You Are What You Eat: Stable Isotope Ecology of Owl Diets in Alberta, Canada

Jason M. Duxbury and Geoffrey L. Holroyd

Abstract.—Stable isotope ratio analysis (SIRA) was used to analyze the trophic level of the diets of three owl species: Barred Owl (Strix varia), Northern Hawk Owl (Surnia ulula) and Great Horned Owl (Bubo virginianus). Barred Owl and Northern Hawk Owl had diets from a similar trophic level. Both the Barred Owl and Northern Hawk Owl had diets from trophic levels that differed significantly from that of the Great Horned Owl. Great Horned Owl had the most diverse isotope ratios indicating the greatest intraspecific variation in diets of the three species of owls. Results of SIRA can help with the determination of owl diets when used in conjunction with traditional methods of studying diet, but they can also stand alone as indicators of unique diet habits or discerning the trophic level of the diets of museum specimens.

The analysis of the ratio of stable isotopes of selected elements was developed by geologists and geochemists over 60 years ago. Their applications of stable isotope ratio analysis (SIRA) included, but were not limited to, isotope hydrology, tracing geomorphic pathways and palaeoclimatology (Ehleringer and Rundel 1989). Geochemists were the first to realize that stable isotope ratios changed in biological systems and began to determine how and why the ratios changed (Craig 1953, Park and Epstein 1960, Wickman 1952). Based on the founding work of the geochemists, the fields of archaeology, anthropology, palaeoecology, and contemporary ecology all began to take advantage of the usefulness of stable SIRA for dietary analyses of prehistoric or contemporary systems (Bombin and Muelenbachs 1985, Chrisholm et al. 1982, DeNiro 1987, Fry 1988, Minagawa and Wada 1984, Miyake and Wada 1967 [in Ehleringer and Rundel 1989], Schoeninger and DeNiro 1984). The use of SIRA in avian ecology is one of the most recent developments with applications in physiology, trophic level determinations, food web tracing and prey selection studies (Alisauskas and Hobson 1993, Hobson 1993, Hobson and Clark 1992, Hobson and Monteverci 1991, Hobson and Sealy 1991, Mizutani et al. 1990, Mizutani et al. 1986, Mizutani and Wada 1988, Thompson and Furness 1995).

Two important properties of stable isotopes in animal tissue permit the interpretation of the trophic level of a species’ diet. First, stable isotope ratios found in tissue represent an average of all isotopes found in the ingested food which are subsequently used in building the tissues of the organism. Secondly, relatively heavier stable isotopes bioaccumulate with each upward step in a food web system due to catabolic processes that favor the elimination of the relatively lighter isotopes which are excreted (Ehleringer and Rundel 1989, Mizutani and Wada 1988, Peterson and Fry 1987). These two characteristics make SIRA a valuable tool in the dietary analysis of owl species.

The classic techniques to determine the diets of raptors are pellet analysis (Errington 1932) and crop/stomach content analysis (Duncan 1966, Errington 1933, Sherrod 1978), prey remains analysis (Craighead and Craighead 1956, Hunt 1993, Meng 1959), and direct observation.
The species of prey can be identified from the analysis of the contents of owl pellets (Errington 1932, Marti 1974). However, prey with more easily digestible components may be under represented in the analysis. Also, the number of prey items is hard to determine since large prey items may be found in more than one pellet and small prey items may be combined into a single pellet (Mermann et al. 1992). Owls may also cache prey, consuming the rest in a subsequent feeding and forming multiple pellets from single prey items (Thomsen 1971).

Stomach or crop content analysis is an excellent way to determine exactly what a raptor has eaten. If the prey is still undigested, it can be accurately identified. However, this technique requires the use of emetics or the death of the predator and provides only single samples of a potentially very variable diet.

Body parts, feathers or fur left at kill sites can provide evidence of prey captures. A list of prey species, their relative abundance and relative contribution to biomass of diet can be determined from prey remains (Bosokowski et al. 1992). When avian prey are delivered to the nests of raptors, feathers are plucked and remain in and near the nest allowing the identification of avian prey. When mammals are consumed there is little remaining. The carcasses of both birds and mammals are removed and rarely are found by researchers. The presence of feathers and not fur biases the results in favor of relatively more avian prey than what is actually consumed (Bielefeldt et al. 1992, Hunt 1993, Quinn 1991).

Direct observation, if done consistently, allows for a more complete tally of prey taken although specific identification can be difficult for small prey (Bielefeldt et al. 1992, Hunt 1993). This technique is also time consuming and compiling a large sample size can be expensive.

