Not to be cited without prior reference to the author.

ICES C.M. 1992 / G:43
Demersal Fish Committee

Food composition and consumption of Chilean hake (Merluccius gayi gayi G.) with special reference to cannibalism.

by

Kim A. Stobberup

Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
2920 Charlottenlund
Denmark

Abstract.

Between November 1990 and April 1991 a total of 1790 stomachs of Chilean hake were collected from the fishery along the coast of Chile between 35°S and 39°S. Assuming equilibrium conditions, the daily food intake was estimated to be 4.1% and 2.2% of body weight for females and males, respectively. Food intake was higher during the spring/summer season than in summer/autumn. Food composition changes with season, depth, fish length, and area. The average weight of the stomach content of females was significantly higher than that for males. Chilean hake in the diet constituted 23% and 4% in weight for females and males, respectively. Chilean hake preys heavily on itself and on Pleuroncodes monodon and further consumes considerable numbers of Strangomera bentincki. VPA in which cannibalism is taken into account shows high mortalities for the age classes 1 and 2.

1. Introduction.

Chilean hake is the most important species caught in the demersal fishery off central Chile (30°-40°S). In 1991 the total catch of Chilean hake was 63,903 tonnes. South of 40°S the another species of hake, Merluccius australis, takes over. North of 30° the demersal fisheries are less important due to the narrow continental shelf (SERNAP, 1991).

There are several studies on the food composition of Chilean hake (Arana & Williams, 1970; Gallardo et al., 1980; Melendez, 1983; Arancibia & Melendez, 1987). Few of these studies have (Arancibia et al., 1986; Arancibia, 1989), however, considered how average stomach content and food composition change with season, depth, sex, and fish length. Furthermore the consumption and the importance of cannibalism is estimated. Previous studies of Merluccius species have demonstrated this genus as important fish predators and cannibals (Durbin et al., 1983; Vinogradov, 1984; Lleonart et al., 1985; Andronov, 1987; Roel & MacPherson, 1988; Konchina, 1989).

The catch of Chilean hake has fluctuated considerably over time. A maximum catch of 128,000 tonnes was reached in 1968 (Aguayo & Robotham, 1984). In the period 1973-1982 the catch stabilized at around 32,000 tonnes. In 1984-1990 it increased again to a level around 50,000 tonnes.

It has been suggested that a combination of overexploitation and the "El Niño" phenomenon have caused this fluctuation (Aguayo & Robotham, 1984). The "El Niño", which was particularly strong in 1972-1973 and 1982-1983, may have affected the Chilean hake stock through decrease or collapse of the food species anchovy, Engraulis ringens, and common sardine, Strangomera bentincki.

2. Materials and Methods.

A total of 1220 stomachs were sampled at sea from December 1990 to April 1991 in the area 35°S-39°S off the coast of central Chile (fig. 1 & 2). The sea temperature and depth were recorded for each haul. In addition 372 stomachs were sampled in November 1990 from a fish processing plant. These stomachs also came from the same area but since the trawlers usually spend 4 to 5 days at sea during each trip and cover a large geographical area it proved impossible to identify the precise location at which the fish had been caught. Length measurements were pooled into a number of length intervals which reflect age. The upper and lower limit was selected in accordance with the growth curve reported by Aguayo & Ojeda (1987). All stomachs were preserved in 4 to 5% buffered formalin.

The analysis followed the standard procedure of measuring length, weighing, and identifying all prey. If a prey species occurred in large numbers only a subsample was measured. The total weight of each prey species was recorded. Unidentified items found in the stomach were distributed among the identified prey species in proportion to their weight. In doing this sex, length, and time of year were as far as possible taken into account. The weight of individual prey items was calculated by length/weight relations given in the literature (Aguayo & Soto, 1978; Arancibia et al., 1986).

Possible differences in weight loss between stomachs preserved in formalin and stomachs kept on ice prior to being sampled at the factory were investigated. Four random samples of 2 X 25 stomachs which were either preserved in formalin or kept in refrigeration for 5 days (5°C), simulating the storage onboard trawlers, were collected onboard the vessels. The subsequent analysis showed no significant different between the iced and formalin preserved stomachs (P>F=0.16; n=25; r-square=0.32) with respect to identification of prey items (taxons). However, the weight of the average stomach content was significantly less in the iced stomachs (P>F=0.02; n=25; r-square=0.50). Weight loss due to refrigeration was therefore compensated for by multiplying values from iced stomachs with a factor 2.9 (stderr=exp(0.397)).

3. Theory.

Analysis of differences in observations caused by independent variables such as season are often conducted using Generalized Linear Model technique (GLM) and the present study follows this trend. These statistical methods assume that the residuals follow a normal distribution. This is seldom the case for stomach content data where the distributions often contain a large amount of zero's and the non-zero observations are highly skewed. Such data has to be transformed. In many cases the non-zero values follow a log normal distribution, and a log transformation is therefore appropriate. However, in this case a ln-transformation of the weight of the stomach content of the full stomachs (fig. 3), did not result in a normal distribution of the residual errors. Instead all stomachs from a certain length class were lumped for each sex and haul and the average stomach content was estimated as:

$$\overline{w}_{P,S} = \frac{w_{P,S} * (N_{R,S} + N_{F,S})}{N_{F,S} * (N_{P,S} + N_{R,S} + N_{E,S})}$$

where:

- $\overline{w}_{P,S}$: avg. weight of prey p, per stomach in sample s.
- $w_{P,S}$: total weight of prey p, per stomach in sample s.
- $N_{F,S}$: number of full stomachs in sample s.
- $N_{R,S}$: number of regurgitated stomachs in sample s.
- $N_{E,S}$: number of empty stomachs in sample s.

