, there is a possibility on significant destruction

Pests

Pests, like mice and rats, should be prevented. A possible solution is to take away the feeding bowls during nights. When using pesticides, the birds should not be able to get in contact with these pesticides.

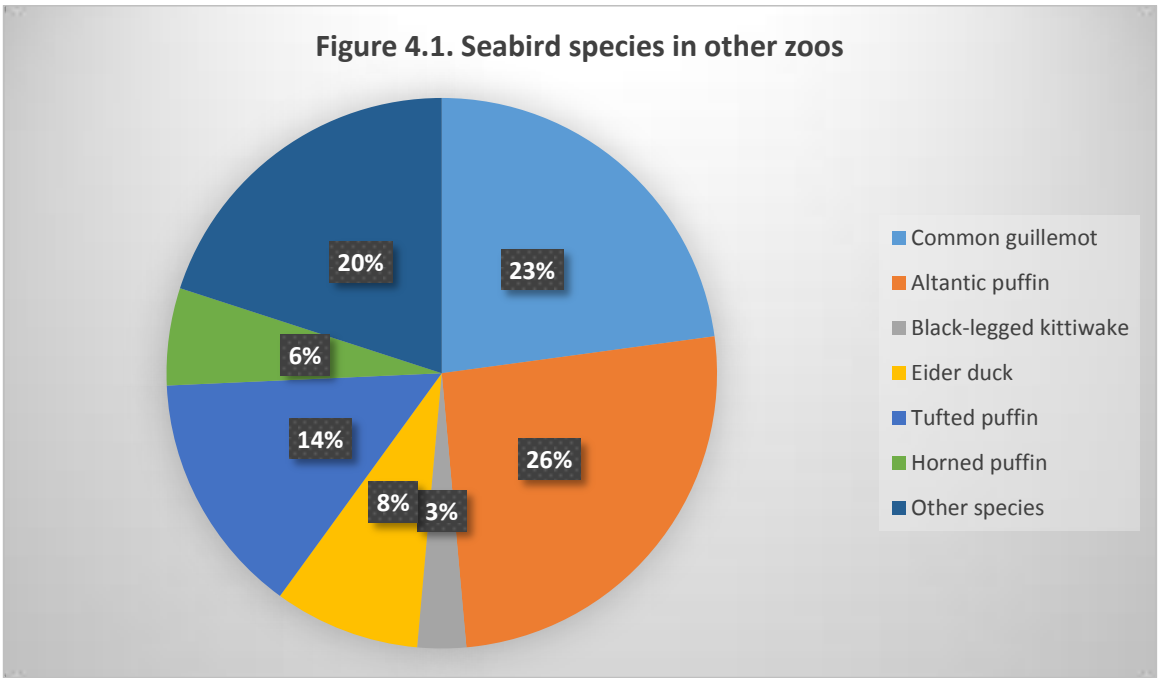
Microbial growth can occur when not cleaning properly, especially when using square feeding bowls. Refuse will remain in the corners of the feeding bowls and bacteria have an environment to grow.

4.2 Diets of seabirds in other zoos

This part of the chapter describes the results of the questionnaires sent to zoos. Thirty one zoos which have one of more of the same species as in Rotterdam Zoo responded to the questionnaire. All zoos had answered the same questionnaire, which can be found in appendix 3. The results are analysed and described below.

4.2.1 Diets of seabirds

13 of 31 zoos have one or more similar species of seabirds in Rotterdam Zoo. These twelve questionnaires were analysed and described below. Figure 4.1 shows the percentages of seabird species in zoos. Other mentioned species are: common tern, pigeon guillemot, crested auklet, whiskered auklet, grey-headed gull, silver gulls and Inca tern. Common eiders are only mentioned when having common eiders in combination with one or more seabird species. All zoos have mixed enclosures.



Chosen fish species

Most zoos choose capelin (*Mallotus villosus)*, lake smelt (*Osmerus mordax*), krill (*Euphausiacea*) and herring (*Clupea harengus*) as food items, which can be seen in figure 4.2. The colour of the bill becomes vivid by giving krill or other crustaceans. These types of food contain carotenoids. Less given species are: smelt (*Osmerus eperlanus*), Atlantic silver sides (*Menidia menidia)*, sprat (*Sprattus sprattus*) and mackerel (*Scomber scombrus*). Four zoos have chosen to give other species: squid, whitebait, whiting and anchovies. The given amount of food ranges from 140g per bird a day to ad libitum. Fifty percent of the zoos have chosen to feed birds ad libitum.

92.3% of participated zoos mix (a few of) abovementioned fish species per feeding moment. Only one zoo feeds only smelt to their birds and no other fishes. Rotterdam zoo gives mostly one fish species per feeding moment, sometimes two.

Vitamins

All participated zoos use vitamins as additives, of which 25% add some extra calcium during breeding seasons. Table 4.5 shows an overview of used vitamins and amounts. Rotterdam Zoo is placed at the end of the table. As seen in table 4.5, the amount of vitamins given in Rotterdam Zoo somewhat higher than in most other zoos. The lowest amount of vitamin A is 417.5 IU per bird, but a few zoos do not give any additional vitamin A to their birds. The highest amount of vitamin A is 2667 IU. The lowest amount of vitamin E is 11.25 mg, the highest is 100mg per bird. Thiamine is the lowest in Rotterdam Zoo (10.5mg), the highest amount is 100mg per bird.

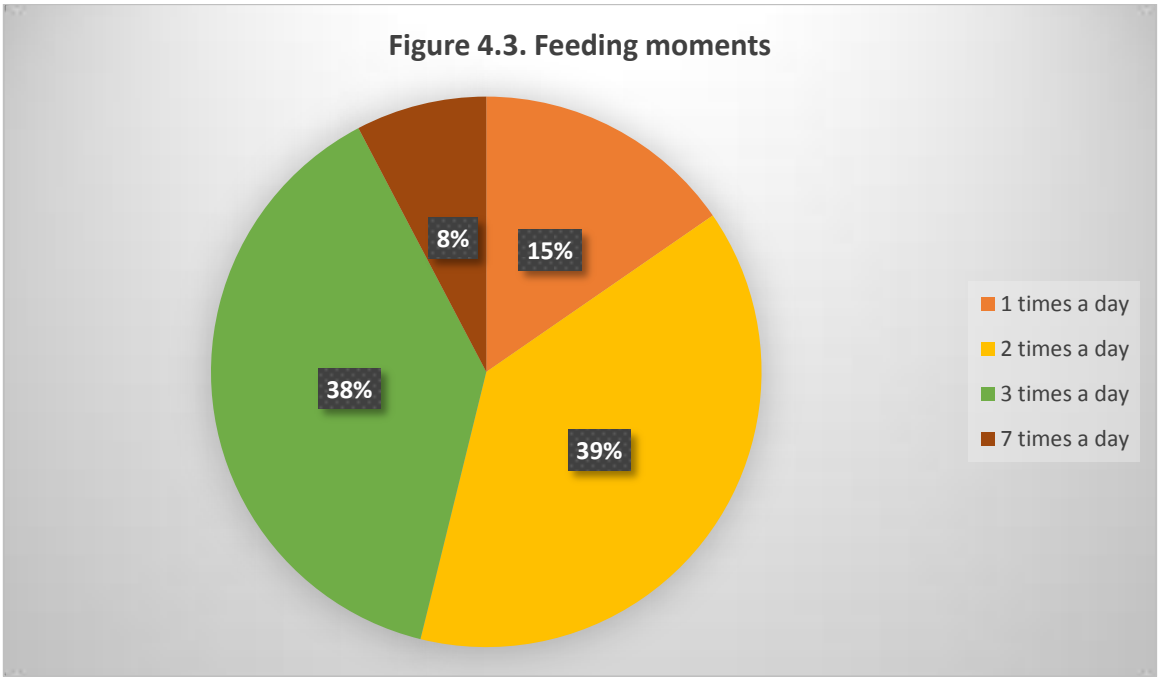
Some zoos have chosen to not feed any vitamin A, because it is already available in the livers of fish, when feeding whole fish. And some zoos have chosen to feed some carotenoids. There are different commercial products with carotenoids on the market for captive seabirds or other piscivorous birds (astaxanthin, canthaxanthin, crustacean meal) (McWilliams, 2008). But, as already mentioned in subchapter 4.1.3 is carotene unstable when exposed to heat, light and air/oxygen. The supplemented fish should not be exposed to these factors, but carotenoids can positively affect bird's health (Møller et. al, 2000).

