BSc Thesis

Reported decrease of PCB in black guillemot eggs during the period 1999 to 2001

Could a change in black guillemot diet be a contributing factor?

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Contents

Samandráttur

Kanning hjá Heilsufrøðiligu Starvstovunni vísti eina signifikanta minking av PCB innihaldi í teistaeggum á árunum 1999 til 2001. Til at finna útav um minkningin stóðst av minni concentration í umhvørvinum ella um hon var orsakað av broyttum føðivali hjá teista, vóru gjørd tvø sløg av kanningum; isotopukanningar (gjørdar av labratori í Kanada) av teistaeggunum og kanningar av magainnihaldi av tríati teistum. Magainnihaldskanningin er samanborin við eina aðra, sum var gjørd í 1998. Isotopukanningarnar vístu at teistin etur meira av føði sum er hægri uppi í føðivevnum en hvat hann gjørdi fyrr. Har ið PCB eru evnir sum konsentrerast upp í gjøgnum føðiketuna, kann broytta føðivalið hjá teistanum ikki forklára minkingina í PCB, og tað er eitt tekn uppá at PCB hevur veruliga minkað í umhvørvinum.

Abstract

A research done by the Food and Environmental Agency had shown a significant reduction of PCB in Black guillemot eggs during the period of 1999 to 2001. This brought up the question weather there is a reduction of PCB in the environment, or Black guillemot has changed diet. Two approaches were used; Stable Isotope Analysis (done by a Canadian Laboratory), and Stomach Content Analysis. The Stomach Content Analysis is compared to another one done in 1998. The Isotope Analysis showed an increase in Black guillemots´ trophic status. PCBs are substances that accumulate as they are transferred up through the food web, so Black guillemots´ increased trophic status does not explain the reduction of PCB. This indicates that the reduction in PCB levels is real.

Introduction

Research done by the Food and Environmental Agency (Heilsufrøðiliga Starvstovan) has shown a reduction in the amount of PCBs in Black guillemot eggs during a period of three years, in 1999-2001 (Hoydal et al., 2001). This brings up the question weather there is a reduction of PCB in the environment, or Black guillemot has changed diet. Our goal is to cast some light on these questions. The methods used are:

1) Stable isotope analyses, of the 58 eggs that had been tested for PCB. They were collected in these three years, from two locations, Koltur and Skúvoy.

2) Stomach content analyses of thirty Black guillemots.

Since PCBs accumulate as they are transferred to higher trophic levels, Black guillemots´ choice of diet can greatly affect its PCB exposure (Braune et al, 2000). The possibility of a switch in diet, and that being the cause of PCB reduction is not unlikely because Black guillemot is known to be opportunistic, feeding on different diet in different localities, and from year to year (Cramp, 1985), and there are examples of reduced PCB in biological monitors, which were caused by a change in diet rather than a decrease in the environment (Herbert et al.2000).

The reduction reported by the Food and Environmental Agency were reductions in Arochlor, PCB 7 (the sum of seven PCB congeners, CB 28, CB 52, CB 101, CB 118, CB 138, CB 153 and CB 180), and the congener CB 53 (Hoydal et al, 2001). Table 1 shows the mean values of PCB 7 and CB 153, in this three year period.

Year	Location	n	PCB 7	CB 153
1999	Koltur	10	2207	1146
1999	Skúvoy	8	1843	956,2
2000	Koltur	10	1424	760,8
2000	Skúvoy	9	1480	740,8
2001	Koltur	10	984,7	449
2001	Skúvoy	10	1131	497,6

Figure 1. Mean values of PCB 7 and CB 153 (µg/kg of lipids) in 58 Black guillemot eggs from Koltur and Skúvoy. Data from Hoydal et al., 2001.

Stable isotope analysis

This technique is based on the acknowledgement that the proportion of the heavier stable isotopes increases, as biomass is transferred up the food web (DeNiro&Epstein, 1980). This means that there is a selection of isotopes in metabolism; animals excrete higher proportion of light isotopes than they incorporate with the diet.

Nitrogen and carbon stable isotopes are commonly used in SIA (Stable isotope analysis). For nitrogen, the fractionation, or discrimination of isotopes, occurs primarily during the metabolism of proteins and amino acids. The enrichment of ^{15}N isotopes between trophic levels is about 3 ‰, so a consumer is expected to have 3 ‰ higher proportion of ^{15}N than its diet. There is less difference of C isotope composition of a consumer and its diet, or ca. 1‰, but ^{13}C can provide information about the source of carbon that enters the food chain (Sagerup et al, 2001).

As Stable Isotope Analysis shows different composition of isotopes for organisms on different trophic levels, it is here used to compare black guillemot's eggs that were collected 1999-2001. If the cause for a reduction of PCB is a change in diet over this time period, they have fed more on diet on lower trophic levels for the later part of this time period, and that could explain the reduction in concentrations of PCB detected.

The ratio of the heavier and the lighter isotopes are usually referred to as δ values, were δX stands for part per thousand from a defined standard value of a stable isotope.

$$\delta X = [(R_{sample}/R_{standard}) - 1)] * 1000$$

Were δX is 15N or 13C. R is the ratio 15N/14/N for nitrogen or 13C/12C for carbon (the ratio of the heavier to the lighter isotope). The defined standard values are the proportions 15N/14/N of nitrogen in the atmosphere, and 13C/12C in the PeeDee limestone (Peterson & Fry, 1987).

The fractionation of isotopes is mass dependent and occurs as atoms with slightly different weights react with slightly different rates. The application of the same force displaces a heavier isotope more slowly than a lighter isotope (Peterson & Fry, 1987). In chemical reactions were all the reactants are converted to a product, the isotopic ratios do not change, the output must be the same as the input. If, on the other hand, the reaction is branched, discrimination may occur so the product will have different isotopic ratio from the reactants (Schoeller, 1999). If fractionation takes place in a reaction chain, it is associated with the first step, the input of the reaction sequence (Peterson & Fry, 1987).

In nature, δ values for nitrogen range from values near zero (for nitrogen fixating plants and cyanobactera) up to 15-20 for top predators in marine systems, were there are many trophic levels (Merwe, 1992). Carbon isotopes fractionate far less than nitrogen isotopes between trophic levels, but they can be used to trace the origin of the organic matter. There is a great difference between δ 13C values of C_3 (average values of -26, 5) and C_4 plants (average values of -12, 5), who have two different photosynthetic pathways, between terrestrial and marine primary producers (Chrisholm B. et al), and between phytoplankton and sea-weeds in marine systems (Kaehler et al., 2000).