The overall average weight was then calculated as a weighted mean based on the sampling intensity:

$$\overline{w}_P = \frac{\sum_{1}^{Ns} (\overline{w}_{P,S} * N_{O_S})}{\sum_{1}^{Ns} N_{O_S}}$$

where:

$\overline{w}_P$: avg. weight of prey p per stomach.

N_S : total number of samples.

No_S : weighting factor;

$N_{T,S}$: total number of stomachs in sample s.

$N_{T,S} > 10$: $No_S = 10$

$N_{T,S} <= 10$: $No_S = N_{T,S}$

The weighting factor has a limit of 20 instead of 10 for the length classes "46+ cm" in males and "56+ cm" in females.

3.1 Evacuation rate.

The food evacuation is assumed to follow the exponential model. Such a model states a linear function of log stomach contents with time. Sampling times were grouped as:

Group :	1	2	3	4
Time :	5:40-7:35	9:00-10:45	12:00-13:45	15:00-17:10

All hauls began within the given time intervals and were thus assigned a value accordingly.

For males, there was a significant decline in stomach content with the time of day (P>F=0.01; n=60; r-square= 0.46). The only other influencing factor found to be significant was the month of sampling (P>F=0.00; n=60; r-square= 0.46). Assuming that males feed at dawn, the estimated evacuation rate is -0.13 t^{-1}

(stderr=0.098) at a temperature of 10.6°C (range: 9°-11°C). The same evacuation rate is applied for females. Time of day was not significant for females, since the stomach content weights were very variable.

3.2 Consumption.

The daily consumption (DR) was calculated for two periods covered in the present study, November to December (spring/summer) and February to April (summer/autumn) using the modified Bajkov formula (Pennington, 1985):

$$DR = 24 * r * avg[w(t)]$$

where r is the evacuation rate and avg[w(t)] is the average stomach content in the two time periods.

3.3 Virtual Population Analysis.

The consumption rates estimated in the present study are asummed constant for the period 1985-1990 (table 1). The number of hakes (CPr) of a certain age class cannibalized was estimated by multiplying the consumption rate (Pr) with the estimated stock number (N):

$$CPr_i = \sum_j Pr_{i,j} * N_j$$

where j is the predator age and i the prey age.

Normal VPA was used with some minor modifications. The number cannibalized of each age class was added to the catch of the fisheries and the notations become (table 2):

C_D : catch (C) + number cannibalized (CPr)
F_D : fishery mortality (F) + predation mortality (M_2)
M_1 : natural mortality due to other causes

The fishing mortality of a certain age class in a cohort in year y is calculated by iteration:
a)

$$\frac{C_{D(y)}}{N_{(y+1)}} = \frac{F_{D(y)}}{M_1+F_{D(y)}} * [(\exp(F_{D(y)}+M_1)) - 1]$$

Estimation of the stock number of a certain age class in year y is calculated by:
b)

$$N_{(y)} = N_{(y+1)} * [\exp(Z_{(y)})]$$

Finally the resulting mortality by predation (cannibalism), M_2, and by fishing, F_D, for each age class follow the equations:

$$M_2 = F_D * (CPr / CPr+C)$$
$$F = F_D * (C / CPr+C)$$

Values of 0.45 for males and 0.3 for females, which are estimates of M (Aguayo & Robotham, 1984), were used as estimates of the natural mortality, M_1.

4. Results.

4.1 Food composition.

The most important prey for the Chilean hake are the euphausiid, Euphausia mucronata, the galatheid crab, Pleuroncodes monodon, the common sardine, Strangomera bentincki, and the Chilean hake. Other fish like Normanichthys crockeri, Trachurus murphyi, Engraulis ringens, and Hippoglossina macrops, stated in order of importance, appeared infrequently in hake stomachs but occasionally may dominate the diet (table 3).

Figure 4 indicates no marked difference in diet between the sexes or length classes. An exception are large females (56+ cm) for which 80% of the diet is Chilean hake, but there is no general trend in cannibalism with length. The female length class "56+ cm" is presented separately due to highly variable stomach content (0-375g) and a clear difference in food composition. Fish in the diet over all length classes constituted 54% and 14% in weight for females and males, respectively. Cannibalism accounted for 23% and 4% in weight, respectively.

Season has an important effect on the diet (fig. 5). Fish were predominantly consumed in November to December. For larger females the diet was fish, irrespective of any influencing factor. Food composition in March deviated markedly and is due to sampling of a southern area (39°S) with extreme depth (200-230m). In this sample the diet consisted almost completely of E. mucronata.

Extreme depths are strongly correlated with certain areas causing unbalance in the data. Therefore interpretation should be cautious. Nevertheless, the influence of depth on food composition shows clear trends (fig. 6). Fish were consumed in shallower waters while euphausiids were consumed in deeper waters. Consumption of galatheid crab appeared to be confined to a depth of 90 to 150m. The diet of larger females consisted of high proportions of jack mackerel, T. murphyi, in depths of 150 to 210m, which again shows the dominance of fish.