A few zoos give extra calcium for egg shell formation during breeding seasons, both 30mg per kg of fish. Calcium deficiency only occurs when feeding fish without viscera or a too high level of phosphorous (McWilliams, 2008).

Table 4.5 'Overview of used additives per participant'				
Zoo no.	**Brand and type**	**Amount a day**	**Content**	**Given amount per bird per day**
1	Mazuri LD301 liquid	2 grams a day for 11 birds	*No English description available*	-
2	Mazuri vita-zu small bird	1 tablet per bird	Per 1 tablet (0.19g): Vitamin A: 835 IU Vitamin E: 22.5 mg Thiamine: 24 mg	Vitamin A: 835 IU Vitamin E: 22.5 mg Thiamine: 24 mg
3	IVZG aquavits powder Calcium carbonate	Both 30 mg per kg fish	1 tablet (weight unknown): Vitamin A: 15,000 IU Vitamin E: 200mg Vitamin B1: 250 mg	- Calcium: 30mg per kg fish
4	Premix, lda Calcium	300 mg per bird a day 30 mg per kg fish	unknown	Vitamin A: - Vitamin E: 100 mg Thiamine: 100 mg Calcium: 30 mg
5	Mazuri multi vitamin	Unknown	unknown	Unknown
6	Mazuri vita-zu large bird, no vitamin A	1/6 tablet, **twice a week**	Per 1 tablet (0.75g): Vitamin A: 0 Vitamin E: 112.5 mg Thiamine: 115 mg	Vitamin A: - Vitamin E: 18.75 mg Thiamine: 19.17 mg
7	Mazuri vita-zu large bird, no vitamin A	1/6 tablet, **twice a week**	Per 1 tablet (0.75g): Vitamin A: 0 Vitamin E: 112.5 mg Thiamine: 115 mg	Vitamin A: - Vitamin E: 18.75mg Thiamine: 19.17 mg
8	Jaapharm vitamin B_1 Univet Pharma vitamin E (both for horses)	1g vitamin E for 3g vitamin B_1 per kg fish	Vitamin E: 3000IU per 28.4g powder Thiamine: 500mg per 30g powder	Vitamin A: - Vitamin E: 95 g/kg fish Thiamine: 50g kg/fish
9	Nekton bio Nekton Multi Nekton MTA Beta carotene Nekton E Mazuri Auklet	Given in ratio: Nekton bio 7.5 Nekton Multi 7.5 Nekton MTA 1.5 Beta carotene 2.0 Nekton E 3.0 Mazuri Auklet 10	unknown	Unknown
10	Mazuri vita-zu small bird	½ tablet per day	Per 1 tablet (0.19g): Vitamin A: 835 IU Vitamin E: 22.5 mg Thiamine: 24 mg	Vitamin A: 417.5 IU Vitamin E: 11.25 mg Thiamine: 12 mg
11	Mazuri powder	**Twice a week**	unknown	Unknown
12	Mazuri vita-zu small bird	1 tablet a day	Per 1 tablet (0.19g): Vitamin A: 835 IU Vitamin E: 22.5 mg Thiamine: 24 mg	Vitamin A: 835 IU Vitamin E: 22.5 mg Thiamine: 24 mg
13	Mazuri Fish Eater tablet Castaxanthin Spirulina	12 tablets for 45 birds (0.267 tablet per bird)	Per 1 tablet (1g): Vitamin A: 10,000 IU Vitamin E: 144 mg Thiamine: 50 mg	Vitamin A: 2666.67 Vitamin E: 38.4 Thiamine: 13.33
Rotterdam Zoo	Mazuri Fish eater tablets	0.21 tablets per bird per day	Per 1 tablet (1g): Vitamin A: 10,000 IU Vitamin E: 144 mg Thiamine: 50 mg	Vitamin A: 2100 IU Vitamin E: 30.25 mg Thiamine: 10.5 mg

Feeding moments

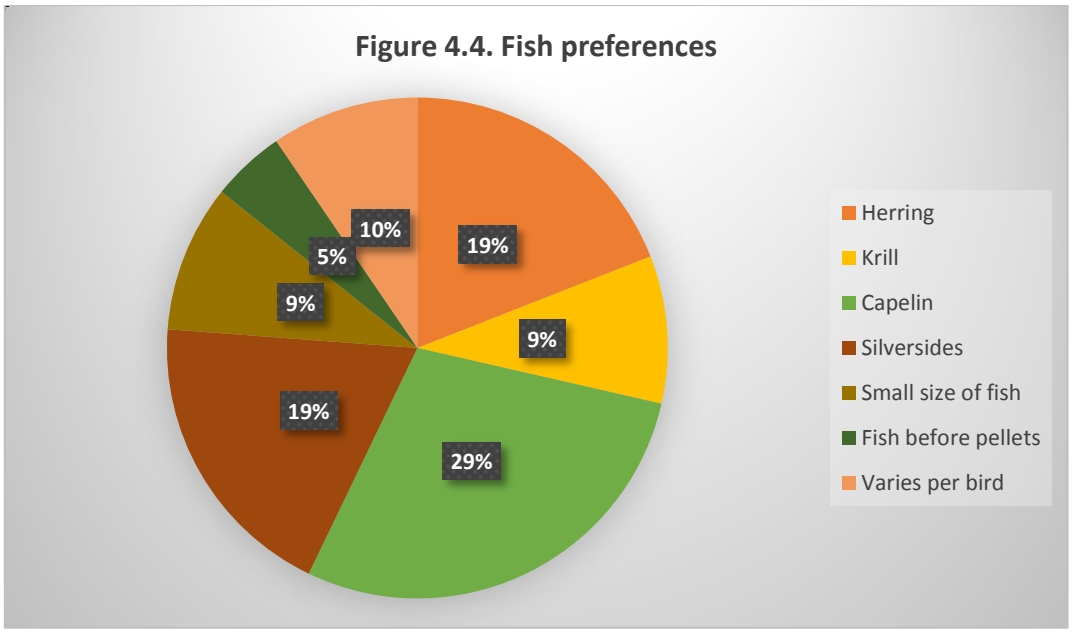
Figure 4.3 shows the feeding moments per day. Most zoos feed their birds 2 or 3 times a day. Only one zoos prefer to feed seven times a day. Two zoos have chosen to feed only one time a day.



Preference

Most seabirds in zoos prefer to eat capelin *(Mollotus villotus)*, herring (*Clupea harengus)*, silversides (*Menidia menidia)* and/or krill (*Euphausiacae)*, as seen in figure 4.4. Krill is mostly used for enrichment, but also for the colour of the beak. Krill contains an amount of carotenoids, which gives the beak a better colour and is also a type of antioxidant. It is unknown what type of krill is given to the birds.

One zoo mentioned that Inca terns prefer to eat at higher places. But this type of bird is not present in Rotterdam Zoo.

