Exxon Valdez Oil Spill
Restoration Project Annual Report

Isotope Ratio Studies of Marine Mammals in Prince William Sound

Restoration Project 95320I
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this report

Donald M. Schell
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for:

Alaska Department of Fish and Game
Habitat and Restoration Division
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Study History: This project originated as part of the Sound Ecosystem Assessment program conducted by the University of Alaska and the Prince William Sound Science Center. In cooperation with K. Frost of Alaska Department of Fish & Game, we began a stable isotope study of harbor seals and potential prey species in Prince William Sound. T. Kline, then of University of Alaska Fairbanks, was a co-investigator but upon taking a position with the Prince William Sound Science Center, the project was split into two parts, with Kline collecting data on lower trophic levels and this project focusing on harbor seals and prey species as needed. In FY96, this project was separated completely, although we are still responsible for all of the stable isotope analyses run for the PWSSC and UAF. Other stable isotope ratio users are also accommodated as required.

Abstract: Two components of this project include provision of analytical services for the stable isotope ratio investigations associated with EVOS projects and investigation of food web relationships and trophic interactions of harbor seals and other top consumers of Prince William Sound (PWS). Through the use of harbor seal tissues collected from native harvested animals and tagging programs, seasonal and migrational information was obtained regarding prey utilization and trophic status at differing locations within PWS and adjacent Gulf of Alaska. Preliminary results indicate that within PWS, harbor seals fall at the top of food chains based on in situ primary and secondary productivity. Isotope ratios along whiskers grown over the past year indicate that some individuals migrate into areas (Gulf of Alaska, presumably) wherein the food web structure is very different and seals feed at a full trophic level below that in PWS or that the isotope ratios of prey are considerably lower in offshore pelagic waters than within PWS. Current analyses of potential food items in these locations lead us to believe the latter hypothesis is correct. Experiments with captive seals to determine whisker growth rates and body tissue turnover times are underway to calibrate observed changes in the wild.

Key Words: *Exxon Valdez* oil spill, food webs, harbor seals, $\delta^{13}C$, $\delta^{15}N$, isotope ratios, *Phoca vitulina*, Prince William Sound.

Citation:

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EXECUTIVE SUMMARY

This report describes the preliminary results of the study on the food webs supporting harbor seals in Prince William Sound. The integrating methodology for this task is the use of natural stable isotope abundances as tracers of carbon and nitrogen transfers through the food webs. During the past three years, vibrissae (whiskers) and other tissues were collected from harbor seals within Prince William Sound and from the surrounding Gulf of Alaska. Samples were obtained from modern animals and from specimens archived at Alaska Department of Fish and Game, the University of Alaska Museum and the National Marine Mammal Laboratory. One to two long vibrissae were cut or pulled from live animals, while harvested or dead animals had all vibrissae removed for analysis. To date, approximately 100 seals have been sampled and most of these have been analyzed. The data from these vibrissae indicate that each has a temporal record of up to several years which may allow comparisons of interannual changes in feeding. When possible, samples from different organ tissues, e.g. muscle and blubber, were also taken. A variety of tissues from a single animal were analyzed to determine isotopic fractionation among the tissues. This has allowed normalization of isotope data to a single tissue type when samples of only a different type were available.

To enable estimation of the time represented by the growth of a whisker, a captive seal was infused with ^{13}C and ^{15}N -labeled glycine in January 1996. A repeat infusion will be made in May 1996 and in fall a whisker will be pulled for analysis. The added label should be visible in the analyzed whisker and will allow estimation of the vibrissae growth rate. In addition, one seal tagged in fall 1994, was recaptured in spring 1996 and whiskers from both time points were analyzed. This revealed that whisker growth is slower than previously thought and is only about 1.5 cm/year. This implies that in the ten cm or so of typical whisker length, several years of feeding are recorded.

Carbon isotope ratios are used as conservative tracers of energy supply between trophic levels (phytoplankton to zooplankton to fishes to top consumers). To establish the required baseline information, we have collected potential prey species of fishes and other organisms from within Prince William Sound and the adjacent Gulf of Alaska. Our findings, although very preliminary at this point include several interesting indications. Stable isotope ratios within harbor seal vibrissae do not appear to fluctuate greatly or with any regular periodicity, although some seals do have large changes between enriched and depleted values. More often there are minor fluctuations in the $\delta^{13}C$ with somewhat larger fluctuations in the $\delta^{15}N$. These shifts in the nitrogen isotope ratios may reflect seasonal changes in prey availability within a small region. Harbor seals tend to have a strong site fidelity and do not migrate extensively, though some have been tracked over many kilometers within a region.

Samples of zooplankton collected by cooperating investigators reveal that primary productivity is much lower in offshore waters as indicated by depletions in both $\delta^{13}C$ and $\delta^{15}N$. These low values provide a distinctive indicator visible in vibrissae of seals that feed in pelagic regions or on prey that have emigrated from offshore areas. Samples of fatty acids from the seals have been analyzed by K. Frost in a collaborating study and have been found to be very different among regions, supporting the hypothesis that seals in differing parts of the sound have very different food web structures.

Archived samples of harbor seals have been analyzed to determine if the trophic structure of the food webs have changed between the period prior to the decline in population and current years. Our data are show that seals taken in 1995 have a similar range in $\delta^{13}C$ but have split in $\delta^{15}N$ values into two trophic levels. One group of animals remains close to those collected 6 and 20 years previously whereas the other group is almost a full trophic level higher. If food resources are reduced approximately 80-90 percent in going up each trophic level, these seals may be nearing a food-limited base. In contrast, seals from southeastern Alaska showed no apparent change in isotope ratios over the period 1975 - 1995.

A conceptual model of harbor seal feeding has been constructed based on the known isotope ratios in lower trophic levels and fishes, primarily capelin, herring and pollock. Predicted isotope ratios in seals from these food sources match observed $\delta^{15}N$ values closely but the measured $\delta^{13}C$ values are higher than predicted. We hypothesize that benthos, which are usually enriched relative to water column species, are more important than previously believed in the food supply to these seals. Sampling of potential prey species will be a major focus in 1996 and 1997.

INTRODUCTION

This annual report describes the preliminary results of the ongoing study of the food webs supporting harbor seals in Prince William Sound. This project also contributes to the Sound Ecosystem Assessment program being conducted by the Prince William Sound Science Center and the Institute of Marine Science, University of Alaska Fairbanks to describe the food chains supporting important commercial fish species that appear to have been impacted by the *Exxon Valdez* oil spill. In addition, it contributes to the studies by the Alaska Department of Fish and Game personnel to determine the reasons for the decline of harbor seal and Steller sea lion populations in Prince William Sound. The project also seeks to better describe the trophic interactions and trophic status of marine mammals, birds and their prey species. The integrating methodology for this wide range of tasks is the use of stable isotope ratios as natural tracers of carbon and nitrogen transfers through the food webs.

Carbon isotope ratios serve as conservative tracers of energy supply between trophic levels (phytoplankton to zooplankton to fishes to top consumers). Seals, cetaceans, birds, etc., acquire the isotope ratios in proportion to the amount of food derived from each differing source. This, in turn, is reflected in the composition of body tissues and in keratinous tissues (claws, feathers, baleen, whiskers) as a temporal record when multiple sources of food are consumed over time and space. This allows the discerning of important habitats and food resources in animals that seasonally migrate or undergo periods of hyper- and hypotrophy.

Nitrogen isotope ratios reflect both the food sources and the trophic status of that animal. As nitrogen in food is consumed and assimilated by a consumer, the heavy isotope is enriched by approximately 3 ‰ with accompanying loss of the lighter isotope through excretion. The enrichment occurs with each trophic step and thus allows the construction of conceptual models and food webs and the assignment of trophic status to species for which dietary data are sparse. The data obtained from these measurements are unique in that they trace materials actually assimilated and thus can be used for more accurate ecosystem modeling.

It can be postulated that the natural stable isotope abundances of PWS biota will shift because of changes in trophic level, food web structure, and primary productivity in the context of the SEA hypotheses, thus providing an independent tool to verify, quantify and model ecosystem processes. The tracer nature of the approach will enable the integration of ecosystem components. It will enable us to monitor both "top down" (predation) and "bottom-up" (food supply) controls on herring and salmon production.

The project is composed of three elements:

1. A research component on marine mammals focusing on the trophic energetics and ecosystem dynamics of harbor seals conducted by Dr. Schell, PI, in cooperation with ADF&G personnel working as part of the marine mammal program. A smaller additional effort using captive animals to calibrate the responses to changing isotopic composition in diet and to determine vibrissae growth rates is also currently under way

2. A research effort closely tied to the study focusing on lower trophic levels having direct application to the testing of hypotheses regarding fisheries resources. This work is being conducted by Dr. T. Kline of the Prince William Sound Science Center in cooperation with the marine mammal component and is described in the report accompanying this section.

3. As the major isotope ratio analysis facility, we have provided analytical services for carbon and nitrogen isotope ratios to other PI's involved with EVOS studies and assisted with the interpretation of the acquired data. This task has required approximately 20% of the analytical and research effort and is continuing.

The objectives of our section of the isotope study continue to include:

1. Collect and analyze samples of harbor seal vibrissae through continued cooperative work with the Alaska Department of Fish and Game in Prince William Sound;

2. Collect and analyze samples of harbor seal prey species including forage fishes, salmon and herring in the vicinity of major haul-outs and high population densities. Samples of seal tissues will be collected from native hunters. These samples will be obtained through assistance by ADF&G personnel monitoring harvests and through the efforts of T. Kline.

3. Perform stable isotope ratio analyses on tissues and organisms collected during the sampling program. Through the use of **carbon** isotope data on taxa collected over geographical regions, the presence/absence of **isotopic gradients** useful in sorting out habitat dependencies will be determined.

4. Assist other research programs in the Prince William Sound ecosystem study by conducting stable isotope ratio analyses on samples provided and aid the interpretation of results. This effort will require approximately 20% of the analytical and research effort.

5. Through the use of **nitrogen** isotope ratios in collected taxa, assign **trophic status** to species in each region. Compare trophic status with predictive models based on conceptual food webs.

6. Determine temporal changes in harbor seal trophic status and food dependencies by comparing isotope ratios along the lengths of vibrissae with prey availability and their isotope ratios. Through the use of captive animals being fed known diets, establish the relationships between whisker growth rate and temporal changes and the fractionation factors between the $\delta^{13}C$ and $\delta^{15}N$ values of diet and consumer.

7. Compare the isotope-ratio derived food web models to predictions by the "lake-river" hypothesis and others being tested by the SEA project as an independent means of validation.

METHODS

The analytical methodology for stable isotope analysis are described in detail in the accompanying report by T. Kline. Sampling of tissues for stable isotope analysis has been described for both bulk tissues (muscle, blubber) and temporally variable tissues (whiskers, claws, etc.) (Schell, et al. 1989; Michener and Schell, 1994). This report includes only the pertinent sampling protocols and a synopsis of the analytical methods.

Forage Fishes

Lower trophic level organisms within Prince William Sound were obtained by T. Kline and analyzed within the scope of this project. Stable isotope ratios for these species were used to construct food webs for harbor seal foraging within the Sound. Samples of a few additional forage fishes from areas of harbor seal haul-outs have been provided by ADF&G personnel and combined with other lower trophic level organisms to assist in assigning trophic status. National Marine Fisheries Service personnel provided forage species from inshore and offshore waters in Southeast Alaska. Isotopic values for these species are used to indicate if species originating in food webs in southeast waters are being transported via the Alaska Coastal Current into the Sound and once there, being utilized as food by seals. Pelagic and benthic species were sampled during shellfish surveys conducted by ADF&G personnel in the western Gulf of Alaska. These prey are being used as indicators of regional isotopic differences. These regions are used to help locate areas of foraging for seals traveling outside Prince William Sound. A National Marine Fisheries Service triennial survey of the entire Gulf of Alaska will take place during the summer of 1996 and is expected to provide prey for areas where data are lacking.

A few grams of muscle tissue was extracted from several samples of each species at a sampling site. The tissues were frozen in a standard -10° C freezer and transported to the stable isotope facility of analysis. Subsamples of the frozen muscle tissues were dried at 60°C, ground for homogeneity and prepared for mass spectroscopy.

Pinnipeds

During the past three years, vibrissae from harbor seals were collected within Prince William Sound and from the surrounding Gulf of Alaska. One to two long vibrissae were cut or pulled from live animals while harvested or dead animals had all their vibrissae removed for analysis. When possible, samples from different organ tissues, e.g. muscle and blubber, were taken for analysis. A variety of tissues from a single animal are analyzed to determine isotopic segregation among the tissues. This will be useful in the future when only one tissue may be available from a seal or sea lion to determine its spatial and trophic distribution.

Vibrissae and tissues from ninety-eight harbor seals have been or continue to be analyzed for stable isotope ratios. Tissues are dried at 60°C, ground for homogeneity and prepared for mass spectroscopy. Vibrissae are scrubbed with steel wool to remove any debris and segmented from base to tip in 2.5 mm segments. Every other segment was analyzed for carbon and nitrogen isotope ratios and the reserved segments were archived for future reference.

Tissues from Prince William Sound, Southeast Alaska and Kodiak harbor seals have been provided by Alaska Department of Fish and Game personnel working as part of the marine mammal monitoring effort. Alaska Department of Fish and Game researchers have provided archived harbor seal tissues, dating from the mid-1970s, for stable isotope comparisons. These comparisons are essential in determining if a dietary shift in harbor seals occurred during the past two decades. The University of Alaska Museum is providing bone tissue from harbor seals from various regions of the Gulf of Alaska from the 1950s to present. The stable isotope ratios of these tissues are being used to compare and contrast to the stable isotope ratios of present samples. By obtaining seal tissues from multiple regions prior to the population decline (pre-1970), any significant changes in these ratios may be an indication of changes in ecosystem productivity over the past several decades.

Analytical Techniques

The samples obtained are dried and powdered for homogeneity and the isotope ratios of carbon and nitrogen determined with a Europa 20/20 mass spectrometer system. The sample is combusted at high temperature and the nitrogen and carbon dioxide gases separated and purified by gas chromatography. These are subsequently led into the mass spectrometer by capillary and the isotope ratios determined. Results are reported in the standard $\delta^{13}C$ and $\delta^{15}N$ notation.

