Modified Volume: A Two-Step Frequency-Volume Method for Ranking Food Types Found in Stomachs of Northern Fur Seals

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INTRODUCTION

Studies on food habits of migrating northern fur seals traditionally use both percent volume and percent frequency of occurrence (frequency being the numbers of stomachs with a particular food type) to determine the relative important of various species in the diet. The results of both methods are usually presented because there is uncertainty as to which most accurately measures the true diet. There has been no universally accepted procedure developed to integrate them. Volumetric measure can be biased by the effects of progressive digestion, and frequency by the exaggerated importance of species eaten incidentally. One of the main difficulties in fur seal research is that the two primary food types, fish and squid, are given consistently different values by each method. The volumetric technique generally ranks squid at less than half that based on frequency. For example, based on all pelagic data collected by the United States and Canada during 1958-74, using volume results in a diet estimated to be 85% fish and 15% squid, while using frequency produces estimates of 61% fish and 39% squid (Perez and Bigg, 1980). The proportions of individual species of fish and squid thus also differs, such that it remains unclear which are most important.

Perez (1979) attempted to avoid this discrepancy by using the Index of Relative Importance (IRI), a method developed by the California Department of Fish and Game to study the food habits of scombrid fishes (Pinkas et al., 1971). In this method, the percent of stomachs containing a species is multiplied by the sum of the percent of the total volume of all stomachs represented by the same species plus the percent of the total count of individual specimens represented by the species to produce an index for each food type. While the method does not account for the inherent biases of its components, it is sometimes thought that its formulation might cause them to cancel each others effects. Perez and Bigg (1980) made further attempts to develop less biased methods and discussed their limitations. The main improvement was the suggestion that by eliminating trace remains ($\leq$ 10 cc), such as squid beaks and fish bones, the frequency and count measures would be more meaningful. This assumed that trace remains sometime accumulate over several days and thus exaggerate the importance of certain species, particularly squid. This modification resulted in seven methods being available by which to analyze stomach contents as based on: volume, frequency, modified frequency, count, modified count, IRI and modified IRI, where the term "modified" means that no trace data is included. However, it was still not evident which method provided the best measure of diet.

In the current report, we propose an eighth method which integrates, in two steps, modified frequency and volume. Henceforth we use the term modified volume to refer to this method. We suggest, on theoretical and experimental grounds, that this method contains the fewest biases of available methods. The method, based on a proposal by Bigg (1980), involves first establishing the fraction of the diet comprised of fish and that of squid by modified frequency. Next, the percentage values for individual food types within fish and within squid are determined from volume. These are adjusted to form a total equivalent to the fraction for each of the two categories as based on frequency. When all of the percentages are thus reproportioned to total 100% of the diet, the result is a relative ranking for individual fish and squid species. It is basically a volumetric measure, weighted for biological differences between fish and squid by modified frequency. Results from the use of this method are compared with those from other methods.

Also discussed in this report are suggestions on how best to deal with cetain food types such as unidentified fish and squid, rarely eaten species, the ranking of different levels of taxa, and the reproportioning of percentages. An example is given to show how data derived by this method can be used to determine the amount eaten of each species.

METHODS

Data from the contents of fur seal stomachs taken by the United States and Canada during 1958-74 were analyzed by each of the seven methods discussed by Perez and Bigg (1980), and by modified volume, the main subject of this paper. Using the data for the seven regions and 20 subregions discussed in Perez and Bigg (1980), 162 analyses were conducted using each of these seven methods, and modified volume, by month and combined months. In each of these analyses, the data were treated similarly in each method. The same taxa of prey were grouped or data apportioned; the same unidentified fish and squid categories were eliminated and identical techniques were used in reproportioning the data. Thus, each of the eight methods yield comparable results. Except for modified volume, in which percentages for fish and squid taxa are calculated independently in determining percent of total, the methods calculate the percentage of a food type in the diet as a fraction of the total (fish and squid combined). The specifics and details in the modified volume method, including grouping of taxa, category elimination, etc. are discussed later in this paper. Details concerning the other seven methods are discussed by Perez and Bigg (1980), who also give the results of these methods when applied to the 1958-74 data, but without including the improvements suggested and utilized herein. Perez and Bigg (1981) discuss the results of the analysis of fur seal feeding by region and month using the modified volume procedure, and provide the results for many cases in which the modified volume technique has been applied.

All analyses based on the 1958-74 data and comparisons of the eight ranking methods were conducted through the use of automatic data processing techniques developed by the senior author. The percentage of stomachs of fur seals taken during 1958-74 containing one or more different species of food (no traces) was determined. The results of the eight ranking methods were compared by three statistical methods (described below): the sum of absolute differences from the average percent, the percentage of equivalence, and the Kendall coefficient of concordance.

The first method used to compare the eight ranking methods involved the sum of the absolute differences between the percentage values for each food type, as derived by each method, and the average percentage value for that food type, as derived by averaging their values from all methods. The mean, standard error and 95% confidence intervals for these sums were calculated for each method.

The percentage of equivalence was also used to compare the relationship of modified volume to each of the seven other commonly used methods. This is simply an index which is derived from the sum of minimum percentages, and hence, is itself a percentage value, which in this case ranges from 0 to 100. This index is derived as the sum of the minimum percentage value for a particular food type by either of two methods being compared (i.e., in this case, modified volume and any one of the other methods), as found by summing over all food types. Thus, if the IRI assigns 10% to walleye pollock and modified volume assigns 34%, 10% is added to the sum of minimum values which as a total is called the percentage of equivalence. Alternatively, if the diet consists of 16 food items, and any one of the eight ranking methods assigns zero percent to a food item, zero is added to the running percentage of equivalence total. This index, which has not been used previously, is similar in design and appearance to the percentage of similarity between two quadrats discussed by Pielou (1975), but not in actual calculation or application. Percentage of equivalence data for 115 of the 162 analyses were compared. The mean, standard error and 95% confidence intervals were calculated, after first transforming the percentage of equivalence data by the arcsine transformation. This was done because percentage data do not follow a nominal distribution, but can often be made to approximate one by the use of this transformation (Zar, 1974).

