NOTORNIS

Journal of the Ornithological Society of New Zealand

ISSN 0029-4470

VOLUME 45 **PART 2** **JUNE 1998**

Foods of Buller's Shearwaters *(Puffinus bulleri)* associated with driftnet fisheries in the central North Pacific Ocean

PATRICK GOULD[1], PEGGY OSTROM[2], and WILLIAM WALKER[3]

[1] Alaska Biological Science Center, U.S. Geological Survey, 1011 East Tudor Road, Anchorage, AK 99503, USA; [2] Michigan State University, Department of Geological Sciences, East Lansing, MI 48824, USA; [3] National Marine Mammal Laboratory, National Marine Fisheries Service, NOAA, 7600 Sand Point Way, NE, Seattle, WA 98115, USA

ABSTRACT

We examined digestive tract contents and stable nitrogen isotope ratios ($\delta^{15}N$) in breast muscles of Buller's Shearwaters *(Puffinus bulleri)* salvaged from squid and large-mesh driftnets in the central North Pacific Ocean. The epipelagic Pacific Saury (*Cololabis saira*) was the predominant prey, making up 71% of prey mass in digestive tracts. The remainder of the diet included small numbers of crustaceans, small fishes, and squids. The high degree of specialization in the diet seems to indicate that in the North Pacific, Buller's Shearwaters usually feed at or near the water surface and rarely pursue food under water. Although these birds have been observed feeding on scraps from fishing vessels, our data suggest that offal comprises less than 10 percent of the diet. Stable nitrogen isotope values provided quantified information on the timing of arrival of migrants into the North Pacific.

KEYWORDS: Buller's Shearwater, *Puffinus bulleri*, food, stable isotopes of nitrogen, fisheries associations.

INTRODUCTION

Buller's Shearwaters *(Puffinus bulleri)* breed only on the Poor Knights Islands of New Zealand during the austral summer (Harper 1983). Young and breeding adults depart breeding colonies in May (Harper 1983; Jenkins 1988) and migrate across the equator to spend the boreal summer in the central North Pacific Ocean. The northward migration path may be through the western rather than the central or eastern Pacific (Everett & Pitman 1993). They arrive in the North Pacific primarily in June and spread slowly north and east (Nakamura & Hasegawa 1979; Guzman & Myres 1983; Wahl 1985). Little is known about their densities within the nonbreeding area. In 1990, 5881 were estimated to have been drowned in high seas driftnets set in the central North Pacific (Johnson *et al.* 1993). This compares with >235,000 Sooty Shearwaters (*P. griseus*) and about 1000 Flesh-footed Shearwaters (*P. carneipes*).

In the Southern Hemisphere, Buller's Shearwaters feed primarily at the water surface with only an occasional complete submersion by pursuit plunging (Harper 1978; Ainley & Boekelheide 1983; Harper 1983). Langlands (1991) reported that they swam with their heads submerged but did not dive. Diving may be hampered by low body-mass (Harper 1978; Marchant & Higgins 1990). Buller's Shearwaters feed on a variety of prey including fishes, cephalopods, and crustaceans (Prince & Morgan 1987). On the breeding islands, birds regurgitated crustaceans, primarily euphausiids; salps and jellyfish were also eaten (Harper 1983). Langlands (1991) noted that these shearwaters occasionally shred large pieces of fish viscera discarded from fishing vessels. However, in the North Pacific, Wahl & Heinemann (1979) reported that Buller's Shearwaters were not attracted to fishing vessels or chum and they never saw these birds feeding on offal. Wahl (1986) suggested that Buller's Shearwaters may feed more at night than other shearwaters.

As part of our investigations into the impacts of high seas driftnet fisheries on marine bird populations (Johnson *et al.* 1993) we examined the digestive tracts and stable nitrogen isotope values ($\delta^{15}N$) in breast muscles of a small sample of Buller's Shearwaters salvaged from driftnets set in the transitional region of the North Pacific. While rates of digestion and retention of fish otoliths and cephalopod beaks have proven problematic in stomach analyses of marine birds (Imber 1973; Duffy & Laurenson 1983; Furness *et al.* 1984), the small size and generally good condition of most of the otoliths and beaks in our samples indicate they represent recently ingested prey. In contrast, the nitrogen isotopic composition of an organism reflects the components of the diet that are assimilated over a longer time period (*i.e.*, an estimated half-life for turnover of muscle tissue ranges from 12.4 to 27 days; Tieszen *et al.* 1983; Hobson & Clark 1992; Hobson *et al.* 1994). The combined approach of using digestive tract and isotope analyses offered a unique opportunity to evaluate both short- and longer-term diets.

The isotope technique is based on the observation that the $\delta^{15}N$ composition of a consumer deviates by a constant amount from its food source (Deniro & Epstein 1978, 1981). The average difference in $\delta^{15}N$ between a consumer and its diet (the trophic fractionation factor) in marine food webs is +3.2‰ (Michener & Schell 1994; but see Mizutani *et al.* 1991 and Hobson & Clark 1992). Because this increase occurs between each trophic level within a food web (Wada *et al.* 1987, Harrigan *et al.* 1989, Ostrom & Fry 1993), $\delta^{15}N$ values provide an index of trophic level.