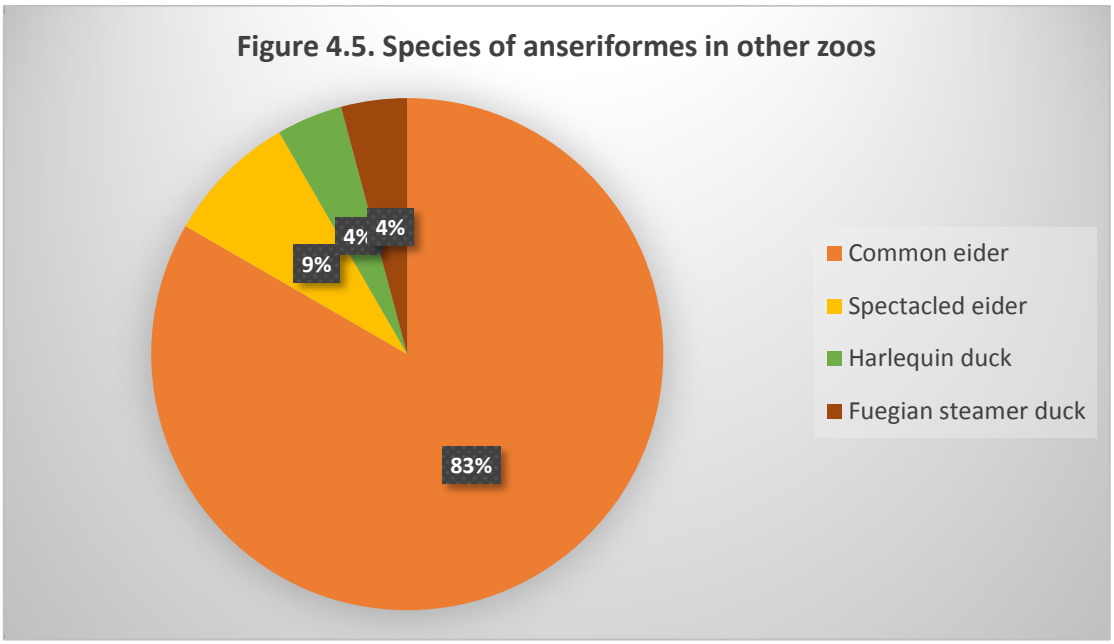


4.2.2 Diets of Anseriformes

Twenty one zoos have common eiders or other similar sea ducks as in Rotterdam Zoo. These 21 questionnaires were analysed in this part of the report.

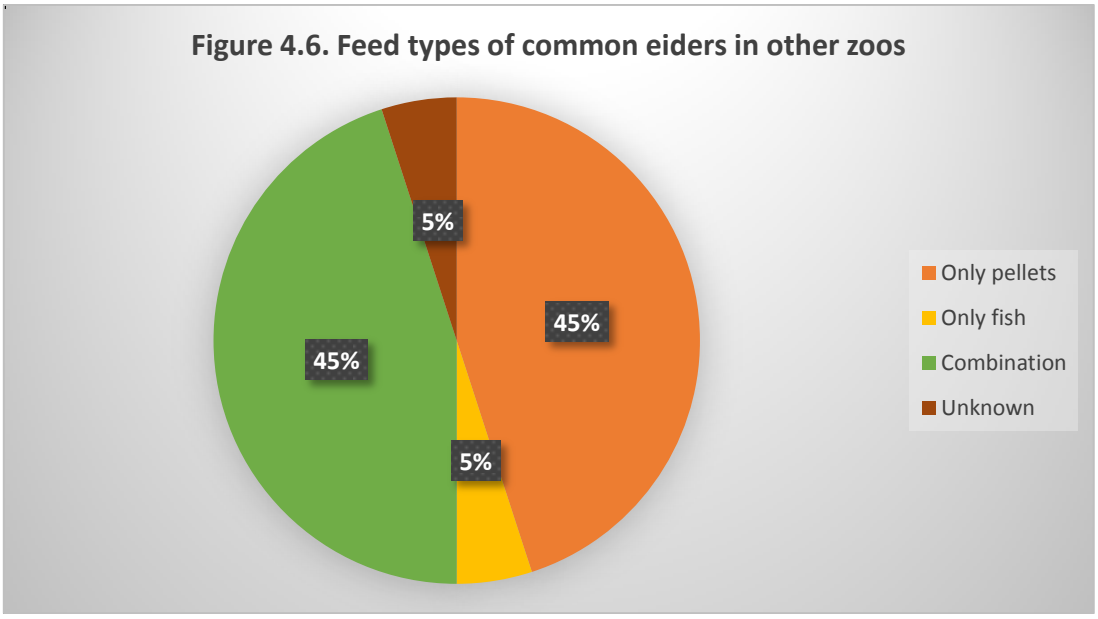
Species

Figure 4.5 presents the percentages of common eiders and other similar species. 83% of the twenty-one zoos have common eiders (*Somateria Mollisimma)*, 9% have spectacled eiders (*Somateria fischeri*), 4% have Harlequin ducks (*Histrionicus histrionicus*) and 4% have Fuegian steamer ducks (*Tachyeres pteneres*).



Feed types

Figure 4.6 shows the types of feed given to common eiders or similar species in other zoos than Rotterdam Zoo. As seen in this figure, most zoos give pellets or a combination of pellets and some fish or vegetables (both 45%). Brands of given pellets are: Arie Blok (AB) Anseres breeder pellets, AB floating Seaduck pellets, Mazuri Seaduck pellets, Mazuri waterfowl diet, SDS Seaduck pellets, Lundi eider, Melior 4255 pellets and Mazuri Flamingo pellets.

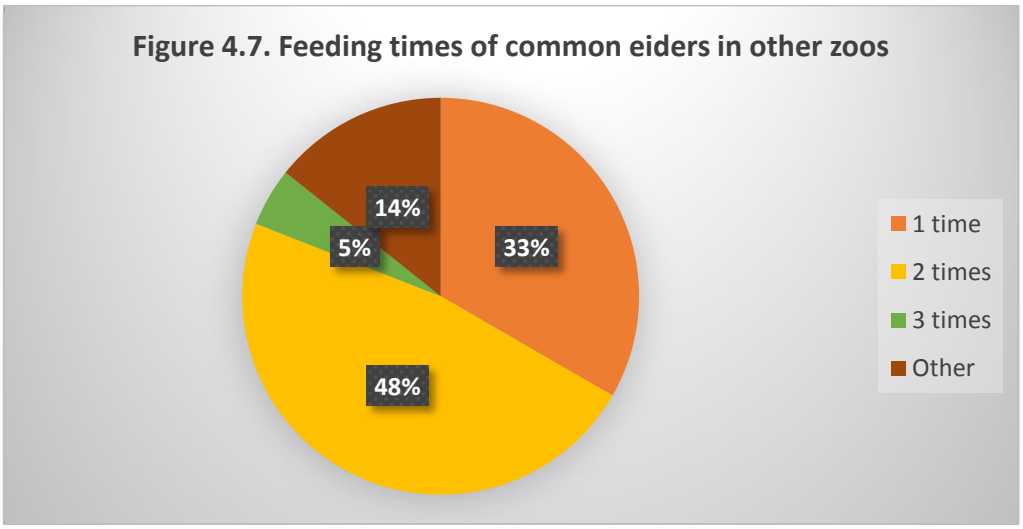


Chosen additives

Chosen additives when feeding fish are: A combination of Nekton S, Nekton MSA and Nekton Bio, Vitamin B_1 of Jaapharm and vitamin E of Univet Pharma, Argent freeze-dried cyclopeeze, A combination of lime and spirulina, Avimix and calcium during breeding season and Claus supramin.

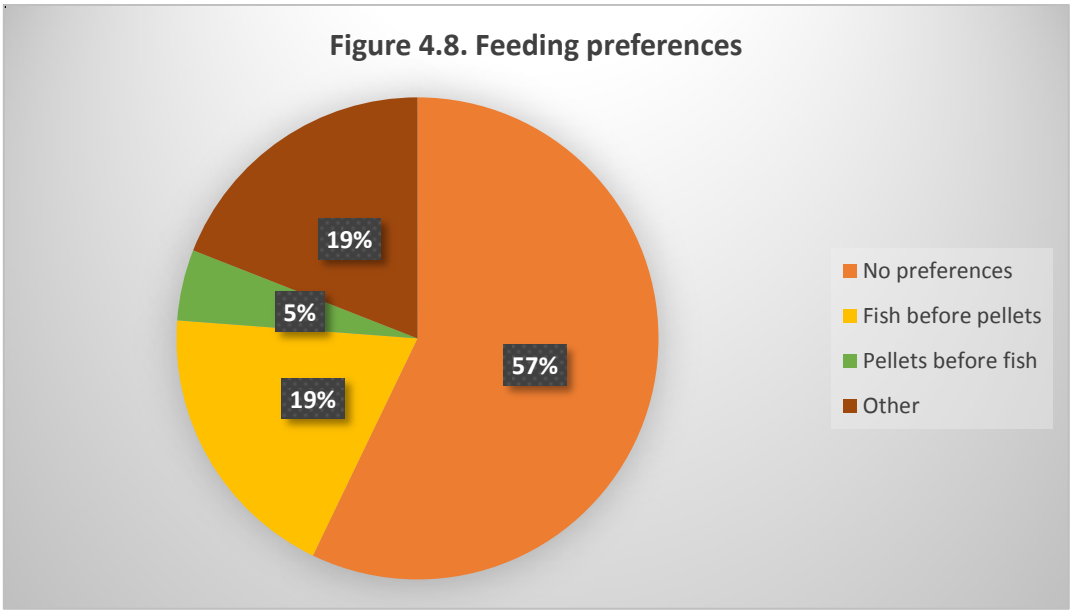
Feeding moments

Figure 4.7 presents the number of feeding moments per day. Most zoos prefer to feed their ducks two times a day (48%), followed by one time a day (33%). Fourteen percent of zoos have chosen other times a day, which are: 3-4 times a day, 2-5 times a day and one zoo is unknown.