Black guillemot

Sources: “Handbook of the Birds of Europe, the Middle East and North Africa, vol. IV” and “Tejsten” by Sten Asbirk.

Black guillemot (*Cephus grylle*) is a small sea bird of the Auk-family (Alcidae). Alcidae includes 22 species of sea birds which are spread over the northern hemisphere. Alcidae in general, are erect, black and white, have a stream-like shape which makes them well adapted for diving. They have short wings which are used for both flying and swimming; their bones are strong and not filled with air as in other birds.

Black guillemot is a medium sized auk, about 30 cm long. It has black plumage in summer and lighter in winter. It has a white patch on the wings, the feet are red, and the head is round with a fine, small bill. The sexes look the same.

They breed in colonies along the cost, preferably on small islands which are free of fox and other mammals that hunt them. They forage by diving near the cost. Being bottom feeders and usually not diving deeper than 10 m, the breeding locality is usually by shallow waters.

Black guillemot is primarily a non-migratory bird and the species includes seven different races; the Faroese race is *Cephus grylle Faeroensis*. Being non-migratory and a top predator in a food chain make it suitable to be used as a monitoring organism for estimating the amount of PCB in the marine environment.

In their feeding they are rather opportunistic than specialists, and change diet according to availability. That will say that there must be a variation from year to year, between localities, and seasons. They feed mainly on fish and crustaceans. Fish is caught mainly in depths of 1-10 m.

In a Norwegian study in winter 76, 9% of the stomachs contained crustaceans, 15,4% fish and 7,7 % contained molluscs.

The diet of young birds is dominated by fish. On Fair Isle (Scotland) in Flatey (Iceland) and in Denmark, butterfish was the most common species and Sandeel the second most common.
Tides are likely to affect feeding rate and which prey is taken. They tend to hunt more inshore in breeding season and offshore during winter.

PCB

Sources:
"PCBs and the Environment", vol. I; "Halogenated Biphenyls, Terphenyls, Naphthalenes, Dibenzodioxins and Related Products" and "Basibog i Økotoksikologi"

PCBs or polychlorinated biphenyls, is a group of synthetic, lipid-soluble hydrocarbons with different degrees of chlorination. They are among the most stable substances ever known, resistant to heat, chemicals, acids, bases, to oxidation and reduction. Their physical properties, stability and resistance, make them very good for their industrial purposes; they are used in electrical equipments, transformers, heat transfer fluids and plastic. Being so stable, they are also very slowly broken down in nature. They are transported by air and oceanic currents and are now spread over the whole globe. Their lipophilic nature ensures their accumulation (the build up over time of substances) and biomagnification (increase in concentration) when they are transferred in the food web. They accumulate especially in fat tissues.Marine food chains are often longer than terrestrial food chains, so top predators in marine systems, such as marine mammals and sea birds, tend to have high concentrations of PCBs.

The common chemical structure of the PCB molecules, is two phenyl rings, with different number of chlorine atoms ($C_{12}H_{10-n}Cl_n$ with n = 1-10). With chlorine substitution from one to ten, there are 209 possible congeners of PCB.

The rate of metabolic excretion depends on the species, the degree of chlorination and the stereochemistry of the congeners. Species with high metabolic rate can excrete PCB faster than species with low metabolic rate. Lower chlorinated congeners are usually eliminated faster from tissues than more chlorinated congeners, the more chlorinated are more lipophile and have greater tendence to accumulate, with some exceptions though, due to the stereochemistry of the different congeners. A non-substituted biphenyl is a planar molecule, but when two or more chlorine atoms are in an ortho-position, the molecule becomes globular because the electrophile chlorine atoms repel each other and force the molecule to bend. For processes such as membrane passage there might be an optimal molecular size and steric configuration, and that will affect bioaccumulation.

In an aquatic system there are three mechanisms of bioaccumulation:
Absorption through gills, uptake through epidermis and consumption of food. Fish tends to have high consentrations of PCBs compared with the trophic level below it, because fish gets assimilates pollutants both through its diet, and through the gills. Seabirds that feed on fish have again, higher consentrations.

The possible ways of degradation of PCBs are photochemical degradation by ultraviolet radiation and microbial degradation. Micro organisms decompose and metabolize PCBs.

PCB in fish and wildlife was first reported in 1966.

Now there have been set restrictions by governments on the usage of PCBs and PCB containing equipments, and its production is greatly limited.

Methods

The work we did includes the stomach content analysis, collecting literature, and some preparation work for the Stable Isotope Analysis, finding and contacting a suitable laboratory to do the analysis, and preparing the samples before they were sent.

Stomach content analysis

The birds were shot at Kirkjubønes on May 2nd, in the evening. They were brought to Torshaven and put in deepfreeze within two hours after the hunt.

Each bird was weighed. Then they were cut from their left side, under the wing, and through the ribs. The gender was registered and the stomach was cut out. The stomachs were weighed, first with its contents, and then they were emptied and washed with water and weighted again. The difference of weights of the stomachs with and without their contents gives the weight of the contents. The stomach contents were moved into a coloured plastic bowl, so the white otoliths could be more easily seen. Then all relevant contents that were not too much digested to analyse were classified, weighed and degree of digestion was registered. (see appendix).
The scale for degree of digestion, which is taken from a compilation on stomach studies, is as follows:

1. Not digested
2. Very little digested, it is possible to classify to species level
3. Partly digested, it is possible to classify to a taxa
4. Almost fully digested, only parts of the animal can be seen
5. Fully digested, it is not possible to see to which taxa the animal belonged to

Using a scale for digestion makes it possible to estimate the relative rate of digestion of different food items, and avoiding over-estimation of the proportion of hard diet items that are more slowly digested.

In stead of weighing the fish remains that were found, the lengths of the otoliths were measured and the fish lengths and weights were estimated by the use of formulas.

Preparation for Stable Isotope Analysis

58 eggs from Koltur and Skúvoy islands, from 1999, 2000 and 2001, were already collected and analysed for PCB. To reduce the cost of the analysis it was decided to mix two and two samples together, but eggs from different places and years kept separate. To hinder contamination of the egg samples, the glass jars were heated to 400 degreese for 8 hours. The samples were weighed and two and two blended together. They were covered with aluminium foil and closed with the jar lids.

The Stable isotope analysis was done in “Stable Isotope in Nature Laboratory”, at the University of New Brunswick in Canada.