When combined with digestive tract data, $\delta^{15}N$ values can be used to determine if fisheries related food is an incidental or regular component of the diet. If prey in digestive tracts accurately represent the assimilated component of the diet, we should observe a 3.2‰ difference between the mean $\delta^{15}N$ of the diet described by digestive tract data and that of the birds' muscle tissue. The average $\delta^{15}N$ of the short-term diet (defined by the digestive tract contents) can be estimated by using mass balance equations. In this approach, the average $\delta^{15}N$ of the diet is determined by taking the sum of the isotope ratio of a prey taxon multiplied by the relative contribution of the prey taxon to the diet for all prey taxa. We report here the findings of our digestive tract investigations, isotopic analyses and mass balance determinations and assess the influences of fisheries on diets of Buller's Shearwaters.

STUDY AREA AND METHODS

Eighty-nine Buller's Shearwaters were salvaged from squid and large-mesh driftnets set by vessels registered in Japan, Taiwan, and the Republic of Korea in 1991 (Ito *et al.* 1993). Anecdotal information was also obtained from a few specimens taken in 1990. The study was conducted in the area bounded by 39-46°N and 160°E-150°W, and between 4 June and 25 October 1991. This portion of the central Pacific is a region of transition from subarctic water to subtropical water. Major oceanographic features of this area include: increasing water temperature and salinity from north to south with rapid changes (fronts) over short distances at the northern and southern boundaries; the Emperor Seamount chain extending from north to south at approximately 170°E; and the easterly flowing North Pacific Current (Roden & Robinson 1988).

Eighty-nine specimens had complete digestive tracts, however, 29 tracts were empty and excluded from further analyses. Of the remaining 60 birds, 18 were female and 42 male. Ages varied from recently fledged juveniles to breeding age adults as judged by the sizes of the bursa of Fabricius (length x width) which ranged from 0 to 423 mm^2 (Siegel-Causey 1990). Twenty percent of the specimens lacked a bursa and were probably of breeding age.

Contents of the 60 digestive tracts were sorted into four categories: cephalopods, fishes, non-cephalopod invertebrates, and inorganic material. Analyses of inorganic material are not included in this report. Each category was weighed and individual items were identified to the lowest possible taxon. Many of the food items were in an advanced state of digestion or had been shredded before consumption. Thus, most identifications of prey and estimates of numbers were based on hard parts such as squid beaks, fish otoliths, or invertebrate exoskeletons, and only a few individual items could be measured and weighed.

Data are presented using four indices (Table 1), each with its own set of biases (Duffy & Jackson 1986). Percent occurrence is the number of digestive tracts containing a particular prey divided by the total number of digestive tracts containing any prey (that is, 60). Percent items is the total number of items in a particular prey divided by the number of items of all prey in all digestive tracts examined. Mass was determined by weighing the digestive tract contents. Since most of the otaliths and squid beaks in our sample weighed <0.1 g, mass in our study is almost entirely undigested muscle and bone and thus primarily a measure of the last one or two meals of the birds. Percent mass is the total mass of a particular prey, divided by the total mass of all prey in all digestive tracts examined. Following Day & Byrd (1989), the index of relative importance (IRI) is from Pinkas *et al.* (1971): IRI = %F(%N+%M), where F = frequency of occurrence, N = number of items, and M = mass of items. The % of IRI is the IRI of a single taxon divided by the IRI of the total diet.

We determined stable nitrogen isotope values of breast muscle tissue from 56 of the 60 specimens used for digestive tract analyses, and from an additional 27 Buller's Shearwaters with empty digestive tracts caught in driftnets from the same area and time period as our digestive tract samples. We also determined $\delta^{15}N$ values for a variety of prey collected from the digestive tracts of marine birds salvaged from driftnets during our study (see Table 2). All samples were lipid extracted and their $\delta^{15}N$ values determined by a modified Dumas combustion (Macko *et al.* 1987).

We used mass balance equations to estimate a mean $\delta^{15}N$ value for the shearwater's diet:

$$\delta_{\text{diet}} = \sum_{i=1}^{j} f_j \delta_j$$

where f_j = the fractional contribution of the food item j, δ = isotopic composition of the food item j, and .

$$\sum_{i=1}^{j} fj = 1.$$

The quantity, δ_{diet}, determined by this mass balance approach, should also be equivalent to δ_{consumer} - estimate of nitrogen isotopic discrimination between the consumer and its diet. The percent IRI was used to determine the fractional contribution of each food item to the diet.

RESULTS

Prey items found in the digestive tracts of Buller's Shearwaters salvaged from squid and large-mesh driftnets in the transitional North Pacific are presented in Table 1. These prey included arthropods (4 taxa), mesogastropods (1 taxon), cephalopods (3 taxa), and fishes (11 taxa). Fishes were the predominant prey with Pacific Saury *(Cololabis saira)* far outnumbering all other species. The Pacific Saury is an abundant near-surface living species (Hart 1973; Odate 1977). Identification of the shredded fish tissue was impossible, but the most likely species involved was Pacific Pomfret (*Brama japonica*). Pacific Pomfret was the major fish species caught in North Pacific driftnet fisheries (Ito *et al.* 1993). It is a large fish that would not likely be eaten whole by seabirds. However, pomfret flesh could have been shredded from fishes entangled in the driftnets or from dead fishes discarded from fishing vessels. Pieces of flesh dropped by other scavenging animals, such as albatrosses, may also have been eaten. Some of the unidentified fish tissue may have been Pacific Saury, but the amount was probably small because sauries are recognizable by their unique bone colouring. It is also unlikely that the unidentified fish were lanternfishes (Myctophidae). Lanternfishes are small fish, most likely eaten whole, and we would have expected to find their otoliths with their tissue because otoliths persist longer in digestive tracts than do tissues. None of the