Preferences

Most common eiders seem to have no preference for feeding place or type of food (57%). The other part, 43%, have preferences: 19% chooses fish before pellets and 19% pellets before fish, the other 5% have preference for food scattered in the water (two zoos), soft feed (one zoo) and one zoo reported that common eiders have a preference for feeding time; mornings and evenings. Figure 4.8 shows the feeding preferences for the common eiders.



4.3 Nutritive values of fish

Table 4.7 on the next page presents the average nutritive values of whole fish, based on dry matter. The nutritive value differs per season and catch and not all values are known. Capelin, sprat and smelt are given to the species in Bass Rock. Herring, silversides and sprat have the highest percentage of crude fat. The highest amount of crude protein is found in capelin, krill and squid. Herring is MSC-certified (Marine Stewardship Council), which is a certification for sustainable fishery. Feeding herring instead of non-certified fish contributes to sustainability. Because most birds prefer to eat small fish can be given chopped herring. Cost prices of fish per kg (for Rotterdam Zoo) are showed in table 4.6. Capelin is the cheapest fish, because it can be supplied for free. Mackerel and sand lance are the most expensive fish species.

Table 4.6. 'Cost prices of fish species, sold to Rotterdam Zoo'

Fish species	Price per kg	Price per day (per 4.2 kg)	Price per year
Capelin	0.00	0.00	0.00
Sprat	0.85	3.57	1303.05
Anchovy	0.85	3.57	1303.05
Herring	0.95	3.99	1456.35
Smelt	0.95	3.99	1456.35
Mackerel	1.10	4.62	1686.30
Sand lance	1.10	4.62	1686.30

Squid, krill and capelin be given as extra during moult, winter and breeding seasons, because these food items contain a high percentage of proteins. Fish with lower percentages of fat can be used for scattering enrichment in water: anchovy, krill and smelt.

Table 4.7. 'Nutritive values of fish'

	Ash (%)	CP (%)	Cfat (%)	Ca (%)	P (%)	Fe (mg/kg)	Zn (mg/kg)	Mg (mg/kg)	Folic acid (mg/kg)	B1 (mg/kg)	A (IU/g)	E (mg/kg)	Biotin (mg/kg)	Panto-thenic acid (mg/kg)	C (Mg/kg)	Linoleic acid (mg/kg)	Linolenic acid (mg/kg)
Anchovy, bay *(Anchoa mitchilli)*	7.38	11.07	2.87	0.77	0.27	127.15	16.82	0.15	1.12	7.79	574.24	102.54	-	3.45	1435.6	1.07	0.18
Blue mussel *(Mytilis edulis)*	5.95	58.33	5.95	0.18	1.46	30.36	160.71	0.04	0.35	1.79	1.93	8.33	-	-	34.52	0.06	0.01
Capelin *(Mallotus villotus)*	15.23	78.68	14.72	5.08	2.54	10.15	86.29	0.01	17.77	27.92	40.61	50.76	0.76	142.13	17.77	-	-
Herring *(Clupea harengus)*	7.9	59.7	31.4	2.5	-	98.2	-	0.1	-	-	22.9	93.3	-	-	-	-	-
Krill *(Euphausiacae)*	13.5	78.75	3.00	2.88	1.81	62.50	293.8	1.44	-	-	-	1150	-	-	-	-	-
Mackerel *(Scomber scombrus)*	10.5	67.70	15.9	2.4	-	158.20	44.4	0.10	-	-	234.80	166.40	-	-	-	-	-
Silversides *(Menidia menidia)*	12.16	62.73	22.9	3.0	2.4	80.60	97.40	0.13	-	-	23.92	226.20	-	-	-	-	-
Smelt *(Osmerus eperlanus)*	2.32	43.95	4.32	-	0.62	-	-	0.06	0.93	-	-	-	0.76	16.32	-	-	-
Sprat *(Sprattus sprattus)*	-	49.74	47.18	0.51	-	-	-	-	-	-	-	-	-	-	-	0.36	0.23
Squid *(Cephalopods)*	7.00	85.63	10.8	-	-	-	-	-	-	-	22.33	330.78	-	-	-	-	-
White bait *(Inanga)*	10.78	68.7	18.61	2.9	2.5	191.9	71.00	0.1	-	-	52.79	285.6	-	-	-	-	-

Chapter 5. Behaviour and feeding methods of captive seabirds

This chapter describes the results of behavioural research of captive seabirds in Rotterdam zoo. It also describes information about the behaviour of captive seabirds obtained by others zoos and experts. Behavioural research is done due to a lack of information about foraging behaviour of seabirds in captivity, and even natural foraging behaviour is quite unknown.

5.1 Results of behavioural studies in Rotterdam Zoo

This subchapter describes the results of the behavioural studies in Bass Rock, the enclosure of the seabirds in Rotterdam Zoo. The results of the behavioural studies include percentages and frequencies of foraging, the time between placing feed bowls and the first time of eating after placement of feeding bowls. The second part describes the fish intake during the observations and also the average fish intake per bird. All results are based on 15 hours of observation per bird species.

5.1.1 Foraging activities

Percentages and frequencies of foraging behaviour

Appendix 8 shows the calculations and frequencies per bird species. Table 5.1 summarizes appendix 8 and shows the average percentages of eating and other foraging behaviour, compared to all other behaviour. The common eiders have only one bowl and eats another type food than the other bird species, which means that the common eiders have no choice for feeding place.

Table 5.1 'Foraging behaviour compared to other behaviour of seabirds in Bass Rock'

	Atlantic puffin	Black-legged kittiwake	Common guillemot	Common eider	Average
Eating left	1.53	2.05	2.91		2.16
Eating right	0.23	0.80	4.21	2.36	1.90
Foraging	0.09	0.17	0.33	0.00	0.15
Standing	26.85	50.36	35.32	8.33	30.22
Resting	37.59	7.57	21.73	19.72	21.65
Grooming	17.31	6.67	12.03	15.28	12.82
Swimming above water	11.06	21.95	19.45	7.08	14.89
Swimming under water	1.06	0.00	2.04	0.00	0.78
Abnormal swimming	0.00	0.00	0.01	40.00	10.00
Scratching	2.55	0.32	0.11	0.28	0.82
Aggression initiator	0.00	0.03	0.01	0.00	0.01
Aggression receiver	0.32	0.00	0.00	0.00	0.08
Interaction	0.00	2.09	0.53	0.00	0.66
Bathing	1.11	1.72	0.73	2.92	1.62
Drinking	0.05	0.03	0.09	3.61	0.95
Flying	0.00	6.02	0.00	0.00	1.51
Displaying	0.00	0.00	0.00	0.42	0.11
Yawning	0.05	0.00	0.00	0.00	0.01
Walking	0.09	0.01	0.46	0.00	0.14
Nestling	0.09	0.21	0.04	0.00	0.09
Total	**100%**	**100%**	**100%**	**100%**	

As seen in table 5.1, the Atlantic puffins only spent 1.85% of their time on eating (1.76%) and other foraging behaviour (0.09%) consisting of begging for food to other birds. The Atlantic puffins seem to have a small preference for the left feeding bowl, as well as the black-legged kittiwake. Black-legged kittiwakes spend 3.02% of their time on eating (2.85%) and other foraging behaviour (0.17%) consisting of eating seaweed on the rocks and trying to take away fish of other birds. Once is seen that a kittiwake has eaten some food of the common

eiders. The common guillemots have the highest percentage of eating (7.12%) and other foraging behaviour (0.33%), which is 7.45% of their time. Conspicuous is that the common guillemots seems to have a preference for the right bowl. The other foraging behaviour of the common guillemots is spent on eating seaweed and take away fish from other birds.