The samples need a complete conversion to a gaseous state. The gas is introduced into collector isotope ratio mass spectrometer, which measures the isotopic ratios, relative to the known standards (Peterson&Fry,1987). More detailed description is in the appendix.

Results

Results of stomach content analyses

The contents were divided into three main groups, crustaceans, fish and molluscs. Figure 1 shows the frequency of occurrence of these groups. The y-value shows the percentage of stomachs in which the elements of each group were found.

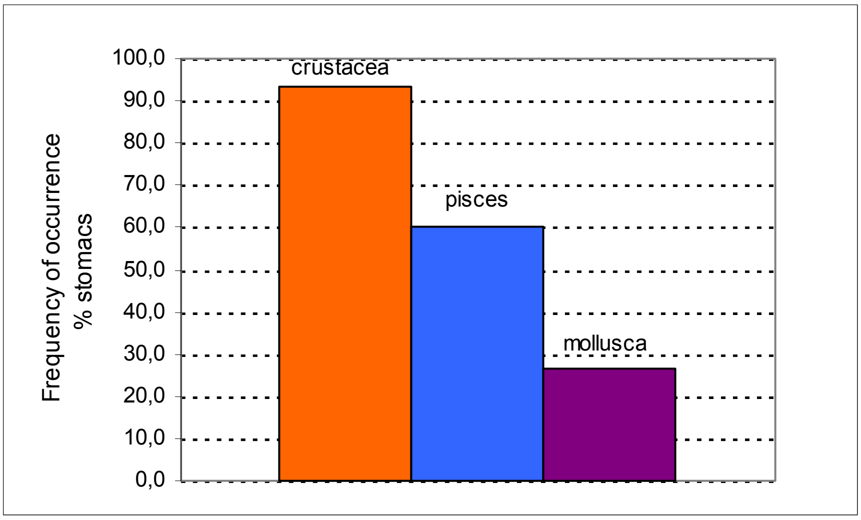

Figure 1.Stomach contents of 30 Black guillemots shot at Kirkjubønes May 2nd 2002. The three main groups of the diet were crustaceans, pisces and molluscs.

The elements were classified to the extent their digestion grade allowed. Frequency and weight percentages of the different elements found in the stomachs are shown in Table 2. The values of the three main groups, crustaceans, fishes and molluscs, are the percentages of stomachs in which they were found. The percentages of the subgroups are the percentages within the main-groupwhich they belong to. Galathea crabs have the “frequency %” 73 and “weight %” 61. This means that 73% of the crustaceans were of the group galathea, and they weighed 61% of the total weight of crustaceans.

The second most common crustaceans were *Pandalus montagui*, which were found in 30% of the stomachs. Among the fish, Ammodytidae was the most common, seen in 17% of the stomachs.

Gastropods were also found in 17% of the stomachs. A Nematode, which is a parasite, was found in one stomach (3% of 30). See-weeds and pebbles were in 20% of the stomachs.

Taxon		frequency%	weight %
Crustacea		**93**	**84**
	Galathea sp.	73	61
	amphipoda		1
	isopoda		1
	Pandalidae		
	Pandalus montagui	11	10
	Pandalus spp.	1	2
	remains	15	25
Pisces		**60**	
	Ammodytidae	64	
	Pholis gunnellus	9	
	Pollachius virens	2	
	Micromesistius poutassou	2	
	Gadus morhua	2	
	pisces remains	21	
Molluska		**27**	**1**
	gastropoda	63	73
	remains	37	27
Nematoda		3	
Other		20	
(sea weed, pebbles)			

Table 2.The frequency of Crustaceans, Pisces and Molluscs and the relative weight and frequency ratios within these groups.

Most of the fish remains found in the stomachs were otoliths, and backbones. When otoliths were found it was possible to classify them and find out which species they belonged to. Figure 2 shows the proportions of the fish species. 64% of the otoliths were from Sand eel (Ammodytidae), the 2nd most common was Butterfish (*Pholis gunnelus)* or 9% of the otoliths. The other species found are Blue whiting (*Micromesistius poutassou),* Coalfish *(Pollachius virenis)* and Cod (*Gadus morhua)*. 21% were fish remains such as back bones, in stomachs were no otoliths were found, and these were only registered as "fish remains".

Taxon	# Fish avg	range
Ammodytidae	5	2,0 -17,0
Pollachius virenis	1	1
Pholis gunnellus	1,3	1,0 - 2,0
Gadus Morhua	1	1
Microcesistius poutassou	1	1

Table 3.The fish species in the stomachs of the 30 Black guillemots.

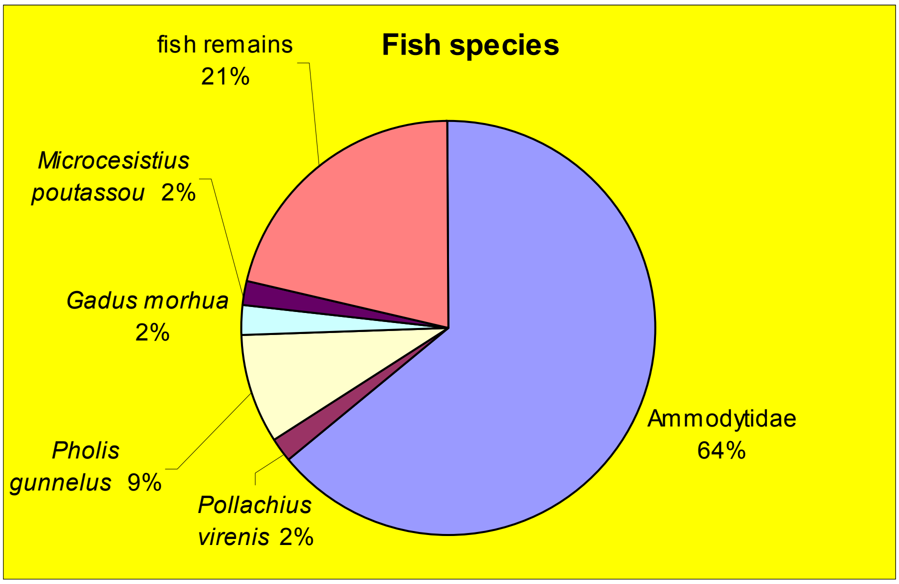

Figure 2.The proportions of the fish species in the stomachs of the 30 Black guillemots.