Captive Animal Studies

Vibrissae growth rate studies were initiated with captive harbor seals to determine if growth rates fluctuate with season, age and, ultimately, diet. An adult harbor seal at Mystic Aquarium in

Connecticut was administered 16 ml of doubly-labeled glycine ($\delta^{13}C$ and $\delta^{15}N$) over a two day period. The sudden increase in ^{13}C and ^{15}N, which was expected to be incorporated by the vibrissae, is expected to create a marked peak in these values corresponding to the time of infusion. This will be used as a marker to establish the growth rate after that time. After four months a second dose of doubly-labeled glycine will be administered (May 1996) and after three additional months, one whisker will be removed for stable isotope analysis. The peaks caused by the labeled amino acid additions should be reflected in the stable isotope ratios along the whisker. The positions of these peaks will be measured and a growth rate established. A second whisker will be analyzed after the subsequent six month period to determine if growth rate is constant throughout the year.

A second type of growth rate experiment is being conducted simultaneously at the Vancouver Aquarium on a captive adult harbor seal and subadult Steller sea lions. A short, anterior whisker and a longer posterior whisker from the muzzle have been cut and are being measured periodically. All segments will be analyzed for their stable isotope ratios in the near future. Phocids and otariids are being fed a similar diet. These data are not yet available in sufficiently complete form for inclusion in this report.

PRELIMINARY RESULTS

Isotope Ratio Variations in Harbor Seals

To date, samples from approximately 100 harbor seals have been analyzed and are listed in Table 1 with the average isotope ratio values from vibrissae. In addition, samples of tissue from archived seals have been used to compare isotope ratios in the pre-decline period with those from current samples. The results are described and shown below. The isotopic data from seal vibrissae from collected within Prince William Sound are shown in Appendix A. These illustrate the $\delta^{13}C$ and $\delta^{15}N$ values at 0.25 cm intervals along the lengths of the whiskers. These samples were collected during tagging operations in Prince William Sound and from native harvested seals. At this point only a few generalizations can be made. Male seals show relatively constant values over the time span represented by the length of the whisker whereas several of the female animals showed a marked change in isotope ratios of both carbon and nitrogen during the same length of time. The cause of this shift currently is not known, but data on zooplankton from the Bering Sea indicate that a major geographic gradient exists between on-shelf and deep water regions with samples from deep water having much more depleted values for both $\delta^{13}C$ and $\delta^{15}N$. Whether this is also true of the Gulf of Alaska is not known but the sampling program for summer 1996 is being designed to test if the same is true south of Montague and Hinchinbrook Islands. Data on large calanoid copepods collected by T. Kline in 1995 appear to validate this hypothesis.

Table 1. Harbor seal vibrissae from Prince William Sound and adjacent regions. Age designation refers to adult (A), pup (P) or subadult (SA) seals. Samples for which data are not reported are currently being analyzed.

Harbor Seal	Sample Date	Sex	Age	Range $\delta^{13}C$	avg. $\delta^{13}C$	Range $\delta^{15}N$	avg. $\delta^{15}N$
HSA1PWS	7 May 1993	M	A	-14.8 to -13.9	-14.5	18.1 to 19.5	18.8
HSA2PWS	7 May 1993	F	SA	-16.2 to -14.8	-15.4	15.3 to 19.0	17.7
HSA3PWS	7 May 1993	M	A	-15.8 to -14.8	-15.2	17.3 to 17.9	17.5
HSA4PWS	7 May 1993	M	A	-16.5 to -15.0	-15.9	15.8 to 17.9	16.7
HSA5PWS	7 May 1993	F	SA	-16.0 to -15.4	-15.8	15.8 to 18.8	17.1
HSA6PWS	8 May 1993	F	SA	-16.4 to -15.0	-15.9	15.4 to 16.7	16.1
HSA7PWS	8 May 1993	F	A	-16.4 to -15.2	-15.7	15.8 to 16.7	16.2
HSA8PWS	8 May 1993	M	SA	-15.7 to -15.2	-15.4	15.5 to 17.9	16.4
HSA9PWS	8 May 1993	M	A	-15.3 to -14.7	-15.0	16.9 to 18.7	17.5
HSA10PWS	8 May 1993	M	SA	-15.6 to -15.1	-15.3	18.1 to 19.2	18.6
HSA11PWS	9 May 1993	M	A	-15.1 to -14.7	-14.9	16.3 to 17.9	16.8
HSA12PWS	9 May 1993	M	SA	-15.2 to -14.2	-14.6	16.1 to 19.3	18.5
HSA13PWS	9 May 1993	F	SA	-16.3 to -16.0	-16.1	15.8 to 17.1	16.4
HSB1PWS	26 April 1994	F	SA	-17.1 to -15.7	-16.4	14.7 to 16.7	15.8
HSB2PWS	27 April 1994	M	SA	-16.6 to -15.7	-16.2	15.2 to 17.3	16.1
HSB3PWS	27 April 1994	F	A	-16.5 to -12.6	-14.6	13.4 to 18.0	16.0
HSB4PWS	27 April 1994	M	SA	-16.2 to -15.3	-16.1	15.8 to 16.6	16.1
HSB5PWS	27 April 1994	M	A	-17.9 to -17.0	-17.5	14.0 to 15.9	14.9
HSB6PWS	28 April 1994	M	A	-17.6 to -15.8	-16.6	13.3 to 16.2	15.0
HSB7PWS	28 April 1994	F	A	-17.8 to -12.5	-15.2	13.7 to 17.4	15.6
HSB8PWS	28 April 1994	M	SA	-17.7 to -15.5	-16.3	13.7 to 16.9	15.6
HSB9PWS	28 April 1994	M	SA	-18.1 to -16.4	-17.1	13.6 to 16.8	15.4
HSB10PWS	28 April 1994	M	A	-17.7 to -14.5	-15.8	15.2 to 17.8	16.2
HSB11PWS	18 Sept. 1994	F	A	-17.9 to -16.3	-17.1	14.7 to 17.1	15.4
HSB12PWS	18 Sept. 1994	F	SA				
HSB13PWS	18 Sept. 1994	M	SA				
HSB14PWS	18 Sept. 1994	M	A	-17.2 to -16.1	-16.6	14.8 to 16.1	15.4
HSB15PWS	18 Sept. 1994	F	SA	-17.0 to -13.2	-15.2	15.8 to 18.9	17.7
HSB16PWS	18 Sept. 1994	F	SA	no vibrissae			
HSB17PWS	18 Sept. 1994	M	SA	-16.6 to -15.5	-15.9	15.5 to 16.3	15.9
HSB18PWS	18 Sept. 1994	M	SA	-16.6 to -16.1	-16.3	15.6 to 17.0	16.2
HSB19PWS	18 Sept. 1994	M	SA	-16.8 to -16.2	-16.4	15.5 to 16.5	16.0
HSB20PWS	18 Sept. 1994	F	SA	-16.5 to -15.8	-16.1	16.1 to 17.2	16.7
HSB21PWS	18 Sept. 1994	M	SA	-17.0 to -14.5	-15.8	15.6 to 17.1	16.4
HSB22PWS	18 Sept. 1994	M	SA	-18.2 to -13.5	-15.1	15.4 to 19.2	17.5
HSB23PWS	18 Sept. 1994	M	A	-17.9 to -16.2	-17.6	14.0 to 15.4	14.4
HSB24PWS	19 Sept. 1994	F	A	-16.1 to -15.6	-15.9	15.6 to 16.8	16.3
HSB25PWS	19 Sept. 1994	F	P	-17.5 to -14.2	-15.1	16.6 to 17.9	17.1
HSB26PWS	19 Sept. 1994	M	SA	-16.5 to -16.0	-16.3	15.0 to 16.6	15.5
HSB27PWS	22 Sept. 1994	F	A	-17.3 to -13.9	-15.4	14.9 to 17.5	16.4
HSB28PWS	22 Sept. 1994	M	A	-17.5 to -15.6	-16.4	14.6 to 16.4	15.7
HSB29PWS	22 Sept. 1994	M	P	-16.7 to -15.2	-15.9	17.5 to 19.2	18.4
HSB30PWS	22 Sept. 1994	F	A	-17.8 to -15.2	-16.9	14.5 to 16.8	15.2
HSB31PWS	22 Sept. 1994	F	SA	-17.7 to -16.1	-16.8	14.6 to 16.7	15.7
HSB32PWS	22 Sept. 1994	F	A	-17.8 to -13.8	-16.1	14.3 to 17.1	15.5
HSB33PWS	22 Sept. 1994	F	SA	-17.8 to -14.3	-16.4	14.7 to 16.6	15.9

Table 1. (Continued)

HSB34PWS22 Sept. 1994MA-17.2 to -14.4-15.3 14.7 to 17.2 16.0
HSB35PWS22 Sept. 1994FA-18.1 to -15.6-16.8 15.0 to 17.4 15.9
HSB36PWS22 Sept. 1994MA-17.9 to -16.8-17.6 14.5 to 16.2 15.1
TATHS1PWS27 Sept. 1994FSA-18.1 t -16.7-17.5 14.4 to 17.8 15.8
TATHS2PWS29 Sept. 1994FSAno vibrissae
TATHS3PWS29 Sept. 1994FA-17.5 to -15.5-17.0 14.3 to 17.1 14.9
TATHS4PWS30 Sept. 1994MA-16.4 to -16.1-15.6 16.1 to 18.7 17.3
TATHS5PWS30 Sept. 1994MA-17.9 to -15.7-16.4 14.4 to 16.1 15.6
TATHS6PWS1 Oct. 1994FP-17.8 to -16.1-16.5 16.0 to 18.3 16.8
TATHS7PWS1 Oct. 1994MP-17.8 to -14.9-15.7 14.3 to 19.8 17.5
HSC1PWS9 May 1995MSA-17.3 to -15.5-16.1 15.3 to 17.6 16.3
HSC2PWS9 May 1995MSA-17.5 to -13.4-14.9 14.6 to 20.0 17.9
HSC3PWS9 May 1995MSA
HSC4PWS9 May 1995MSA-17.5 to -16.1-16.6 14.1 to 17.2 15.8
HSC5PWS9 May 1995MSA-17.5 to -15.6-16.2 14.6 to 16.9 15.8
HSC6PWS11 May 1995FSA-17.2 to -15.4-16.2 15.3 to 16.8 16.1
HSC7PWS11 May 1995MSA-17.6 to -15.1-16.2 14.2 to 16.9 15.7
HSC8PWS11 May 1995FA-17.8 to -14.3-16.4 14.1 to 16.8 15.3
HSC9PWS11 May 1995FSA-18.0 to -15.1-15.9 16.5 to 18.8 17.8
HSC10PWS11 May 1995MSA-17.2 to -12.8-14.1 16.0 to 18.9 17.9
HSC11PWS11 May 1995FSA-15.0 to -13.7-14.3 16.7 to 17.3 17.0
HSC12PWS11 May 1995MA-16.5 to -16.0-16.1 15.6 to 16.9 16.2
HSC13PWS11 May 1995FSA
HSC14PWS11 May 1995MA
HSC15PWS12 May 1995MA
HSC16PWS12 May 1995MA
HSC17PWS12 May 1995FSA
HSC18PWS12 May 1995MSA
HSC19PWS12 May 1995FSA
HSC20PWS14 May 1995FA
HSC21PWS14 May 1995FSA
HSC22PWS14 May 1995MSA
HSC23PWS25 Sept. 1995FSA
HSC24PWS25 Sept. 1995FP
HSC25PWS26 Sept. 1995FSA
HSC26PWS26 Sept. 1995FA
HSC27PWS26 Sept. 1995FA
HSC28PWS26 Sept. 1995MSA
HSC29PWS26 Sept. 1995MSA
HSC30PWS26 Sept. 1995FA
HSC31PWS26 Sept. 1995MA
HSC32PWS26 Sept. 1995MA
HSC33PWS26 Sept. 1995FSA
HSC34PWS26 Sept. 1995FSA
HSC35PWS26 Sept. 1995FP
HSC36PWS26 Sept. 1995FSA
HSC37PWS27 Sept. 1995MA
HSC38PWS27 Sept. 1995FA
HSC39PWS27 Sept. 1995FSA
HSC40PWS27 Sept. 1995MA
HSC41PWS28 Sept. 1995MSA
HSC42PWS28 Sept. 1995MSA

Benthic and pelagic organisms have been from Southeastern Alaska have been provided by National Marine Fisheries personnel for analysis of isotope ratios. These samples will provide data on the isotope ratios in potential prey from that region which is essentially "upstream" of Prince William Sound in the Alaska Coastal Current. This information may help in the interpretation of the often large excursions in isotope ratios evident in several of the vibrissae collected from female seals. Further samples from offshore waters in the Gulf of Alaska will be available following the NMFS Triennial Groundfish Survey scheduled for summer 1996. Personnel on this cruise have agreed to provide us with subsamples from catches.

Stable isotope ratios within harbor seal vibrissae do not appear to fluctuate greatly or with any regular periodicity, although some seals do have large changes between enriched and depleted values. More often there are minor fluctuations in the $\delta^{13}C$ with somewhat larger fluctuations in the $\delta^{15}N$. These shifts in the nitrogen isotope may be seasonal changes in prey availability within a small region. Harbor seals tend to have a strong site fidelity and do not migrate extensively, though some have been tracked over many kilometers within a region.

Results are still pending in regards to the rate at which vibrissae grow. A harbor seal who had a vibrissae sampled in September 1994 was recaptured and, subsequently, resampled in April 1995 in Southeast Alaska (Figure 3). During that seven month period, the vibrissae on this adult seal grew 1.5 cm. This time period was during the winter months and the seasonal physiology of these animals, excluding parturition, is relatively unknown. Therefore, it is unknown if this measured growth rate is constant throughout the year or if it varies with season. Major inflection points along the length of the two vibrissae match and may be subtle demarcations of season. They may coincide with shifts in the predominate prey species or a change in environmental productivity. Low primary productivity will result in depleted carbon and nitrogen isotope ratios (Laws et al. 1995).

Archived Seal Samples

Archived muscle tissues from Prince William Sound harbor seals were compared with recently sampled vibrissae from animals of the same region (Figure 4). Stable isotope values for muscle tend to most accurately reflect the stable isotope ratios for the whole animal (DeNiro and Epstein 1978). The fractionation of ^{13}C during formation of keratin in the vibrissae was determined by analyzing both muscle and vibrissae from the same animals. Subsistence harvest harbor seals were used from Southeast Alaska. The average $\delta^{13}C$ values for vibrissae were found to be typically enriched by 1.3 ppt relative to muscle from the same seal. The average $\delta^{13}C$ values in seals increased by 0.2 ppt between 1975 and 1989 and by another 0.2 ppt between 1989 and 1995.