Finally, the nonparametric Kendall coefficient of concordance (W) was used to compare statistically the eight different methods of assessing relative importance of food items. It was used to determine if the results obtained by the various methods are correlated, as it measures the extent of association among several sets of rankings of a number of observations. Comparisons of total diet (comprised of all food items assigned importance by any of the eight methods) were made by this test. This test is useful in determining the agreement among three or more variables, and is similar to the Spearman rank correlation coefficient for two sets of data, however, it is much simpler than computing an average of rho values obtained by the Spearman test for all possible pairs of rankings of prey by the eight methods. A high or significant value of W may be interpreted as meaning that each of the methods of assessing prey importance within the diet result in similar rankings of the prey in the diet. Siegel (1956) discussed the procedures and formulae involved in the use of the test.

RATIONALE

The development of the two-step modified volume method resulted from an examination of the limits inherent in the laboratory measurements of each item from the stomach contents and recognition of potential biases brought about by the nature of the food species and the seal.

Measurement Limitations

Species identification for the stomach contents of pelagically collected seals was relatively easy for undigested or partially digested remains. However, where digestion was advanced, exact identification was often difficult and thus such specimens were assigned to some higher or more collective taxonomic group. This was particularly so for squid, many of which were recorded only as unidentified. Using the entire data base, unidentified squid comprised 13% of all squid by volume, 25% by modified frequency and 31% by ordinary frequency (Perez and Bigg, 1980, tables 48a-b). Thus, unidentified squid is an important category to include in analyses. The accuracy of volume measurement was reasonably high except for advanced stages of digestion where species separation became difficult. The frequency of occurrence was more easily recorded than volume, since only one individual of a species was required from a stomach for it to be noted as a food type. The count of individuals within a species was more difficult to record than volume at advanced stages of digestion. Also, the count was not recorded in some cases. Of the total occurrences of food in the 1958-74 data, 5% do not have count information recorded. These errors require that the count be excluded as a ranking method for the present data. Additionally, no data on size or age class of prey specimens were recorded, further decreasing the effectiveness of these data. Thus the choice of potential methods was restricted to only volume and frequency.

Biological Biases

The following potential biological biases were considered:

Feeding and collection time

While there is much variability in the daily feeding pattern of seals, the typical pattern consists of nocturnal or crepuscular feeding (see Figure 1; and also Spalding, 1964, p. 14). On the average, stomachs contain the largest amounts of food at sunrise. Rarely are seals collected earlier to know the extent of nocturnal feeding. Through the day, stomachs contain progressively less food remains, reaching a low point in late afternoon. As dusk approaches, the amount of food increases. Seals were taken generally from about 0800-1600 hours. Thus, as the day progressed, digestion in the stomach increasingly removed evidence of what was eaten during the main feeding period. Some feeding occurred during the day.

Volume and frequency

Volume and frequency measure different aspects of diet and each contains potential biases. Volume measures the biomass of food present in the stomach. However, the effects of digestion can distort the importance of species which differ in availability through the day as could be caused by species specific variations in vertical migrations. Frequency measures the proportion of seals which are feeding on a particular species. It does not consider information on prey size (volume) or abundance in the stomach contents of an individual fur seal. An average of 31% of all stomachs examined contain more than one food type (Table 1). However, the largest stomach contents by volume generally consisted of only one type of prey which represented the main meal (Perez, 1979, tables 18-19). The stage of digestion has little effect on frequency.

Digestion rates

Differences in the rate of digestion between prey species in the stomachs of seals would influence the accuracy of volume as a measure of species importance. Little is known about rates of digestion. However, it seems reasonable to suggest that squid are digested more quickly than fish. Squid are more soft-bodied and have a relatively larger surface area for more rapid digestion than fish. Wada (1971) observed that for the same time of collection squid were generally more digested than some species of fish. He ascribed at least part of this to a greater rate of digestion for squid. He also suggested that differences existed in digestion rates among fish due to the type of skin and firmness of flesh. There is some experimental evidence from a captive seal that squid (*Loligo*) is digested more quickly than herring (*Clupea*) (Bigg 1981). After 3.5 hr., 409 g of herring were digested to 18% while 226 g of squid flesh were completely digested. There was no difference in the proportion digested after 1.5 hr. (65%) indicating that the rate changes over time, increasing faster for squid than for fish.

Accumulation of solid remains

Another important aspect of digestion involves the time that the solid parts from digested squid (i.e., eye lenses, beaks, pens) and fish (i.e., bones, otoliths, eye lenses, scales) remain in the seal stomachs. Bigg (1981) discusses recent experimental evidence from killed captive seals that squid beaks are retained in the stomachs up to 34 hr after feeding. No fish remains were found after 12 hr. It appears that the irregular and relatively large shape of squid beaks acts to block their passage out of the stomach. Their indigestible nature also ensures that they will remain obvious for identification. All parts of fish, however, are apparently reduced to such a size as to pass out of the stomach. It is possible that the bony parts of large fish are retained longer than small fish. But, because all fish parts are digestible, they could not accumulate to the extent squid beaks accumulate. An accumulation of squid beaks over several days feeding will exaggerate the importance of squid by measure of ordinary frequency.

The bias caused by the accumulation of beaks is eliminated by excluding from the sample those stomachs with trace remains (solid remains of $\leq$10 cc) used as the only evidence of a food type being present. Thus only prey species which have flesh present are considered in this frequency measure, called modified frequency. The effect of removing stomachs with trace remains from the sample is to reduce the importance of squid to a value which is approximately midway between ordinary frequency and volume. For example, using all pelagic data collected by the United States and Canada during 1958-74, squid decreased from an average of 39% of the diet (61% for fish) by ordinary frequency to 25% by modified frequency compared to 15% by volume (Perez and Bigg, 1980, table 62). The marked change upon removal of trace data is further evidence of the accumulation of squid beaks in seal stomachs.

