Urbanization of the Silver Gull: Evidence of Anthropogenic Feeding Regimes from Stable Isotope Analyses

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Abstract.—Access to human-derived food is thought the major cause of population increases in many gull species, and the degree to which urbanized gulls depend upon anthropogenic food may be resolved by isotopic benchmarks. Stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) were compared between Silver Gulls breeding at a remote, non-urbanized site (Furneaux Island Group, Bass Strait) and those at an urban (Hobart) colony in Tasmania to distinguish potential differences in feeding regime. Analyses of whole blood stable isotopes revealed that non-urbanized gulls tended to have a mixed diet from several sources, while urban gulls fed on a separate food web from and a more freshwater origin. No differences in the stable isotope ratios were detected between sexes or among breeding periods. Birds from Hobart tended to feed at a higher trophic position after egg-laying than before, and reflected a change in food preference. These results provided critical baseline data to measure the degree of urbanization of Silver Gulls in Tasmania in order to study potential health impacts of anthropogenic food on birds. *Received 27 January 2010, accepted 24 August 2010.*

Key words.—anthropogenic diet, *Chroicocephalus novaehollandiae*, Silver Gull, stable isotopes, Tasmania, urbanization.

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Silver Gulls (*Chroicocephalus novaehollandiae*) are viewed as pests in Australian urban environments (Smith *et al.* 1991) with the largest colonies occurring close to major human settlements and their refuse (Meathrel *et al.* 1991). As with most gulls, Silver Gulls are variously described as gregarious scavengers (Higgins and Davies 1996), opportunistic (Smith *et al.* 1991) or omnivorous with a diverse prey base (Ottaway *et al.* 1985). Their natural prey are diverse and include: plants, cnidarians, squid, annelids, insects, crustaceans, arachnids, small fish, frogs, birds and mammals (Higgins and Davies 1996). Silver Gulls around urban areas are reported to show a marked dependence on anthropogenic food sources, and their diets are well documented (Smith *et al.* 1991; Smith 1992; Smith and Carlile 1992, 1993a, b). The dependence on human-derived food may increase their reproductive success and survival rates, as documented for some larids (Brousseau *et al.* 1996; Hebert *et al.* 2002). Sources of human-derived foods are at garbage dumps and garbage bins in recreational areas, restaurants and fast food outlets (Ottaway *et al.* 1988). Evidence of human-derived foods was observed in 85% of 487 regurgitations by Silver Gulls from Big Island, near Sydney, New South Wales (Smith and Carlile 1993a).

We postulated that the isotopic signatures of gulls feeding naturally (non-urban) would differ from those eating anthropogenic food (urban). The research reported here was part of a larger study on the effects of an anthropogenic diet on Silver Gulls in Tasmania, which included comparisons of body condition, blood biochemistry, egg chemistry and reproductive success between gulls nesting on remote Bass Strait islands and in urban Hobart (reported elsewhere in Auman 2008; Auman *et al.* 2008).

Stable isotopes fixed in tissues of predators reflect past diet, and this useful tool is used widely to study the diet and trophic relationships of seabirds (e.g. Hobson *et al.* 1994;

Thompson *et al.* 1999; Hedd *et al.* 2010). Analyses are based on the premise that the ratio of stable isotopes in the proteins of consumers reflects that of their prey (Hobson *et al.* 2002). For example, the ratio of $^{13}C/^{12}C$, designated $\delta^{13}C$, can be used to determine whether a predator's diet is of terrestrial or marine origin, or a mixture of both. The ratio of $^{15}N/^{14}N$ ($\delta^{15}N$) measures the degree of trophic enrichment, or approximate trophic position, and type of diet consumed in seabirds (Hobson 1990; Hobson *et al.* 1994; Sydeman *et al.* 1997; Hebert *et al.* 1999; Hobson *et al.* 2002). As animal tissues are enriched in ^{15}N as compared to their diets due to preferential excretion of the lighter isotope (DeNiro and Epstein 1981), $\delta^{15}N$ values exhibit enrichment of 3-5‰ at each trophic level (Minagawa and Wada 1984; Bearhop *et al.* 1999; Bearhop *et al.* 2001). We chose to use whole blood as the tissue since it did not require the sacrifice of the bird and its isotopic content reflects the recent diet, over the past one to five weeks (Hobson and Clark 1992).