TABLE 1 - Percent occurrence, numbers of items, mass, and index of relative importance (IRI) of prey items identified to lowest taxon in Buller's Shearwaters from the transitional North Pacific, 1991. Minor importance (<0.05% mass or IRI) is indicated by +; additional prey items found in digestive tracts of specimens from 1990 are indicated by *.

Prey	Occurrence (%)	Number of prey items	Mass (g)	Index of relative importance
Sample size	60	363	955.9	7029.2
Non-cephalopod invertebrates				
Unidentified invertebrates	1.7	0.3	1.0	+
Crustaceans				
Lepas fascicularis	5.0	3.6	1.6	0.4
Lepas sp.	3.3	3.6	1.2	0.2
Euphausiacea	1.7	55.1	1.9	1.4
Unidentified Gammaridae	*	*	*	*
. Unidentified Shrimp	1.7	0.3	+	+
Mesogastropods				
Janthina sp. (egg cases)	1.7	0.6	+	+
Cephalopods				
Unidentified Cephalopoda	5.0	0.8	0.9	0.1
Unidentified Teuthoidea juveniles	1.7	0.3	+	+
Ommastrephidae				
Ommastrephes bartrami	*	*	*	*
Onychoteuthidae				
Onychoteuthis borealijaponicus	3.3	0.6	+	+
Histioteuthidae				
Histioteuthis sp.	1.7	0.3	+	+
Fish				
Unidentified fish	31.7	5.2	19.5	11.2
Engraulidae				
Engraulis japonica	1.7	0.6	+	+
Bathylagidae				
Bathylagus ochotensis	1.7	0.3	+	+
Photichthyidae				
Ichthyococcus sp.	3.3	0.6	+	+
Myctophidae				
Protomyctophum sp.	1.7	0.3	+	+
Electrona risso	5.0	2.8	+	0.2
Lampanyctus regalis	1.7	0.3	+	+
Lampanyctus jordani	5.0	3.0	3.0	0.4
Lampanyctus ritteri	1.7	0.3	+	+
Diaphus theta	1.7	0.3	+	+
Unidentified Myctophid	5.0	1.4	+	0.1
Paralepididae				
Paralepis atlantica	1.7	0.3	+	+
Scomberesocidae				
Cololabis saira	66.7	19.6	71.0	85.9

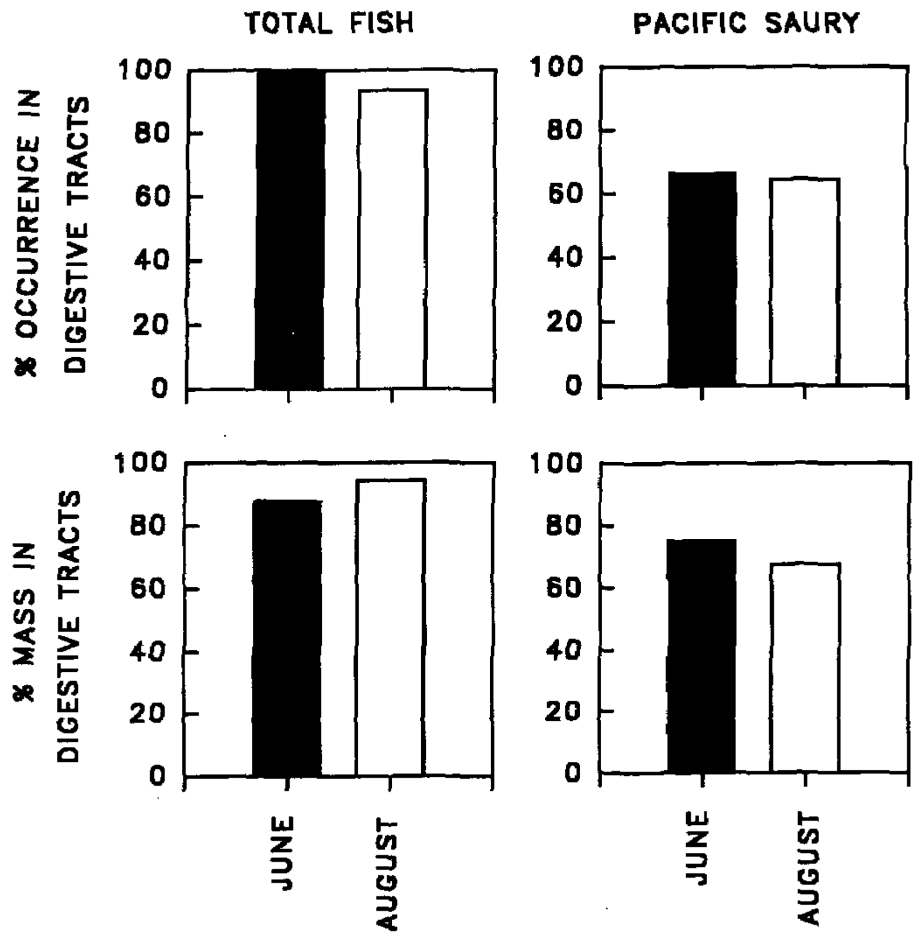

FIGURE 1 – Fish component of the diet of Buller's Shearwater in the central North Pacific comparing June and August 1991. June digestive tracts: n = 18; mass = 402.9g. August digestive tracts: n = 31; mass = 322.5g.