The common eiders spent 0% on foraging behaviour and 2.36% on just eating. Also can be seen in table 5.1 that common eiders spent 40% of their time on abnormal swimming, which is swimming back and forth in front of the window on the visitors site, even when there are no visitors. Unknown is why these birds show this type of behaviour.

Time between placing feed bowl and eating

Table 5.2 shows the time between the placement of the feeding bowl and the first moment of eating after the placement of the feeding bowl, per observation moment (every 2.5 minutes). Conspicuous is that Atlantic puffins have more time between the placement of the feeding bowls and the time of starting to eat than the other birds. The Atlantic puffins also receive most aggression, which can be seen in table 5.1. Both can be signs of submission.

Table 5.2 'Time between placing feed bowl and first moment of eating'

Observation number and time	Atlantic puffin	Black-legged kittiwake	Common guillemot	Common eider (placed 1 time a day)
1 (7:45 AM -8:45 AM)	5	2.5	2.5	10
2 (12:00 AM–01:00 PM)	0	12.5	2.5	-
3 (03.00 PM – 04.00 PM)	15	2.5	7.5	-
4 (7:45 AM -8:45 AM)	22.5	15	7.5	>60
5 (12:00 AM–01:00 PM)	> 60	2.5	30	-
6 (03.00 PM – 04.00 PM)	42.5	0	10	-
7 (7:45 AM -8:45 AM)	27.5	0	0	20
8 (12:00 AM–01:00 PM)	20	25	2.5	-
9 (03.00 PM – 04.00 PM)	10	32.5	7.5	-
10 (7:45 AM -8:45 AM)	32.5	> 60	> 60	32.5
11 (12:00 AM–01:00 PM)	> 60	12.5	> 60	-
12 (03.00 PM – 04.00 PM)	2.5	> 60	20	-
13 (7:45 AM -8:45 AM)	10	0	0	> 60
14 (12:00 AM–01:00 PM)	> 60	10	2.5	-
15 (03.00 PM – 04.00 PM)	15	10	17.5	-
Average including > 60	25.5	16.33	15.33	36.5
Average without > 60	13.5	8.33	7.33	20.83

5.1.2 Feed intake

Average (fish) intake

Table 5.3 "Average fish intake" shows the average intake per part of the observed days. Every period includes five hours of observation per bird species, which means that there is a total observation time of fifteen hours per bird species. There is also made a distinguish between the left and right feeding bowl. The figures that are showed in table 5.3 are the numbers of eaten fish, not the amounts of fish in grams or kilograms. The common eiders are not calculated as the other birds, because the common eiders have only one feeding bowl and get also other feed. It was impossible to measure their feed intake per feeding moment, so only frequencies per part of the day are noted.

Table 5.3 "Average fish intake"								
	Period 1: 07:45 AM - 08:45 AM		Period 2: 12:00 AM - 01:00 PM		Period 3: 03:00 PM – 04:00 PM			
	L	R	L	R	L	R	Averages	
Averages per bird per 5 hours	3.670	1.000	0.670	0.000	4.670	0.000	**1.668**	Atlantic puffin
	4.170	1.840	4.757	1.048	3.703	2.639	**3.026**	Kittiwake
	2.286	0.714	1.190	1.333	0.952	2.809	**1.547**	Common guillemot
	2		3		4.5		**3.167**	Common eider
Averages (common eiders not included)	**3.375**	**1.185**	**2.206**	**0.794**	**3.108**	**1.816**	**2.080**	
Averages per bird per 5 hours	0.730	0.200	0.130	0.000	0.930	0.000	**0.332**	Atlantic puffin
	0.834	0.368	0.951	0.210	0.741	0.528	**0.650**	Kittiwake
	0.457	0.143	0.238	0.267	0.190	0.562	**0.310**	Common guillemot
	0.40		0.60		0.9		**0.633**	Common eider
Averages (common eiders not included)	**0.674**	**0.237**	**0.440**	**0.159**	**0.620**	**0.363**	**2.493**	

Preferences for feeding place

As earlier mentioned, the Atlantic puffins and the Black-legged kittiwakes seem to have a preference for the left feeding bowl. This can be also seen in table 5.3. The Atlantic puffin has eaten 9.01 fish out of the left bowl and only 1 fish out of the right bowl, and the kittiwake has eaten 12.63 fish out of the left bowl and 5.527 fish of the right bowl. Again, the common guillemots divided their fish intake per bowl; 4.428 fish out of the left bowl and 4.856 of the right one. These differences per feeding bowl were statistically tested per bird species by making use of a paired samples test, because the results are normally distributed. The results and used values can be found in appendix 6.

Table 5.4 presents the results of the paired samples test. The hypothesis is:

- H_0-hypothesis = There is no significant difference between the fish intake of the left bowl and the right bowl.
- H_1-hypothesis = There is a significant difference between the fish intake of the left bowl and the right bowl.

Table 5.4 "Results of the paired samples test for the preference of feeding bowl"							
Species	Mean	Standard deviation	Confidence interval (95%)		t	df	P
			Lower	Upper			
Puffin	0.533	0.746	0.120	0.946	2.277	14	**0.015**
Kittiwake	0.469	0.675	0.096	0.843	2.693	14	**0.017**
Common guillemot	0.022	0.481	-0.289	0.244	-0.179	14	**0.861**

A confidence interval of 95% is used to test significance. The calculated significance for the Atlantic puffin is 1.5% (P = 0.015), for the black-legged kittiwake 1.7% and 86.1% for the common guillemot, as described in table 5.4 "Results of the paired samples test for preference of feeding bowl". The H_0-hypothesis can be rejected for the Atlantic puffin ($P=0.015 < 0.025$) and kittiwakes ($P=0.017 < 0.025$), but the H_0-hypothesis must be retained for the common guillemots ($P=0.861 > 0.025$).

Preferences for feeding time

There is also is tested whether there is a preference for feeding time: period 1 (8:45AM), period 2 (12:00PM) or period 3 (03:00PM). This should be known to feed effective when given additives like vitamins or medication. This is tested by a one way ANOVA test, all values were normally distributed.

Hypothesis

- H_0-hypothesis = There is no significant preference for fish intake at a part of the day
- H_1-hypothesis = There is a significant preference for fish intake at a part of the day

Table 5.5 "ANOVA results of preferences for time"

	SS	df	Mean square	f	P	Species
Between groups	1.067	2	0.533	1.664	***0.208***	Atlantic puffin
Within groups	8.656	27	0.321			
Between groups	0.016	2	0.008	0.017	***0.983***	Black-legged kittiwake
Within groups	12.126	27	0.449			
Between groups	0.149	2	0.075	0.613	***0.549***	Common guillemot
Within groups	3.287	27	0.122			
Between groups	2.533	2	1.267	0.679	***0.526***	Common eider
Within groups	22.400	12	1.867			

None of the birds have a significant preference for a specific part of the day; Atlantic puffins (P=0.208 > 0.025), kittiwakes (P=0.983 > 0.025), common guillemots (P=0.845 > 0.025) and common eiders (P = 526 > 0.025).

5.1.3 Daily fish intake

Appendix 7 shows the results and calculations of the given and eaten feed of the Atlantic puffins, black-legged kittiwakes and common guillemots. Common eiders are described in subchapter 5.1.4 "Daily intake of Anseres sea duck pellets". The birds eat an average amount of 4.231 kilograms a day, which is 92.94 grams for each bird.

5.1.4 Daily intake of Anseres sea-duck pellets

Table 5.6 presents the daily intake of common eider pellets. Column two (period 1) present the amount of feed that is given as starting amount of feed. Period 2 and 3 show the amount left in the feeding bowl at that moment. The common eiders eat around 208 grams a day, which is 104g per bird per day.