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It was decided not to weigh the fish remains because most of the fishes were too much digested for the weight to give a picture of the importance of fish in relation to other diet icons. The lengths of the otoliths of the most dominant fish species in the diet, Ammodytidae, were measured and formulas were used to estimate the lengths and the weights of the fishes. Figures 3, 4 and 5 show the lengths of otoliths, estimated fish length and fish weights respectively.

The correlation between the lengths of otoliths and fish is:

Fish length = 18,76 + 45,75 * otolith length, $r^2 = 0{,}953$

And the correlation between otolith length and fish weight:

Fish Weight = 0,6041 * otolith length ^{2,763}, $r^2 = 0{,}962$

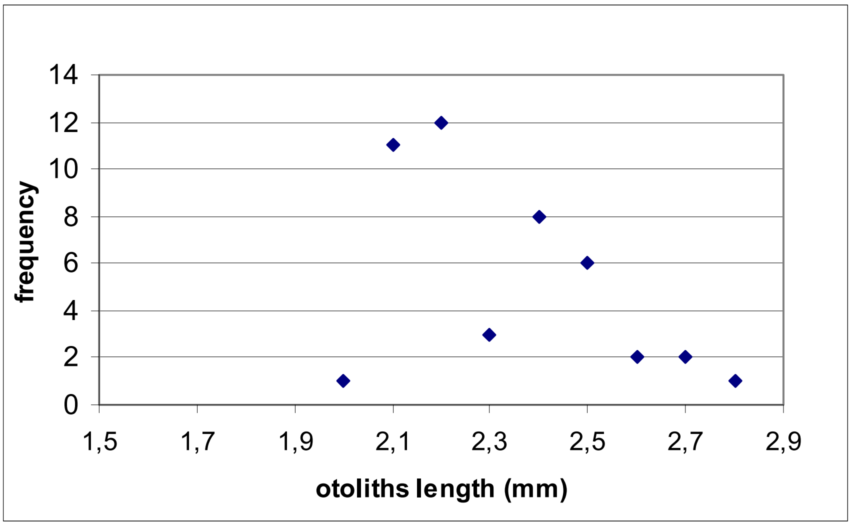

Figure 3.Otolith lengths of Ammodytidae.

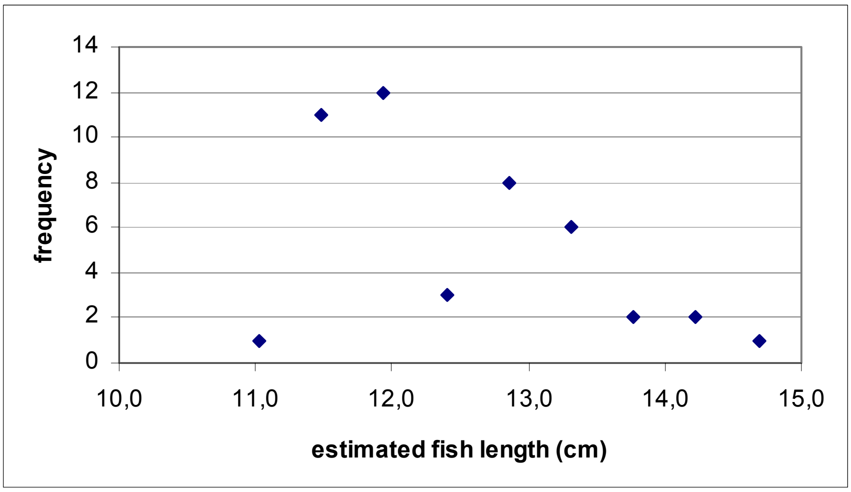

Figure 4.Estimated lengths of Ammodytidae.

The most common size of Ammodytidae taken, is between 11 and 14 cm, that weighs 3-10 gram.

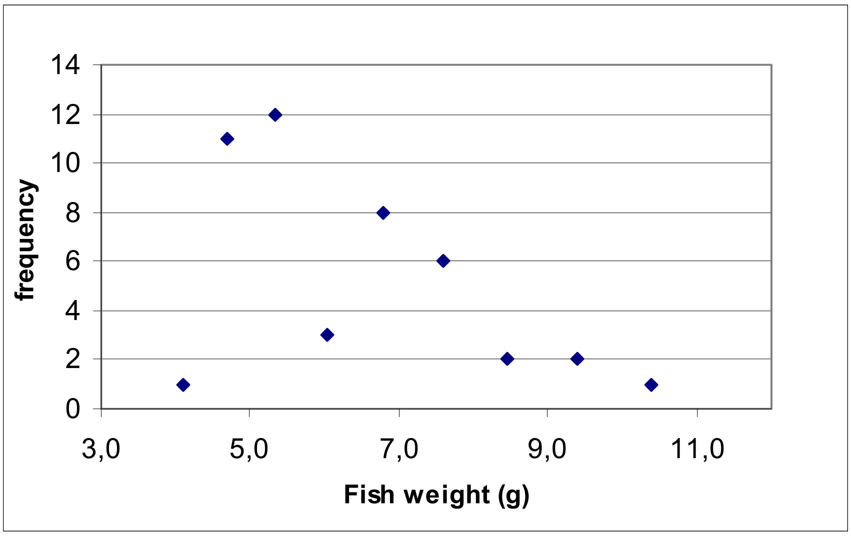

Figure 5.Estimated weights of Ammodytidae.

Results of Stable Isotope Analysis

Figures 6-8 and table 3, show the results of stable isotope analysis of the eggs from Koltur and Skúvoy. The pattern shows that δC and δN have increased during the three years, 1999-2001 in both locations. The average δC values for the first years are -21,22 and -21,80 for Koltur and Skúvoy eggs respectively, and the last year they are -19,36 for Koltur eggs and -18,03 for Skúvoy eggs. This is an increase of 1,86 and 3,77 for Koltur eggs and Skúvoy eggs respectively. The increase of δN is a bit less in both locations. The averages for the first year are 9,89 in Koltur eggs and 10, 54 in Skúvoy eggs. The averages the last year are 11,40 for Koltur eggs and 12, 65 for Skúvoy eggs. The increases are 1,51 for Koltur eggs and 2,11 for Skúvoy eggs.