In the absence of *a priori* hypotheses regarding Silver Gull isotope ratios, a dual-isotope approach was taken in this study. Our specific aims were to determine whether Silver Gull $\delta^{13}C$ and $\delta^{15}N$ ratios in whole blood differed between: 1) gulls nesting in urban Hobart and on remote Bass Strait islands, 2) sexes, and 3) period in the breeding season. We hypothesized that the isotopic ratios of the gulls nesting in Hobart would reveal that gulls there were more reliant human-derived food (more terrestrial/freshwater) than gulls nesting away from the urban environment whose isotopic ratios would reflect the consumption of more natural (i.e. more marine) foods. Also, we tested whether isotopic ratios could detect dietary differences between the sexes (males provision pre-laying females, Mills and Ryder 1979) and dietary switching pre- and post-laying as documented for other gulls (Pierotti and Annett 1987; Lindsay and Meathrel 2008).

METHODS

Study Area and Species

The Queen's Domain Slipway in central Hobart (Fig. 1; 42°52' 34.69 S 147°°20'16.14 E) was chosen as the urbanized Silver Gull colony based on its close proximity (within 10 km) to local garbage dumps, restaurants and fast food shops that are reliable, accessible sources of anthropogenic food. In the remote Furneaux Island Group in Bass Strait, Silver Gulls at Great Dog Island (Fig. 1; 40°14'47.32 S 148°14'14.64 E) and Nobby's Rocks, Killiecrankie (39°50'08.69 S 147°50'00.19 E) were examples of remote, non-urbanized colonies. Both latter sites were more than 20 km from any source of anthropogenic food, and the nearest sources beyond that were small garbage dumps serving fewer than ten households. Based on a census of Flinders Island and all neighboring islands observable from binoculars, the Silver Gull population was estimated to be a maximum of approximately 50 pairs of adult birds (Auman, pers. obs.).

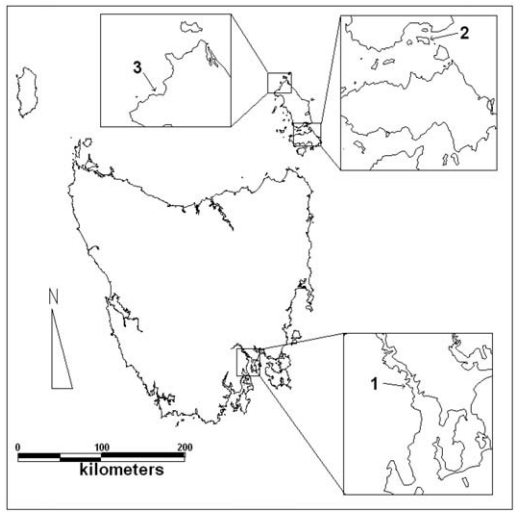

Figure 1. Location of colonies used to study the effects of anthropogenic food on the stable isotopes of whole blood in Silver Gulls. Urbanized colony at the Queen's Domain Slipway in Hobart (1); remote, non-urbanized colonies at Great Dog Island (2) and Nobby's Rocks, Flinders Island (3), Tasmania, Australia.

To capture Silver Gulls, drop traps (Mills and Ryder 1979) were used on active nests (i.e. containing eggs) within the Hobart colony. Few Silver Gulls were detected breeding in the Furneaux Group and birds occurred in mixed (breeding, as evidenced by the edematous brood patches, and non-breeding) groups. Gulls were trapped as groups using a zap net (Underhill and Underhill 1987).

A 0.5 ml blood sample was extracted from the brachial vein of Silver Gulls using a 23-gauge needle after surface sterilization. Blood was collected in the late morning (8:00-12:00 hours, to avoid variation in blood chemistry related to circadian rhythms) and stored on ice until returned to the laboratory within six hours. The sampling of the gulls' blood was restricted to the breeding season, since at this time gulls minimize the range of their foraging trips, thus maximizing the effect of a localized diet (Bertellotti and Yorio 1999). Food sources were expected to be largely anthropogenic at the Hobart colony as human-derived food is readily available, although marine food is also accessible.