Isotope Ratios in Prey Species

The Prince William Sound prey plot (Figure 1) was created using the stable isotope values for phytoplankton, zooplankton, juvenile and adult herring, juvenile and adult pollock and harbor seals. Hypothetical seals were added to the plot to depict seals feeding primarily on herring and the other primarily on adult pollock. The actual $\delta^{15}N$ values for harbor seals in the Sound represent the anticipated trophic step from herring and juvenile pollock but the $\delta^{13}C$ is greater than expected for either species. Similar to work done in the Bering Sea, areas of the Gulf of Alaska are being refined into smaller, isotopic regions to better define feeding areas for traveling phocids or transport of prey into Prince William Sound (Figure 6).

Harbor seals do not migrate extensively but some have been tracked over many kilometers within a region. Harbor seal isotope ratios are often more enriched in ^{13}C than anticipated from common prey in the regions in which they live. The source(s) of these enriched values may be from offshore prey moving into the environment or from benthic prey which are often enriched relative to pelagic prey. We are currently analyzing potential prey species from these environments.

Figure 6 compares the isotope ratios in the seal whiskers with the values found for potential prey and other species resident in Prince William Sound. The values for most of the samples indicate that the seals fit the expected trophic enrichments in $\delta^{15}N$ and closely match the $\delta^{13}C$ of Prince William Sound prey. However, the most enriched values present in the females do not match prey from Prince William Sound but have depleted $\delta^{15}N$ values that may result from migration into deep water feeding areas outside of the Sound. Determination of the causes for these variations is part of the focus for 1996-7.

Captive Animal Studies

Through cooperation with Keith Hobson of the Canadian Wildlife Service, we were able to acquire whiskers from two harp seals that had been held in captivity and fed known diets of herring. The whiskers from these animals were analyzed along their lengths and are being compared with the isotopic composition of the diets. This work is almost complete. Preliminary results indicate that the seals closely reflect the diet, remaining within 1.5‰ in carbon and within approximately the same range in $\delta^{15}N$ but showing the expected 3‰ trophic enrichment. The data from this experiment has been assembled into a manuscript upon completion of the remaining diet and tissue samples. Other experiments using Steller sea lions are being conducted on a related project and the data from those experiments should prove useful in helping us interpret the seal data as the sea lions continue to grow their whiskers over multiple years. Harbor seals were assumed to shed their whiskers during the annual molt but our data indicates this is not true and that whiskers may represent a multiyear record of feeding.

Isotope Ratios in Potential Prey

The wide selection of potential prey items in Prince William Sound that may be consumed by harbor seals have been collected over the past field seasons or was obtained from archived samples. These data are reported by T. Kline as part of the SEA program conducted by the Prince William Sound Science Center. Samples of harbor seal prey species including forage fishes, salmon and herring in the vicinity of major haul-outs and high population densities have been collected by us and are currently being analyzed.

Interactions with Other Studies

Our main cooperative work has been with K. Frost of the Alaska Department of Fish and Game in conjunction with their tagging and physiology studies in harbor seal. This work will be reported by that study component and is only briefly described here. Samples of seal blubber have been analyzed for fatty acid composition to estimate the sources of food being passed up the food chain. This work has found sharp changes in fatty acid composition across relatively short geographical distances and between seals captured in Prince William Sound and offshore. As a potentially excellent means of independent validation of the trophic insights gained from stable isotope ratios, we are working closely with this project.

The interaction with the modeling component of the SEA program will intensify during the months ahead. As more data are acquired, we will be able to test model assumptions and predictions by independent comparison using the isotopic model as a validation measure. Although similar carbon isotope labels in different members of the marine community may be indistinguishable, the trophic changes predicted will lead to testable shifts in the isotope ratios of nitrogen.

To date the interaction with other studies on top consumers has been limited to the acquisition of whiskers from archived carcasses of sea otters and sea birds. Following the analysis and interpretation of these samples in 1996, further investigations will be planned linking the top consumers of Prince William Sound into an ecosystem trophic model. Currently available data are being synthesized by the principal investigators and will be reported by them.

CONCLUSIONS

The three aspects addressed by this program are progressing well and there are no perceived reasons for alteration of the scope of work at this time.

Captive seal studies: Data are not yet available to establish absolute whisker growth rates on seals at this time. The experiments are ongoing and will be concluded over the next year. Recapture of a tagged seal has yielded a single animal growth rate of approximately 2 cm/year.

Analytical services for stable isotope ratio determinations: The mass spectrometry service has had full usage by this project, the SEA program and other EVOS projects supporting sea otter and sea bird studies. At six months into the fiscal year, over 4000 samples have been run and a new backlog is building as the spring field season gets underway. No serious machine problems have arisen during the past six months and all data have been made available to the P.I. and collaborators in a timely manner.

Harbor seal trophic energetics: The seal tissues available are now largely analyzed and the data sets are in the process of analysis. The comparisons of archived and modern seal tissues indicate that modern seals in Prince William Sound have separated trophically into two distinct groups. We are not prepared to state the reasons for this separation until a comprehensive analysis of prey data has been completed. This will require coordination with the stable isotope aspects of the SEA program. From models of trophic transfers we note that there is strong suggestion that the seals are relying on a largely benthic-derived diet, but potential prey data for benthos are still largely unsampled. Summer 1996 sampling will focus on filling this data gap. Fatty acid composition information on the same seals from which our samples were taken is now being compiled by K. Frost of ADF&G. These data will assist in attempting to detail the food web structure in different regions within Prince William Sound.

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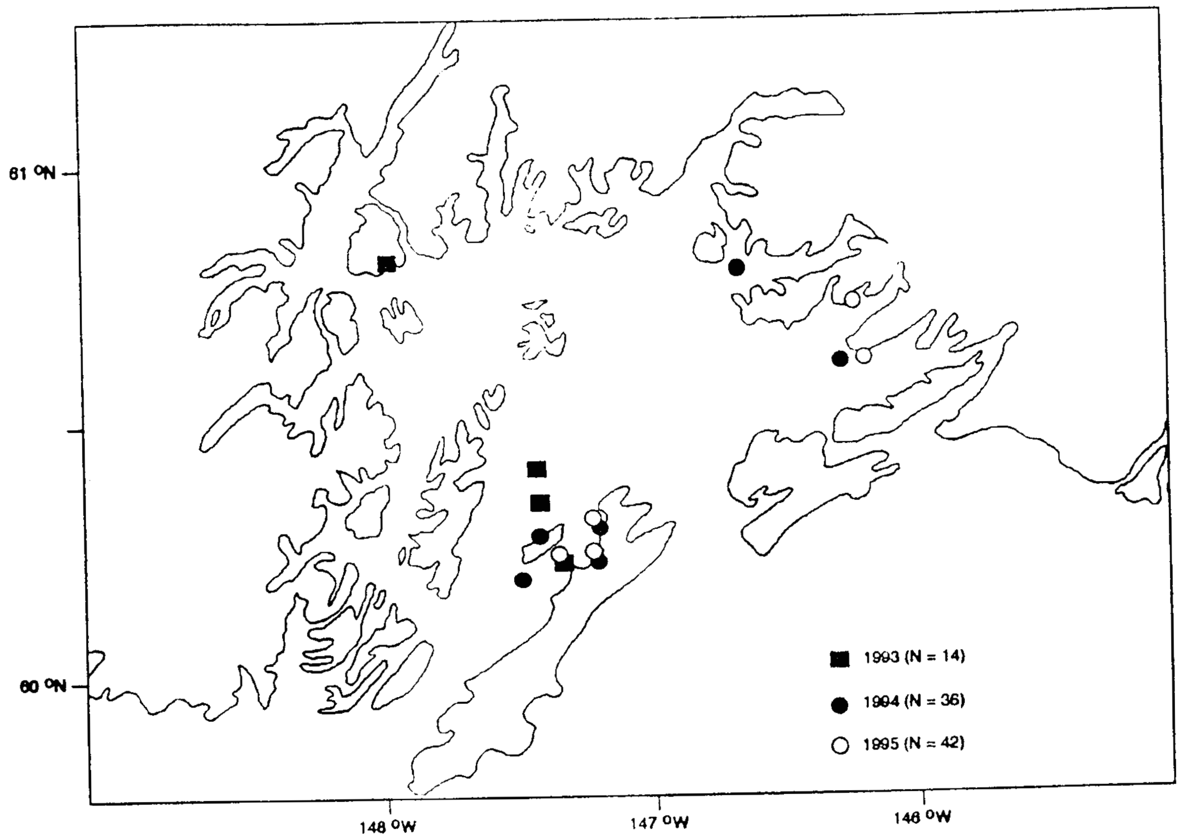


Figure 1. Sample locations for harbor seals in Prince William Sound, 1993-1995.

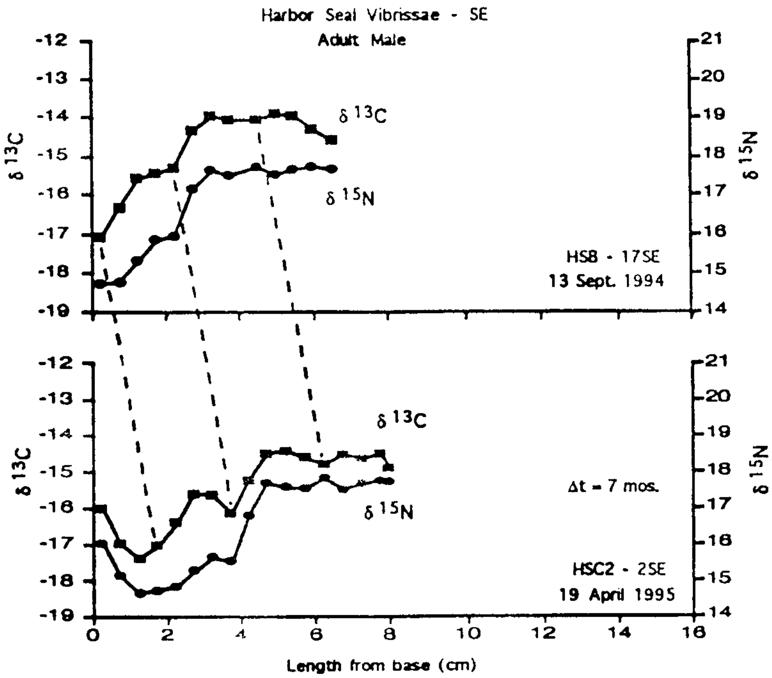


Figure 2. Vibrissae from the same recaptured harbor seal sampled in southeast Alaska. Vibrissae sampled in September 1994 (upper plot) are contrasted with a vibrissae taken from the seal seven months later (lower plot).

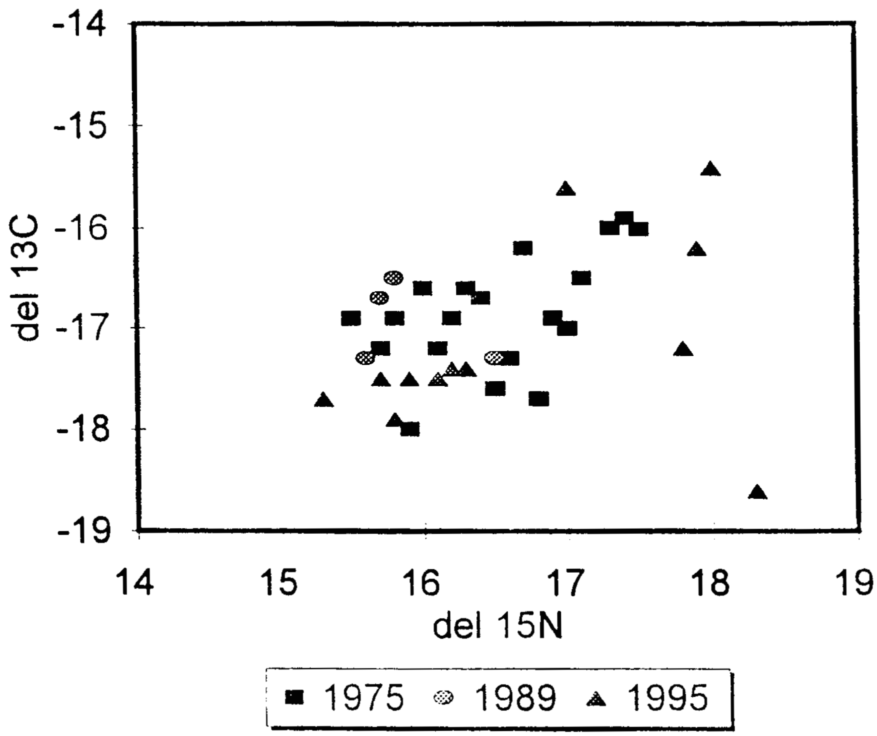


Figure 3. Archived harbor seal muscle tissue (1975, 1989) and vibrissae (1995). Vibrissae have been adjusted to muscle by -1.3°/oo enrichment.