myctophid otoliths in our sample were associated with bones or flesh. The average diet remained remarkably stable from June through October as illustrated by the similarities between June and August (months with the largest sample sizes) in Figure 1.

In 83 specimens of Buller's Shearwater the stable nitrogen isotope values ranged from 10.9 to 18.6‰. We suspected that because the turnover rate of nitrogen in muscle tissue is 2+ weeks, a wide range in values could indicate a difference between newly arrived migrants and birds that had been feeding in the North Pacific for more than two weeks. To determine if a temporal trend in $\delta^{15}N$ existed in our data, we stratified samples by month (Figure 2). Nitrogen isotope values in June were high (range 11.4-18.6‰) as was the standard deviation (mean 14.9‰ ± 2.3 *s.d.*), relative to July (range 11.3-16.4, mean 13.4‰ ± 1.5 *s.d.*), August (range 10.9-17.8, mean 12.7‰ ± 1.1 *s.d.*) and September-October (range 11.2-13.2, mean 12.2‰ ± 0.6 *s.d.*). Between month variation was significantly greater than within month variation. June was significantly different from August, September, and October

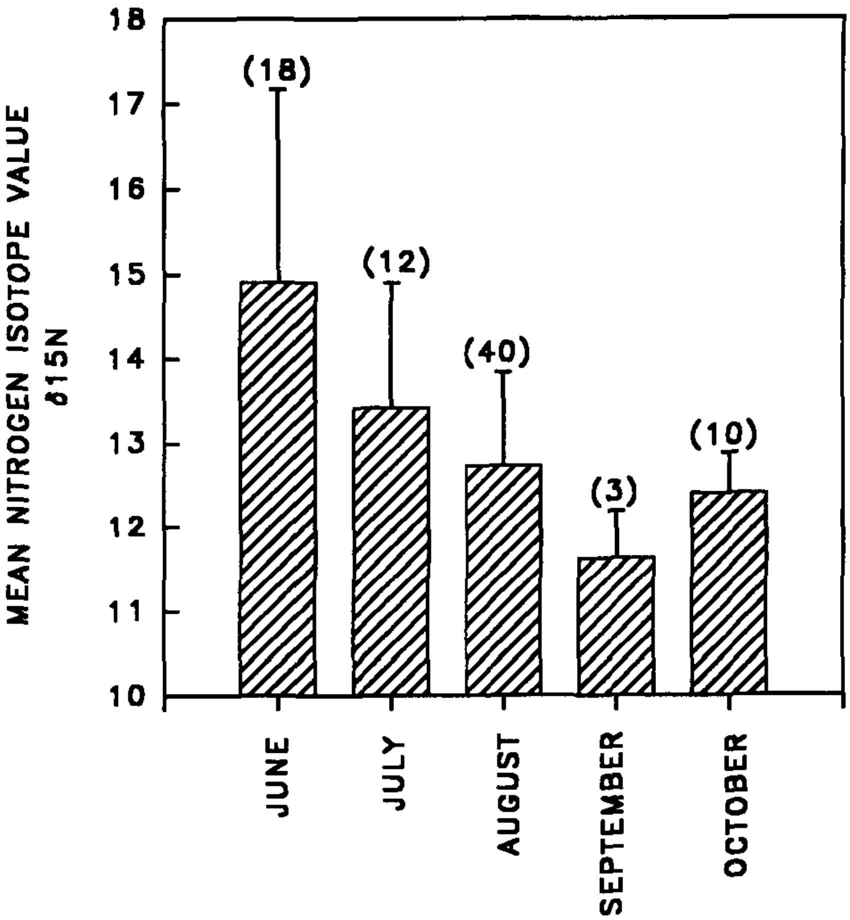

FIGURE 2 – Monthly variation in mean nitrogen stable isotope values ($\delta^{15}N$) for Buller's Shearwaters in the central North Pacific. Error bars indicate standard deviations. Sample sizes are in parentheses.

(Sheffe's F = 9.17, *d.f.* = 4,78, *P*< 0.0001; means presented in Figure 2). July did not differ significantly from any other month, while August, September, and October did not differ significantly from each other (Sheffe's F = 9.17, *d.f.* = 4,78, *P*< <0.0001; means presented in Figure 2). In June, $\delta^{15}N$ values were evenly distributed between 11.4‰ and 18.6‰ (Figure 3). In July and August, values shifted towards the lower end of that range. By September-October, all of the individuals had $\delta^{15}N$ values between 11.1‰ and 13.2‰. Although the small size of our sample set precludes a rigorous MANOVA, t-tests (*P* <0.05) indicate that there was no bias in terms of sex or age class for the June samples relative to any other month.