Hobart birds were captured between 2-12 November and 14-24 December 2004 (N = 40), and the Furneaux birds between 19 November and 2 December 2004 (N = 20). Hobart birds were classified as being either in the pre-egg (N = 17) or incubating (N = 23) phase. The Furneaux birds could not be categorized in this manner because some were breeding on inaccessible offshore islands and others were non-breeding residents. Hence, Furneaux gulls were simply classified as breeders (N = 10) or non-breeders (N = 10) (i.e., bearing or lacking a well-developed brood patch). The sex of the birds was determined via a discriminant function using total head plus bill length (Woehler *et al.* 1989). A bird with an overall total head plus bill length of greater than 83.4 mm was classified as male (N = 24), whereas a bird of lesser total head to bill length was classified as female (N = 16). In many cases for Hobart gulls, both birds of the nesting pair were caught, and therefore their sex could be confirmed, assuming that male was the larger of the two (e.g. Helfenstein *et al.* 2004).

Isotope Selection and Analyses

Isotopic analyses allowed an extension of the limited information on diet given by regurgitants. Quantitative estimation of $\delta^{15}N$ was used to determine trophic position, and the quantitative estimation of $\delta^{13}C$ was an indicator of foraging area (terrestrial vs. marine). Carbon isotopes have different biogeochemical reaction rates that result in different $\delta^{13}C$ values; the $\delta^{13}C$ in marine carbon pools is generally enriched in birds by about 7‰ over freshwater pools (Bearhop *et al.* 1999), and animal tissues do not alter $\delta^{13}C$ significantly in higher trophic levels (Hobson and Welch 1992).

Whole blood was chosen for isotopic analyses because it is a metabolically active tissue with a high turnover rate, reflecting the recent (1-5 weeks) (Hobson and Clark 1992; Romanek *et al.* 2000) and, therefore, localized diet. One half milliliter of whole blood was placed into a glass tube and stored in 70% ethanol, which does not alter stable-isotope ratios (Hobson *et al.* 1997).

Samples were analyzed at the Australia National University Stable Isotope Laboratory. Lipids were not extracted prior to analysis as the lipid component was assumed to be less than 1% total wet mass in whole blood (after Bearhop *et al.* 2000). Entire samples were dried in an oven at 80°C, and then 1-2 mg subsampled. Subsamples were run on a CE Instruments EA1110 elemental analyzer and a Micromass IsoChrom Continuous flow isotope ratio mass spectrometer. Two or three standards for carbon and nitrogen (beet sugar, cane sugar, glucosamine, gelatine, alanine and nylon fishing line) were included for every ten samples. Errors for the replicate samples were 0.22 per mil for $\delta^{13}C$ and 0.21 per mil for $\delta^{15}N$. The isotopic precision on the mass spectrometer of nitrogen reference pulses was better than 0.08 per mil and on carbon dioxide pulses better than 0.05 per mil. Results are expressed as the parts-per-thousand (‰) difference between the ratio measured and that in international standards PeeDee Belemnite (PDB) for carbon and atmospheric air for nitrogen.

We did not consider the possibility of using stable-isotope mixing models (e.g. Phillips and Gregg 2003; Moore and Semmens 2008) for two reasons. First, our examination of regurgitants (see below) identified a wide array of potential prey items, and if pooled to reduce the number of possible sources, the variances would be large and therefore imprecise. Second, no discrimination factors are published for Silver Gulls. Discrimination factors, or the amount of change in $\delta^{13}C$ and $\delta^{15}N$ between source and consumer, are species-specific (Bond and Jones 2009), and small changes in discrimination factors can affect model output significantly (Bond and Diamond, accepted).

Conventional Dietary Assessment

Silver Gulls occasionally regurgitated food during handling. Regurgitants were collected and the contents identified, acknowledging food items were biased against soft-bodied prey, did not reflect differing digestive rates and were often difficult to identify (Duffy and Jackson 1986; Ogden *et al.* 2004; Lindsay and Meathrel 2008). Although regurgitants are indicative of only the last meal and not long-term feeding strategies (Romanek *et al.* 2000), these samples yielded dietary information used to supplement and confirm the stable isotope analyses (Sanger 1987; Sydeman *et al.* 1997; Knoff *et al.* 2001), a preferred approach when neither method alone will provide sufficient information (Barrett *et al.* 2007; Inger and Bearhop 2008).