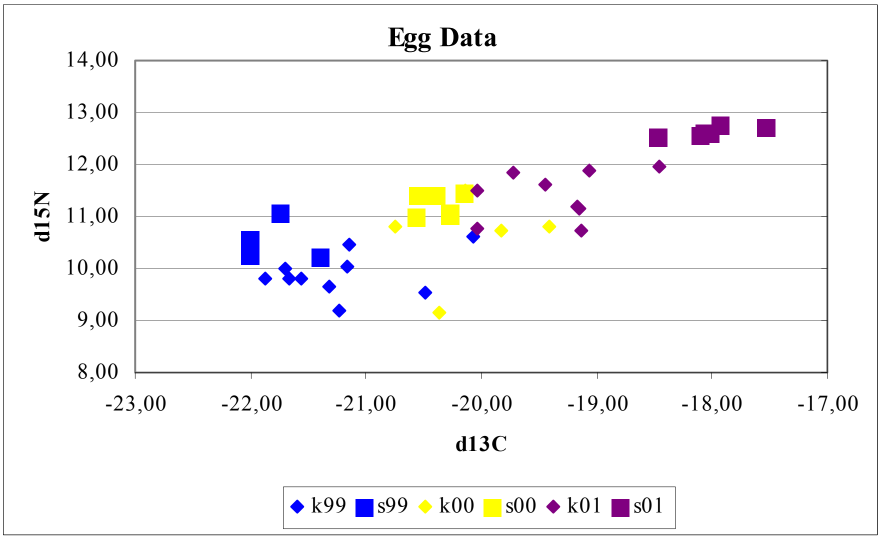

Figure 6.Isotopes signatures of the eggs collected in Koltur (k) and Skúvoy (s), in 1999, 2000 and 2001.

Figure 6 shows the isotope signatures of the eggs from both Koltur and Skúvoy together. Figures 11 and 12 show the same data, but the locations are separate.

Site+year	δC min	δC max	δC AVG	δN min	δN max	δN AVG
K99	-21,87	-20,07	-21,22	9,19	10,63	9,89
K00	-20,75	-19,42	-20,10	9,14	11,50	10,60
K01	-20,04	-18,05	-19,36	10,18	11,89	11,40
S99	-22,02	-21,41	-21,80	10,23	11,07	10,54
S00	-20,59	-20,15	-20,37	11,03	11,45	11,23
S01	-18,47	-17,54	-18,03	12,55	12,79	12,65

Table 4.The ranges and averages in δC and δN values for the eggs collected in Koltur (K) and Skúvoy (S) in ´99,´00 and ´01.

Figure 7 shows the isotopic signatures from the Koltur-eggs. There is a general increase between the years for both d13C and d15N. The values are a bit scattered. The signatures for Skúvoy (figure 8) show very clustered values and clear distinction between the years, especially in d13C values.

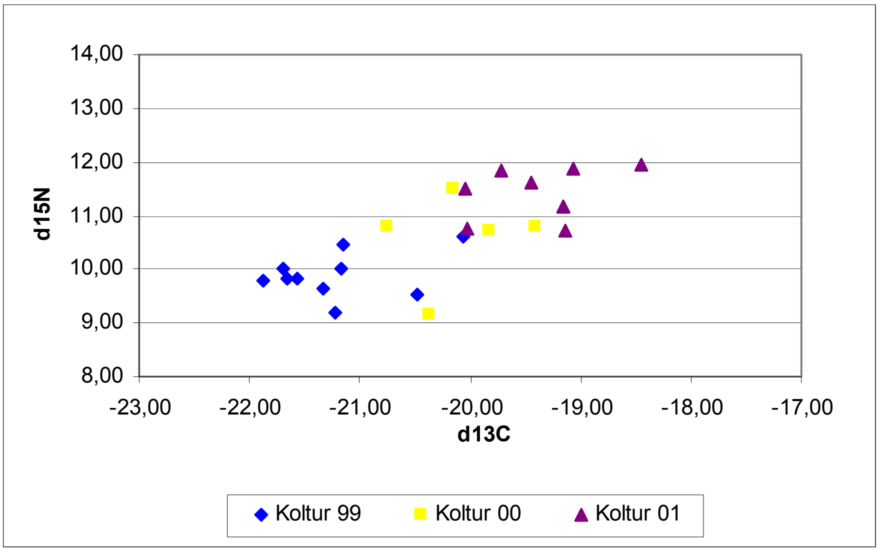

Figure 7. Isotope composition of Black guillemot eggs from Koltur, collected in 1999, 2000 and 2001.

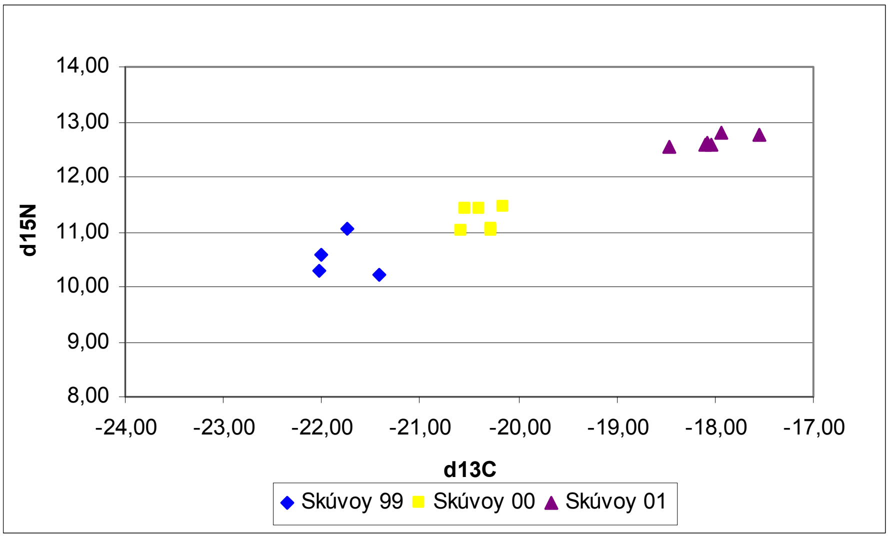

Figure 8. Isotope composition of Black guillemot eggs from Skúvoy, collected in 1999, 2000 and 2001.

Discussion

There has been much written on the merit of stable isotope analysis in ecological studies, and the drawbacks of examining stomach contents (Sagerup et al.,2001; Hobson et al.,1994). Content analysis reflect what an animal has eaten but not what it assimilates, and therefore it does not show which part of the diet are of importance in the energy-flow. It can give biased results because some food is more quickly digested than other and the ingested food needs to be identifiable and present at the time of examination. The proportion of the non-digestible hard body items tends to be overestimated. SIA can overcome some of these problems, because the isotope ratios that are measured are of the food that is assimilated.