Modified Frequency or Volume

The preceding discussions indicate that the best choices for methods of data analysis are volume and modified frequency. However, neither alone seems adequate to describe diet. Their biases often work in opposite directions. We suggest, therefore, that if both are incorporated into one method, using a two-step procedure, the results would provide a better description of the true diet than either alone. As outlined earlier the first step in the process is to establish the proportion of the diet comprised of fish and cephalopods as based on frequency and the second, the proportion of the diet comprised of individual species within fish and within cephalopods based on volume. Although they are infrequently consumed, octopi should not be ignored, and thus, the cephalopod taxon level should be used at this step in the analysis.

Modified frequency is probably the most accurate method for step one. This is because squid are more soft-bodied and appear to digest more quickly than fish. As the main collection time was not until 3-10 hr after the end of the main feeding period, progressive digestion would result in squid being under-represented by volume. Modified frequency is less sensitive to the effects of digestion. Spalding (1964, p. 9) notes that with small sample sizes, frequency is a better measure than volume. For example, the biomass from a few stomachs collected in the morning will outweigh many taken in the afternoon and thus the food types determined from animals sampled in the morning will have an exaggerated importance.

Volume is likely to be the best measure for step two. This is because relative volume of the individual food types are compared within the two groups. Digestion rates within squid and within fish are probably more similar than between fish and squid. Thus, the main advantage of using modified frequency for step one is absent in step two. In small samples volume could exaggerate the importance of species which differ in the times for which they are available to the seal.

Modified frequency used in step two would probably exaggerate the number of important species through incidental feeding on these species. Based on all 1958-74 data pooled, modified frequency increases the number of important species by 29% over volume (from 15 to 21 food types) for step two. The use of modified frequency seems more appropriate in step one where only two food types are considered in studies of the fur seal diet.

PROCEDURE

Before food types can be ranked or statistical tests performed, consideration must be given to the treatment of different levels of taxa, rarely eaten species, and adjustment of percentages to total 100% of the diet. Appendix Table A-1 lists all food items and objects identified in the stomachs of fur seals taken in the eastern North Pacific Ocean and eastern Bering Sea during 1958-74 by the United States and Canada. Included are 68 types of fish and 14 cephalopods. Some levels of taxa overlap and must be either pooled with higher taxa or proportionally divided among component species. This avoids ranking one food type partially against itself. Table 2 lists those taxa of fur seal prey which are pooled or proportionally divided among component taxa. The categories of unidentified fish and squid were kept to establish the ratio of all fish to all cephalopods, but omitted for the ranking of individual food items except where they were the only food items in a sample.

Within individual analyses (e.g., by month, region, age, sex), we excluded all food types which comprised $\leq$1% of the total volume of fish or cephalopods. This figure was arbritrary, but necessary to increase the effectiveness of statistical tests which compare the order of the resulting ranking of species. Without a lower limit on importance, food types which are rarely eaten would increase the variance of such tests because the irregular occurrences change the lower ranking orders in a non-meaningful way.

The percentages of all food types were reproportioned to total 100% of the diet so that comparisons between regions, sexes, ages and months can be made using equivalent percentages. In the first step, the initial sum of the percent modified frequency for cephalopods plus fish exceeds 100% because some stomachs contain both fish and cephalopods. Thus, the two percentages are proportionally reduced to total 100%.[1/] In the second step, the proportion of food types within fish is determined as if fish were 100% of the diet. Food types of $\leq$1% importance are removed and all remaining figures proportionally reduced to total the estimated proportion of fish in step one. The same procedure is used for species of cephalopods. This proportional reduction will result in some species being less than 1% in importance in spite of such values having been omitted earlier. Table 3 shows an example of how the two-step, modified volume method is used to assess relative importance of various species in the diet of fur seals off Washington during January.

COMPARISONS WITH OTHER METHODS

Comparisons were made to determine how different the percentage values from the two-step, modified volume method are from the seven other methods used in the past. The Kendall coefficient of concordance was used to compare the rank order of percentage values derived for each food type by each of the eight methods, for 162 combinations of region and month. For this test each food item was assigned a rank by each of the eight methods, and the ranking orders were compared. To make species compositions equivalent between methods, the percentages within the other seven were reproportioned to total 100% after data from prey which comprise $\leq$1% of total diet were removed. In the test only 3 of the 162 analyses showed significant differences by the Kendall coefficient of concordance. This indicates that all of the methods assign essentially the same order of ranking for food types. However, this does not imply that the absolute percentages for each food type are the same between methods.

1/ This is also equivalent to calculating frequency of occurrence of fish and cephalopods by summing the total number of stomachs containing a food type for all food types, and scaling down to give percentage composition of diet. This is discussed by Hynes (1950).

The second test was to calculate an average percentage for each food based on all eight methods and to determine which method came the closest to the average. Table 4 shows the results of 162 tests for various combinations of data by region and month. The closest to the average was the IRI, modified volume and modified frequency, being within 33-34%. Frequency, count and modified count were the most different, being within 45-47%. While those methods closest to the average are not necessarily the most accurate, it can be argued that when diet is viewed through a variety of different techniques, the biases of each are cancelled and thus the average is relatively accurate.

The third test compared the percentage of equivalence between the percentages derived by modified volume and those for each of the seven other methods. For this, the smallest from each pair of percentages for a food type was summed. Thus, the more similar the other methods are to the two-step, modified volume procedure, the higher the sum of the percentage of equivalence, to a maximum of 100%. Table 5 gives the results from 115 analyses of the 1958-74 data by month and region. Modified volume assigns percentages which are closest to the volumetric method (89%), with modified frequency a close second (82%). The lowest association is with count (65%). The latter is known to be an inaccurate method when used with existing fur seal data.