Statistical Analyses

We used a multivariate analysis of variance (MANOVA) to test for differences in $\delta^{13}C$ and $\delta^{15}N$ among locations, sexes, and period during the breeding season. When there was a significant difference in either $\delta^{13}C$ or $\delta^{15}N$ ($P < 0.05$), we used a univariate ANOVA with Games-Howell post-hoc multiple comparison tests (Games and Howell 1976; Day and Quinn 1989) to determine where the differences lay. Results were presented as x ± 1 SD (N).

RESULTS

Isotopic Signatures

We found that all interaction terms (location*sex, period*sex, and sex*location) were insignificant (all $P > 0.21$), so we constructed a reduced-parameter model that included main effects only (location, sex, period of the breeding season). Isotope ratios differed between locations (Wilks' $\lambda = 0.873$, $P = 0.029$) and over the breeding season (Wilks' $\lambda = 0.827$, $P = 0.041$; Fig. 2), but not between the sexes (Wilks' $\lambda = 0.973$, $P = 0.49$). Univariate analysis of $\delta^{13}C$ revealed no difference among periods during the breeding season from either location ($F_{2,53} = 1.68$, $P = 0.20$), and a significant effect of only location ($F_{1,53} = 6.00$, $P = 0.018$, Hobart < Furneaux). No significant difference was found in $\delta^{15}N$ between locations ($F_{1,53} = 1.60$, $P = 0.21$), but there was a difference among periods of the breeding season for gulls from Hobart (incubation > pre-incubation).

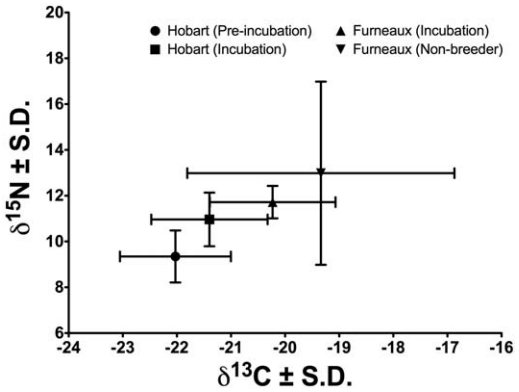

Figure 2. Stable isotope values (x ± 1 SD) from whole blood of Silver Gulls from Hobart and the Furneaux Island Group, Tasmania, Australia, by breeding period.

Regurgitants

Table 1 presents a list of the food items identified in the diet of Silver Gulls from the urban population at Hobart and the remote population in the Furneaux Group. The contents of regurgitants differed substantially between the two populations (Sorensen's index of similarity = 0.19, where 1.0 is a perfect match and 0.00 is completely dissimilar) with gulls from the Furneaux Group consuming many more natural food types than the urban gulls from Hobart.

DISCUSSION

Analyses of whole blood $\delta^{13}C$ signatures indicated that the Silver Gulls' diet in Hobart was generally freshwater/terrestrial in origin, whereas in the Furneaux Island Group it was from mixed sources. Analyses of regurgitants revealed that although both Hobart and Furneaux Silver Gulls consumed invertebrates, Hobart gulls ate much more refuse from vertebrate sources. Only one Hobart bird regurgitated a naturally-occurring marine food item (hyalid amphipods), but regurgitants reflect a single meal only and not long-term foraging patterns.

Although isotopic studies from different ecosystems are not directly comparable, the data in this study for $\delta^{13}C$ values in Silver Gulls showed similar trends to those from previous studies of other urbanized larids. Herring Gulls (*L. argentatus*) from the Great Lakes that ate terrestrial food, including garbage, were more enriched in $\delta^{13}C$ than those eating aquatic foods (Hebert *et al.* 1999). Glaucous-winged Gulls (*L. glaucescens*) which fed at dumps and on agricultural lands exhibited a more terrestrial contribution of $\delta^{13}C$ values in their bone collagen compared to Western Gulls (*L. occidentalis*) with a natural diet of mainly marine-derived food (Hobson 1987). Research on Kelp Gulls (*L. dominicanus*) in South Africa showed that the birds that fed from a local garbage dump were significantly enriched in $\delta^{13}C$ values in their bone collagen compared to birds which fed from an undisturbed beach (Steele 1990).