The drawback of stable isotope analysis is the difficulty of interpreting the isotope ratios, and the interpretation demands a great understanding of isotopic flow in natural systems. Instead of substituting biological stomach studies with chemical isotope analysis, the combination of those two methods should give a better picture of ecological interactions (Thompson et al., 1999).

Even though both of these methods are used in this study, this is not a combination, because the Stable Isotope Analysis and the stomach studies were done on different individual birds, which were collected in different years. Therefore, we will not attempt to compare directly the results of the isotope analysis and the stomach content analysis.

Because the birds we studied were shot at only one place on one occasion, it would not be right to make general conclusion on Black guillemots' diet, based on these observations. We will still attempt to compare the results to earlier research on Black guillemots´ diet.

Beinta Johannessen did a study on Black guillemots´diet, on a whole year basis, in 1998 in connection with Icelandic, Faroese, Norwegian, study (Dam, 2000). 125 birds where shot from April 1996 to February in 1997. The results were set up as "summer diet", the stomach contents of birds shot from April to August, and "winter diet" from birds shot in September to February. The birds were collected from Sveipur and Hestur. The number of guillemots collected in the winter was 72 and in the summer 53 were collected. Crustaceans were found in 72% of the birds caught during winter and 82% of the summer birds, compared to 93% of the stomachs we studied. The crustaceans weighed 50% of the total diet in winter and 53% in summer, now 84% of the total weight. Then, pisces were found in 19% and 64% of the birds caught in winter and summer respectively, now pisces were in 60% of the stomachs. Molluscs were found in 58% and 9% of the birds shot in winter and summer respectively, compared to 27% now. The weight ratios of molluscs relative to the total diet weight, were 40% for winter and 0% for summer, now it was 1%. The huge increase in the proportion of Crustaceans, may be partly due to the fact that the weight ratio of fiches were excluded in this study, because the fishes were to much digested. Therefore, crustaceans get unusually high weight ratios.

Johannessens results showed that Black guillemots diet varies during the year; they feed on crustaceans the whole year, but switches between fish and gastropods, from summer to winter. The reason for this is thought to be variation in the availability of fish. Sandeel, which is the most important fish species in Black guillemots´ diet, digs itself down into the bottom during winter and is available to seabirds only in summer. In the winter, when Sandeel is not available, molluscs become more important in Black guillemots´ diet.

Otoliths lengths from Ammotidae were measured and fish length and weight estimated by using formulas. There is a great uncertainty in these estimations. It must be taken into account that the otoliths were not all new and fresh, but partly digested. Their lengths that were measured are therefore the minimum original lengths. Two sources of error are the uncertainty of the formulas because of natural individual variation and the fact that the otoliths may have been reduced in size because of being partly digested.

According to the results of the stomach content analysis, the most important food items for Black guillemots are Galathea, and Ammodytidae. Galathea were the most common prey items in the Black guillemots stomachs, now and in ´96-´97. We were unable to find data on what Galathea crabs feed on, and their trophic status. They may live on particulate organic matter, which originates from all parts of the fauna and flora in their environment.

Sand eel is the most dominant fish species in Black guillemots´ diet. Here below is data on the relative abundance of Sand eel juveniles, on the Faroese shelf, collected by Jákub Reinert (Figure 9). The abundance of Sand eels increased over the three year period in which the guillemot eggs were collected (1999-2001). That might partly explain the increase of δN and δC between the years. If Sand eel has become more important food item on this time period, the overall trophic status of Black guillemot has increased. On the Faroese Shelf, Sand eel is known to feed primarily on copepods in the summer (Gaard E.,oral com.), so according to its summer diet it is on the third trophic level. As mentioned earlier, Sand eel digs itself to the sandy bottom in the winter, and may feed on benthic fauna, worms and benthic copepods (Jónsson,1992.).

The abundances of Sand eel were similar and relatively low in 1996 and 2002, when the stomach content analysis of guillemots were performed, and the proportions of Sand eel of the diets, in these years were also similar; 60% and 64% respectively (of the summer diet).

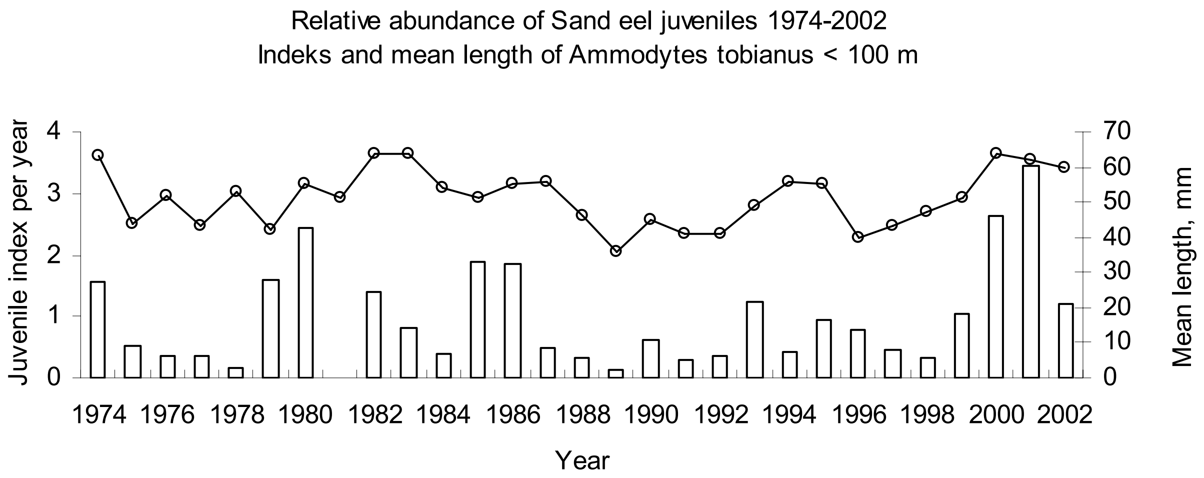

Figure 9.Relative abundance (bars) and mean length (line) of Sand eel 0-group from 1974 to 2002 in the upper 100 m of the sea on the Faroese Shelf, Data provided by Jákup Reinert.

A drawback of the sample preparation for the stomach contents analysis, is that samples were mixed into pairs. The results show the average values for the pairs but the individual variation of the original egg samples is unknown. If the isotope signatures of individual samples had been measured in stead of the mixtures, the results would probably have been more scattered, and not so clustered as they are. The results may show greater difference of the delta values between the years, than individual samples would have done.