Table 5.6 "Daily intake of Anseres sea-duck pellets"

Day	Period 1 - 07:45 AM	Period 2 - 12:00 AM	Period 3 - 04:00 PM	Out next day	Eaten amount per day
1	130g	100g	39g	4g	126g
2	145g	92g	- (+148)	-	293g
3	150	131	54 (+100g)	22	271g
4	150	150	131	1	149g
5	200	192	165	-	200g
Averages	**775 IN**	**Eaten: 22g**	**Eaten: 55.2g**	**Eaten: 126.6g**	**207.80g**

5.1.5 Food for fish in Bass Rock

Fish, that are present in the enclosure of Bass Rock, are fed five times a week. The fish are not fed on Monday and Wednesday. It is unknown whether the seabirds in Bass Rock eat from the food of the fish. Table 5.7 presents the number of birds that has eaten from the fish food, per bird species. This is observed for five days.

Table 5.7 "Eaten fish food per bird species"

	Number of birds eating from fish food, per bird species			
Day and time	Atlantic puffins	Black-legged kittiwakes	Common guillemots	Common eiders
1 - 00:10 PM	3	0	17	0
2 – 03:00 PM	0	2 (+ 3 flying)	10	0
3 – 00:15 PM	1	0 (+ 2 flying)	11	0
4 – 03:10 PM	2	3 (+ 4 flying)	12	0
5 – 02.45 PM	0	0	16	0

The common guillemots seem to eat the most feed from the fish. These birds dive and swim under water till all fish food is eaten. Only a few black-legged kittiwakes dive on the surface to catch fish food. Other kittiwakes have tried to catch fish, but did not catch any fish food. The Atlantic puffins eat only some fish food when they are still in the water.

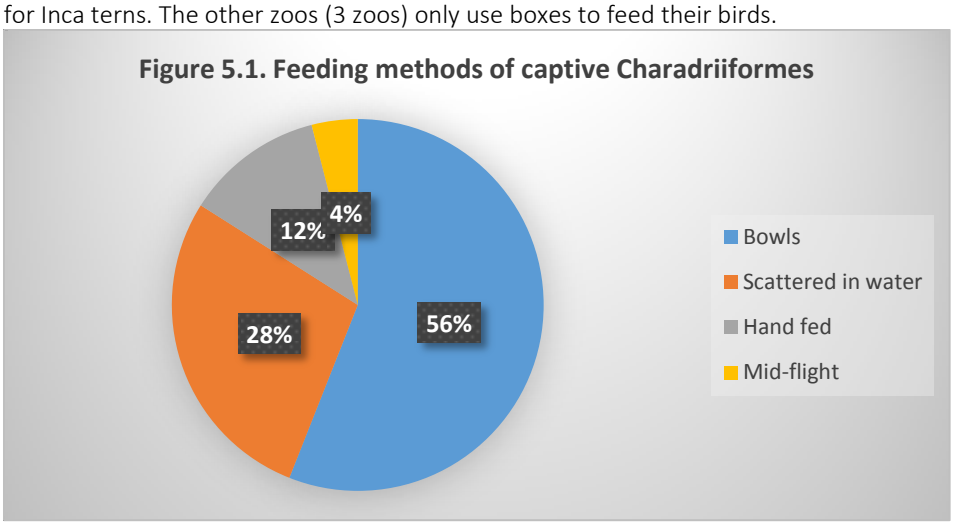
5.2 Results of other zoos

This subchapter describes the results of questionnaires sent to other zoos. The used questionnaire can be found in appendix 3. 'Questionnaire for zoos'.

5.2.1 Seabirds

Feeding methods

Figure 5.1 shows the percentages of used feeding methods in other zoos. Rotterdam Zoo only uses metal bowls and refreshes the food three times a day, unless the birds have not eaten anything in the morning. Then, the food is refreshed two times a day. During summers, the quality of the fish can reduce, when the fish is not eaten within a few hours. 56% of the zoos choose to feed in bowls and 28% choose to scatter food in the water, as seen in figure 5.1. Only one zoo feed Inca terns (*Larosterna inca*) by way of mid-flight feeding, a method that requires some training, even as hand feeding birds. Twelve percent of the questioned zoos chooses to hand-feed the birds. These results include all methods together, but most of the zoos use a combination: 10 zoos use a combination of feeding methods, of which 6 uses a combination of bowls and scatter fishes in the water, 3 zoos use a combination of bowls and hand feeding and only 1 zoo uses bowls in combination with mid-flight feeding for Inca terns. The other zoos (3 zoos) only use boxes to feed their birds.



Materials

Materials of feeding bowls are: plastic (2) and stainless steel (7), four zoos did not mention any type of material for their feeding bowls.

Advantages and disadvantages of feeding methods

Table 5.8 gives an overview of the advantages and disadvantages of the feeding methods used by other zoos. These advantages and disadvantages are mentioned by zoos.

Table 5.8 'Advantages and disadvantages of feeding methods of Seabirds'

Method	Advantages	Disadvantages
Hand feeding	During weight sessions in combination with feeding, there is a good individual control	Amount of food varies among different zookeepers that are feeding the birds
	Good individual control of behaviour and appetite	Birds recognize zookeepers, when change zookeeper, the acceptance of food varies
	Individual control and potential medication are easier	Takes more time
	More accurate	Not all birds show up every time, some never want to eat by hand feeding
	Easier to feed vitamin fish and control whether birds eat vitamins	
	Isolation of birds from the group can be noticed	
	Ability to monitor the daily food intake	
	Allow the zookeepers to weight the birds and check them individually	
	Easy to check vitamin intake	
Scattered in water	Good individual control of the birds	Birds can rarely dive for food as the fish takes all the food in the water
	Able to monitor keenness and food intake	Scatter feed in the water can leave a slight oil film on the water which can affect the bird's plumage
	The birds show more natural feeding behaviour than feeding bowls or hand feeding	
	The feeding behaviour is stimulated, because hunting and diving are part of their natural behaviour	
Bowls	Less stress	Exact food intake per bird is unknown
	Independence of birds from the zookeepers, especially during breeding seasons	
	Good availability of food	
	Less time consuming	Atlantic puffins reduce their swim- and hunting behaviour
	Less costs	Atlantic puffins do not eat from the same feeding tray as gulls, so there must be placed more than three feeding trays in the enclosure
	No pressure for the birds to seeking food	The exact food intake is unknown
		Puffins get disinterested when feeding method is used for ~2 days
Mid-flight feeding	Exercises the flight muscles	

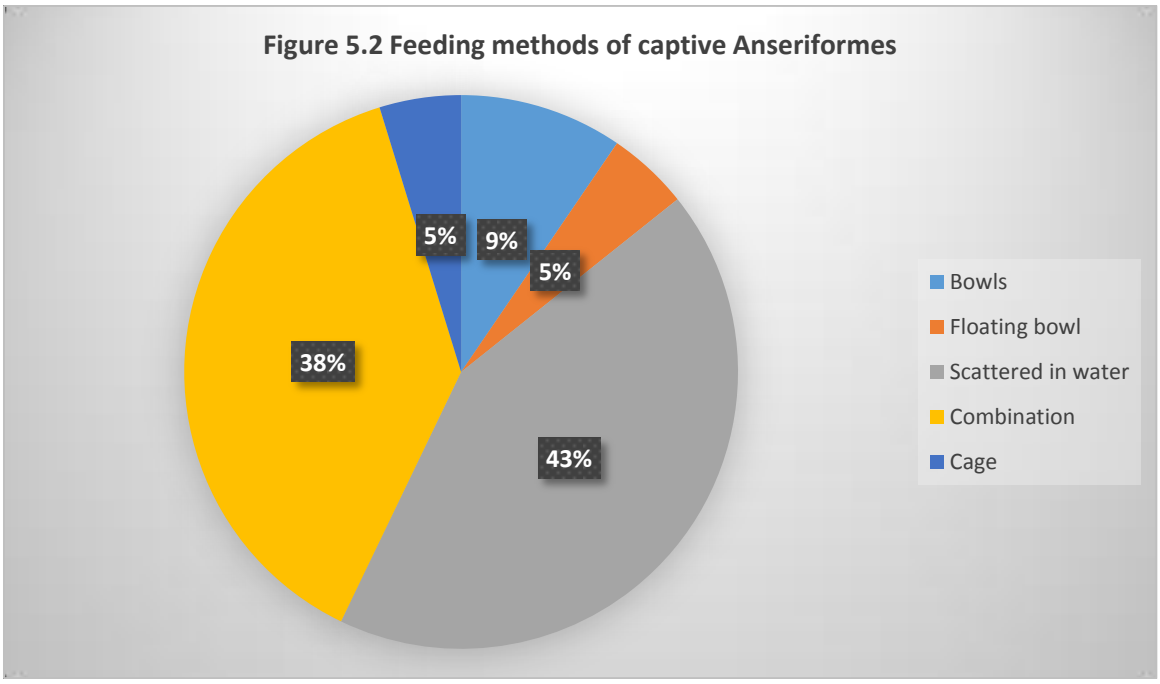
Abnormalities of birds

One question of the questionnaire was whether the birds had some abnormalities or diseases which may be related to nutrition. None of the participated zoos have had some problems related to nutrition. Unknown is whether these answers are reliable.