4.2 Consumption.

The average stomach was significantly influenced by time of year (P>F=0.01), sex (P>F=0.00), and fish length (P>F=0.00) (n=194; r-square=0.27). Females have a significantly higher stomach content than males (factor: x1.78; stderr=(exp(0.198)). The average stomach content varies strongly with season (fig. 7).

The estimated average daily ration is 4.1% for females and 2.2% for males. However, the values are considered to be unreliable for the male length class "46+ cm" and the female length class "56+ cm" as a result of high variance (table 4). Excluding these classes and differentiating between seasons give the values 2.7% and 1.4% for spring and autumn, respectively.

Bioenergetic calculations were done to check the validity of the consumption estimates. The same energy equivalents as given by Paul et al. (1990) were used, since the prey types are very similar. Overall averages for the estimated metabolism are 383 and 163 mgO_2/kg/hour for females (avg.weight=604g) and males (avg.weight=449g), respectively, without including the largest fish for both sexes (table 4). The estimated metabolism can be compared with a routine metabolism of 112 mgO_2/kg/hour for fed cod (weight=1kg), Gadus morhua, under normal activity and a temperature of 10°C (Brett & Groves, 1979). Furthermore the conversion efficiency was calculated for the length class 23 to 30 cm, giving the result of 17% for females and 11% for males.

Aside from euphausiids, all prey species contributing to the diet of Chilean hake are commercially important. In spite of this, calculations were done only for Chilean hake, the common sardine, Strangomera bentincki, and the galatheid crab, Pleuroncodes monodon considering the sporadic appearance of other items in the hake stomachs.

The estimated consumption by hake of these three species are given in table 5. Comparing these estimates with the fishery in 1990, we find that hake eats 11.5 times the catch of hake (52,820 tonnes) and eats 0.8 times the catch of common sardine (285,757 tonnes) (SERNAP, 1990). A total consumption of 467 thousand tonnes P. monodon can be compared with a catch of 346 tonnes in 1991 (SERNAP, 1991).

4.3 VPA.

The results of a VPA including cannibalism are given in table 6a and 6b, but these results are influenced by the unreliable daily ration estimates for the larger length groups. Furthermore, it is difficult to estimate the stock number of these groups, since they consist of several age classes. It was therefore decided to exclude them, thereby underestimating the mortality for the age classes 4, 3, and especially 2. Predation and cannibalism by hake primarily affect the 0 age class of the three species involved (table 5). For age classes 1 and 2 it can be seen that cannibalism results in high mortalities (table 6a & 6b).

5. Discussion.

The variability of fish stomach contents is generally high which also has been shown in the present study. Only 26% of the variation on the average stomach content could be explained when taking sex, month and length into consideration. The significantly higher food intake in females may be explained by the difference in growth between sexes. Differentiating between sexes is seldom in this type of study, but higher food intake in females has also been reported for Merluccius bilinearis (Bowman, 1984). Higher food intake outside the reproductive season, from March to November for the Chilean hake, has been reported in other studies of Merluccius species (Stauffer, 1985; Bowman, 1984; Montecchia et al., 1990). Seasonal fluctuation in the average stomach content appears to be normal, e.g.Merluccius bilinearis (Durbin et al., 1983), and may be due to food availability.

5.1 Food composition.

In Chile only few studies have been based on weight analysis of stomach contents, and to facilitate comparison only one similar study is included in the following. Table 7 show good agreement between studies both on a qualitative and a quantitative basis, although Strangomera bentincki and

Normanichthys crockeri were only found in the present study. Discrepancies for the larger length classes in respect to the importance of Pleuroncodes monodon and the generally higher occurrence of Engraulis ringens can be explained by the difference in sampling area, since Arancibia (1989) covered a different area (36°-37°S) compared to the present study (fig. 1).

Unfortunately there is a great lack of information on the migration of the species involved. Knowledge of their distribution can be helpful in understanding the influences which have emerged in the present study. E. mucronata is endemic to the Chile-Peru Current System (Antezana, 1970) and would supposedly be available as constant potential food for the Chilean hake. P. monodon is found along the whole Chilean coast until 41°S at a depth ranging from 70 to 200m. During January and February they are more restricted to deeper waters (200-300m) (Bahamonde et al., 1986) which is consistent with the higher fish proportion found in the diet of hake at this time. S. bentincki is distributed between 30°S and 42°S (IFOP, 1980). The fishery season for the latter species and E. ringens is generally between November and March. This implies that these species migrate. Chilean hake is distributed between 23°S and 47°S and there is a tendency towards movement to deeper waters during winter (c. 180m) (Aranda et al., 1988).

A similar relationship between the high occurrence of euphausiid in the stomach and greater depths was reported for Merluccius bilinearis (Bowman, 1984). The consumption of fish is generally concentrated on individuals of the 0 age class which are restricted to coastal areas. The predation on fish is therefore expected to be greater during the spring/summer. There seems to be a shift to P. monodon as summer progresses and the diet may consist of greater quantities of P. monodon and E. mucronata during the winter, when hake move to deeper waters.