Combining the above techniques removes some of the biases, but may not always be temporally, physically, or financially possible. Stable isotope ecology can be applied to enhance these techniques and help interpret their associated biases. SIRA represents the average of the isotopes ingested, and with increasing trophic level there is bioaccumulation of the relatively heavier isotopes. Studies of marine birds demonstrated that the ratio of $^{15}\text{N}/^{14}\text{N}$ increases by 2 to 4% (parts per mil) with each trophic level (Hobson 1993). These ratios are passed on to the consumers in each ecosystem (Fry et al. 1978). SIRA by itself can provide some insights on the diets of birds. However, SIRA used in conjunction with more traditional diet study methods provides a more complete picture of diet.

In a previous experiment using a known food chain at a captive Peregrine Falcon (Falco peregrinus) breeding facility, we demonstrated that both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ increased in a stepwise pattern (unpubl. data, fig. 1). Since the samples of wild owls came from different ecosystems, carbon ratios are less important since base levels are determined by the ecosystems that the owls inhabited (DeNiro 1987, DeNiro and Epstein 1978). Therefore, only the bioaccumulation properties of $^{15}\text{N}$ are used in this paper.

To demonstrate how SIRA can be used in owl diet studies, $^{15}\text{N}/^{14}\text{N}$ ratios in feathers from Northern Hawk Owls (Surnia ulula), Barred Owls (Strix varia) and Great Horned Owls (Bubo virginianus) from the boreal ecoregion of Alberta were analyzed. The difference and variance in trophic levels of prey of owls within and between species, combined with pellet/prey analysis, can provide an interpretation of what possible prey items were being consumed.

![Figure 1.—$\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values of a known food chain of captive Peregrine Falcons and their food source.](image)
METHODS

Flight feathers were retrieved from road-killed owls, at nest sites, and museum specimens and body feathers were collected from nestlings at the time of banding. Feathers were washed with soap and distilled water to remove debris and external contaminants. To ensure complete combustion of the sample tissue, each feather was then cut into very fine fragments with stainless steel scissors and ground even finer with a mortar and pestle. Incomplete combustion leads to unreliable values resulting from altered ratios (Owens 1987). Fine feather particles were washed with diethyl ether to remove contaminants and lipid tissue. A mass spectrometer needs a minimum amount of sample gas, so the amount of the sample was dependent upon the predicted amount of nitrogen and carbon in the sample tissue: approximately 15 percent nitrogen and 50 percent carbon (Kemp and Rogers 1972, Reed and Woods 1964). About 0.230-0.280 mg per sample were then combusted in an elemental analyzer that was interfaced with a mass spectrometer in a continuous flow mode. A standard of atropine powder was sampled and the analytical error of the mass spectrometer was measured to be ±0.174‰.

All tissues are expressed in δ15N notation according to the following formula:

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\delta^{15}N = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000 (\%) \]

Rstandard is the ratio of the isotopes in the standard (natural air for nitrogen) and Rsample is the ratio of the isotopes in the sample tissue. The relative amount of naturally occurring heavy isotopes is less than 1 percent, therefore, final numbers are always multiplied by 1,000 and presented in the per mil (‰) notation (parts per thousand).

RESULTS

Stable isotope ratio analysis was performed on 56 Great Horned Owl feathers, 15 Northern Hawk Owl feathers, and 21 Barred Owl feathers (table 1). In increasing relative amount of heavy nitrogen, the Barred Owl had the lowest mean (δ15N = 6.845 ± 1.086), the Northern Hawk Owl had a mean of (δ15N = 7.137 ± 1.103) while the Great Horned Owl had the greatest mean (δ15N = 8.698 ± 1.913). The ranges of δ15N values for each species in increasing order was found to be 3.8 for Northern Hawk Owls, 4.3 for Barred Owls, and 8.9 for Great Horned Owls. The difference between the isotope ratios in the samples from the Great Horned Owl were statistically higher that for the other two species (Barred Owl: t-test, p < 0.0001; Mann-Whitney U, p < 0.0001; Northern Hawk Owl: t-test, p < 0.0002; Mann-Whitney U, p < 0.002). However, the difference between Barred Owl and Northern Hawk Owl ratios was not statistically significant (t-test, p = 0.4378; Mann-Whitney U, p = 0.5962).