The temporal decline in $\delta^{15}N$ values suggests the gradual assimilation of a new, ^{15}N depleted, food source by birds arriving in the North Pacific. Our $\delta^{15}N$ data indicate that by August the diet of most birds reflect this new food source. Thus we conservatively assume that stable nitrogen isotope values that are higher than the upper end of the 95% confidence interval for individuals for the combined August-October sample (95% c.i. = 10.6-14.6‰) reflect migrants that have been in the

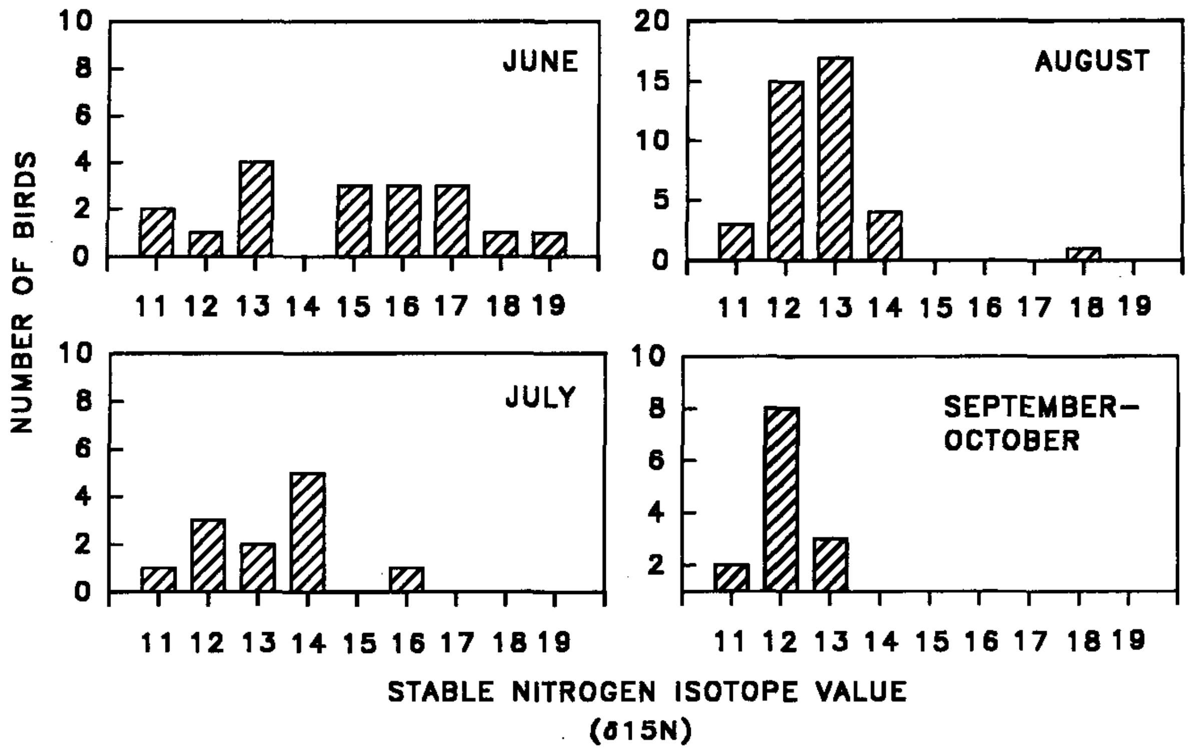

FIGURE 3 – Number of birds at various $\delta^{15}N$ values. Stable isotope values rounded off to nearest whole number (i.e., 11 = 10.5 to 11.4).

area for less than two weeks. Among the June birds, over 61% (11 of 18) had isotope values >14.6‰ as compared to 8% (1 of 12) in July and 3% (1 of 40) in August.

To conduct mass balance determinations for Buller's Shearwater in the North Pacific, we used the mean August-October $\delta^{15}N$ value (12.6‰) to represent the average $\delta^{15}N$ for North Pacific Buller's Shearwater. The estimate of the $\delta^{15}N$ of the diet based on mass balance equations (10.0‰, Table 2), allowed us to calculate a trophic fractionation factor ($\delta^{15}N_{shearwater}$ - $\delta^{15}N_{diet}$) of +2.6‰. This estimate reflects fractionation effects between Buller's Shearwaters and their North Pacific diet as defined by the digestive tract contents of our sample.

DISCUSSION

Stable nitrogen isotope values that exceeded the 95% confidence interval for individuals in the August-October sample (>14.6‰) likely reflect an isotopically unique diet at least partially assimilated prior to the birds arrival in our study area. Since the turnover rate of nitrogen in breast muscle tissue is 2+ weeks, values exceeding 14.6‰ should represent birds recently arrived in the North Pacific. The change in $\delta^{15}N$ values we observed could also result if the migrants shift their diet from high trophic level organisms in the South Pacific to lower trophic level prey in the North Pacific. This possibility is not supported in the literature where low trophic level consumers such as crustaceans are suggested as important components of the diet. Although data are lacking, we assume that shearwater prey such as

TABLE 2 - Mass balance equations for Buller's Shearwater in the central North Pacific Ocean. Sample sizes are provided in parentheses following each taxon.