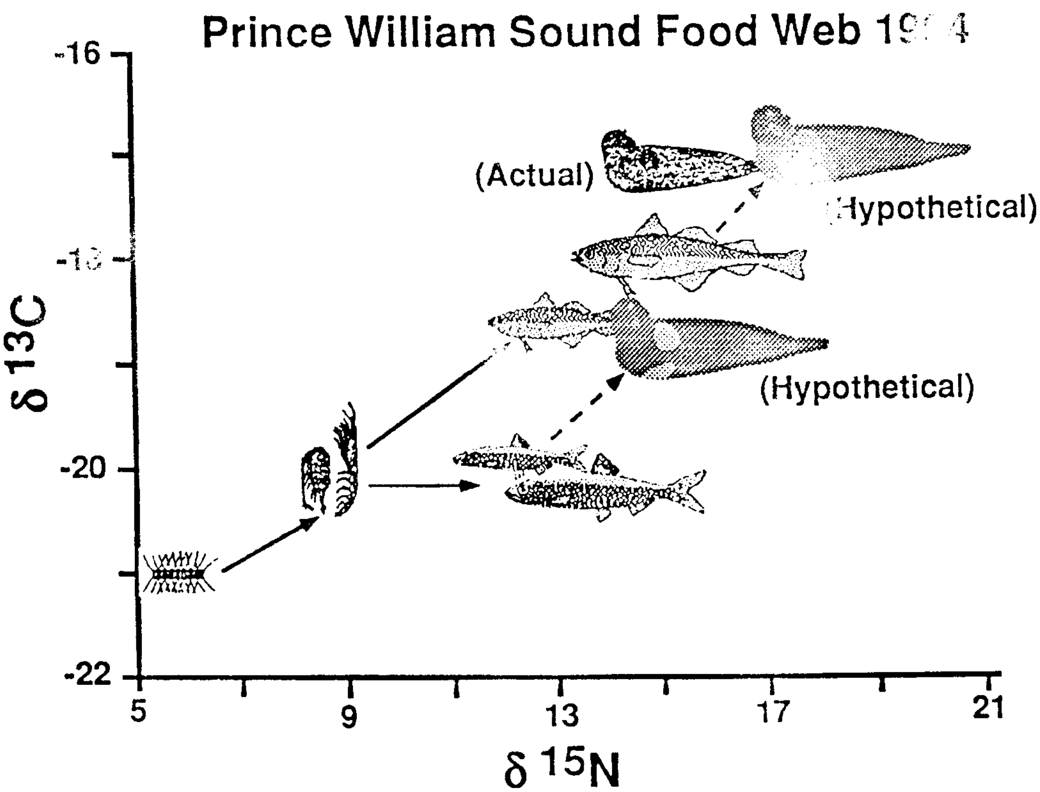


Figure 4. Hypothetical food web for harbor seals in Prince William Sound using carbon and nitrogen isotope ratios for calanoid copepods, juvenile and adult herring and juvenile and adult pollock.

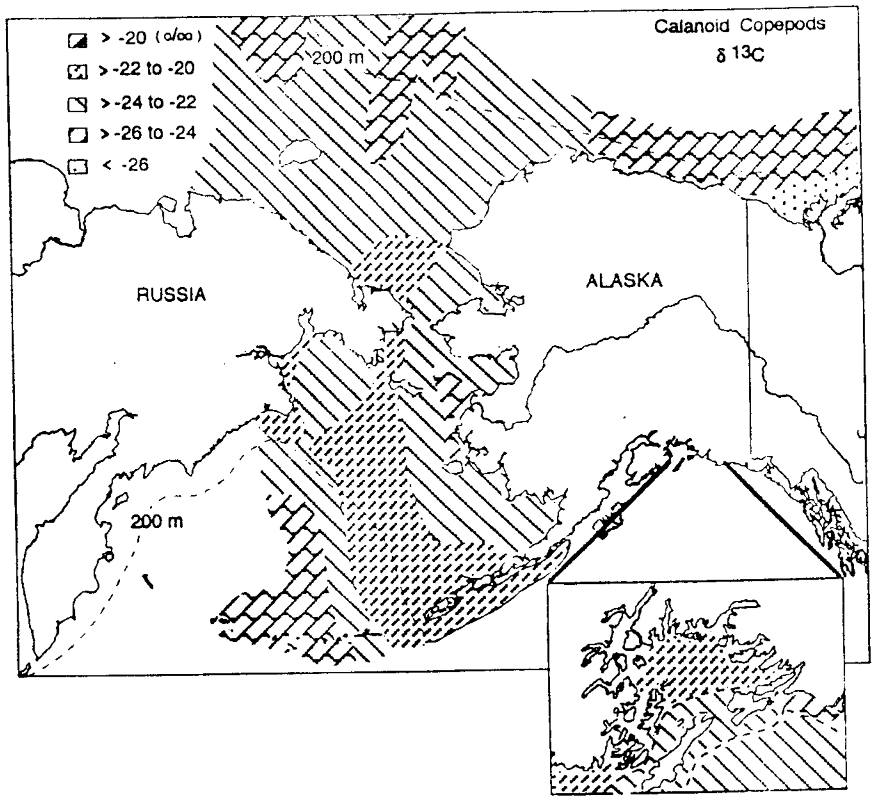


Figure 5. $\delta^{13}C$ isotope contours for calanoid copepods in the Bering and Chukchi seas. The Prince William Sound insert shows estimated contours based on analyzed lower trophic level organisms.

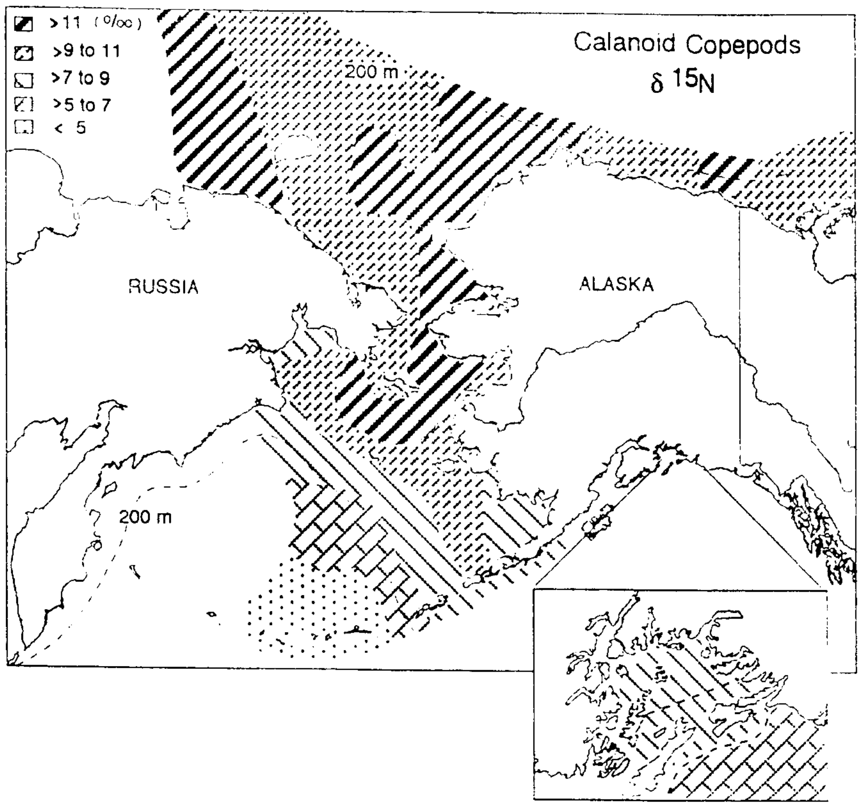
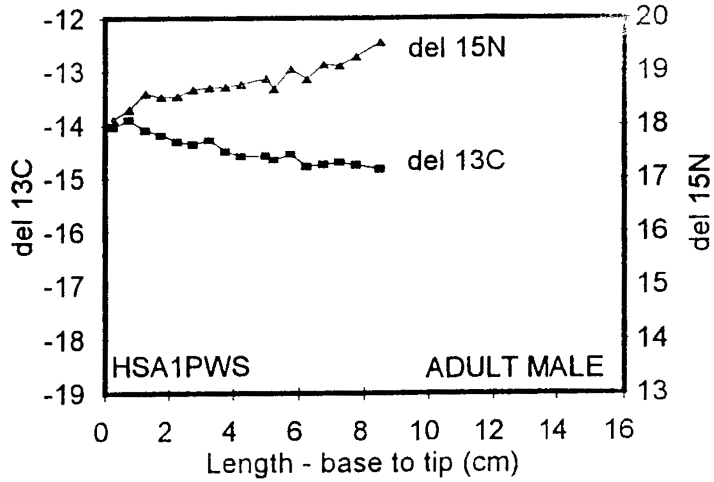
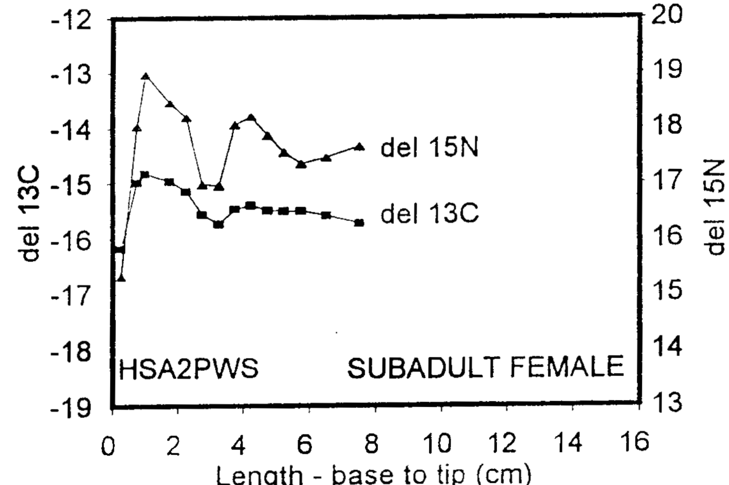


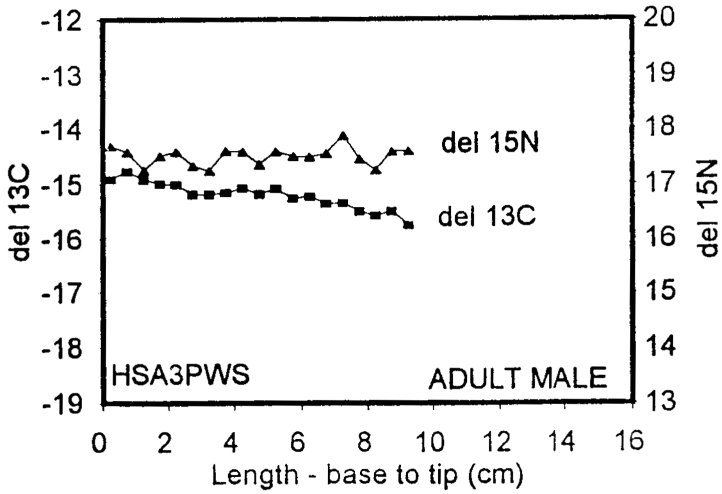
Figure 6. $\delta^{15}N$ isotope contours for calanoid copepods in the Bering and Chukchi seas. The Prince William Sound insert shows estimated contours based on analyzed lower trophic level organisms.

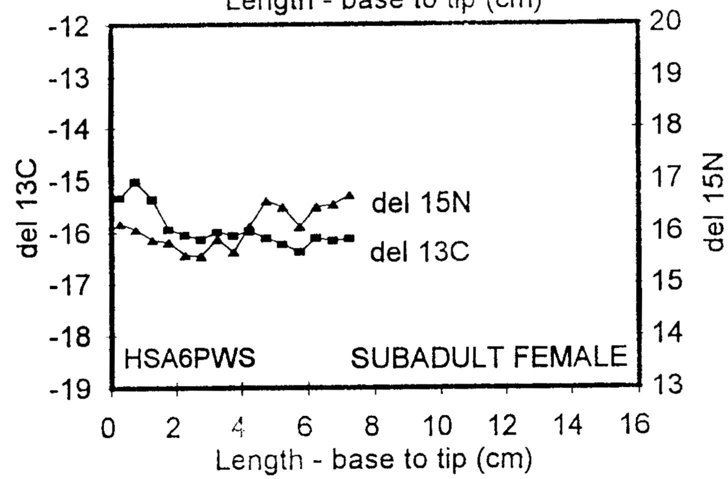
Appendix I.

SEAL ISLAND, PWS   MAY 1993



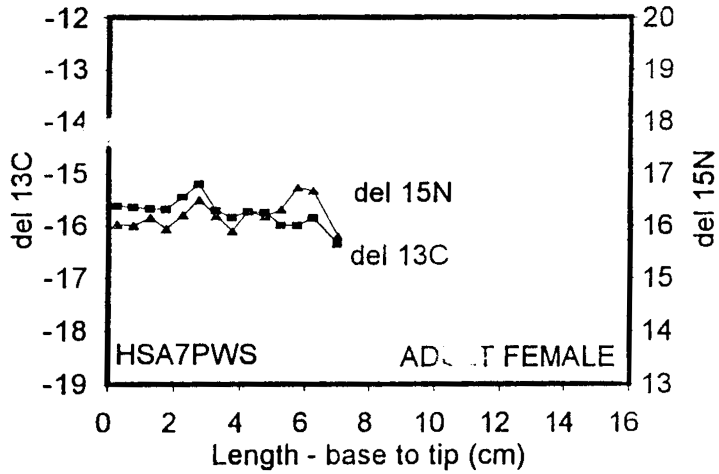


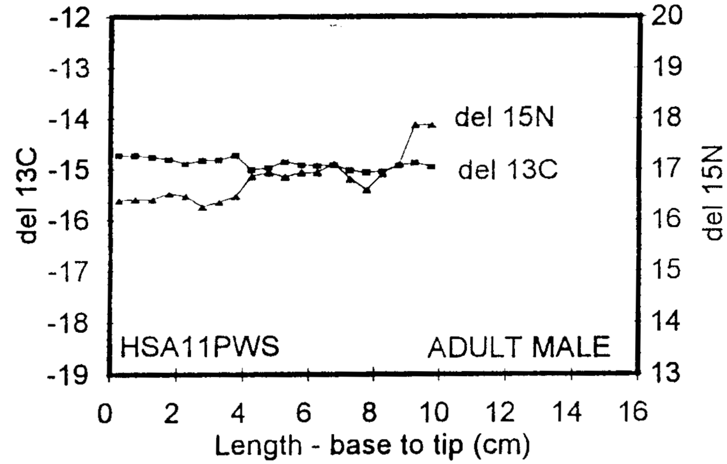


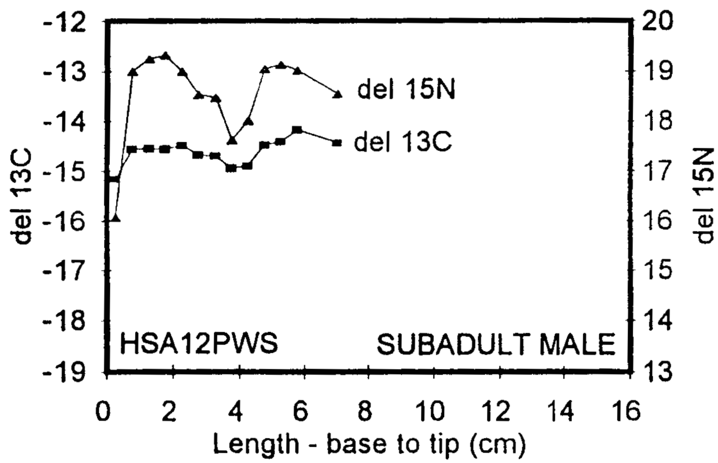


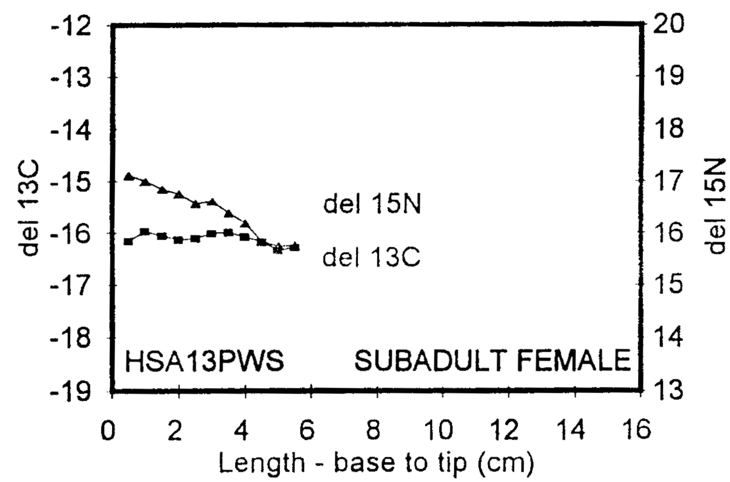
Appendix I.