DISCUSSION

Birds feeding at high trophic levels will have a relatively higher ratio of stable isotopes because of the bioaccumulation of heavy isotopes (DeNiro 1987, Fry 1988, Minagawa and Wada 1984, Owens 1987, Wada et al. 1987). The mean δ15N values indicate that the Barred Owls and Northern Hawk Owls sampled in this study were feeding on prey found at relatively lower trophic levels than were the Great Horned Owls that were sampled. However, since most owls concentrate their diets on herbivorous mammals (Earhart and Johnson

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<th>Barred Owl</th>
<th>Northern Hawk Owl</th>
<th>Great Horned Owl</th>
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<tr>
<td>Mean (n)</td>
<td>6.845 (21)</td>
<td>7.137 (15)</td>
<td>8.698 (56)</td>
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<tr>
<td>Standard deviation</td>
<td>1.086</td>
<td>1.103</td>
<td>1.913</td>
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<tr>
<td>Maximum</td>
<td>9.100</td>
<td>9.240</td>
<td>13.650</td>
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<td>Minimum</td>
<td>4.810</td>
<td>5.470</td>
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<td>Range</td>
<td>4.290</td>
<td>3.770</td>
<td>8.890</td>
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Table 1.—Descriptive statistics for δ15N values of owl feather samples. All numbers are per mil (‰).
1970, Marti 1974, Roth and Powers 1979, Taylor 1984), the isotope values indicate that some of the Great Horned Owls took more prey that were from higher trophic levels (such as birds and insects) than did the owls with feathers with low isotope ratios (fig. 2).

The differences in the variation of isotope ratios within each species indicates the variability of the diet of individual owls. The isotope ratio in each sample represents the average of the trophic levels of a single owl’s prey while it grew the feather. The mean and variation in SIRA values of the Barred Owl and Northern Hawk Owl are very similar indicating that their diets are from similar trophic levels and that each owl species is likewise taking prey from a low trophic level. These owls are probably consuming primarily herbivorous rodents supplemented by insectivorous mammals and birds and presumably there is little variation between the diets of all the individual owls. The higher the SIRA values for a given owl, the more that owl is probably capturing animals located at a relatively higher trophic level.

The range of SIRA values for the Great Horned Owl is almost twice that of both the Barred Owl and the Northern Hawk Owl, supporting literature that the diet of the Great Horned Owl has much more variability than the other two owl species (Aigner et al. 1994, Brodie and Maser 1967, Knight and Erickson 1977, Marti 1974, Orians and Kuhlman 1956, Weir and Hanson 1989). The upper range of Great Horned Owl values suggests that these owls are taking second or possibly third trophic level feeders (fig. 2).

The two uppermost samples of Barred Owl demonstrate how SIRA can be used in dietary studies (fig. 2). One owl’s diet was studied, while the other had an unknown diet as the feather was removed from a museum specimen. Using traditional diet study methods of pellet and prey remains analysis, the owl with the highest value is known to have consumed a high proportion of birds and frogs (L. Takats, Graduate Student, Department of Renewable Resources, University of Alberta, pers. comm.). Such a diet would produce relatively high SIRA values because of the insectivore habits of the prey. Also, aquatic systems have relatively higher δ¹⁵N values because they contain more trophic levels than terrestrial systems (Goering et al. 1990). With this pattern, one may predict that the museum specimen with the unknown diet, had also been consuming insectivores at a frequency comparable to the live owl. Using SIRA in conjunction with traditional methods helps indicate that the birds and frogs may play a vital role in this particular owl’s diet. If similar prey items were found in prey remains or pellets near a nest, but the SIRA value of the nesting owls were low, then it could be assumed that these prey items were rarely caught. Caution must be used to make such conclusions without the use of traditional methods along with SIRA, but SIRA can be an indicator of diets that may require closer examination. If an individual owl were still alive, the isotope results may suggest that the researcher return to the study site, reuse traditional methods, but now knowing what possible prey items to look for, potentially making the diet study more complete.

**CONCLUSION**

The known bioaccumulation properties of ¹⁵N can be used to study the diets of any organism. For owls, SIRA can play a very useful role particularly when used with more traditional diet study methods to produce a more comprehensive view of the owls diet. The averaging of isotope ratios helps to reduce some of the

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![Figure 2.—δ¹⁵N values of three owl species: Barred Owl (BAOW), Northern Hawk Owl (NHOW) and Great Horned Owl (GHOW). Northern Hawk Owls have a less variable diet (a) than Great Horned Owls (b). Knowing the diet of one Barred Owl can lead to predictions of the prey selection of another Barred Owl with an unknown diet (c).](image-url)
biases associated with more traditional diet study techniques. SiRA can be used alone in studies where pellet and/or prey analysis or long-term nest observations are not possible because of temporal, physical, or monetary limitations. It may also be used on specimens to generalize or estimate their diet.

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LITERATURE CITED