According to Bearhop *et al.* (1999), marine signatures for $\delta^{13}C$ are grouped from -12 to -16‰, mixed $\delta^{13}C$ -16 to -20‰, freshwater $\delta^{13}C$ -20 to -26‰. The mean $\delta^{13}C$ signature of Hobart Silver Gulls diet could then be categorized as generally freshwater/terrestrial, whereas the mean dietary signature for the Furneaux gulls suggested a mixed source. The isotopic values found in garbage are quite diverse but tend to reflect protein from herbivorous domestic animals such as poultry, cattle, pigs and sheep (Hebert *et al.* 1999). Hobart birds had a significantly more terrestrial-like $\delta^{13}C$ value, suggesting a tendency for more anthropogenic food sources. Birds from both locations are likely to consume a mixture of terrestrial and marine resources, resulting in variation in both carbon and nitrogen isotopic signatures (Bearhop *et al.* 1999). The regurgitated foods from dumps, garbage bins and handouts in urbanized gulls showed immense variety, making determination of a terrestrial component more complicated. Further study is needed (e.g. Silver Gull discrimination factors) to better quantify the reliance on anthropogenic food sources.

No differences between sexes were found in either the nitrogen or carbon isotopic signatures. Similarly, Hobson (1987) also found that there were no differences in $\delta^{13}C$ values between male and female Western Gulls, suggesting a lack of dietary specialization based on dependence upon terrestrial pro-

Table 1. Presence (+)/absence (-) of the natural and human-derived food items identified in the diet of Silver Gulls from urban Hobart and the remote Furneaux Islands Group, Tasmania, Australia, November-December 2004. The number of gulls from which samples were analyzed is given in brackets.

Source of food item and type	Hobart (n = 20)	Furneaux Group (n = 5)
Natural:		
Plant fruits:		
Bower Spinach (*Tetragonia implexicoma*)	—	+
Coast Beard-heath (*Leucopogon parviflorus*)	—	+
Tea Tree (*Leptospermum* spp.)	—	+
Invertebrates:		
Hyalidae (intertidal amphipods)	+	—
Insects:		
Chrysomelidae (leaf beetles)	+	—
Scarabaeidae (dung beetles)	+	+
Cerambycidae (long horn beetles)	+	—
Histeridae (clown beetles)	—	+
Carabidae (tiger beetles)	—	+
Formicidae: *Polyrachis* spp. (black ants)	+	—
Diptera pupae (flies)	—	+
Anthropogenic:		
Meat:		
chicken	+	—
hamburger	+	—
ham/bacon	+	—
cat food pellets	+	—
dog food pellets	+	—
gristle/cartilage	+	—
Vegetables:		
potatoes	+	—
lentils	+	—
carrots	+	+
green pepper	+	—
onions	+	+
Other:		
pasta	+	—
bread	+	—
grass	+	—
paper	+	—
paint chips	+	—
cigarette butts	+	—

tein, between sexes during the breeding season. Smith *et al.* (1991) reported a decreasing proportion of human-derived food consumed by Silver Gulls during the nesting season in New South Wales, but our study did not confirm those results. We did not detect differences in either carbon or nitrogen isotopes between breeding and non-breeding birds in the Furneaux Island Group. The urbanized gulls increased their trophic position between pre-incubation and incubation periods, but likely a result of available refuse rather than a dietary shift. Regurgitants showed no evidence of dietary switching.

Based on regurgitant data only, urban and natural diets were not distinct; one gull from the Furneaux Island Group regurgitated cooked peas, carrots and onions. Food may have been scavenged from a picnic area garbage can located close to the trapping area, or possibly from local residents' garbage, as no active local dump existed. Common Dung Beetles, long horn beetles and black ants in the Hobart samples were likely to

have represented foraging in pastures. Dung beetles were also seen in Furneaux Gull samples, but the dipteran pupae were probably from beached kelp (Meathrel, pers. obs.). These data indicated that individual diets were not distinct separate categories. Furthermore, stable isotopes of whole blood integrate diet over several weeks, whereas regurgitants represent the preceding meal only. The variance in both isotopes suggested individual specialization in feeding strategies and has been reported in other gulls (Pierotti and Annett 1990).