5.2 Consumption.

The evacuation rate estimate agrees well with estimates from emperical equations (Durbin et al., 1983; Roel & MacPherson, 1988) for a temperature of 10.6°C. The difference is that it is considered valid for a mixed diet in the present study, while this rate is considered valid only for small crustaceans in the cited articles. A failure to meet the assumption that males feed at dawn in the present study would lead to an underestimate. This has not been the case.

The estimated daily rations in the present study are very similar to 2.4% in spring and 1.9% in autumn found for Merluccius bilinearis (Durbin et al., 1983). The estimates differ from 0.2% in spring and 1.9% in autumn reported for Chilean hake (Arancibia, 1989), which is considered to be low. The latter study estimated the consumption of P. monodon exclusively, but since the evacuation rate used is the same, the results were adjusted and give the stated values.

Since all sampling occurred during daytime and since fish were caught with a trawl, the results on the food composition and the average stomach content may be biased. The consumption results of the present study seem nevertheless to be reasonable, since the study period is considered the time at which food availability is higher and spawning activity is relaxed.

Competition between hake and jack mackerel for euphausiids (Aguayo & Robotham, 1984) could have led to the situation with high cannibalistic behaviour. If this is true then the current situation can be generalized for the period 1985-1990, since jack mackerel had attained a high biomass by this time. Consumption rates are therefore assumed constant for the period 1985-1990 in the VPA incorporating cannibalism, which is a crucial assumption. Considering the fairly stable catch during this period the procedure seems reasonable.

The presented VPA differs from the traditional VPA (Bustos et al., 1991) only in the fishing mortality for the age class 2, giving the average values of 0.001 and 0.0035, respectively. On the other hand the mortality due to cannibalism has important implications, since these mortalities affect the biomass estimates for the age classes 0 to 2. For the age class 0 in hake it was regarded unrealistic to estimate M_2 on the basis of the limited data from the present study.

The consumption estimates in the present study should be considered preliminary. Nevertheless it has clearly been shown that Chilean hake preys on P. monodon and S. bentincki, and that cannibalism is important. Other species, fx anchovy, may be important when taking migration and area into consideration. Sampling of Chilean hake during the winter is necessary since similar studies have only covered the spring/autumn period. The daily ration results for the larger hakes should be improved, thus enabling the estimation of mortalities on hake and other exploited species by these larger hakes. The amount of fish (80%) in the diet of larger hakes further emphasizes the importance of Chilean hake as a predator and cannibal.

Acknowledgements.

I am indebted to Henrik Gislason and Hans Lassen, from the Danish Institute for Fisheries and Marine Research, for their criticism and advice. I thank the Institute for Fisheries Research (INPESCA), Talcahuano, for their hospitability and for making it possible to carry out the present study, in particular Dr. Hugo Arancibia and Dr. Dagoberto Arcos. Furthermore I thank the firm "El Golfo" for allowing access to their trawlers and factory, Mr. Sergio Mora (IFOP), and the many who have helped during the whole process.

References.

Aguayo, M., & Soto, S. (1978). Edad y crecimiento de la sardina común (Strangomera bentincki) en Coquimbo y Talcahuano. Serie Invest. Pesq., IFOP, Santiago.

Aguayo, M., & Robotham, H. (1984). Dinámica poblacional de merluza común (Merluccius gayi gayi). Invest. Pesq.(Chile) 31: 17-45.

Aguayo, M., & Ojeda, V. (1987). Estudio de la edad y crecimiento de merluza común (Merluccius gayi gayi Guichenot, 1848) (Gadiformes - Merluciidae). Invest. Pesq. 34: 99-112.

Andronov, V.N. (1987). Daily feeding rhythm and daily rations of Cape Hake Merluccius Capensis Castelnau in the Namibian area. Colln. scient. Pap. int. Comm. SE. Atl. Fish. 14(1): pp 39-50.

Antezana, T. (1970). Eufáusidos de la costa de Chile. Su rol en la economía del mar. Rev. Biol. mar., Valparaíso, 14(2): 19-27.

Arana, P., & Williams, S. (1970). Contribución al conocimiento del régimen alimentario de la merluza (Merluccius gayi). Inv. Mar. 1(7): 139-154.

Arancibia, H., Toro, J., Fernandez, V., & Meléndez, R. (1986). Estimación de la mortalidad por depredación del langostino colorado (Pleuroncodes monodon) por la merluza común (Merluccius gayi) en el área 35°45' S - 37°10' S. In: La Pesca en Chile; P. Arana (ed). UCV, Valparaíso pp 57-67.

Arancibia, H., & Meléndez, R. (1987). Alimentación de peces concurrentes en la pesquería de Pleuroncodes monodon Milne Edwards. Invest. Pesq. (Chile) 34: 113-128.

Arancibia, H. (1989).Distribution patterns, trophic relationships and stock interactions in the demersal fish assemblage off central Chile. Dr. rer. nat. thesis,Bremen University; 221 pp.

Aranda, E., Young, Z., Aguayo, M., & Chomalí, S.J. (1984 reimpressión - 1988). Perfíl indicativo del sector pesquero nacional; merluza común (Merluccius gayi gayi). CORFO, Chile (AA 85/12); 131 pp.

