

Digestive Efficiency and Energy Requirements of Captive-reared Common Loons (*Gavia immer*)

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ABSTRACT

Many wild Common Loons have been exposed to mercury contamination; this study will help increase understanding of how it affects their lives by providing information about digestive efficiency. The assimilated mass coefficient (AMC) for eight captive-reared Common Loons (*Gavia immer*) was determined by this study to be 80% of dry fish. Rainbow trout was the species of fish fed to these eight birds. Bomb calorimetry was used to determine the amount of energy consumed by each bird as well as the amount of energy excreted. The digestive efficiency is determined by subtracting the energy excreted from the energy consumed (Digestive efficiency = Food intake - Excreta).

INTRODUCTION

The Upper Midwest Environmental Sciences Center (UMESC) of La Crosse Wisconsin and the Wisconsin DNR are conducting a study, "Assessing the Ecological Risk of Mercury Exposure in Common Loons (*Gavia immer*)". Loon eggs were taken from lakes in northern Wisconsin and the loons were captive-reared at the UMESC. A total of thirty-two birds were used for the study. Twenty-four birds were used for the assessment of mercury contamination and were divided into a control group and groups given mercury in a high dose, medium dose, and low dose. Their behaviors were analyzed; in addition, growth was measured and tissues were collected for later analysis. The other eight birds were used in bioavailability and digestibility studies and did not receive mercury doses. The fecal samples for this study were collected from these eight latter birds.

The digestibility trials were performed at the UMESC when the birds were 21-days old. The birds were placed in separate wire mesh cages for a 36-hour time period. During this time fish consumption was recorded and the fecal samples were taken and labeled. A Parr bomb calorimeter was used to determine the energy content of the fish and the fecal material. Based on the energy consumed and the energy left in the feces the amount of energy utilized by the bird can be determined, this is also referred to as digestive efficiency:

$$\text{Energy utilized} = \text{Food intake} - \text{Excreta}$$

This study correlates with the mercury study at the UMESC by providing information related to digestion that can be useful in understanding mercury contamination by the digestion of mercury contaminated fish. Digestive efficiency and energy requirements are not well understood for Common Loons.

This study attempts to gain a better understanding of how loons utilize their food as energy as well as how efficiently they use this energy. Although not much research has been done regarding the energy efficiency of loons, various studies have considered other fish-eating species which can be used for comparison to the data of this study.

A previous study has concluded that food type determines efficiency more readily than does taxonomic group (Castro et al., 1988). Species from different taxonomic orders extract similar amounts of energy from the same food source. The average value for assimilation efficiency for fish eating species was determined to be 77.2% (± 1.12) by Castro et al. (1988).

The values determined in this study and in other digestibility studies are expressed as assimilated mass coefficient (AMC) or metabolized energy coefficient (MEC). Digestive coefficients are defined as the amount of energy absorbed by the bird (Robbins, 1983). It is difficult to separate urine and feces in samples from birds, so the MEC in birds combines losses of fecal, urinary, and gaseous energy as a function of gross energy (Robbins, 1982).

$$\text{MEC} = \frac{\text{gross energy} - \text{urinary and fecal energy} - \text{gaseous energy}}{\text{Gross energy}} \times 100$$

METHODS

Fecal pellets

Fecal samples were collected from eight, thirty-six day old *Gavia immer* (Common Loons) at The Upper Midwest Environmental Sciences Center (UMESC). The procedure for collection was outlined in the protocol from the mercury study in progress at UMESC. The fecal samples collected were dried in a freeze dryer until thoroughly dried. Half of each dried sample was homogenized with a mortar and pestle. Three pellets were made from each homogenous sample with a pelletizer. If a pellet was brittle a drop of water was added to hold the pellet together. The pellets were placed in a freeze dryer until there was a 1% or less mass change. The pellets were stored in a desiccator pending bombing.