Silver Gull populations in Australia have increased for over 50 years, both in number and size of colonies (Smith 1992; Smith and Carlile 1992, 1993b). However, populations of Silver Gulls in southeast Tasmania show an overall decreasing trend (Coulson and Coulson 1998; Wakefield 2005; Wakefield and Hayward 2006). Whether the decrease is due to improved garbage dump management, competition with naturalized Kelp Gulls (Coulson and Coulson 1998), or decreasing individual and reproductive fitness is unclear. Synanthropy between humans and Silver Gulls has also been reported in Tasmania for over 30 years (Skira and Wapstra 1990). However, evidence that increased consumption of human-derived food has benefited Silver Gulls has not been found, and the impacts on gulls that consume this anthropogenic food are unknown. Lack of evidence may render any programs to control the number of gulls premature until the level of reliance on anthropogenic food, and the health effects of its consumption on gulls, is measured.

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LITERATURE CITED

Auman, H. J. 2008. Effects of anthropogenic food on the body condition, biochemistry, stable isotopes and egg quality in Silver Gulls *Larus novaehollandiae* in Tasmania. Unpublished Ph.D. Thesis, University of Tasmania, Hobart, Australia.

Auman, H. J., C. E. Meathrel and A. Richardson. 2008. Supersize me: Comparing body condition of Silver Gulls (*Larus novaehollandiae*) from urbanized and remote, non-urbanized areas. Waterbirds 31: 122-126.

Barrett, R. T., K. Camphuysen, T. Anker-Nilssen, J. W. Chardine, R. W. Furness, S. Garthe, O. Hüppop, M. F. Leopold, W. A. Montevecchi and R. R. Veit. 2007. Diet studies of seabirds: a review and recommendations. ICES Journal of Marine Science 64: 1675-1691.

Bearhop, S., D. R. Thompson, S. Waldron, I. C. Russell, G. Alexander and R. W. Furness. 1999. Stable isotopes indicate the extent of freshwater feeding by cormorants *Phalacrocorax carbo* shot at inland fisheries in England. Journal of Applied Ecology 36: 75-84.

Bearhop, S., M. A. Teece, S. Waldron and R. Furness. 2000. Influence of lipid and uric acid on $\delta^{13}C$ and $\delta^{15}N$ values in avian blood: implications for trophic studies. Auk 117: 504-507.

Bearhop, S., D. R. Thompson, R. A. Phillips, S. Waldron, K. C. Hamer, C. M. Gray, S. C. Votier, B. P. Ross and R. W. Furness. 2001. Annual variation in Great Skua diets: The importance of commercial fisheries and predation on seabirds revealed by combining dietary analyses. Condor 103: 802-809.

Bertellotti, M. and P. Yorio. 1999. Spatial and temporal patterns in the diet of the Kelp Gull in Patagonia. Condor 101: 790-798.

Bond, A. L. and I. L. Jones. 2009. A practical introduction to stable-isotope analysis for seabird biologists: Approaches, cautions and caveats. Marine Ornithology 37: 183-188.

Brousseau, P., J. Lefebvre and J. F. Giroux. 1996. Diet of Ring-billed Gull chicks in urban and non-urban colonies in Quebec. Colonial Waterbirds 19: 22-30.

Coulson, R. and G. Coulson. 1998. Population change among Pacific, Kelp and Silver Gulls using natural and artificial feeding sites in southeastern Tasmania. Wildlife Research 25: 183-198.

Day, R. W. and G. P. Quinn. 1989. Comparisons of treatments after an analysis of variance in ecology. Ecological Monographs 59: 433-463.

DeNiro, M. J. and S. Epstein. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochimica et Cosmochima Acta 45: 341-351.

Duffy, D. C. and S. Jackson. 1986. Diet studies of seabirds: A review of methods. Colonial Waterbirds 9: 1-17.