Bahamonde. N., Henríquez, G., Zuleta, A., Bustos, H., & Bahamonde, R. (1986). Population dynamics and fisheries of squat lobsters, family Galatheidae, in Chile. In: North Pacific Workshop on Stock Assessment and Management of Invertebrates; Jamieson & Bourne (eds). Can. Spec. Publ. Fish. Aquat. Sci. 92: 254-268.

Bowman, R.E. (1984). Food of silver hake, Merluccius bilinearis. Fish. Bull. 82(1): 21-35.

Brett, J.R., & Groves, T.D.D. (1979). Physiological Energetics. In: Fish Physiology Vol VIII. Hoar, W.S., Randall, D.J., Brett, J.R. (eds); Academic Press, London; pp 280-344.

Bustos, R., Aguayo, M., Sateler, J., Donoso, J., Aviles, S., & Vera, C. (1991). Diagnóstico de las principales pesquerías nacionales demersales (peces), zona centro-sur, 1990. Estado de situación del recurso. IFOP, Inst. Fom. Pesq., Chile (SGI-IFOP91/7); 62 pp.

Durbin, E.G., Durbin, A.G., Langton, R.W., & Bowman, R.E. (1983). Stomach contents of silver hake, Merluccius bilinearis, and Atlantic cod, Gadus morhua, and estimation of their daily rations. Fish. Bull. 81(3): 437-450.

Gallardo, V.A., Bustos, E., Acuña, A., Diaz, L., Erbs, V., Meléndez, R., & Oviedo, L. (1980). Relaciones ecológicas de las comunidades bentónica y bento-demersal de la plataforma continental de Chile central. Informe Final Convenio Subsecretaría de Pesca / Universidad de Concepción; 325 pp.

IFOP (1980). Catálogo de recursos pesqueros, Chile. Corporación de Fomento de la Producción, Santiago; 46 pp.

Konchina, Y.V. (1989). Feeding of South African Cape hake, Merluccius capensis. J. Ichthyology vol. 29(5): 62-70.

Lleonart, J., Salat, J., & Macpherson, E. (1985). Un MSVPA (Multispecies Virtual Population Analysis) emperico. aplicación a la merluza del Cabo, considerando el canibalismo y la depredación de la rosada. Int. Symp. Upw. W. Afr., Inst. Inv. Pesq., Barcelona vol. 2: pp 1041-1052.

Meléndez, R. (1983-1984). Alimentación de Merluccius gayi (Guichenot) frente a Chile central, (32°05' S - 36°50' S). Bol. Mus. Nac. Hist. Nat. Chile 40: 145-151.

Montecchia, C.L., Crupkin, M., & Trucco, R.E. (1990). Seasonal variations in biochemical and physiochemical properties of actomysin and energy content of the liver, gonads and muscle of mature Argentine hake, Merluccius hubbsi Marini. J. Fish Biol. 37: 837-843.

Paul, A.J., Paul, J.M., & Smith, R.L. (1990). Energy ingestion and conversion rate in pollock (Theragra chalcogramma) fed different prey types. J. Cons. int. Explor. Mer 46:232-234.

Pennington, M. (1985). Estimating the average food consumption by fish in the field from stomach contents data. Dana 5:81-86.

Roel, B.A., & MacPherson, E. (1988). Feeding of Merluccius capensis and M. paradoxus off Namibia. S. Afr. J. mar. Sci. 6: 227-243.

SERNAP (1990). Anuario estadístico de pesca. Servicio Nacional de Pesca, Ministerio de Economia, Fomento y Reconstrucción, Chile; 191pp.

SERNAP (1991). Anuario estadístico de pesca. Servicio Nacional de Pesca, Ministerio de Economia, Fomento y Reconstrucción, Chile; 200pp.

Stauffer, G.D. (1985). Biology and life history of the coastal stock of Pacific whiting, Merluccius productus. Mar. Fish. Rev. 47(2): 2-7.

Vinogradov, V.I. (1984). Food of silver hake, red hake and other fishes of Georges Bank and adjacent waters, 1968-1974. NAFO Sci. Coun. Studies, 7: 87-94.

Table 1: Consumption rates expressed as kg hake consumed per hake and numbers consumed per hake. The prey age groups are: 0=0-139mm; 1=140-229mm; 2=230-299mm. Results from the study period are generalized for the first and second half of a year.

FEMALES		FIRST HALF OF YEAR			
	AGE	L (cm)	L (mm)	KG/FISH	N/FISH
	2	23-30	000-139	0.263	173.9
	3	31-37		0.000	
	4	38-42	000-139	0.098	65.0
	5	43-47	000-139	0.015	9.7
	6	48-51	000-139	0.038	25.0
	6	48-51	140-229	0.573	26.2
	7	52-55		0.000	
		LAST HALF OF YEAR			
	2	23-30	000-139	0.175	835.4
	3	31-37	000-139	0.008	36.4
	3	31-37	140-229	1.189	30.6
	4	38-42	000-139	0.001	4.3
	5	43-47	000-139	0.018	87.8
	6	48-51	000-139	1.544	7353.7
	6	48-51	140-229	4.780	123.1
	7	52-55	000-139	0.184	875.5
	7	52-55	230-299	6.613	64.3
MALES		FIRST HALF OF YEAR			
	AGE	L (cm)	L (mm)	KG/FISH	N/FISH
	2	23-30	000-139	0.056	37.1
	3	31-37	000-139	0.115	76.2
	4	38-42	000-139	0.085	56.5
	5	43-45		0.000	
		LAST HALF OF YEAR			
	2	23-30		0.000	
	3	31-37		0.000	
	4	38-42	000-139	0.001	5.4
	5	43-45	000-139	0.004	19.1

Table 2: The catch (thousands) of females and males in the fishery. The number predated (thousands) is calculated by summing the total predated by males and females, thereafter dividing by 2 assuming that half are males and half are females.