These tests indicate that the modified volume method produces results which are reasonable when compared with those previously used.

FUTURE USE OF THE MODIFIED VOLUME METHOD

The data derived from modified volume can be used to determine the amount of food eaten when additional data become available on the caloric content of food species and the caloric requirement of seals. Table 6 provides an example using reasonable, although artificial, data. The percent of each food type in the diet is multiplied by the caloric value of that food type. When these new values are proportionally reduced to total 100% of the diet, new percentages are created which now more accurately reflect the relative importance of diet items, because the food types are then weighted for their caloric content.

These new values can be converted to the actual amount eaten when it is known what the caloric requirements are for each age, sex and reproductive condition. Such work is being conducted by the junior author at the Pacific Biological Station. An active nonpregnant adult female typically needs about 5000 K cal/day to maintain body weight. The proportions of known diet in the wild, weighted for caloric content, can then be applied to the typical needs as established from captive studies, to estimate the amount of each food item consumed.

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REFERENCES

Bigg, M. A.
1980. Comments on future analyses of food habits of fur seals. Typed report, 5 p. Dep. Fish. Oceans, Pac. Biol. Stn., Nanaimo, British Columbia. 17 July 1980.

1981. Digestion rates of herring and Loligo by northern fur seals. Unpublished report, submitted to the 24th annual meeting, North Pac. Fur Seal Comm., Tokyo. Dep. Fish. Oceans, Pac. Biol. Stn., Nanaimo, British Columbia.

Hynes, H. G.
1950. The food of freshwater sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius), with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36-58.

Perez, M. A.
1979. Preliminary analysis of feeding habitss of the northern fur seal in the eastern North Pacific and Bering Sea, p. 180-245. In: H. Kajimura et al, Preliminary analysis of pelagic fur seal data collected by the United States and Canada during 1958-74. Unpublished report, March 1979. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

Perez, M. A. and M. A. Bigg.
1980. Interim report on the feeding habits of the northern fur seal in the eastern North Pacific Ocean and eastern Bering Sea, p. 4-172. In: H. Kajimura et al, Further analyses of pelagic fur seal data collected by the United States and Canada during 1958-74, Part 2. Unpublished report, March 1980. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

1981. An assessment of the feeding habits of the northern fur seal in the eastern North Pacific Ocean and eastern Bering Sea. Unpublished report, submitted to the 24th annual meeting, North Pacific Fur Seal Commission, Tokyo. April 1981. Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, WA.

Pielou, E. C.
1975. Ecological Diversity. John Wiley and Sons, New York, 165 p.

Pinkas, L., M. S. Oliphant and I. L. K. Iverson.
1971. Food habits of albacore, bluefin tuna, and bonito in California waters. Calif. Dep. Fish Game, Fish. Bull. 152, 105 p.

Siegel, S.
1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York, 312 p.

Spalding, D. J.
1964. Comparative feeding habits of the fur seal, sea lion, and harbour seal on the British Columbia coast. Fish. Res. Board Canada, Bull. 146, 52 p.

Wada, K.
1971. Food and feeding habits of northern fur seals along the coast of Sanriku. Bull. Tokai Reg. Fish. Res. Lab. 64: 1-37. In Japanese. (Transl. Natl. Mar. Fish. Serv., NOAA, Rockville, MD).

Zar, J. H.
1974. Biostatistical analysis. Prentice Hall, Englewood Cliffs, N.J., 620 p.

TABLE 1. Percentage of stomachs containing food (no traces) by number of different prey species present in the stomach contents of each seal taken by the United States and Canada, 1958-74, by region (months combined).

Region	Number of Different Species of Prey in Stomachs of Individual Fur Seals						
	1	2	3	4	5	6	7
California	65.7	28.0	4.9	1.0	0.3	-	-
Oregon	69.0	22.5	8.5	-	-	-	-
Washington	67.8	23.7	6.5	1.4	0.5	0.2	-
British Columbia	66.5	28.8	4.2	0.6	-	-	-
Gulf of Alaska	88.6	10.0	1.4	0.1	-	-	-
Western Alaska	72.1	25.6	2.0	0.3	-	-	-
Eastern Bering Sea	61.1	22.4	11.8	4.0	0.6	-	0.1
All regions combined	68.9	22.8	6.4	1.6	0.4	-	-

TABLE 2. List of food items identified in the stomachs of fur seals (1958-74), taken by the United States and Canada in the eastern North Pacific Ocean and eastern Bering Sea, and grouped into single new food category designations(2-a) or data apportioned among related component taxa (2-b) for analyses of diet by modified volume. 1/

2-a --- Food items grouped into single new food category designations:

Food item identified in stomach contents	New food category designation for analysis by modified volume
Unidentified Salmonidae	Salmonidae
Oncorhynchus spp.	"
Oncorhynchus gorbuscha	"
Oncorhynchus keta	"
Oncorhynchus kisutch	"
Oncorhynchus nerka	"
Oncorhynchus tshawytscha	"
Salmo gairdneri	"
Unidentified Myctophidae	Myctophidae
Tarletonbeania crenularis	"
Symbolophorus californiensis	"
Lampanyctus sp.	"
Unidentified Trachipteridae	Trachipteridae
Trachipterus altivelis	"
Sebastes spp.	Scorpaenidae
Sebastes alutus	"
Sebastes entomelas	"
Sebastes jordani	"
Unidentified Cyclopteridae	Cyclopteridae
Aptocyclus ventricosus	"
Unidentified Anarhichadidae	Anarhichadidae
Anarhichas orientalis	"
Unidentified Octopoda	Octopoda
Ocythoe tuberculata	"
Onychoteuthis sp.	Onychoteuthidae
Onychoteuthis borealijaponicus	"
Moroteuthis robusta	"