Fish pellets

Two frozen rainbow trout, comparable in size to the fish fed to the birds during the digestibility trial, were homogenized into two separate samples and made into pellets that were used to determine the energy content in the loons' diet. A modified blender with a small cup (~12 oz.) was used to homogenize the samples. The frozen fish were cut up into small pieces (~2 cm) and placed in the blender along with enough dry ice to fill the cup. Once the sample was homogenous it was transferred to a cup placed in a freezer without the cover to allow the dry ice to sublime. Once the dry ice had sublimed, the sample was placed in the freeze dryer until thoroughly dry. Each sample was then made into three pellets, following the same procedure as was used for the fecal pellets.

Bomb Calorimetry

A Parr oxygen bomb calorimeter was used to determine the calorific value of the fecal and rainbow trout pellets. Benzoic acid was used to calibrate the bomb and the same steps were followed for the fecal and fish pellets as described in the next few sentences. After the mass of the pellet and ignition cup were weighed and recorded, they were set in the bomb with an ignition wire touching the pellet and avoiding the cup. One ml of distilled water was placed in the bomb, the bomb was closed, filled with 25 ATMs of oxygen that was released to rid the bomb of nitrogen, and the bomb was then again filled with 25 ATMs of oxygen for the

combustion. The water bucket had the same mass for each run and the temperature of the water was 19-21°C. The bomb was placed in the water bucket and given five minutes to equilibrate the temperature of the system. After the five-minute equilibration, the temperature of the water bath was recorded every minute for five minutes to ensure the correct initial temperature of the system. After the five one minute readings, the bomb was ignited. After ignition, temperature readings were taken every 15 seconds for three minutes. After the three minutes, readings were taken every minute until there were seven equilibrium points (but no less than 25 minutes running time).

Calculations

Table 1. Definitions, units, and calculations.

Symbol and units	Definition	Equation
DMI(g)	Dry mass of food intake	Amount of fish consumed x amount of dry tissue in fish
DMI(g/d)	Food intake per day	DMI(g)/days in digestibility trial
BM(kg)	Body mass of the bird	
DMI(g/d)/BM(kg)	Removes effect of body mass on consumption	
Exc DM(g)	Total excreta, dry mass	
Kf(kj/g)	Gross energy per gram of fish	$\frac{\Delta T-2467^*}{(\text{Dry mass} - \text{ash}) - (\text{wire} \times 2.3)}$
GEI(kcal)	Gross energy intake	DMI(g/d) x Kf(kcal)
GEI(kj/kg)	Gross energy intake per kg of body mass	GEI(kcal)/BM(kg)
Ke(kj/g)	Gross energy content of excreta	Same as Kf
MEI(kcal)	Metabolized energy intake	GEI (kcal) - Ke(kcal)
MEC	Metabolized energy coefficient, proportion of food energy	$\frac{(\text{DMIg/d} \times \text{Kf}) - (\text{Excg/d} \times \text{Ke kj/g})}{\text{DMIg/d} \times \text{Kf}}$
AMC	Assimilated mass in coefficient, proportion of food dry mass	$[\text{DMI(g/d)} - \text{Exc(g/d)}]/\text{DMI(g/d)}$

Not all calculations have been analyzed in this study but remain useful for comparison with other studies.

* As determined for this study

Relevant parameters, including dry mass of food intake (DMI) per number of days (1.5) in the digestibility trial, adjusted DMI for body mass of each bird, gross energy intake (GEI), and metabolized energy intake (MEI) were calculated as shown in Table 1.

The energy of the fish (Kf) and the energy in the fecal samples (Ke) were calculated very similarly. The change in temperature (ΔT) was determined using bomb calorimetry. The energy equivalent of the bomb calorimeter (2467 kcal) was determined during bomb calibration with benzoic acid. The energy content of the wire (2.3kcal/cm) is taken into consideration. Energy content of fish (Kf) and fecal (Ke) material is determined by:

$$Kf \text{ or } Ke = \frac{(\Delta T \times 2467)}{(\text{Dry mass of pellet - ash}) - (\text{wire} \times 2.3)}$$

Metabolized energy coefficient (MEC) is the proportion of food energy the bird utilizes:

$$MEC = \frac{[DMI \text{ (g/d)} \times kf \text{ (kj/g)}] - [Exc \text{ (g/d)} \times Ke \text{ (kj/g)}]}{[DMI \text{ (g/d)} \times Kf \text{ (kj/g)}]}$$

Assimilated mass coefficient (AMC) is the proportion of food dry mass the bird utilized:

$$AMC = \frac{[DMI \text{ (g/d)} - Exc \text{ (g/d)}]}{DMI \text{ (g/d)}}$$

RESULTS

The energy content of rainbow (Kf) trout was determined by this study to be 26.92 kj/g. This value is an average of six samples, three from each of two fish.