The isotope signatures in Koltur were more scattered than the signatures from Skúvoy. That indicates that Black guillemots in Koltur have fed at a greater variety of trophic levels than the birds in Skúvoy. The difference between the locations and the variance between the years are likely caused by difference of diet availability (Braun et al.2000).

The results of the Stable Isotope Analysis showed an unusual increase in $\delta^{13}C$ compared to $\delta^{15}N$. It is most common that $\delta^{15}N$ increase is higher than that of $\delta^{13}C$, when there is an increase of trophic status (Godley et al. 1998; Hebert C. 2001; Minagawa&Wada,1984). Here, on the other hand, $\delta^{13}C$ increased more than $\delta^{15}N$. $\delta^{13}C$ is often used as an indicator of the C origin and the primary production, distinguishing between high d13C values of inshore benthic feeding, and lower $\delta^{13}C$ of more offshore pelagic feeding (Thomson et al, 1999; Hodum & Hobson, 2000, Braun et al, 2000). The results could indicate that Black guillemot has changed its dietary preference from being more pelagic, to more inshore benthic feeding.

New primary production on the Faroese shelf increased from 1999 to 2000, and then there was a slight decrease in 2001 (Gaard et al, 2002). The availability of Sandeel increased during these years, as mentioned earlier. Therefore it is unlikely that Black guillemot changed its diet from pelagic fish to more benthic feeding.

Phytoplankton binds CO_2 /HCO_3^- in the sea during photosynthesis, so the $\delta^{13}C$ value of the food chain depends on the input, the fractionation of phytoplankton. $\delta^{13}C$ of surface ocean waters (which is mostly bicarbonate) is 0 (the same proportion of 13C and 12C as in PeeDee limestone, a defined standard value), and algal fractionation results in values of -19 to -24 (Peterson&Fry, 1987). Phytoplankton isotopic composition varies with latitude and water temperature, $\delta^{13}C$ values rise with increased water temperature (Lajtha&Michener, 1994). A biochemical food web study suggested that fractionation of plankton varies with growth rate (Wada et al, 1985). Low ^{13}C content of phytoplankton (large fractionation) was associated with low temperature which affected the HCO_3^- /CO_2 equilibrium, and low light intensity. Phytoplankton spring bloom on the Faroese Shelf occurs under high light intensity and grows quickly, so they can be expected to have relatively high $\delta^{13}C$ values, if these assumptions are correct. This does not explain the variations of ^{13}C between the years, but they may be attributed to environmental factors that affected the phytoplankton fractionation, the input of the food web.

Conclusion

The results of the Stable isotope analysis show that the trophic status of Black guillemot has increased during the period from 1999-2001. The increase in trophic status at the same time which its PCB level decreases, indicates that PCB levels in the ecosystem have gone down. Significant declines in PCB levels have also been reported in North American seabirds, from the Baltic and the Barents Seas. These decreases are associated with restrictions in the usage of PCBs in North America since the 1970s (Braun et al. 2000). The trophic status change of Black guillmot can be associated with the variation of availability of Sandeel and there is no connection between Black guillemots´ changed diet and PCB reduction.

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Appendix

1.Bird weights, stomach contant weithghts and stomach contents.

		stomic contents		
wbird (g)	wstom cont (g)	crustacea	pisces	moluska
437	5,93	1	0	0
393	2,69	1	1	0
433	5,36	1	0	0
368	1,6	1	0	1
400	1,17	1	0	0
387	2,81	1	0	1
413	1,42	1	0	0
419	1,03	1	0	1
418	1,98	1	1	0
399	3,43	1	0	0
409	6,14	1	0	0
381	0,69	1	0	0
401	1,39	1	1	1
394	0,48	1	1	0
439	14,83	1	0	0
456	2,49	1	1	1
440	8,05	1	1	0
394	0,13	1	1	0
420	0,56	1	1	1
393	2,05	1	1	1
460	3,25	1	1	0
437	1,9	1	1	0
420	2,26	1	1	0
436	2,97	1	0	0
373	3,48	1	1	0
403	2,69	1	1	1
453	9,63	1	1	0
404	5,18	0	1	0
441	2,35	1	1	0
446	1,36	0	1	0

2. Stomach contents

bird nr.	contents	tot. weight st. cont.(g)	weight (g)	number individ.	digestion grade	# individ crustac	pisces	moluska
1		5,93						
	galathea		1,48	2	3			
	Pandalus montagui		0,88	3	3			
	crustacea remains		0,52	1	4			
						6		
2		2,69						
	idotea		0,03	1	3			
	crustacea remains		0,1	1	4			
	pisces							
	Pholis gunnellus			1				
	*Pollachius virens****			1				
						2	2	
3		5,36						
	galathea		1,6	7	3			
	Pandalus montagui		0,4	2	2			
						9		
4		1,6						
	crustacea remains		0,2	1	4			
	molluska(ga)		0,03	2	4			
						1		2
5		1,17						
	galathea		0,3	2	4			
						2		
6		2,81						
	galathea		0,11	1	4			
	see weed		1,61					
	gastropoda		0,1	3	3			
	pisces remains							
						1	1	3
7		1,42						
	galathea		0,33	1	4			
						1		
8		1,03						
	galathea		0,55	4	4			
	gastropoda		0,02	1	4			
						1		1
9		1,98						
	galathea		0,12	1	4			
	pisces remains							
	Pebbles		0,1	2				
						1	1	

bird nr.	contents	tot. weight st. cont.(g)	weight (g)	number individ.	digestion grade	frequency of occurance		
						crustac	pisces	moluska
10		3,43						
	galathea		0,2	1	4			
	crustacea remains		0,58	4	4			
						5		
11		6,14						
	crustacea							
	galathea		0,84	2	3			
	pandalus montagui		0,17	1	2			
						5		
12		0,69						
	Crustacea remains		0,59	1	4			
	pisces remains							
						1	1	
13		1,39						
	Crustacea remains		0,08	1				
	molluska remains		0,04	1				
	pisces							
	Ammodytidae-n3			2				
	pebbles		0,1	2				
						1	2	1
14		0,48						
	galathea		0,35	4	4			
	pisces remains							
						4	1	
15		14,83						
	galathea		9,56	10	2			
						10		
16		2,49						
	galathea		0,28	1	4			
	crustacea remains		0,04	1	4			
	gastropoda		0,07	1	3			
	pisces remains							
						2	1	1
17		8,05						
	galathea		0,68	1	2			
	pandalus spp.		0,2	2	3			
	pandalus montagui		1,6	3	2			
	pisces							
	*Gadus morhua**			1				
						6	1	
18		0,13						
	Crustacea remains		0,02	1	4			
	pisces remains							
						1	1	