Games, P. A. and J. F. Howell. 1976. Pairwise multiple comparison procedures with unequal *n*'s and/or variances: A Monte Carlo study. Journal of Educational Statistics 1: 113-125.

Hebert, C. E., J. L. Shutt and R. O. Ball. 2002. Plasma amino acid concentrations as an indicator of protein availability to breeding Herring Gulls (*Larus argentatus*). Auk 119: 185-200.

Hebert, C. E., J. L. Shutt, K. A. Hobson and D. V. C. Weseloh. 1999. Spatial and temporal differences in the diet of Great Lakes Herring Gulls (*Larus argentatus*): Evidence from stable isotope analysis. Canadian Journal of Fisheries and Aquatic Sciences 56: 323-338.

Hedd, A., D. A. Fifield, C. M. Burke, W. A. Montevecchi, L. Macfarlane Tranquilla, P. M. Regular, A. D. Buren and G. J. Robertson. 2010. Seasonal shift in the foraging niche of Atlantic Puffins *Fratercula arctica* revealed by stable isotope ($\delta^{15}N$ and $\delta^{13}C$) analyses. Aquatic Biology 9: 13-22.

Helfenstein, F., E. Danchin and R. H. Wagner. 2004. Assortative mating and sexual size dimorphism in Black-legged Kittiwakes. Waterbirds 27: 350-354.

Higgins, P. J. and S. J. J. F. Davies (Eds.). 1996. Handbook of Australian, New Zealand and Antarctic Birds. Oxford University Press, Melbourne, Australia.

Hobson, K. A. 1987. Use of stable-carbon isotope analysis to estimate marine and terrestrial protein content in gull diets. Canadian Journal of Zoology 65: 1210-1213.

Hobson, K. A. 1990. Stable isotope analysis of Marbled Murrelets: evidence for freshwater feeding and determination of trophic level. Condor 92: 897-903.

Hobson, K. A. and R. G. Clark. 1992. Assessing avian diets using stable isotopes I: Turnover of ^{13}C in tissues. Condor 94: 181-188.

Hobson, K. A. and H. E. Welch. 1992. Determination of trophic relationships within a high Arctic marine food web using $\delta^{13}C$ and $\delta^{15}N$ analysis. Marine Ecology Progress Series 84: 9-18.

Hobson, K. A., J. F. Piatt and J. Pitocchelli. 1994. Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology 63: 786-798.

Hobson, K., H. Lisle Gibbs and M. L. Gloutney. 1997. Preservation of blood and tissue samples for stable-carbon and stable-nitrogen isotope analysis. Canadian Journal of Zoology 75: 1720-1723.

Hobson, K. A., A. Fisk, N. Karnovsky, M. Holst, J. M. Gagnon and M. Fortier. 2002. A stable isotope ($\delta^{13}C$, $\delta^{15}N$) model for the North Water food web: Implications for evaluating trophodynamics and the flow of energy and contaminants. Deep-Sea Research Part II-Topical Studies in Oceanography 49: 5131-5150.

Inger, R. and S. Bearhop. 2008. Applications of stable isotope analysis to avian ecology. Ibis 150: 447-461.

Knoff, A. J., S. A. Macko and R. M. Erwin. 2001. Diets of Laughing Gulls (*Larus atricilla*) at the Virginia Coast Reserve: Observations from stable isotope analysis. Isotopes in Environmental Health Studies 37: 67-88.

Lindsay, M. C. M. and C. E. Meathrel. 2008. Where, When and How? Limitations of the techniques used to examine dietary preference of Pacific Gulls (*Larus pacificus*) using non-consumed parts of prey and regurgitated pellets of prey remains. Waterbirds 31: 611-619.

Meathrel, C. E., J. A. Mills and R. D. Wooller. 1991. The Silver Gull in Australia and New Zealand. Acta Congressus Internationalis Ornithologici 20: 2390-2395.

Mills, J. A. and J. P. Ryder. 1979. Trap for capturing shore and seabirds. Bird-Banding 50: 121-123.

Minagawa, M. and E. Wada. 1984. Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between $\delta^{15}N$ and animal age. Geochimica et Cosmochimica Acta 48: 1135-1140.