SEAL ISLAND, PWS MAY 1993



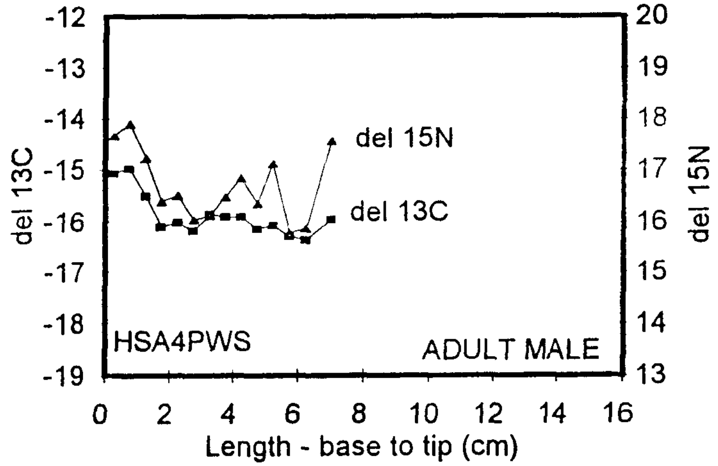


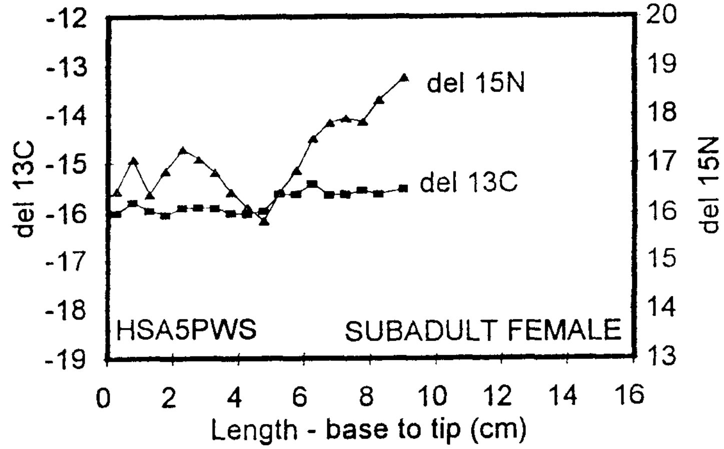


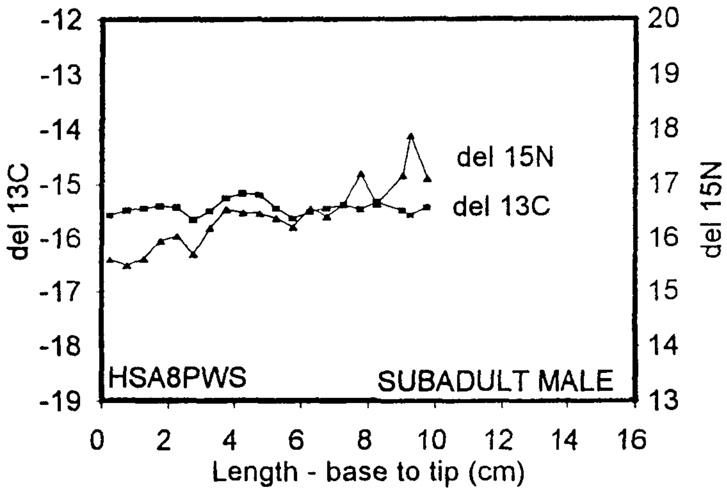


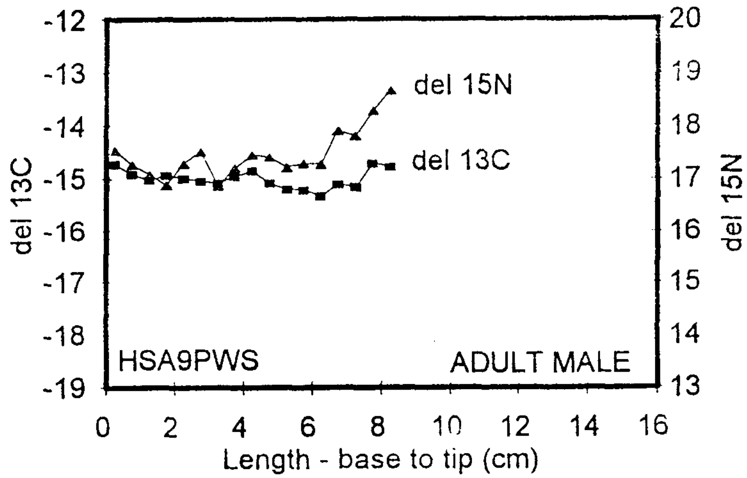
Appendix I.

APPLEGATE ROCKS, PWS   MAY 1993



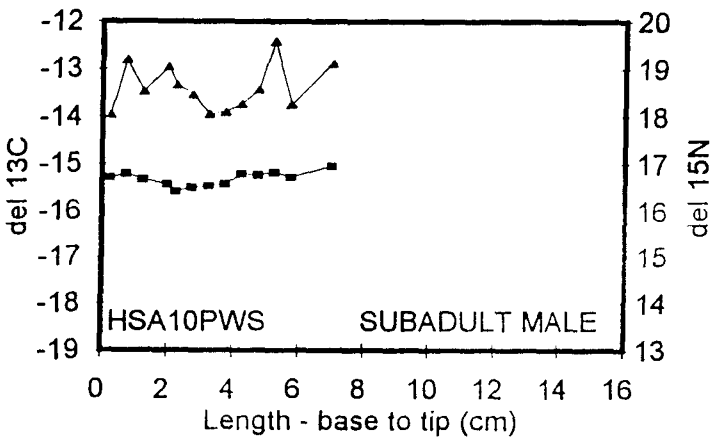






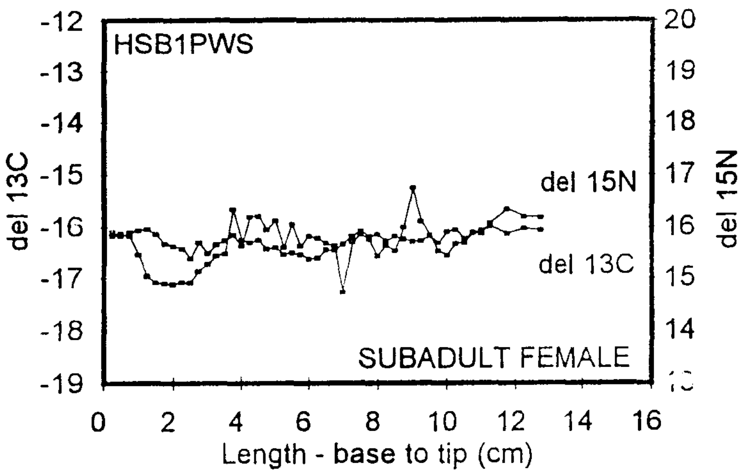
Appendix I.

APPLEGATE ROCKS, PWS MAY 1993



Appendix I.

GREEN ISLAND, PWS APRIL 1994



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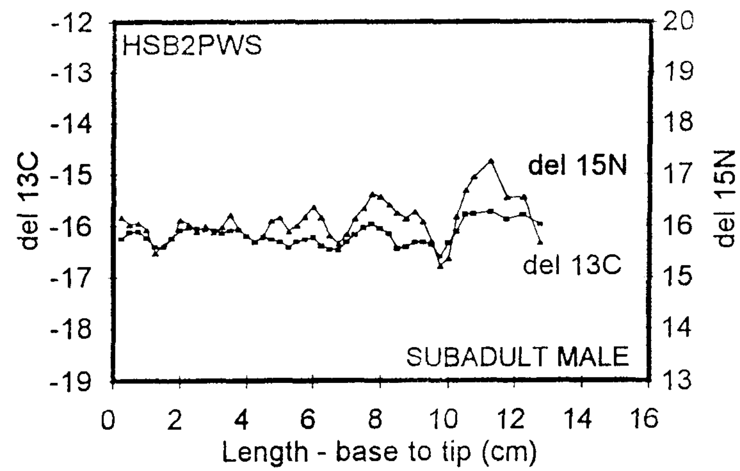
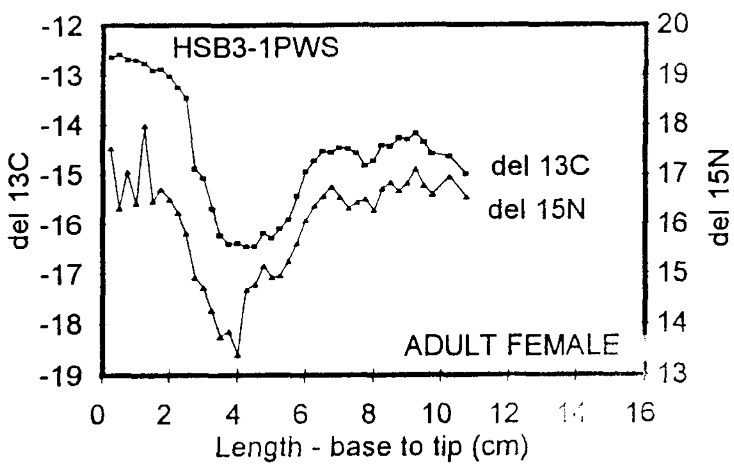
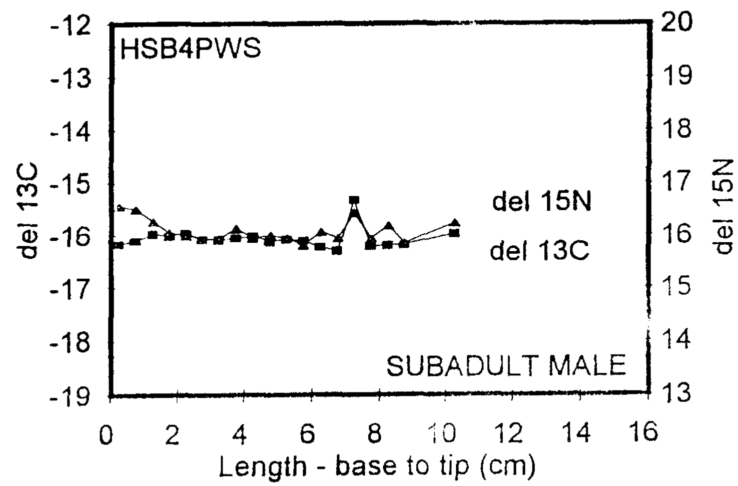


Appendix I.