5.2.2 Anseriformes

Feeding methods

Figure 5.2 shows the percentages of feeding methods in other zoos. As seen in this figure feed other zoos 43% in the water, mostly floating pellets. 38% of zoos a uses a combination of different methods, mainly combinations of bowls and food scattered in the water. 9% of the zoos uses only bowls to feed common eiders or similar bird species, which is the same method as in Rotterdam Zoo. One zoos uses a floating bowl and one zoo uses a cage in the water to feed their birds. The birds have learnt to dive under the cage, where the feed is scattered in the water. It just took a few minutes for all birds to learn to dive under the cage (S. Nasir, personal communication, April 14, 2015).



Advantages and disadvantages of feeding methods

Table 5.9 gives an overview of the advantages and disadvantages of the feeding methods used by other zoos. The results are mentioned by other zoos.

Table 5.9 'Advantages and disadvantages of feeding methods of Anseriformes'

Method	Advantages	Disadvantages
Scattered in water	The birds come up to the zookeeper, so the individual health and issues can be checked and noticed earlier	It is difficult to check the individual quantity of food
	The birds can feed naturally on the water	Other wild birds can eat from the food also
	The contact with birds is better, than feeding in bowls, to check health	
	Every bird gets enough to eat, because the feed can be scattered on different places	
	Scattering in the water lessons the competition between birds	
	It is easier to spot birds which may not eat	
	There is less food wastage, because the zookeepers stop feeding when the birds are not interested anymore	
	Ease of use: it takes less time and there are no feeding bowls needed	
	The birds enjoy feeding in the water as enrichment	
Bowls	The food is available for the whole day	The exact food intake is unknown
	Less time and less costs, because it is more efficient to feed in bowls	Wild birds can eat easily from the bowls
	There is food loss and contamination of food with faeces and bio agents compared to floating pellets	
	It is easier to feed in bowls than scatter it in the water	
	This method avoids scraping in the enclosure	
Cage	The birds get all they need without worrying about other birds taking the food	No disadvantages noticed
	The costs are lower, because there is less loss of feed	
Floating bowl	A floating bowl ensures that penguins do not eat their food	Not mentioned

Abnormalities

Only one zoo had once aspergillosis, other zoos never had any problems that were related to nutrition. It is unknown whether these answers are reliable.

5.3 Alternative feeding methods

Besides abovementioned feeding methods of other zoos are some methods available. Most methods are suitable as enrichment method.

Grain in bowls

The first method is mentioned by Tinus Boomstra of Kasper Faunafood, as enrichment. This method can be used for sea ducks. Several bowls are filled with some duck grain, and placed just below the water surface. Gulls cannot eat from the grain this way, but sea ducks enjoy this enrichment. There should be noticed that a maximum of 25% of the daily food intake can be given as enrichment, otherwise the bird eat too much from the enrichment and too less of the normal food.

Advantages:

- Gulls or other bird cannot steal this enrichment
- Sea ducks enjoy this type of enrichment
- By using duck grain, the composition of grain is sufficient
- Not an expensive way of feeding enrichment

Disadvantages:

- More time consuming than using one bowl
- There should be noticed that birds also eat sufficient amounts of pellets
- There must be investigated which place is the best place for these bowls.

Bowl placement

Another way to provide birds with food is to change bowls every day of feeding place and use more bowls on somewhat hidden or difficult reachable places. Birds have to try to find food items and have to undertake some action to get these items. Birds which are able to fly in the enclosure, can be fed on somewhat higher places

Advantages:

- Birds have less competition
- Birds can choose their feeding bowl
- Birds have to search for food, which stimulates natural behaviour, although it is not a natural way to feed in bowls

Disadvantages:

- There is a possibility that some places are not suitable for these birds, or some places where birds would not eat

Other methods

Other, more time consuming or expensive methods are:

- Release of fish when touching something
- Fish attached at cords, placed into the water

Chapter 6. Discussion

This chapter describes the discussion, based on chapter 3. 'Natural diet and foraging behaviour', chapter 4. 'Diets of captive seabirds' and chapter 5. 'Behaviour and feeding methods of captive seabirds'. The study is based on a main question and some sub-questions. The main question of research was: "How should the seabirds at Rotterdam Zoo be provided in their nutritional needs in a way that is as close as possible to their natural situation?" This chapter reflects on the results of this study, including strengths and weaknesses.

6.1 Discussion of methods

Reliability and validity

Literature study
A lot of literature is used to complete this study, but a part of this used literature is older literature. It is unknown whether these studies are recent enough. The reliability will be lower. Also was expected that there was a lack of scientific information, which came true. This lack of information was especially for the nutritional requirements of the bird species, but it is, unfortunately, too expensive for researchers to investigate these requirements. It takes a lot of time and money for doing research, but there are too less zoos or other instances that keep captive seabirds, compared to the input of research.

Behavioural study
Behavioural research is done per group of bird species, and within one week per bird species. The used sampling method was scan sampling per 2.5 minutes. Only frequencies were noted. An advantage of this method is that data of multiple birds can be collected simultaneously. But the chosen method and times limit this study to a global view of the bird's behaviour. This means that the feed intake and behaviour per individual bird remain unknown and there is a possibility that birds were eating less or more in that one week of observations. Besides that, the time interval of 2.5 minutes is not optimal, but the group of kittiwakes and common guillemots was too big to measure in intervals per 30 seconds or per 1 minute. The time interval and start of each 'scan' or observation moment was every time the same. Observations were also done from the same side of the enclosure, the visitors site. This should not influence the bird's behaviour.

Questionnaires to other zoos
One, unambiguous questionnaire was used to collect data about diets and feeding methods of other zoos. Thirty one zoos filled in this questionnaire, but the information was not always completed. Missing information and vagueness were asked to the zoos.

Almost every zoos answered "no" on the question: "Did you notice some abnormalities in behaviour, disease, reproduction, etc. that might be influenced by feed or feeding method?". It is impossible that none of the zoos have ever had any problems in behaviour, reproduction of other problems related to nutrition of feeding methods. Especially Atlantic puffins are very sensitive birds that quickly can have problems with plumage or health. A lot of zoos are known to regularly have problems with aspergillosis (H. Schmidt, personal communication, May 26, 2015).

Expectations and feasibility

Expected was that the current feed was enough to meet nutritional requirements of the birds. But, as far as these requirements are known, can the current feed be improved by adding carotene, and calcium when needed, before and during breeding seasons. However, exact amounts of carotene and calcium are unknown.

The feeding method was expected to be improved. This improvement can be made in different ways, which is described below.

The lack of information was also true. Especially bird specific nutritional requirements were quite unknown and were attained by the experiences of other zoos and experts.

Hypothesis

It was unknown whether the current feeding method was good enough to continue. The H_0-hypothesis mentioned in the introduction of this report can be rejected. This hypothesis was: "There is *no improvement* possible to provide the seabirds of Rotterdam zoo in nutritional needs in a way that is as close as possible to their natural situation".

The current diet of seabirds in Rotterdam Zoo can be improved by adding carotenoids as vitamin A for the colouring of the beak and extra antioxidant during the breeding season. Calcium only has to be added when problems in egg shell formation occur in breeding season, because a sufficient amount of calcium is already available in the viscera of fish (Nijboer, 2015).