2-b --- Food items and related component taxa for which data is redistributed proportionally: 2/

Food item for which data is to be apportioned to its related component taxa according to their relative proportions within the data sample	Related component taxa to which data is proportionally redistributed within the data sample
Unidentified Clupeidae	Alosa sapidissima
"	Clupea harengus pallasi
Unidentified Osmeridae	Hypomesus pretiosus
"	Mallotus villosus
"	Thaleichthys pacificus
Unidentified Gadidae	Gadus macrocephalus
"	Merluccius productus
"	Microgadus proximus
"	Theragra chalcogramma
Unidentified Hexagrammidae	Pleurogrammus monopterygius
Unidentified Trichodontidae	Trichodon trichodon
Unidentified Bathymasteridae	Bathymaster signatus
Unidentified Pleuronectiformes	Bothidae
"	Pleuronectidae
Bothidae	Citharichthys sp.
Pleuronectidae and Unidentified Pleuronectidae	Atheresthes stomias
"	Hippoglossus stenolepis
"	Lyopsetta exilis
"	Reinhardtius hippoglossoides
Unidentified Gonatidae	Gonatus sp.
"	Berryteuthis magister
"	Gonatopsis borealis
Unidentified Chiroteuthidae	Chiroteuthis sp.

1/ See appendix table A-1 for more detailed information on taxonomic relationships and a complete list of food items identified in the contents of fur seal stomachs during 1958-74.

2/ Food items listed in appendix table A-1 which are listed as an unidentified family or order category, except the two categories unidentified fish or squid (unidentified Teuthoidea), have been redesignated as the family or order name without the unidentified designation, but not listed in this table (e.g.,Cottidae).

TABLE 3. An example of the two-step method derivation of percentages of modified volume using data on the diet of fur seals off Washington during January, based on data from the contents of stomachs taken during 1958-74 by Canada and the United States. (Original data from Perez and Bigg, 1980, table 14-b)

STEP ONE -- Determine the percentage of fish and cephalopods within the diet.

	Modified frequency of occurrence	
	Number	Percent
Number of stomachs with fish (no traces)	172	81.90
Number of stomachs with cephalopods (no traces)	38	18.10
Sum	210	100.00

STEP TWO -- Calculate the percentage of modified volume for all important food items.

	Original volumetric data		First intermediate data 1/		Second intermediate data 2/		Third intermediate data 3/		Percent modified volume 4/
Food Item	cc	%	cc	%	cc	%	cc	%	%
Fish:									
Lampetra tridentata	325	0.27	325	0.27	325	0.27 (R)	-	-	-
Alosa sapidissima	3659	3.00	3659	3.08	3659	3.08	3659	3.09	2.53
Clupea harengus pallasi	54819	44.95	54819	46.20	54819	46.20	54819	46.33	37.94
Engraulis mordax	6005	4.92	6005	5.06	6005	5.06	6005	5.08	4.16
Unidentified Salmonidae	13006	10.67	13006	10.96	29846	25.15 5/	29846	25.22	20.66
Oncorhynchus spp.	6337	5.20	6337	5.34	-	-	-	-	-
Oncorhynchus gorbuscha	2408	1.97	2408	2.03	-	-	-	-	-
Oncorhynchus keta	295	0.24	295	0.25	-	-	-	-	-
Oncorhynchus kisutch	6273	5.14	6273	5.29	-	-	-	-	-
Oncorhynchus nerka	553	0.45	553	0.47	-	-	-	-	-
Oncorhynchus tshawytscha	780	0.64	780	0.66	-	-	-	-	-
Salmo gairdneri	194	0.16	194	0.16	-	-	-	-	-
Unidentified Osmeridae	10	0.01	10	0.01	-	-	-	-	-
Mallotus villosus	3195	2.62	3195	2.69	3200	2.70 6/	3200	2.70	2.21
Thaleichthys pacificus	3430	2.81	3430	2.89	3435	2.89 6/	3435	2.90	2.38
Merluccius productus	1368	1.12	1368	1.15	1368	1.15	1368	1.16	0.95
Sebastes spp.	8137	6.67	8137	6.86	8137	6.86	8137	6.88	5.63
Anoplopoma fimbria	7854	6.44	7854	6.62	7854	6.62	7854	6.64	5.44
Unidentified	20	0.02	20	0.02 (R)	-	-	-	-	-
Total	118668	97.31	118668	100.00	118668	99.98	118323	100.00	81.90
Cephalopods:									
Loligo opalescens	3206	2.63	3206	97.71	3206	97.71	3206	97.71	17.69
Unidentified Gonatidae	75	0.06	75	2.29	75	2.29	75	2.29	0.41
Total	3281	2.69	3281	100.00	3281	100.00	3281	100.00	18.10
Grand Total	121949	100.00	-	-	-		-	--	100.00

(R) = Removed from analysis of data.

1/ Calculate the percentage of food items within fish and within cephalopods only, not as a percentage of the grand total.

2/ Remove data from unidentified fish and unidentified squid categories if they are not the only food items within fish and cephalopods respectively. Also, lump food items listed in table 2-a, and apportion data of food items in table 2-b to their related component taxa.

3/ Remove food items from analysis for which their percentage value is less than or equal to 1.0%, and reproportion the remaining data percentage values within fish and within cephalopods to sum to 100% each.

4/ Adjust the percentage values of the remaining food items to sum within fish and within cephalopods to the totals for fish and cephalopods determined in step one (modified frequency of occurrence percentages).

5/ This is the result of lumping the component taxa of the family Salmonidae, and the category is now referred to as simply as Salmonidae.