Table 2 shows the energy content of fecal material (Ke) for the eight Common Loons, as an average for three samples from each bird. There is consistency in fecal energy content between the eight loons.

Table 2. Energy content of fecal material.

Sample ID	Average Energy (kj/g)
1	13.66
2	14.57
3	14.32
4	14.49
5	14.11
6	14.22
7	13.69
8	14.19

The metabolized energy coefficient (MEC) and assimilated mass coefficient (AMC) of Common Loon determinations are presented in Table 3.

Table 3. Food intake, body mass, gross energy intake, energy content of feces, MEC, and AMC as determined for the average of eight Common Loons.

	Food intake(g)	Body mass (kg)	Gross energy intake (kcal/kg BM)	Energy content of feces (kj/g)	MEC	AMC
Mean	306.13	0.994	2192.37	59.27	0.56	0.80
Range	126.4-411.7	0.89-1.20	2997.43-1114.61	57.19-61.00	0.32-0.78	0.90-0.70

DISCUSSION

Karasov (1990) stated that approximately three-fourths of energy ingested by loons is obtained from the three food types: fish, mammal, and bird. The AMC (0.80) determined in this study is slightly higher than that reported by Karasov (1990). The AMC determined for our loons is also higher than the average AMC (0.77 ± 1.12) for fish-eating birds determined by Castro et al. (1988) who determine the average using data ranging between 95.00-69.20, and including many species of birds such as Adelle Penguin, Cape Gannet, Great White Pelican, and Bald Eagle (Table 4). Of the species listed in Table 4, the Adelle Penguin, White Ibis, and Wood Stork have AMCs most similar to Common Loons.

Table 4. Comparison of AMC between various fish-eating bird species.

Species	AMC	Fish type
Adelle Penguin	80.00	unknown
Black-footed Penguin	76.46	anchovies
Cape Gannet	74.20	anchovies
Cape Gannet	79.40	pilchard
Cape Gannet	76.10	anchovies
Cape Gannet	69.20	stockfish
Great White Pelican	84.90	pollack
White Ibis	80.00	shelled shrimp and anchovies
Wood Stork	79.00	fish
Cattle Egret	95.00	beef
Bald Eagle	75.00	salmon

Summary of data from Castro et al. (1988)

The Adelle Penguin is a diving bird like a loon, but inhabits very different environmental conditions and is flightless unlike loons. Both the White Ibis and Wood Stork are temperate birds like loons but they are not divers. The Red-breasted Merganser, Common Merganser, or Double-crested Cormorant would provide a better comparison with the Common Loon. Mergansers are temperate fish-eating birds and divers. A Double-crested Cormorant is also a temperate fish-eating bird and forages by making surface dips (Ehrich, 1988).

Differences in the amount of energy metabolized are due to the food type, comparing for example meat foods with nectar or seed foods, and have little to do with the individual animal (Castro et al. 1988). This may account for why the AMC for Common Loons is so similar to species of birds living in very different environmental conditions like the White Ibis and Adelie Penguin. Fish vary in energy density and nutrient composition (Hilton et al. 1998), which could account for the small variations in metabolism between fish-eating birds. The variance in AMC caused by different species of fish in a diet is not substantial and an average for fish-eating birds is still useful.

This study makes an important contribution to the mercury study at UMESC by providing information pertaining to the metabolism of the Common Loon. Methylmercury is lipid soluble and has a slow rate of excretion, therefore it accumulates in organisms exposed to it. There is a biomagnification of methylmercury in organisms higher in the aquatic food chain, including loons (Korthals, 1986). If a loon metabolizes 80% of its diet, it can be assumed that they are metabolizing 80% of the mercury in a contaminated fish. Further investigation of mercury contamination is being conducted.

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