		FEMALES				
FISHERY CATCH						
AGE\YEAR	1985	1986	1987	1988	1989	1990
2	467.3	342.4	231.9	224.8	46.0	717.4
3	1915.7	1347.0	1179.0	1023.4	2032.5	2698.2
4	2921.7	1846.1	2817.9	2088.1	3523.8	3676.7
5	3439.7	2449.1	4770.3	3866.5	6098.5	5564.0
6	3267.5	2535.2	4725.2	4633.0	4308.0	8644.8
7	2749.9	2275.5	3291.0	4335.6	3710.8	6123.3
8	2704.8	1956.1	2445.4	3474.1	3161.2	3394.7
9	2415.9	2625.1	2406.8	3606.1	2029.6	2600.4
10	1570.5	2071.0	1582.5	2652.1	1755.5	1249.0
11	744.1	886.1	988.0	1749.5	1273.6	781.1
12	356.3	249.9	365.4	638.9	1003.5	691.4
13	158.2	79.5	165.2	377.2	704.6	550.0
NUMBERS PREDATED (by both males and females !)						
0	2.03E+08	2.14E+08	1.9E+08	1.67E+08	2.01E+08	2.27E+08
1	3361299	3362320	4140715	3296440	3694716	4543564
2	707004.5	592770.9	475789.7	509932.8	473976.1	631761.5
		MALES				
FISHERY CATCH						
AGE\YEAR	1985	1986	1987	1988	1989	1990
2	804.2	477.9	299.9	323.8	161.9	587.3
3	2705.4	2071.9	1573.3	1550.3	1013.1	2674.5
4	4950.5	3692.1	3942.8	4067.5	3788.8	5813.7
5	6618.2	4235.6	6909.1	7263.3	7955.0	793.9
6	6788.4	3842.9	5888.8	7146.1	5109.8	12123.4
7	3024.3	2958.2	2902.4	3774.2	5023.1	5583.5
8	1559.8	1989.9	1717.7	1805.2	4590.3	3108.4
9	1002.3	923.8	968.2	1077.5	2764.3	1473.8
10	364.5	376.4	289.9	340.8	1282.4	368.7
11	114.7	139.0	57.0	68.2	431.6	317.1
12	33.8	19.1	75.3	106.7	156.5	89.3
NUMBERS PREDATED (by both males and females !)						
0	2.03E+08	2.14E+08	1.9E+08	1.67E+08	2.01E+08	2.27E+08
1	3361299	3362320	4140715	3296440	3694716	4543564
2	707004.5	592770.9	475789.7	509932.8	473976.1	631761.5

Table 3: The diet of Chilean hake, in percent of total weight.

Eu: Euphausia mucronata
Pm: Pleuroncodes monodon
Pa: Pterygosquilla armata
Mg: Merluccius gayi gayi
Sb: Strangomera bentincki
Nc: Normanichthys crockeri
Tm: Trachurus murphyi
Er: Engraulis ringens
Hm: Hippoglossina macrops

			PERIOD : NOVEMBER - DECEMBER								
L (cm)	fish-rati	Eu	Pm	Pa	Mg	Sb	Nc	Tm	Er	Hm	SUM
FEMALE											
23-30	0.48	51.7	0.0	0.0	25.9	0.0	0.0	0.0	22.4	0.0	100.0
31-37	0.46	52.0	1.6	0.6	42.7	2.1	0.0	0.0	1.0	0.0	99.9
38-42	0.06	78.5	7.9	7.4	0.1	5.6	0.0	0.0	0.0	0.0	99.5
43-47	0.21	66.5	1.1	7.4	0.8	20.1	0.0	0.0	0.1	0.0	96.1
48-51	0.76	9.2	5.3	0.8	75.5	0.0	0.0	0.0	0.0	0.0	90.8
52-55	0.74	1.5	23.4	0.7	73.7	0.0	0.0	0.0	0.0	0.0	99.3
56+	0.97	0.0	2.0	0.5	81.8	0.0	0.0	3.9	0.0	0.0	88.3
MALE											
23-30	0.00	99.8	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	100.0
31-37	0.01	96.8	2.4	0.1	0.0	0.6	0.0	0.0	0.0	0.0	99.9
38-42	0.18	73.9	4.2	4.2	0.1	17.5	0.0	0.0	0.0	0.0	99.8
43-45	0.01	85.8	3.9	8.2	0.2	1.0	0.0	0.0	0.0	0.0	99.1
46+	0.01	3.0	0.4	5.1	0.3	0.2	0.0	0.0	0.0	0.0	9.1
			PERIOD : FEBRUARY - APRIL								
L (cm)	fish-rati	Eu	Pm	Pa	Mg	Sb	Nc	Tm	Er	Hm	SUM
FEMALE											
23-30	0.56	0.0	43.5	0.7	55.8	0.0	0.0	0.0	0.0	0.0	100.0
31-37	0.42	37.9	19.6	0.0	0.0	28.3	14.0	0.0	0.0	0.0	100.0
38-42	0.55	2.8	39.4	2.3	5.8	39.1	10.3	0.0	0.0	0.0	99.8
43-47	0.23	5.6	68.1	2.8	0.7	21.5	0.6	0.0	0.0	0.0	99.4
48-51	0.34	7.4	57.7	0.6	22.5	6.2	5.1	0.0	0.0	0.0	99.5
52-55	0.82	0.1	7.3	10.3	0.0	37.8	16.1	0.0	0.0	28.0	99.7
56+	0.99	0.0	0.7	0.1	82.3	3.1	2.2	11.3	0.0	0.4	100.0
MALE											
23-30	0.46	0.0	54.1	0.0	11.2	34.7	0.0	0.0	0.0	0.0	100.0
31-37	0.42	13.8	43.1	0.5	15.6	26.6	0.0	0.0	0.0	0.0	99.6
38-42	0.13	2.3	81.1	2.4	8.4	2.3	2.8	0.0	0.0	0.0	99.2
43-45	0.02	7.0	89.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	97.5
46+	0.20	9.3	68.7	1.1	0.0	19.6	0.0	0.0	0.0	0.0	98.8