6/ The data of unidentified Osmeridae was apportioned to *Mallotus* and *Thaleichthys* respectively, according to their relative proportions. The total cc of biomass of both species is 6625, or 48.23% for *Mallotus* and 51.77% for *Thaleichthys*. Thus:

Mallotus villosus = 3195 cc + (48.23% X 10 cc = 4.8 cc) = 3199.8 cc
Thaleichthys pacificus = 3430 cc + (51.77% X 10 cc = 5.2 cc) = 3435.2 cc

TABLE 4. Comparison of the results from eight ranking methods using the sum of the absolute differences between the percentage values for each food type, as derived by each method, and the average percentage value for that food type, as derived by averaging their values from all methods. Comparisons were made on 162 combinations of data by region and month.

Ranking Method	Mean	Standard Deviation	Standard Error	95% Confidence Interval
Volume	39.73	21.68	1.70	36.37 - 43.09
Modified volume	34.50	18.01	1.41	31.71 - 37.29
Frequency	47.46	18.07	1.42	44.66 - 50.26
Modified frequency	34.14	20.65	1.62	30.94 - 37.34
Count	44.89	25.74	2.02	40.90 - 48.88
Modified count	44.89	21.98	1.73	41.48 - 48.30
IRI	32.88	15.92	1.25	30.41 - 35.35
Modified IRI	38.35	15.88	1.25	35.89 - 40.81

N=162

TABLE 5. Comparison of the percentages for food types derived from modified volume with those from the seven other methods as based on their percentage of equivalence. Comparisons were made from 115 combinations of data by region and month.

	Percentage of Equivalence				
	Arcsine Transformed Data			Original Data	
Ranking Method	Mean	Standard Deviation	Standard Error	Mean	95% Confidence Interval
Volume	71.39	12.05	1.12	89.42	87.34 - 92.05
Frequency	57.93	11.16	1.04	71.59	68.52 - 74.98
Modified frequency	64.90	9.86	0.92	81.69	79.50 - 84.38
Count	53.88	15.03	1.40	65.10	60.57 - 68.50
Modified count	56.40	13.90	1.30	69.19	65.19 - 73.43
IRI	59.35	12.33	1.15	73.77	70.45 - 77.42
Modified IRI	60.33	11.86	1.11	75.24	72.14 - 78.71
All 8 Ranking Methods Simultaneously Compared	41.81	12.55	1.17	44.50	40.44 - 48.48

N=115

TABLE 6. An example of the application of the results from modified volume to determine the amount of each food item eaten by nonpregnant adult female fur seals off Washington during January.

Food Item	Percent modified volume (%)	Estimated caloric content of prey (Kcal/g)	Percent energy required daily (%) 1/	Energy required daily (Kcal) 2/	Biomass of food consumed (g) 3/
Fish:					
Alosa sapidissima	2.5	1.6	2.4	120	75
Clupea harengus pallasi	37.9	2.0	44.7	2235	1117
Engraulis mordax	4.2	1.8	4.5	225	125
Salmonidae	20.7	1.8	22.0	1100	611
Mallotus villosus	2.2	1.8	2.3	115	64
Thaleichthys pacificus	2.4	1.6	2.3	115	64
Merluccius productus	1.0	1.6	0.9	45	28
Scorpaenidae	5.6	1.6	5.3	265	166
Anoplopoma fimbria	5.4	1.6	5.1	255	159
Cephalopods:					
Loligo opalescens	17.7	1.0	10.4	520	520
Gonatidae	0.4	1.0	0.2	10	10
Total	100.00		100.0	5000	2939

1/ The percent of energy required daily is derived by multiplying the estimated caloric content of prey by the percent modified volume, and reproportioning the results to sum to 100%.

2/ The energy required daily by food item is derived by multiplying the total energy (Kcal) required by the percent energy required daily for that food item.

3/ The biomass of food consumed is derived by dividing the energy required daily for a food item by the estimated caloric content of that food item.

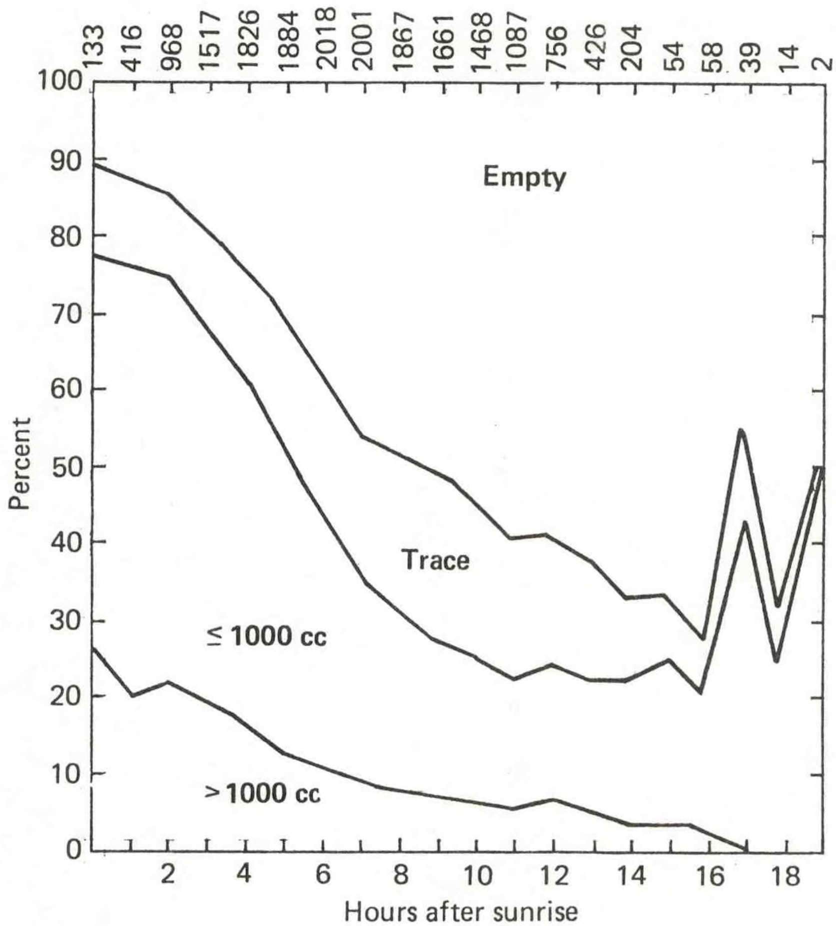

Figure 1. The percent of stomachs containing food in relation to hours after sunrise in the eastern North Pacific Ocean and eastern Bering Sea (combined months) 1958-74. The sample size is shown at the top of the figure. From Perez (1979).