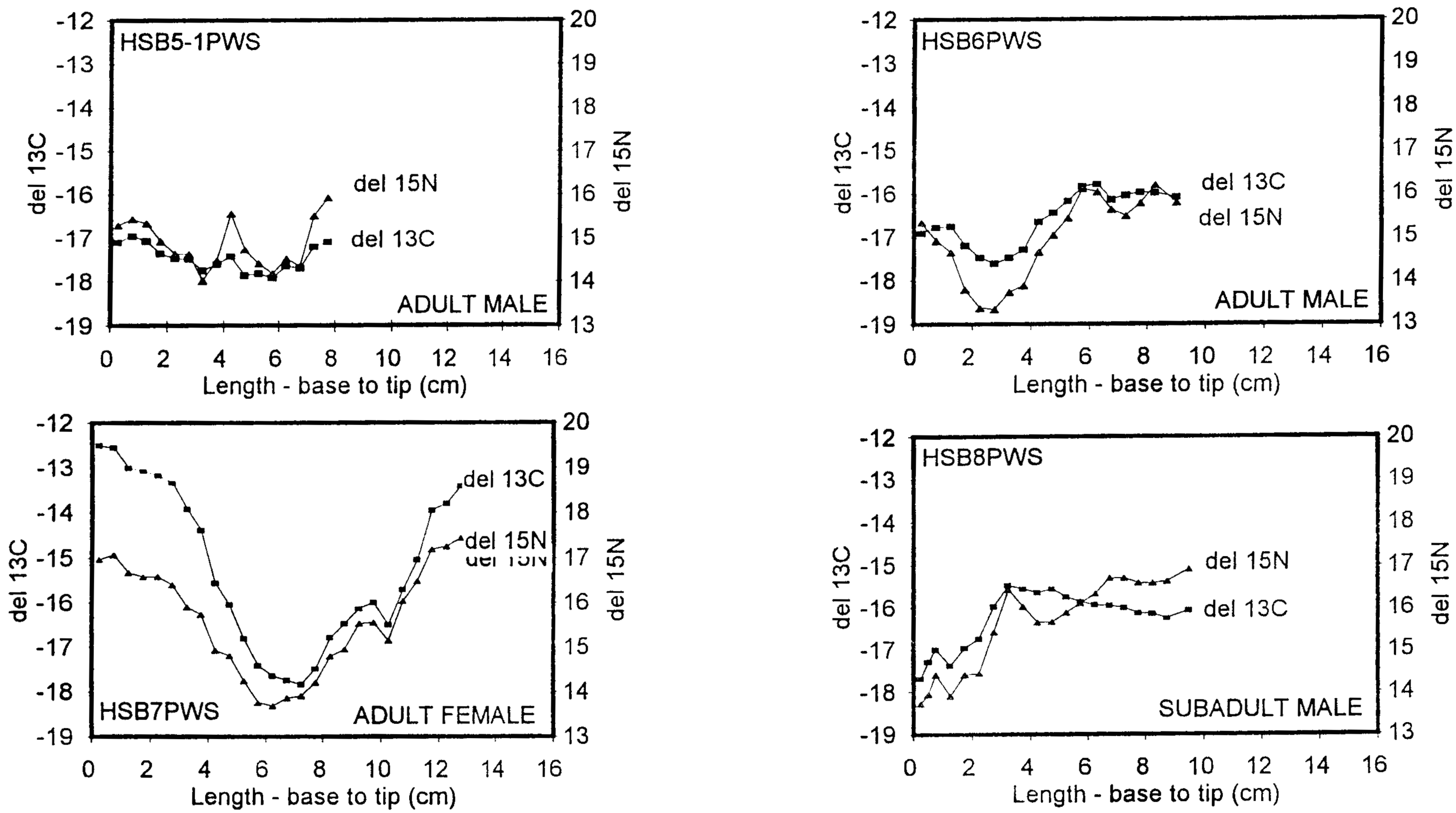
PORT CHALMERS, PWS APRIL 1994





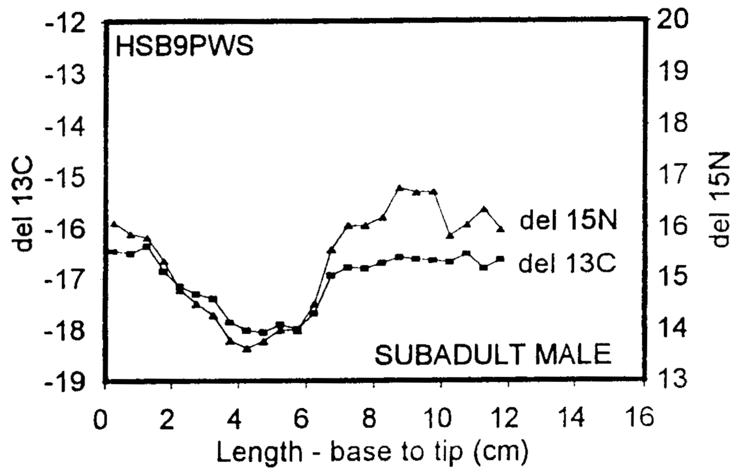
Appendix I.

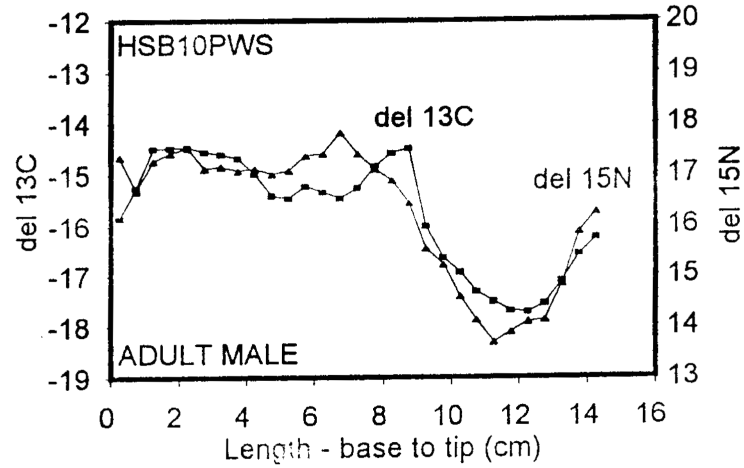
STOCKDALE HARBOR, PWS   APRIL 1994



Appendix I.

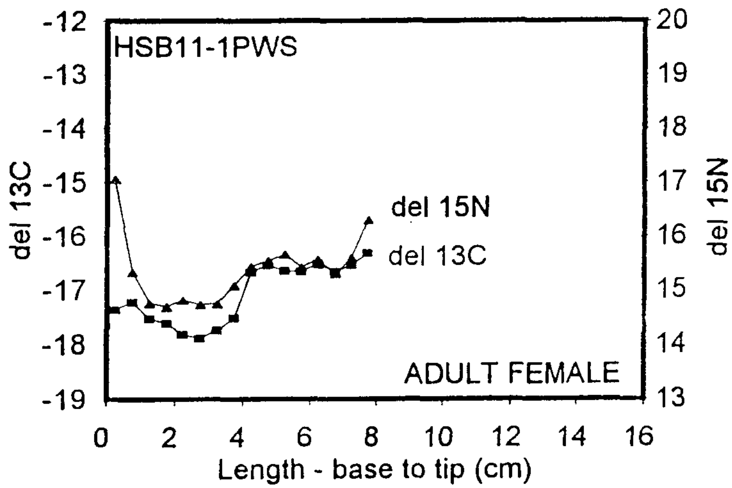
STOCKDALE HARBOR, PWS APRIL 1994

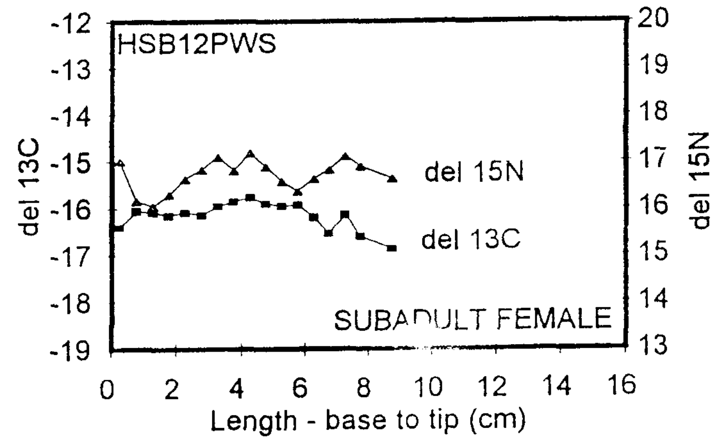


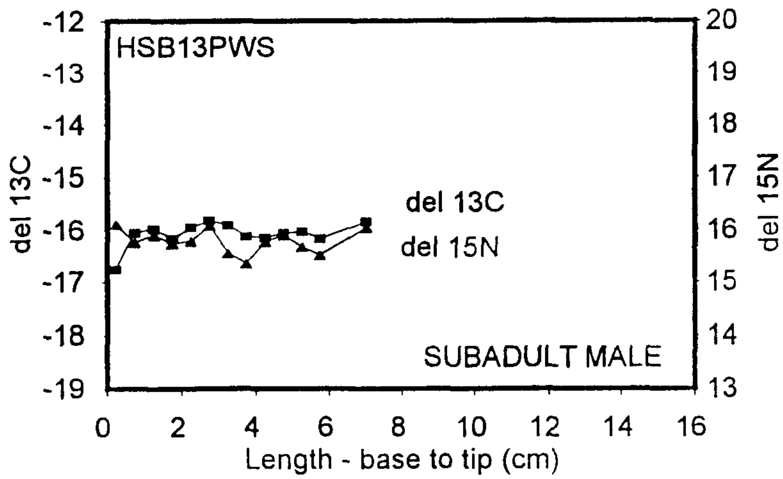


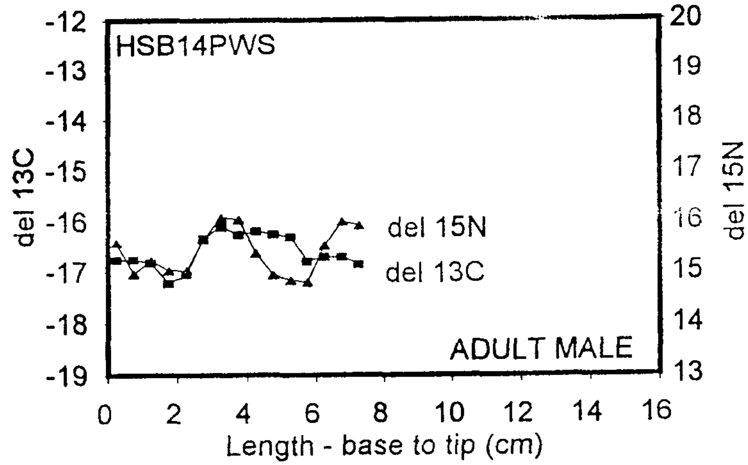
Appendix I.

CHANNEL ISLAND, PWS   SEPTEMBER 1994









Appendix I.

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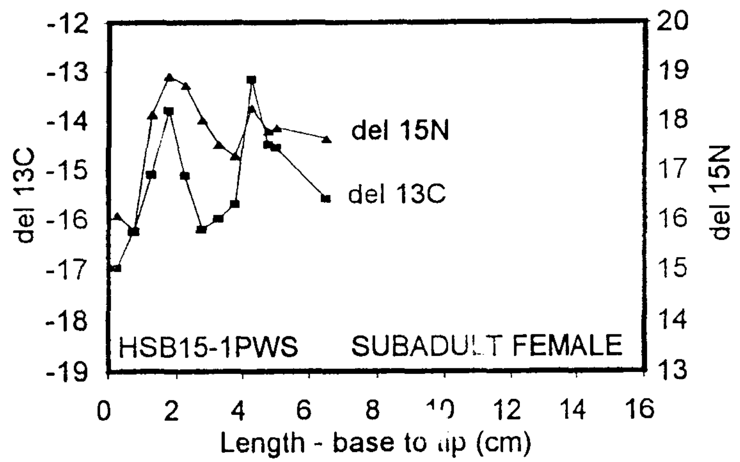