6.2 Discussion of results

Results literature study
Results of literature study presented the most important anatomical characteristics and natural diets and foraging behaviour of seabirds; Atlantic puffins, black-legged kittiwakes, common guillemots and common eiders. As expected, there was a lack of information about the diets of captive seabirds, even as on nutritional requirements of wild living seabirds. Found literature about nutrition of captive animals was mainly based on experiences and not on scientific research. Thereby, feeding birds in mixed enclosures requires some extra attention and knowledge. There was only one zoo, worldwide, which have the same composition of birds as in Rotterdam Zoo. Every bird species have other behaviour and requirements, and in wild, a bird can choose which behaviour or feed items it eats. The space to catch preys and show behaviour is also bigger. Birds in captivity should adapt their behaviour to a smaller and denser living place.

Also is investigated that gulls (black-legged kittiwakes) show more aggressive behaviour than other birds. *Alcidae* show also aggressive behaviour, but less than kittiwakes. This situation is given for birds in wild. Scientific information about aggression during foraging in captivity could not be found also.

Another important aspect is that the content of fish, percentage of fat and protein for example, differs per season and catch (Lauzon et al, 2010).

Results behavioural study
Results of behavioural results presented only the behaviour of seabirds in the Bass Rock enclosure of Rotterdam Zoo. This study is only done in Rotterdam zoo, but not in other zoos to compare it. Unknown is what type of behaviour is showed in other zoos. The current diet and vitamin intake was also investigated in this part. A difference in vitamin intake and vitamin recommendation was found, but unknown is whether this recommendation is similar to the requirements of the birds, because exact nutritional requirements are unknown. The recommendation was based on similar birds species and experiences, as well as the 20% loss of vitamin powder during storage. It is not evidenced that the average loss during storage is around 20%. According this recommendation are the birds fed too less of vitamin A and too much of vitamin B_1 and E. The vitamin A can be filled up by giving carotene, unknown is whether an excess of carotene can influence bird's health.

The lowest time of foraging was for Atlantic puffins (1.85%) and highest for common guillemots (3.02%). Both are low percentages of foraging, because the foraging time in the wild is around 20% (Davoren and Montevecchi, 2003). Conspicuous was that common eiders spent 40% of their time on abnormal swimming. This all could be signs of boredom or too easily available food. Food is easily available and birds do not have to hunt for feed. Maybe enrichment can improve the time of foraging.

The time between the placement of bowls and first moment of eating was also measured. The average times show that Atlantic puffins and common eiders will start to eat after 25 minutes. This could be signs of submission or saturation, but is only measured for one week and should be further investigated. A significant difference was measured in feeding preference for the Atlantic puffin and Black-legged kittiwake. Common eiders have only one bowl, which means that there could not be a preference for feeding bowl.

Results questionnaires

Questionnaires were sent to more than 55 zoos, but only 31 zoos have filled in the questionnaire. The validity of questionnaires is lower than visiting these zoos. It only gives an indication of diets and behaviour in other zoos. Unknown is whether these zoos filled in the questionnaires truthfully and whether given diets are considered as optimal. This information is also based on experiences and maybe little scientific research.

Chapter 7. Conclusion

This chapter describes the conclusion of this study. The main question of this research was: "How should the seabirds at Rotterdam Zoo be provided in their nutritional needs in a way that is as close as possible to their natural situation?"

The bird specific nutritional needs are quite unknown, but there are some evidenced facts. Evidenced is that protein is considered as the most important nutrient, especially during breeding seasons. Methionine and cysteine are considered as limiting amino acid in marine fish. The recommended protein intake is unknown, but the protein content of commercial sea bird diets ranges from 14-32%. Sea birds of Northern coasts have generally a higher need for proteins and the intake of proteins in breeding season should also be higher, probably is the requirement for proteins between 25 and 30%. Essential fatty acids are linoleic acid and α-linoleic acid. Around 2% of dietary fat is needed for absorption of fat-soluble vitamins and carotenoids, but specific requirements of fatty acids remain unknown. An excess of fat can cause problems with the plumage of the birds and a higher need of vitamin E. Vitamin A (as retinol), thiamine and E are considered as most important vitamins, because these vitamins become unstable during storage. Requirements for these vitamins are 10,000 IU of vitamin A, 150-160 IU of vitamin E and 50 mg of thiamine. Besides retinol, is evidenced that carotenoids, a type of vitamin A, can influence the body condition and colouration of beaks positively. The right amount is unknown. Other vitamins will be sufficient when feeding whole fish.

Anseriformes (Common eiders)

The current diet of common eiders consist of Anseres sea-duck pellets of Kasper Faunafood, fed ad libitum. This diet can be used whole year. The best way to feed the common eiders is to scatter pellets in the water, if fish in the enclosure do not eat from it. Otherwise, the sea-duck pellets can be placed in several bowls on different places in the enclosure instead of placing one feeding bowl on one place. The amount of feed should be higher during breeding seasons, winter and moult.

There is not given any enrichment for common eiders. Enrichment can be given by placing bowls of grain into the water or giving some blue mussels that are already a little bit opened. Common eiders forage also in surface waters by head-dipping, which can be showed when feeding in the water.

Atlantic puffins, black-legged kittiwakes and common guillemots

The diet of seabirds should consist of different fish species instead of one species per feeding moment, including vitamins. Carotene has a positive effect on the health of birds and is considered as unstable nutrient. The amount of carotene depends on the type of carotenoids and should be investigated first. During breeding seasons should be given some extra calcium when problems with egg shell formation occur. The natural foraging behaviour could be stimulated by using other feeding methods or make use of enrichment. Common guillemots forage mainly by plunge-diving, Atlantic puffins by diving and kittiwakes more on surface diving.

A combination of methods should be used for the Seabirds to accomplish the natural needs of the birds. The best method would be to scatter a low amount of low-fat fish in water, only if fish do not eat from this food, and placing also at least three different feeding bowls in the enclosure with a mixture of different fish species, including vitamins. As enrichment can be given some krill or squid and feed can be spread over the whole enclosure.

Because of the high percentage of proteins can squid, krill and herring be given as extra when birds need it: during moult, winter and breeding seasons. Fish with lower percentages of fat can be used for scattering enrichment in water: anchovy, krill and smelt. When chicks are hatched can be given some small fishes that birds can feed to their chicks (sand lances). The given fish species should be higher in proteins and energy.

Chapter 8. Recommendations

A lot of knowledge gaps were noticed during this research. This chapter describes the recommendations for further studies.

Recommendations for Rotterdam Zoo

1. The improvement of water quality when feeding (high fat) fish in the water will be also a recommendation for further study. Especially Atlantic puffins are sensitive to oil on the water and probably many zoos have some problems with this.

2. The composition of birds in the enclosure can limit the stimulation of behaviour. Gulls and common guillemots are more dominant than Atlantic puffins, when only scattering in the water, puffins probably do not eat or eat less. There should be considered if the number of kittiwakes and common guillemots should be reduced.

3. Behavioural research in Rotterdam Zoo should be extended and compared to the behaviour of similar birds in other zoos or captive enclosures. There is missing information on feeding behaviour and effects of different feeding methods on the behaviour of seabirds.

4. Stereotype behaviour of the common eiders should be also investigated to find out why these ducks are showing this type of behaviour.

5. The effect of carotene and calcium during and after breeding seasons. It is unknown whether this type of vitamin A and calcium affect the health of the birds.

6. The percentages of fat in fish that is fed to the birds, to determine which types of fish can be scattered in the water.

General recommendations

1. First of all should be investigated what bird specific requirements are, or at least for Seabirds and Anseriformes in general. Especially Atlantic puffins, because these birds are more sensitive than the other seabirds. The feed of the common eiders is quite established, but not based on scientific information.

2. Also should be investigated what amount and types of vitamins and minerals are needed. These numbers are, again, based on experiences. The effect of vitamins on health and (re)production of captive seabirds is unknown

3. The influence of light (UVB and UVA) on the birds' health should also be investigated. As well as natural sunlight as artificial light. There are a few zoos which are experimenting with different lights, and have positive results, but unknown is whether these results are connected to (sun)light.

4. Percentages of vitamin loss during storage (vitamin powder and tablets) should be investigated.

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