bird nr.	contents	tot. weight st. cont.(g)	weight (g)	number individ.	digestion grade	frequency of occurance crustac	pisces	moluska
19		0,56						
	Crustacea remains		0,05	1	4			
	gastropoda		0,07	1	2			
	pisces remains							
						1	1	1
20		2,05						
	Crustacea remains		0,12	1	4			
	molluska remains		0,1	1	4			
	pisces remains							
	see weeds							
						1	1	1
21		3,25						
	galathea		0,61	2	4			
	pisces							
	Ammodytidae			2				
						2	2	
22		1,9						
	Crustacea remains		0,14	1	4			
	pisces							
	Ammodytidae			2				
						1	2	
23		2,26						
	Crustacea remains		0,17	1	4			
	pisces							
	Ammodytidae			2				
	sea-wead							
	pebbles		0,72	6				
						1	2	
24		2,97						
	galatea		1,41	6	4			
						6		
25		3,48						
	Crustacea remains		0,17	1	4			
	pisces							
	Pholis gunnellus			1				
						1	1	
26		2,69						
	Crustacea remains		0,01	1	4			
	molluska remains		0,03	1	4			
	pisces							
	Ammodytidae			17				
	pebbles		0,02	3				
						1	17	1

bird nr.	contents	tot. weight st. cont.(g)	weight (g)	number individ.	digestion grade	frequency of occurance crustac	pisces	moluska
27		9,63						
	galathea		1,26	8	4			
	pisces		2,17	4	3			
	Pholis gunnellus			2				
	ampipod				3			
	isopod				3			
	nematoda							
						10	2	
28		5,18						
	pisces							
	Ammodytidae			5				
	Microcesistius							
	*poutassou***			1				
							6	
29		2,35						
	Crustacea remains		1,23	5	4			
	pisces remains							
						5	1	
30		1,36						
	galathea		0,02	1	4			
	pisces remains					1	1	
total			**32,18**			**89**	**47**	**11**

* 0 year old, * *1year old ***2year old

3. Egg samples

species, Id	amount of white and yolk		location
Cg-0143+Cg-0144	1,156+1,112	2,268	Koltur,1999
Cg-0145+Cg-0146	1,362+1,312	2,674	Koltur,1999
Cg-0148+Cg-0149	1,189+1,371	2,56	Koltur,1999
Cg-0150+Cg-0151	1,217+1,152	2,369	Koltur,1999
Cg-0152+Cg-0147	1,095+1,033	2,128	Koltur,1999
Cg-0153+Cg-0154	1,107+1,005	2,112	Skuvoy,1999
Cg-0155+Cg-0156	0,81+0,8	1,61	Skuvoy,1999
Cg-0157+Cg-0158	1,072+0,989	2,061	Skuvoy,1999
Cg-0159+Cg-0160	1,02+1,03	2,05	Skuvoy,1999
Cg-0161+Cg-0162	1,314+1,299	2,613	Koltur, 2000
Cg-0163+Cg-0164	1,203+1,137	2,34	Koltur, 2000
Cg-0165+Cg-0166	1,55+2,026	3,576	Koltur, 2000
Cg-0167+Cg-0168	0,998+1,009	2,007	Koltur, 2000
Cg-0169+Cg-0170	1,211+1,042	2,253	Koltur, 2000
Cg-0171+Cg-0172	1,391+1,39	2,781	Skuvoy,2000
Cg-0173+Cg-0174	1+1,064	2,064	Skuvoy,2000
Cg-0175+Cg-0176	1,654+1,64	3,294	Skuvoy,2000
Cg-0177+Cg-0178	1,04+0,962	2,002	Skuvoy,2000
Cg-0179	1,326	1,326	Skuvoy,2000
Cg-0180+Cg-0181	1,256+1,225	2,481	Koltur,2001
Cg-0182+Cg-0183	1,025+1,484	2,509	Koltur,2001
Cg-0184+Cg-0185	0,963+1,028	1,991	Koltur,2001
Cg-0186+Cg-0187	1,005+1,099	2,104	Koltur,2001
Cg-0188+Cg-0189	1,304+1,243	2,547	Koltur,2001
Cg-0190+Cg-0191	0,994+1,101	2,095	Skuvoy,2001
Cg-0193+Cg-0194	1,042+1,016	2,058	Skuvoy,2001
Cg-0195+Cg-0196	1,014+1,029	2,043	Skuvoy,2001
Cg-0197+Cg-0198	1,028+1,019	2,047	Skuvoy,2001
Cg-0199+Cg-0192	1,005+1,413	2,418	Skuvoy,2001
		66,381	

4. For analyzing carbon and nitrogen.

- Dry field samples in an oven at 60 degrees Celsius for 24 hours.
- Pulverize the dried sample with a mortar and pestle or a ball mill grinder, ensuring a fine homogenous powder.
- Weigh out 200 micro grams of the dried homogenous sample into a tared small tin capsules.
- Fold the tin capsule into a tight, compressed ball with the sample inside.
- Load into auto sampler starting with a blank. The sequence consists of standards, reference materials, samples and duplicate samples.
- The Auto Sampler is driven by compressed air, which rotates sampling cone, allowing sample to drop into the combustion tube of the Elemental Analyzer (Finnigan -ThermoQuest NC2500).
- Shot of oxygen that helps with flash combustion, which breaks all organic bonds and the sample becomes a gas.
- Helium is the carrier gas and is used to carry the sample through the instrument.
- Chromium Oxide, Silver Cobaltus Oxide help with oxidation
- Oxidation Process forms compounds such as Nitrous Oxides and Carbon Dioxide. Nitrous Oxide is converted into N_2 ;CO_2 bond is so strong it stays in tact.
- Reduction Process Eliminates extra Oxygen converting nitrous oxide into nitrogen.
- Chemical used in the reduction tube is copper.
- The sample then travels through the water trap consisting of Magnesium Perchlorate to remove any water.
- The N_2 and CO_2 gas are separated by elution through a gas chromatograph column and flow directly into a mass spectrometer (Finnigan -ThermoQuest Delta Plus) for detection.
- Delta values are calculated using N_2 & CO_2-reference gases and corrected using IAEA N1, N2,CH6 and CH7 standards.