Food category	$\delta^{15}N$ (mean± 2 *s.e.*)	% of diet	$\delta^{15}N$ contributed to diet
Non-cephalopod invertebrates (20)	7.8 ± 0.8	2.1	0.16
Miscellaneous squid (5)	11.6 ± 1.9	0.1	0.01
Unidentified fish (10)	10.9 ± 1.3	11.2	1.22
Lanternfishes (7)	10.6 ± 0.3	0.7	0.07
Pacific Saury (10)	9.9 ± 1.2	85.9	8.50
Total diet			9.97
$\delta^{15}N$ of Buller's Shearwater (54)	12.6 ± 0.3		
$\delta^{15}N$ of diet	10.0		
Fractionation factor	+2.6		

* Analyses assume that all scavenged, unidentifiable fish material was Pacific Pomfret. Isotope values for miscellaneous squid were derived from a sample of *Berryteuthis anonychus* (1), *Octopoteuthis deletron*(1), *Histioteuthis dofleini* (2) and *Taonius pavo* (1). Miscellaneous fish (e.g., *Bathylagus* sp.) made up less than 0.2% of the diet and their inclusion in this table would not change the derived values.

Pacific Saury also do not change to lower trophic level food between June and October.

High isotope values for migrating Buller's Shearwaters relative to local birds, could result if the isotopic composition at the base of the food web at their feeding grounds in the South Pacific is higher than that in the North Pacific. This possibility of spatial variation at the base of the food web is supported by a consideration of isotopic variation in $\delta^{15}N$ values of particulate organic material between continental shelf and deep ocean environments (Wu *et al.* 1997). Migration has been used to explain variability in isotopic signatures for Wilson's Storm-Petrel *Oceanites oceanicus* (Rau *et al.* 1992) and Sooty *Puffinus griseus* and Short-tailed *P. tennuirostris* Shearwaters (Minami *et al.* 1995). Within the Atlantic Ocean, nitrogen isotope values for the open ocean are approximately 5‰ lower than those on continental shelves (Altabet *et al.* 1991; Ostrom *et al.* 1997). If this same trend occurs in the Pacific Ocean, Buller's Shearwaters which feed on the continental shelf (Harper 1983) around New Zealand would have higher isotope values than those that forage entirely within the open waters of the North Pacific transition zone. In this case, the result would be consistent with our observations of high $\delta^{15}N$ values associated with individuals migrating from their breeding area.

Literature records of Buller's Shearwaters in the North Pacific indicate that most migrants arrive in June. Stable nitrogen isotope values in our study indicate that 61% of the birds in June are recently arrived migrants (<2 weeks residency). Since turnover of nitrogen in muscle tissue is a gradual process, the exceptionally high value (17.8‰) recorded on the third of August is almost certainly that of a newly arrived bird. This suggests that migrants continue to arrive in the area through at least the end of July.

Digestive tract contents suggest that upon arrival, these birds concentrate their foraging on small fish, especially Pacific Saury, supplemented with a variety of invertebrates. This diet changes little through the rest of their stay. This is consistent with this shearwater's habit of feeding primarily at or near the surface of the water. W. Walker (unpubl. observ.) has seen these fish leaping clear of the surface during the day. Hart (1973) reports that juveniles are pelagic and occur near the surface and that, in general, sauries are usually encountered at the surface, although they may also occur as deep as 229 m. In addition, sauries are attracted to the surface of the water at night by lights of fishing vessels (Sato 1981; Gould unpubl. observ.). Shearwaters feeding at night should thus find them easy prey. Lanternfishes are vertical migrants that also occur in surface waters at night. Their presence in digestive tracts of Buller's Shearwaters also suggests nocturnal feeding by these birds. Lanternfishes are, however, infrequent in the diet of Buller's Shearwaters, relative to sauries, possibly because they are mesopelagic species that migrate towards, but do not always reach, the surface at night. The scarcity of lanternfishes in the diet might also reflect an emphasis in diurnal rather than nocturnal feeding by Buller's Shearwaters.

Our sample is biased by birds attracted to driftnets and offal. However, the only direct evidence of Buller's Shearwaters scavenging from the North Pacific driftnet fisheries is the trace amount of neon flying squid tissue (*Ommastrephes bartrami*) in our sample (Table 1). This large squid is the target species for the squid driftnet fisheries and represents the single largest biomass of animals caught by all high seas driftnets in the North Pacific (Ito *et al.* 1993). Circumstantial evidence for Buller's Shearwaters feeding on offal comes from the shredded fish tissue that we found in the digestive tracts. P. Gould (unpubl. observ.) has observed Buller's Shearwaters picking up scraps from offal discarded from driftnet research ships in the North Pacific. The 32 percent occurrence and 10 percent portion of total IRI of unidentified fish tissue in digestive tracts suggests that scavenging by this species accounts for only a small portion (<10%) of the diet. In addition, when Buller's Shearwaters are scavenging, they appear to be actively selecting fish from the offal in preference to other available items such as squid.

The +2.6‰ fraction factor derived from mass balance equations in our study is lower than the predicted value of +3.2‰. Since we found little indication of birds scavenging high trophic level foods from fishing operations, our digestive tract samples probably under-represent low trophic level foods such as soft-bodied invertebrates. Such low trophic level foods (*e.g.*, *Velella* sp.; we have one sample, 3 individuals, from the central North Pacific that had an average $\delta^{15}N$ value of 3.9‰) are known to be eaten by many marine birds (Harrison 1984). Such prey undergo rapid and complete digestion and thus infrequently show up in digestive tract analyses.