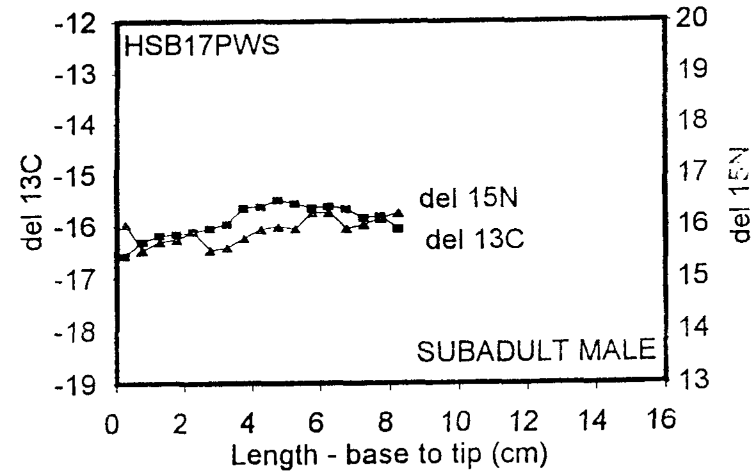

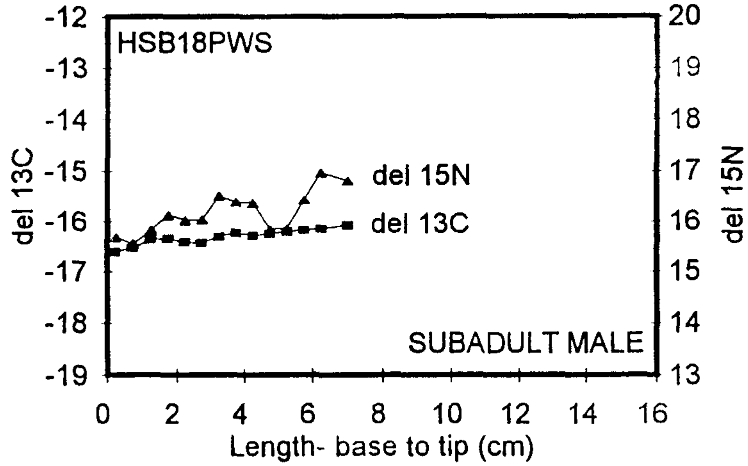

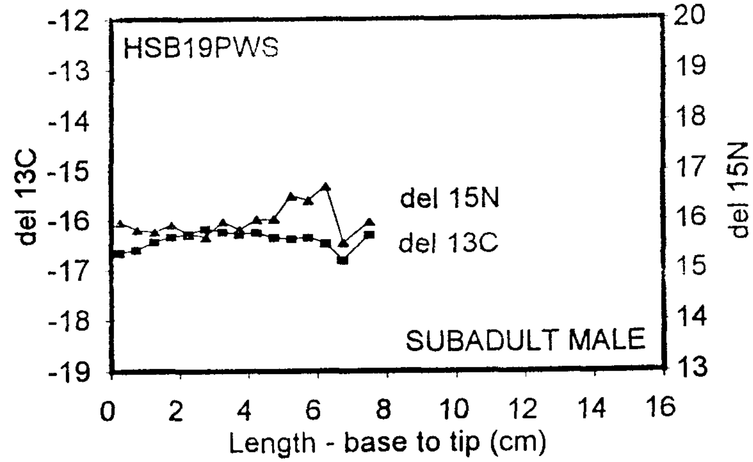

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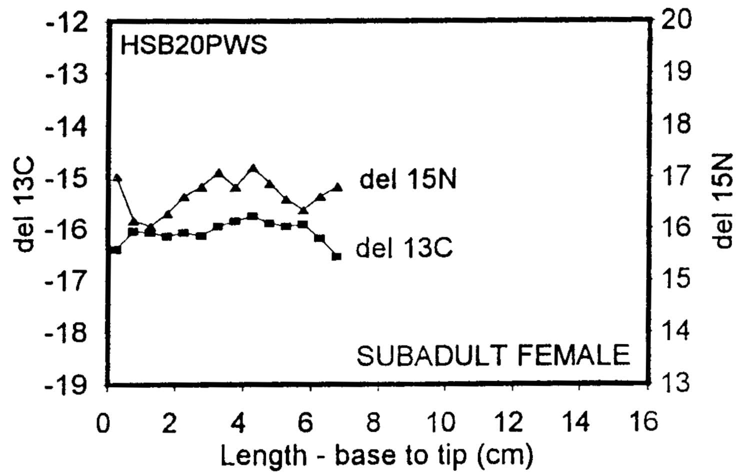
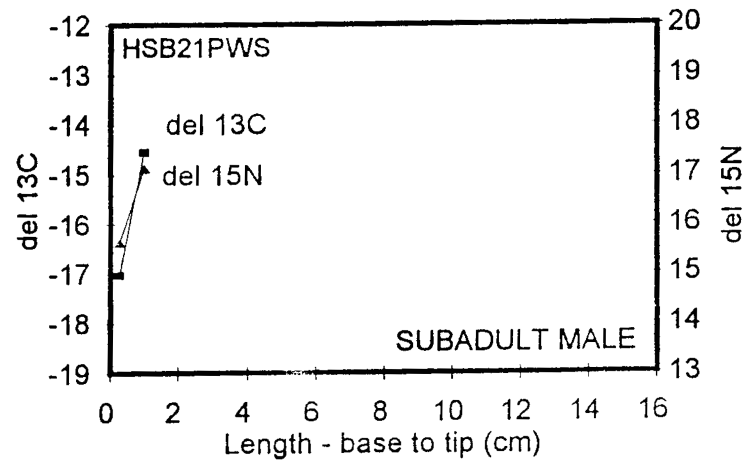
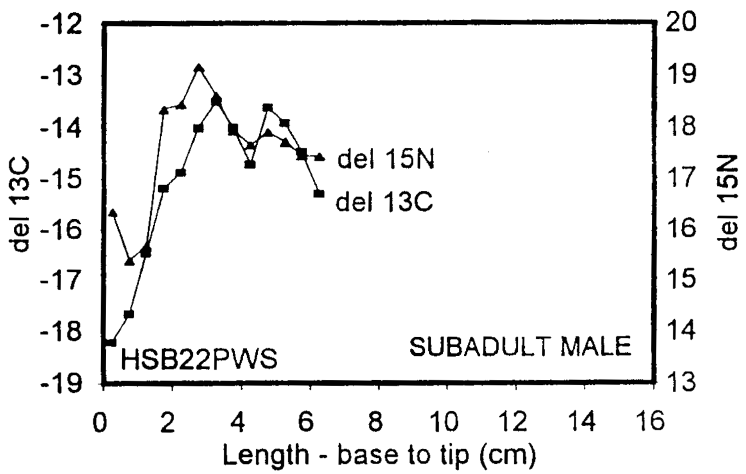
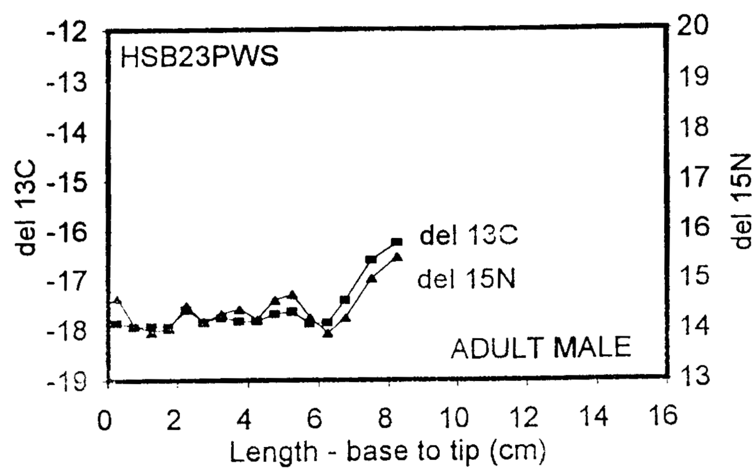
CHANNEL ISLAND, PWS SEPTEMBER 1994



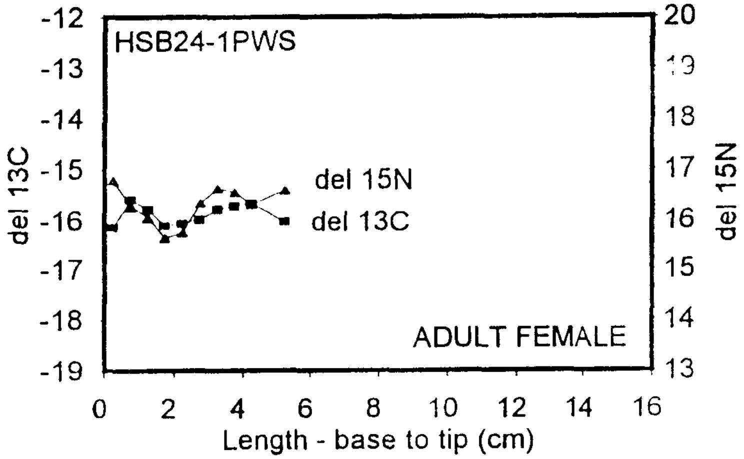


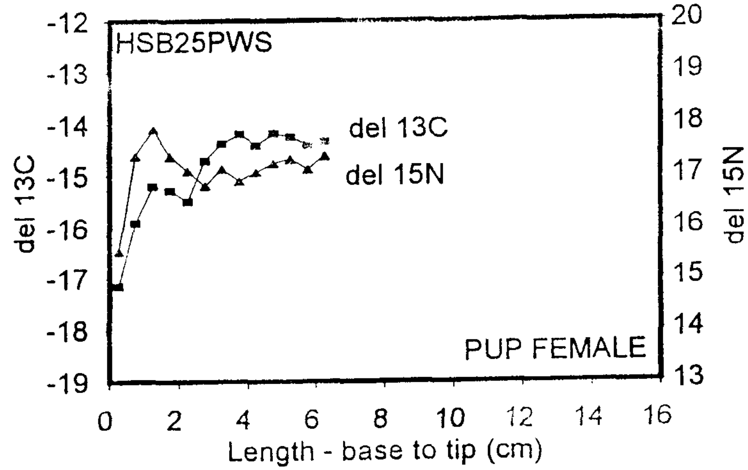


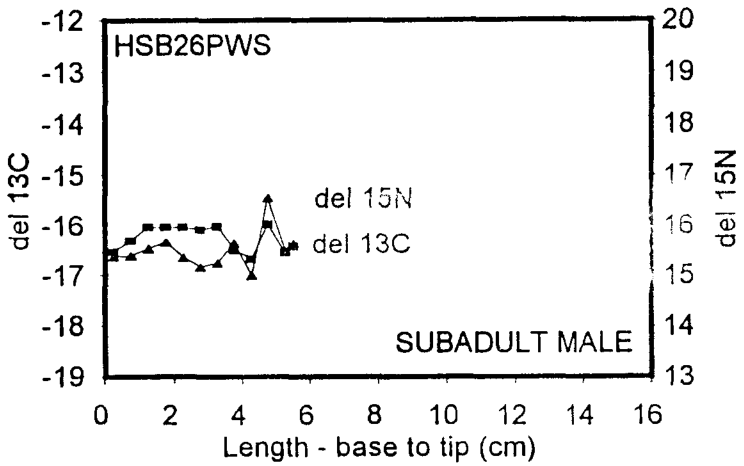


Appendix I.

GRAVINA ISLAND, PWS SEPTEMBER 1994

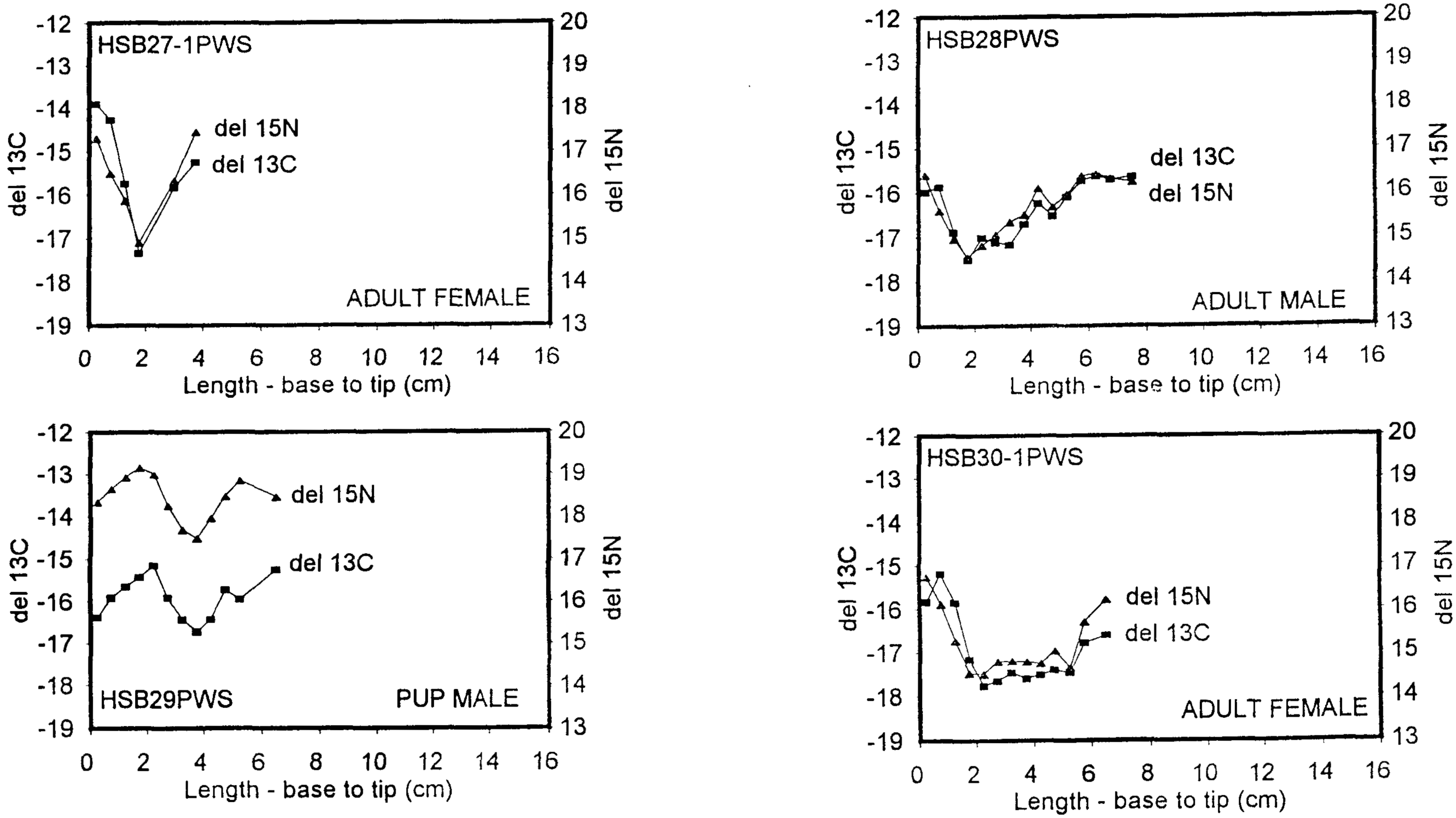






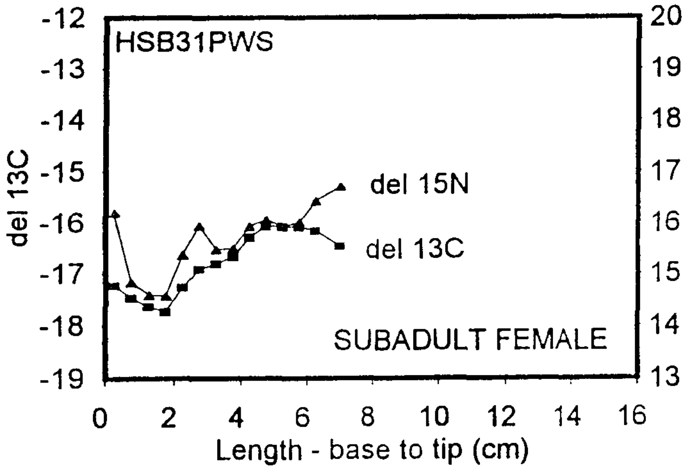
Appendix I.

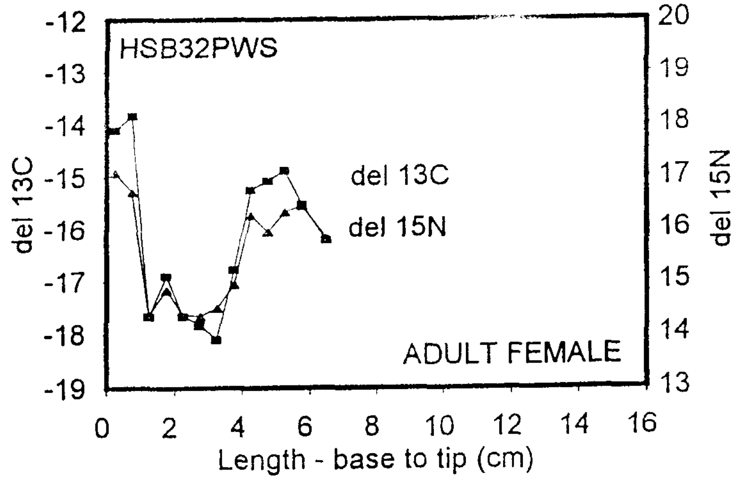
PORT CHALMERS, PWS   SEPTEMBER 1994

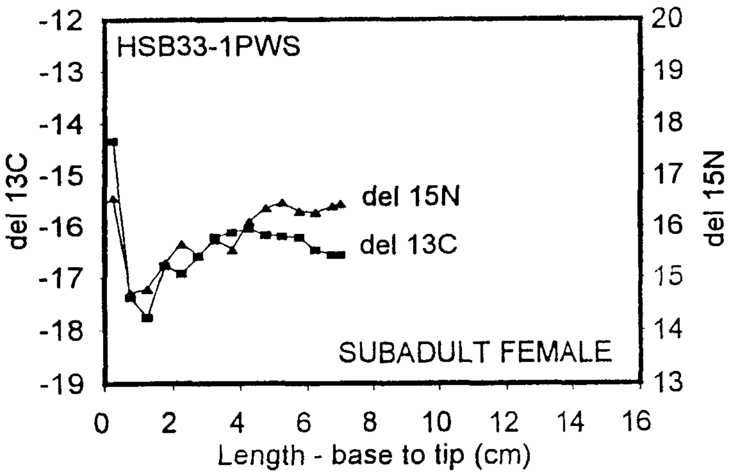


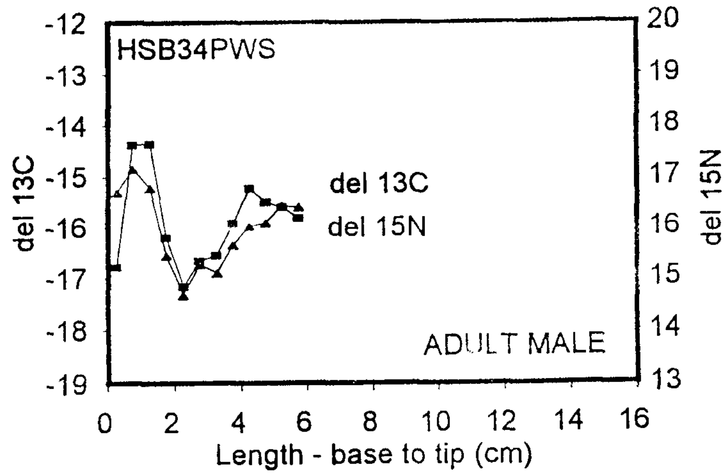
Appendix I.