APPENDIX

TABLE A-1.--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurrence (non-trace material).

Taxonomic Group

FISH:[1/] (6501)

Order Petromyzontiformes (Petromyzontia; Hyperoartii)
Petromyzontidae
Lampetra tridentata (Gairdner)--Pacific lamprey
(formerly Entosphenus tridentatus(32)

Order Squaliformes
Squalus acanthias Linnaeus--Spiny dogfish(1)

Order Chimaeriformes (Chimaerae)
Chimaeridae
Hydrolagus colliei (Lay and Bennett)--Spotted ratfish (5)

Order Clupeiformes (1055)
Clupeidae
Unidentified--Family Clupeidae (10)
Alosa sapidissima (Wilson)--American shad (68)
Clupea harengus pallasi Valenciennes--Pacific herring (990)
Engraulidae
Engraulis mordax--Northern anchovy (1155)

Order Salmoniformes (454)
Salmonidae-trouts
Unidentified--Family Salmonidae (109)
Oncorhynchus spp.--Salmon (283)
Oncorhynchus gorbuscha (Walbaum)--Pink salmon (19)
Oncorhynchus keta (Walbaum)--Chum salmon (13)
Oncorhynchus kisutch (Walbaum)--Coho salmon (27)
Oncorhynchus nerka (Walbaum)--Sockeye salmon (6)
Oncorhynchus tshawytscha (Walbaum)--Chinook salmon (12)
Salmo gairdneri (Richardson)--Steelhead (rainbow) trout (4)

Osmeridae--smelts (1205)
Unidentified--Family Osmeridae (31)
Hypomesus pretiosus (Girard)--Surf smelt (10)
Mallotus villosus (Muller)--Capelin (1061)
Thaleichthys pacificus (Richardson)--Eulachon (113)
Bathylagidae--Deepsea smelts (171)
Melanostomiidae (Melanostomiatidae)--Scaleless dragonfishes
Tactostoma macropus Bolin--Longfin dragonfish (Arrow-fish) (1)

TABLE A-1.--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurrence (non-trace material)--continued.

Taxonomic Group

Order Myctophiformes (Iniomi)
- Scopelosauridae
  - Scopelosaurus sp. (1)
- Paralepidae (Paralepididae)
  - Paralepis atlantica Kroyer --Duckbill barracudina (17) (formerly Magnisudis barysoma)
- Myctophidae--Lanternfishes
  - Unidentified--Family Myctophidae (38)
  - Tarletonbeania crenularis (Jordan and Gilbert)--Blue lanternfish (13)
  - Symbolophorus californiensis (Eigenmann & Eigenmann)--California lanternfish (formerly Myctophum californiense) (1)
- Lampanyctus sp. (1) (formerly Lampanyctus nannochir)
- Anotopteridae--Daggertooths
  - Anotopterus pharao Zugmayer--Daggertooth

Order Atheriniformes (Beloniformes; Synentognathi)
- Scomberesocidae--Sauries
  - Cololabis saira (Brevoort)--Pacific saury (351)
- Atherinidae--Silversides
  - Atherinopsis californiensis Girard--Jacksmelt (16)

Order Gadiformes (Anacanthini) (1340)
- Gadidae--Codfishes
  - Unidentified--Family Gadidae (133)
  - Gadus macrocephalus Tilesius--Pacific cod (17)
  - Merluccius productus (Ayres)--Pacific hake (605)
  - Microgadus proximus (Girard)--Pacific tomcod (3)
  - Theragra chalcogramma (Pallas)--Walleye pollock (584)
- Zoarcidae--Eelpouts (1)

Order Gasterosteiformes (Thoracostei; Hemibranchii; Lophobranchii; Solenichthyes)
- Gasterosteidae--Sticklebacks
  - Gasterosteus aculeatus Linnaeus--Threespine stickleback (95)

Order Lampriformes (Allotriognathi, Lampridiformes)
- Trachipteridae--Ribbonfishes
  - Unidentified--Trachipteridae (4)
  - Trachipterus altivelis Kner--King-of-the-salmon (formerly Trachipterus trachypterus (3)

TABLE A-1--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurrence (non-trace material)--continued.