The stable isotope and digestive tract content data presented in this study expands our understanding of resource partitioning by marine birds associated with fisheries. High-seas driftnet fisheries offer an abundant food supply to opportunistic individuals. The type and amount of food derived from the fishery, however, differs among taxa. For example, whereas Buller's Shearwaters selectively supplement their diet with small amounts of fish, Black-footed Albatross (*Diomedea nigripes*) consume large amounts of neon flying squid (Gould *et al.* 1997). The degree to which stomach content data reflect long-term feeding habits of birds can be assessed with stable isotope data. Another important contribution of our work is the suggestion that nitrogen isotope data can provide a tool for evaluating migration that extends what can be assessed based on visual observations.

ACKNOWLEDGEMENTS

The National Marine Fisheries Service and U.S. Fish and Wildlife Service provided financial and logistical support for this project. We especially thank Linda Jones of the former, and Kent Wohl of the latter organization. We thank all of the people who worked with us in the 1990-1991 High Seas Driftnet Observer Programs, especially Shannon Fitzgerald and the scientific observers who obtained the specimens for us. Sievert Rohwer, and staff at the Burke Museum, University of Washington, prepared the specimens and removed the digestive tracts and breast muscle tissues. Larry Spear of Point Reyes Bird Observatory, sorted and weighed the digestive tract contents. Alan Kohn and Katie O'Reilly identified the non-cephalopod invertebrates in the digestive tracts. We thank Patrick O'Connor, Kevin Pilichowski, Lisa Koch, and Amanda Straky of Michigan State University for sample preparation for isotopic analysis and data base management. We thank Vivian Mendenhal, Tom Smith, and Robert Stehn for reviewing the first draft of the manuscript, and the peer reviewers who reviewed the final draft.

LITERATURE CITED

AINLEY, D.G.; BOEKELHEIDE, R.J. 1983. An ecological comparison of oceanic seabird communities of the south Pacific ocean. Pp. 2-23 *in* Schreiber, R.W. (ed.) Studies in Avian Biology No. 8. Cooper Ornithological Society. Allen Press Inc., Lawrence, Kansas

ALTABET, M.A.; DEUSER, W.G.; HONJO, S.; STIENEN, C. 1991. Seasonal and depth related changes in the source of sinking particles in the North Atlantic. Nature 354: 136-139.

DAY, R.H.; BYRD, G.V. 1989. Food habits of the whiskered auklet at Buldir Island, Alaska. Condor 91: 65-72.

DENIRO, M.J.; EPSTEIN, S. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochimica Cosmochimica Acta 42: 495-506.

DENIRO, M.J.; EPSTEIN, S. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochimica Cosmochimica Acta 45: 341-351.

DUFFY, D.C.; JACKSON, S. 1986. Diet studies of seabirds: a review of methods. Colonial Waterbirds 9: 1-17.

DUFFY, D.C.; LAURENSON, L.J.B. 1983. Pellets of the Cape Cormorant as indicators of diet. Condor 85: 305-307.

EVERETT, W.T.; PITMAN, R.L. 1993. Status and conservation of shearwaters of the North Pacific. Pp. 93-100 *in* Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D. (eds.) The Status, Ecology, and Conservation of Marine Birds of the North Pacific. Canadian Wildlife Service Special Publication, Ottawa, Canada.

FURNESS, B.L.; LAUGKSCH, R.C.; DUFFY, D.C. 1984. Cephalopod beaks and studies of seabird diets. Auk 101: 619-620.

GOULD, P.; OSTROM, P.; WALKER, W. 1997. Trophic relationships of albatrosses associated with squid and large-mesh drift-net fisheries in the North Pacific Ocean. Can. J. Zool. 75: 549-562.

GUZMAN, J.R.; MYRES, M.T. 1983. The occurrence of shearwaters (*Puffinus spp.*) off the west coast of Canada. Can. J. Zool. 61: 2064-2077.

HARPER, P.C. 1978. The plasma proteins of some albatrosses and petrels as an index of relationship in the Procellariiformes. N.Z. J. Zool. 5: 509-548.

HARPER, P.C. 1983. Biology of the Buller's shearwater (*Puffinus bulleri*) at the Poor Knights Islands, New Zealand. Notornis 30: 299-318.

HARRIGAN, P.; ZIEMAN, J.C.; MACKO, S.A. 1989. The base of nutritional support for the gray snapper (*Lutjanus griseus*): an evaluation based on a combined stomach content and stable isotope analysis. Bull. Mar. Sci. 44: 65-77.

HARRISON, N.M. 1984. Predation on jellyfish and their associates by seabirds. Limnol. Oceanogr. 29: 1335-1337.

HART, J.L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Board Canada, No. 180.

HOBSON, K.A.; CLARK, R.G. 1992. Assessing avian diets using stable isotopes I: turnover of 13C in tissues. Condor 94: 181-188.

HOBSON, K.A.; PIATT, J.F.; PITOCCHELLI. 1994. Using stable isotopes to determine seabird trophic relationships. J. Anim. Ecol. 63: 786-798.