PORT CHALMERS, PWS SEPTEMBER 1994



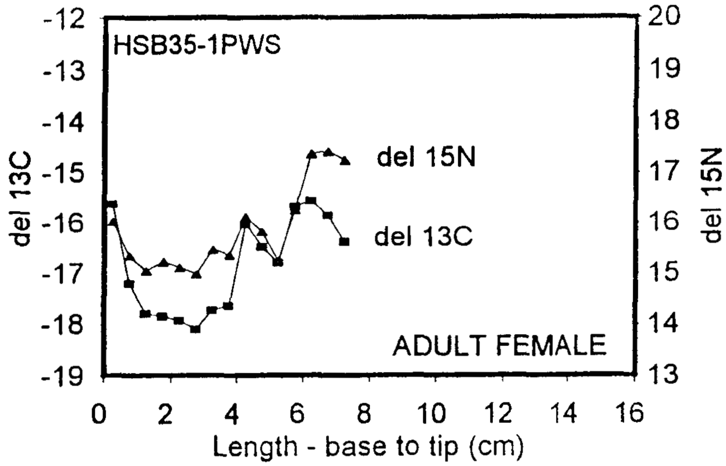


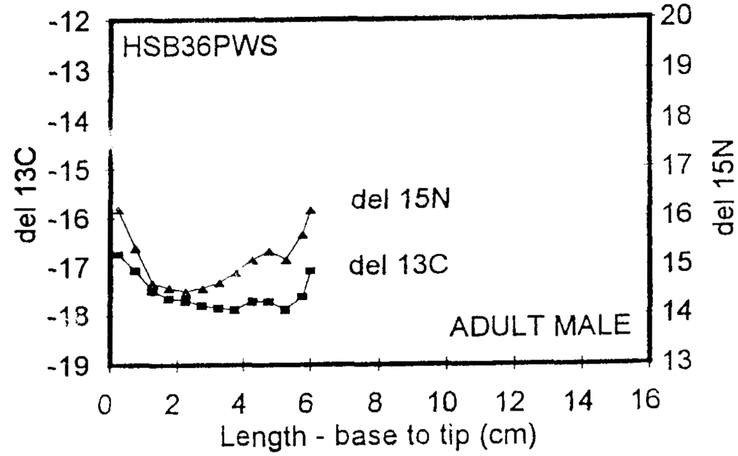




Appendix I.

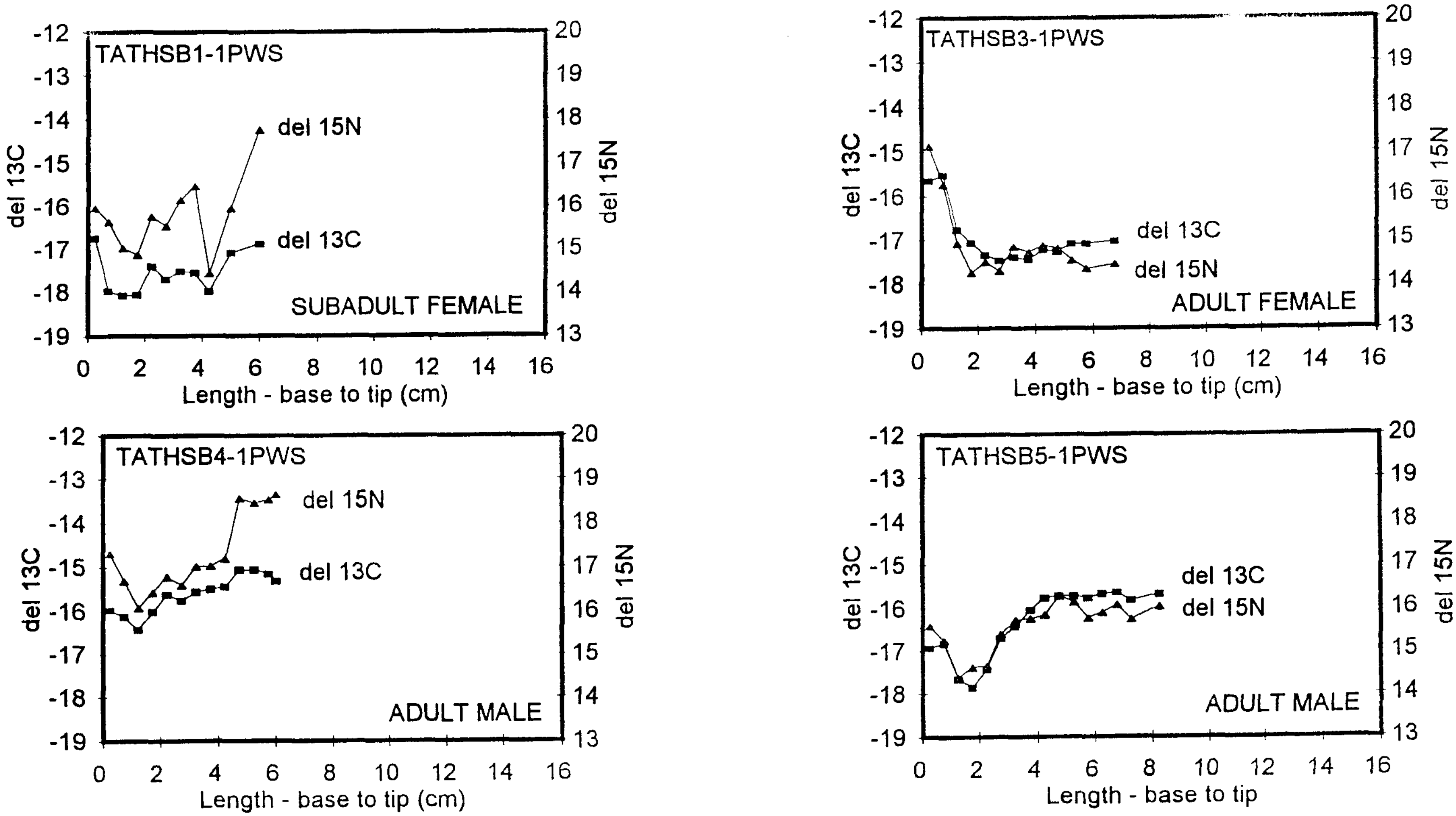
PORT CHALMERS, PWS   SEPTEMBER 1994





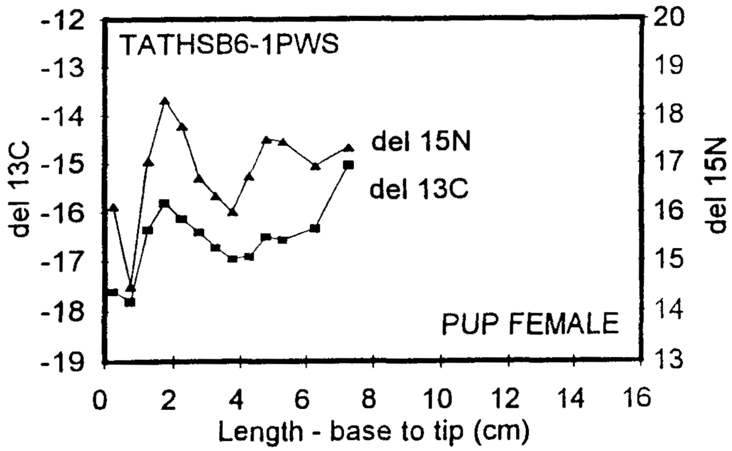
Appendix I.

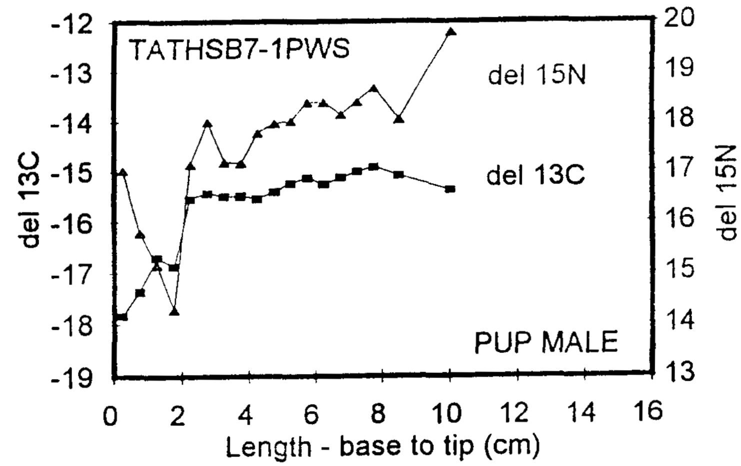
TATITLIK, PWS   SEPTEMBER 1994



Appendix I.

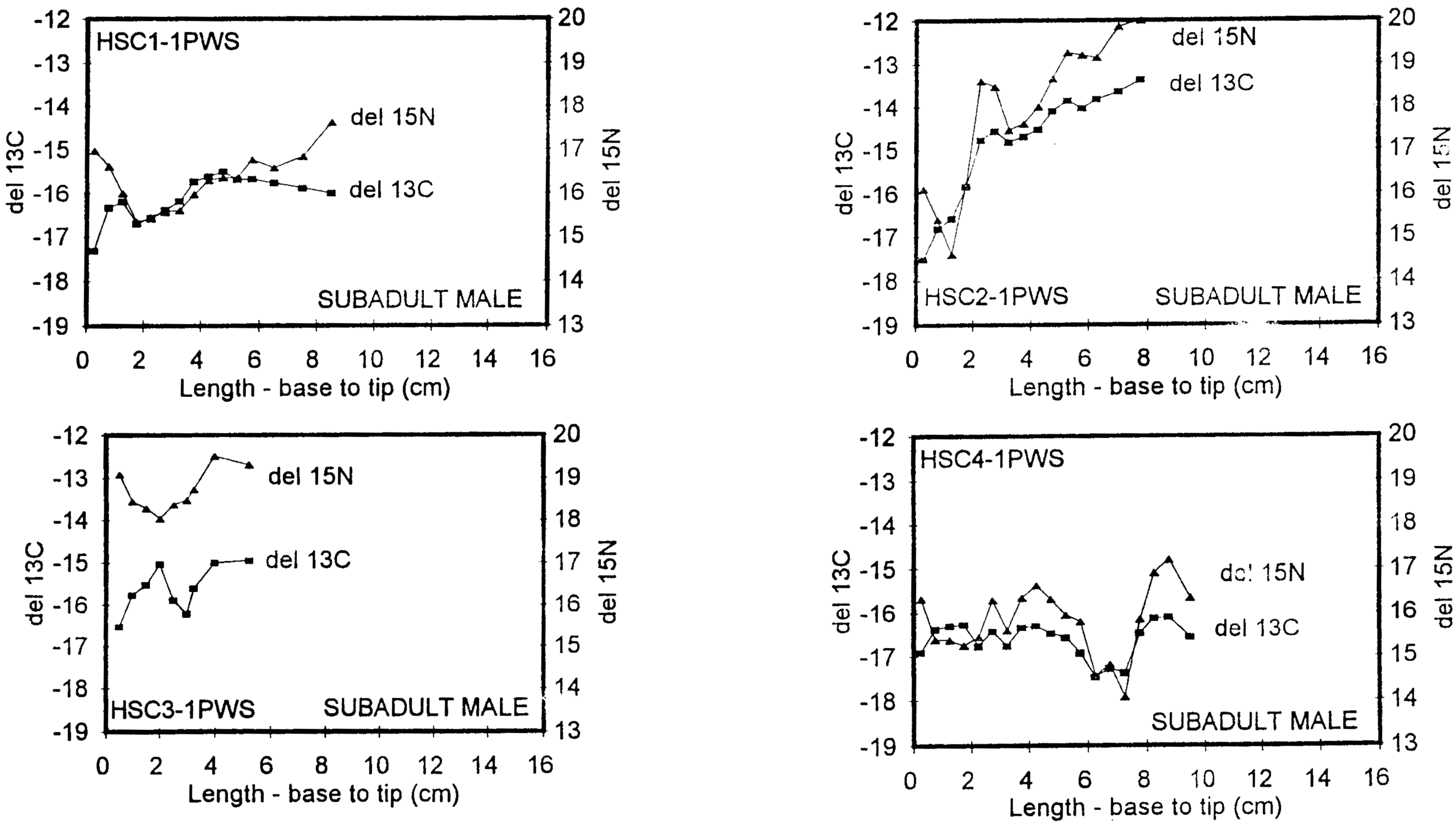
TATITLIK, PWS SEPTEMBER 1994





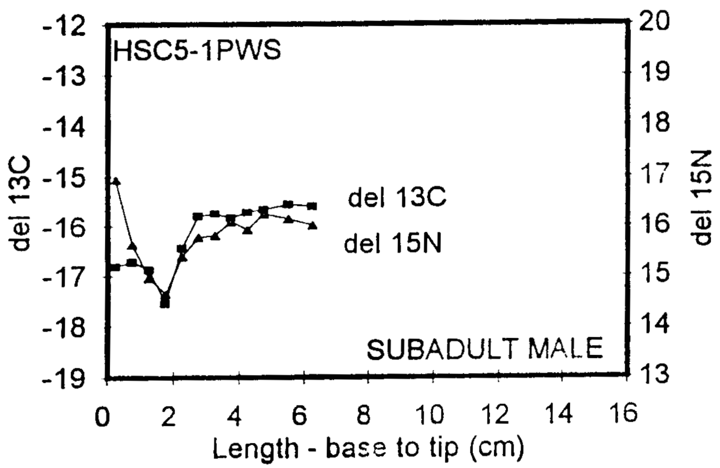
Appendix I.

DUTCH GROUP, PWS MAY 1995



Appendix I.

DUTCH GROUP, PWS   MAY 1995



Appendix I.

OLSEN BAY, PWS   MAY 1995