Taxonomic Group
Order Perciformes (Percomorphi; Acanthopterygii)
Carangidae--Jacks and pompanos
Trachurus symmetricus (Ayres)--Jack mackerel (74)
Sciaenidae--Drums (1)
Bramidae--Pomfrets
Brama japonica Hilgendorf--Pacific pomfret (formerly Brama rayi) (5)
Kyphosidae--Sea chubs
Medialuna californiensis (Steindachner)--Halfmoon (4)
Scombridae--Mackerels and tunas
Scomber japonicus Houttuyn--Chub mackerel (formerly Pacific mackerel)
Scorpaenidae--Scorpionfishes (340)
Sebastes spp. (formerly Sebastodes spp.) (326)
Sebastes alutus (Gilbert)--Pacific ocean perch (formerly Sebastodes alutus (6)
Sebastes entomelas (Jordan and Gilbert)--Widow rockfish (formerly Sebastodes entomelas) (2)
Sebastes jordani (Gilbert)--Shortbelly rockfish (8)
Anoplopomatidae--Sablefishes
Anoplopoma fimbria (Pallas)--Sablefish (130)
Hexagrammidae--Greenlings (136)
Unidentified--Family Hexagrammidae (3)
Pleurogrammus monopterygius (Pallas)--Atka mackerel (133)
Cottidae--Sculpins
Unidentified--Family Cottidae (2)
Cyclopteridae--Lumpfishes and snailfishes
Unidentified--Family Cyclopteridae (9)
Aptocyclus ventricosus (Pallas)--Smooth lumpsucker (2)
Trichodontidae--Sandfishes
Unidentified--Family Trichodontidae (1)
Trichodon trichodon (Tilesius)--Pacific sandfish (4)
Ammodytidae--Sand lances
Ammodytes hexapterus Pallas--Pacific sand lance (612)
Bathymasteridae--Ronquils
Unidentified--Family Bathymasteridae (2)
Bathymaster signatus Cope--Searcher (1)
Anarhichadidae--Wolffishes
Unidentified--Family Anarhichadidae (4)
Anarhichas orientalis Pallas--Bering wolffish (3)

TABLE A-1.--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurence (non-trace material)--continued.

Taxonomic Group
Order Perciformes (Percomorphi; Acanthopterygii) continued
Stromateidae--Butterfishes
Tetragonurus cuvieri Risso--Smalleye squaretail (1)
Order Pleuronectiformes (Heterosomata) (139)
Unidentified--Order Pleuronectiformes (1)
Bothidae--Lefteye flounder
Citharichthys sp. (6)
Pleuronectidae--Righteye flounders
Unidentified--Family Pleuronectidae (28)
Atheresthes stomias (Jordan and Gilbert)--Arrowtooth flounder (9)
Hippoglossus stenolepis Schmidt--Pacific halibut (1)
Lyopsetta exilis (Jordan and Gilbert)--Slender sole (3)
Reinhardtius hippoglossoides (Walbaum)--Greenland halibut (Greenland turbot) (91)
Order Batrachoidiformes (Haplodoci)
Batrachoididae--Toadfishes
Porichthys notatus Girard--Plainfin midshipman (8) (formerly Northern midshipman)
Unidentified--Fish (all species, families and orders) (279)
CLASS CEPHALOPODA[2/] (2115)
Order Octopoda--Octopods (5)
Unidentified--Order Octopoda (3)
Family Ocythoidae
Ocythoe tuberculata Rafinesque (2)[3/]
Order Teuthoidea (Decapoda)--Squids (2111)
Unidentified--Order Teuthoidea (includes all unidentified squids)
Suborder Myopsida
Family Loliginidae
Loligo opalescens Berry (316)
Suborder Oegopsida
Family Onychoteuthidae (399)
Onychoteuthis sp. (272)
Onychoteuthis borealijaponicus Okada (171)[4/]
Moroteuthis robusta Verrill (1)
Family Enoploteuthidae
Abraliopsis sp. (9)
Family Octopoteuthidae
Octopoteuthis sp. (1)

TABLE A-1.--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurrence (non-trace material)--continued.

Taxonomic Group
Order Teuthoidea (Decapoda)--Squids--continued.
Suborder Oegopsida continued.
Family Gonatidae (968)
Unidentified--Family Gonatidae (199)
Gonatus sp.
(formerly _Gonatus fabricii_ Lichtenstein) (182)
Berryteuthis magister Berry (491)
(formerly _Gonatus magister_ Berry)
Gonatopsis borealis Sasaki (572)
formerly _Gonatopsis_ sp.)
Family Chiroteuthidae
Unidentified--Family Chiroteuthidae
Chiroteuthis sp. (3)
MISCELLANEOUS:
Class Aves--Birds (19)
Phylum Mollusca--Unidentified (Includes all mollusks not assigned a separate category)
Class Gastropoda
Class Pelecypoda
Phylum Arthropoda
Class Crustacea--Unidentified (includes all crustaceans not assigned a separate category)
Order Amphipoda--suborders Gammaridea and Hyperiidea
Order Isopoda
Orders Caligoida and Lernaeopodoida--Parasitic copepods
Subclass Cirripedia
Unidentified Tube worm
Unidentified Invertebrates (includes all invertebrates not assigned a separate category)
Rocks, pebbles, gravel or sand
Inorganic material--except rocks, pebbles, gravel, sand or hard parts of fish, cephalopods, birds and arthropods
Organic material--undigested material, kelp or other seaweeds

TABLE A-1.--List of fishes, cephalopods, other invertebrates and objects identified in the stomachs of fur seals collected by Canada and the United States in the eastern North Pacific Ocean and Bering Sea. The numbers in parentheses indicate frequency of occurrence (non-trace material)--continued.

Taxonomic Group

1/ Taxonomic classification generally follows that in: "A List of Common and Scientific Names of Fishes from the United States and Canada", Fourth Edition, 1980, American Fisheries Society, Special Publication No. 12; with the exception of the order Myctophiformes, which follows that in: "Deepwater Fishes of California", by J. E. Fitch and R. J. Lavenberg, Univ. of California, Berkeley and Los Angeles, 1968.

2/ Taxonomic classification generally follows that in: "The Systematics and Areal Distribution of Pelagic Cephalods from the Seas off Southern California" by Richard E. Young, Smithsonian Contribution to Zoology, No. 97, Washington, D. C., 1972; and "Review of Gonatidae (Cephalopoda) from the North Pacific", by T. Okutani, Japanese Journal of Malacology, 27(1):31-34, 1968.

3/ Previously identified as Tremoctopus sp.

4/ Previously listed as Onychoteuthis banksii.

This appendix table was originally presented with the numbers of stomachs containing food, including trace occurrences, in Perez (1979).