IMBER, M.J. 1973. The food of Grey-faced Petrels (*Pterodroma macroptera gouldi* Hutton), with special reference to diurnal vertical migration of their prey. J. Anim. Ecol. 42: 645-662.

ITO, J.; SHAW, W.; BURGNER, R.L. (eds.) 1993. Symposium on biology, distribution and stock assessment of species caught in the high seas driftnet fisheries in the North Pacific Ocean. Int. North Pac. Fish. Comm. Bull 53, Vancouver, Canada.

JENKINS, J.A.F. 1988. The distribution of Buller's Shearwater (*Puffinus bulleri*) in New Zealand coastal waters and in the Tasman Sea. Notornis 35: 203-215.

JOHNSON, D.H.; SHAFFER, T.L.; GOULD, P.J. 1993. Incidental catch of marine birds in the north Pacific high seas driftnet fisheries in 1990. Pp. 473-483 *in* Ito, J.; Shaw, W.; Burgner, R.L. (eds.) Symposium on Biology, Distribution and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean. Int. North Pac. Fish. Comm. Bull. 53, Vancouver, Canada.

LANGLANDS, P.A. 1991. Buller's shearwaters foraging around fishing vessels. Notornis 38: 266.

MACKO, S. A.; ESTEP, M.F.; HARE, P.E.; HOERING, T.C. 1987. Isotopic fractionation of nitrogen and carbon in the synthesis of amino acids by microorganisms. Isotope Geoscience 65: 79-92.

MARCHANT, S.; HIGGINS, P.J. (eds.) 1990. Handbook of Australian, New Zealand and Antarctic birds. Volume 1, Part A. Oxford Univ. Press, Melbourne.

MICHENER, R.H.; SCHELL, D.M. 1994. Stable isotope ratios as tracers in marine aquatic food webs. Pp. 138-157 *in* Lajtha, K.; Michener, R.H. (eds.) Stable Isotopes in Ecology and Environmental Science. Blackwell Scientific, Oxford.

MINAMI, H.; MINAGAWA, M.; OGI, H. 1995. Changes in stable carbon and nitrogen isotope ratios in sooty and short-tailed shearwaters during their northward migration. Condor 97: 565-574.

MIZUTANI, H.; KABAYA, Y.; WADA, E. 1991. Nitrogen and carbon isotope compositions relate linearly in cormorant tissues and its diet. Isotopenpraxis 4: 166-168.

NAKAMURA, K.; HASEGAWA, M. 1979. A brief note on distribution of Buller's shearwater, *Puffinus bulleri*, in Japan and adjacent seas. J. Yamashina Inst. Ornith. Vol. II: 123-127.

ODATE, S. 1977. On the distribution of Pacific saury in the North Pacific Ocean. Res. Inst. North Pac. Fish., Hokkaido Univ. Spec. Vol.: 353-381. (In Japanese).

OSTROM, P.H.; FRY, B. 1993. Sources and cycling of organic matter within modern and prehistoric food webs. Pp. 785-798 *in* Engel, M.H.; Macko, S.A. (eds.) Organic Chemistry, Plenum Press, N. Y.

OSTROM, N.E.; MACKO, S.A.; DEIBEL, D.; THOMPSON, R.J. 1997. Seasonal variation in the stable carbon and nitrogen isotope biogeochemistry of a coastal cold ocean environment. Geochimica Cosmochimica Acta 14: 2929-2949.

PINKAS, L.; OLIPHANT, M.S.; IVERSON, I.L.K. 1971. Food Habits of Albacore, Bluefin Tuna, and Bonito in California Waters. Calif. Fish and Game, Fish Bull. 152.

PRINCE, P.A.; MORGAN, R.A. 1987. Diet and feeding ecology of procellariiformes. Pp. 135-170 *in* Croxall, J.P. (ed.) Seabirds, Feeding Ecology and Role in Marine Ecosystems. Cambridge Univ. Press, Cambridge.

RAU, G.H.; AINLEY, D.G.; BENGTSON, J.L.; TORRES, J.J.; HOPKINS, T.L. 1992. $^{15}N/^{14}N$ and $^{13}C/^{12}C$ in Weddel Sea birds, seals, and fish: implications for diet and trophic structure. Marine Ecology Progress Series 84: 1-8.

RODEN, G.I.; ROBINSON, A.R. 1988. Subarctic frontal zone in the northeastern Pacific: mesoscale structure and synoptic description. Harvard Open Ocean Model Rep., Rep. Material Oceanogr. No. 31: 1-27.

SATO, M. 1981. Some considerations on the "North to south turning migration" mechanism of the Pacific Saury, *Cololabis saira* (Brevoort). Res. Inst. North Pac. Fish. Hokkaido Univ., Spec. Vol.: 73-78.

SIEGEL-CAUSEY, D. 1990. On use of size of the bursa of Fabricius as an index of age and development. J. Field Ornithol. 61: 441-444.

TIESZEN, L.L.; BOUTTON, T.W.; TESDAHL, K.G.; SLADE, N.A. 1983. Fractionation and turnover of stable carbon isotopes in animal tissues: implications for $\delta^{13}C$ analysis of diet. Oecologia 57: 32-37.