*The food of males "46+ cm" in the period Nov-Dec consisted of 91% juvenile Brachyura.

Table 4: Daily consumption of hake. Avg. stomach content (w), variance, and avg. fish weight are given. "Sample" stands for the number of pooled samples. Daily ration (DR) is given in weight and as a percent of bodyweight.

			PERIOD : NOVEMBER - DECEMBER					
	Age	Lgthcl	avg w	Variance	Sample	Fishwgt	DR	DR
	(years)	(cm)	(g)		(n)	(g)	(g)	(%)
FEMALE :								
	2	23-30	1.20	.	1	180.0	3.756	2.09
	3	31-37	5.00	1.199	11	331.9	15.584	4.70
	4	38-42	2.64	0.353	9	473.3	8.240	1.74
	5	43-47	4.10	1.285	8	640.5	12.787	2.00
	6	48-51	14.91	16.503	9	812.7	46.526	5.72
	7	52-55	16.42	28.132	7	974.8	51.217	5.25
	8+	56+	107.15	817.770	11	1549.4	334.304	21.58
MALE :								
	2	23-30	0.66	.	1	170.2	2.073	1.22
	3	31-37	1.23	0.082	10	338.2	3.840	1.14
	4	38-42	3.51	0.598	10	455.8	10.958	2.40
	5	43-45	4.31	0.981	9	591.6	13.456	2.27
	6+	46+	26.00	72.144	8	844.4	81.111	9.61
			PERIOD : FEBRUARY - APRIL					
	Age	Lgthcl	avg w	Variance	Sample	Fishwgt	DR	DR
	(years)	(cm)	(g)		(n)	(g)	(g)	(%)
FEMALE :								
	2	23-30	0.84	0.017	4	180.5	2.615	1.45
	3	31-37	0.91	0.102	7	289.1	2.835	0.98
	4	38-42	3.00	0.920	12	477.5	9.372	1.96
	5	43-47	3.58	1.127	14	638.7	11.180	1.75
	6	48-51	4.83	2.858	9	813.5	15.069	1.85
	7	52-55	5.32	4.753	7	985.4	16.611	1.69
	8+	56+	27.05	136.893	11	1822.5	84.398	4.63
MALE :								
	2	23-30	0.89	0.011	3	197.2	2.772	1.41
	3	31-37	1.32	0.140	9	311.7	4.105	1.32
	4	38-42	1.82	0.354	10	475.6	5.675	1.19
	5	43-45	1.69	0.263	5	596.2	5.273	0.88
	6+	46+	0.75	0.071	9	738.3	2.352	0.32

Table 5: The estimated consumption of the three main prey items in the last half of 1990 and the first half of 1991.

Merluccius gayi gayi				
Prey	Last half, 1990		First half, 1991	
Age:Lgth	Tonnes	Numbers	Tonnes	Numbers
0:0-139	86740,2	4,13E+11	73472,5	4,87E+10
1:140-229	2,97E+05	7,65E+09	20066,9	9,16E+08
2:230-299	1,3E+05	1,26E+09	0	0
Total	5,13E+05	4,22E+11	93539,3	4,96E+10
Strangomera bentincki				
Prey lgth	Last half, 1990		First half, 1991	
Age:Lgth	Tonnes	Numbers	Tonnes	Numbers
0:0-80	51819,8	1,04E+11	1,61E+05	1,42E+11
2:81-116	0	0	10277,9	4,05E+09
Total	51819,8	1,04E+11	1,71E+05	1,46E+11
Pleuroncodes monodon				
Prey lgth	Last half, 1990		First half, 1991	
Age:CL	Tonnes	Numbers	Tonnes	Numbers
0:0-9	10674,7	9,7E+10	1,27E+05	2,08E+11
1:10-13	6443,5	4,64E+09	2,58E+05	2,66E+11
2:14-17	35490,3	1,27E+10	0	0
3:18-20	4437,1	9,19E+08	2953,0	7,05E+08
24+	14717,4	9,18E+08	0	0
xxx*	7432,3	3,75E+09	0	0
Total	79195,2	1,2E+11	3,88E+05	4,75E+11

*XXX: No sampling to determine length composition. An overall average of prey weight is used to estimate numbers.