Moore, J. W. and B. X. Semmens. 2008. Incorporating uncertainty and prior information into stable isotope mixing models. Ecological Letters 11: 470-480.

Ogden, L. J. E., K. A. Hobson and D. B. Lank. 2004. Blood isotopic ($\delta^{13}C$ and $\delta^{15}N$) turnover and diet-tissue fractionation factors in captive Dunlin (*Calidris alpina pacifica*). Auk 121: 170-177.

Ottaway, J. R., R. Carrick and M. D. Murray. 1985. Dispersal of Silver Gulls, *Larus novaehollandiae* Stephens, from breeding colonies in South Australia. Australian Wildlife Research 12: 279-298.

Ottaway, J. R., R. Carrick and M. D. Murray. 1988. Reproductive ecology of Silver Gulls *Larus novaehollandiae* Stephens in South Australia. Australian Wildlife Research 15: 541-560.

Phillips, D. L. and J. W. Gregg. 2003. Source partitioning using stable isotopes: Coping with too many sources. Oecologia 136: 261-269.

Pierotti, R. and C. A. Annett. 1987. Reproductive consequences of dietary specialization and switching in an ecological generalist. Pages 417-422 *in* Foraging Behavior (A. C. Kamil, C. Krebs and R. Pulliam, Eds.). Plenum, New York, New York.

Pierotti, R. and C. Annett. 1990. Diet and reproductive output in seabirds. BioScience 40: 568-574.

Romanek, C., K. Gaines, A. Bryan, Jr. and I. Brisbin, Jr. 2000. Foraging ecology of the endangered Wood Stork recorded in the stable isotope signature of feathers. Oecologia 125: 584-594.

Sanger, G. A. 1987. Trophic levels and trophic relationships of seabirds in the Gulf of Alaska. Pages 229-257 *in* Seabirds: Feeding Ecology and Role in Marine Ecosystems (J. P. Croxall, Ed.). Cambridge University Press, Cambridge, U.K.

Skira, I. J., and J. E. Wapstra. 1990. Control of Silver Gulls in Tasmania. Corella 14: 124-129.

Smith, G. C. 1992. Silver Gulls and emerging problems from increasing abundance. Corella 16: 39-46.

Smith, G. C. and N. Carlile. 1992. Silver Gull breeding at two colonies in the Sydney-Wollongong region, Australia. Wildlife Research 19: 429-441.

Smith, G. C. and N. Carlile. 1993a. Food and feeding ecology of breeding Silver Gulls (*Larus novaehollandiae*) in urban Australia. Colonial Waterbirds 16: 9-17.

Smith, G. C. and N. Carlile. 1993b. Methods for population control within a Silver Gull colony. Wildlife Research 20: 219-226.

Smith, G. C., N. Carlile and I. Louwerse. 1991. The importance of human refuse as a food source for Silver Gulls *Larus novaehollandiae*. Australian Bird Watcher 14: 24-27.

Steele, W. K. 1990. Distribution, diet and kleptoparasitic behaviour of gulls (Aves: Laridae) in the Southwestern Cape Province, South Africa. Unpublished Ph.D. Thesis, University of Cape Town, Cape Town, South Africa.

Sydeman, W. J., K. A. Hobson, P. Pyle and E. B. McLaren. 1997. Trophic relationships among seabirds in central California: Combined stable isotope and conventional dietary approach. Condor 99: 327-336.

Thompson, D. R., K. Lilliendahl, J. Solmundsson, R. W. Furness, S. Waldron and R. A. Phillips. 1999. Trophic relationships among six species of Icelandic seabirds as determined through stable isotope analysis. Condor 101: 898-903.

Underhill, L. G. and G. D. Underhill. 1987. The zap net: An elastic-propelled variation of the cannon net. Safring News 16: 21-24.

Wakefield, W. C. 2005. The 2004 winter gull count in southeast Tasmania. Tasmanian Bird Report 31:12-13.

Wakefield, W. C. and E. R. Hayward. 2006. Winter gull count, June 2005. Tasmanian Bird Report 32:20.

Woehler, E. J., P. Park and L. B. Parr. 1989. Sexing adult Silver Gulls *Larus novaehollandiae* by external measurements with confirmation by dissection. Corella 13: 126-129.