Table 6a: VPA incorporating cannibalism for females. Estimated stock numbers are in thousands.

		N - STOCK NUMBERS				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	4968032	4671825	5530435	4558702	5324923	6365417
2	956502.6	894092.1	686166.3	691517.7	657766.2	887292.8
3	100450.2	126085.4	170094.3	114396.1	92147.6	96132.4
4	75421.1	72773.8	92251.8	124998.4	83869.6	66523.1
5	46977.6	53371.1	52330.3	65927.8	90811.7	59114.4
6	37617.0	31859.0	37441.3	34688.1	45530.9	62056.5
7	29936.7	25073.1	21433.1	23701.1	21741.3	30046.6
8	25434.7	19826.2	16628.8	13069.8	13862.4	12941.7
9	15320.4	16530.6	13015.3	10231.6	6730.1	7579.2
10	7007.5	9288.3	10006.5	7590.4	4526.8	3263.6
11	2834.7	3854.5	5118.1	6062.8	3377.5	1869.8
12	902.3	1467.6	2101.4	2949.7	3006.1	1425.1
13	523.4	367.4	874.1	1245.2	1641.2	1376.7
		F - MORTALITY				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.001	0.001	0.001	0.001	0.000	0.002
3	0.022	0.012	0.008	0.010	0.026	0.033
4	0.046	0.030	0.036	0.020	0.050	0.066
5	0.088	0.054	0.111	0.070	0.081	0.115
6	0.106	0.096	0.157	0.167	0.116	0.175
7	0.112	0.111	0.195	0.236	0.219	0.267
8	0.131	0.121	0.186	0.364	0.304	0.358
9	0.200	0.202	0.239	0.515	0.424	0.498
10	0.298	0.296	0.201	0.510	0.584	0.574
11	0.358	0.307	0.251	0.402	0.563	0.646
12	0.598	0.218	0.223	0.286	0.481	0.800
13	0.425	0.286	0.245	0.426	0.671	0.608
		M2 - MORTALITY (CANNIBALISM)				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	1.415	1.618	1.779	1.636	1.492	1.588
2	1.725	1.359	1.491	1.715	1.623	1.581

Table 6b: VPA incorporating cannibalism for males. Estimated stock numbers are in thousands.

		N - STOCK NUMBERS				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	5813294	4856375	6202221	5101272	5874318	7039737
2	1121100	1154905	585571	849760	772751	959152.5
3	185208.0	181209.1	282755.3	27428.8	155532.6	134389.4
4	119513.7	115953.3	113904.3	179046.9	16265.2	98369.6
5	60465.5	72293.3	71016.0	69511.9	110948.3	7408.4
6	41322.3	33342.6	42752.0	39837.0	38601.2	64466.5
7	17111.8	21018.3	18234.6	22629.3	19795.2	20594.0
8	7031.0	8538.0	11076.1	9347.4	11466.1	8699.2
9	3674.5	3262.6	3888.1	5713.0	4545.1	3764.2
10	1618.0	1561.2	1360.3	1722.8	2797.9	807.4
11	246.7	746.5	706.2	640.4	831.4	798.1
12	118.6	69.2	367.0	405.3	354.6	200.3
		F - MORTALITY				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	0.000	0.000	0.000	0.000	0.000	0.000
2	0.002	0.001	0.002	0.001	0.000	0.001
3	0.018	0.014	0.007	0.073	0.008	0.025
4	0.053	0.040	0.044	0.029	0.336	0.076
5	0.145	0.075	0.128	0.138	0.093	0.142
6	0.226	0.154	0.186	0.249	0.178	0.263
7	0.245	0.191	0.218	0.230	0.372	0.403
8	0.318	0.337	0.212	0.271	0.664	0.570
9	0.406	0.425	0.364	0.264	1.278	0.644
10	0.324	0.343	0.303	0.279	0.804	0.800
11	0.821	0.260	0.105	0.141	0.973	0.657
12	0.428	0.412	0.290	0.389	0.761	0.772
		M2 - MORTALITY (CANNIBALISM)				
AGE\YEAR	1985	1986	1987	1988	1989	1990
1	1.166	1.665	1.538	1.437	1.362	1.434
2	1.371	0.956	2.609	1.247	1.299	1.496

Table 7: Food composition per length class expressed as a percent of the total weight. Results are averaged for both studies.

	Arancibia (1989)				Present study		
\ Lgth Species	17-25	26-35	36-50	51-66	23-37	38-51	52+
M.gayi	38	8	10	7	14	6	47
P.monodon	23	33	41	50	37	50	4
E. mucronata	11	42	10	1	30	17	0
S. bentincki	-	-	-	-	15	17	16
N. crockeri	-	-	-	-	4	3	9
E.ringens	11	9	12	5	6	-	-

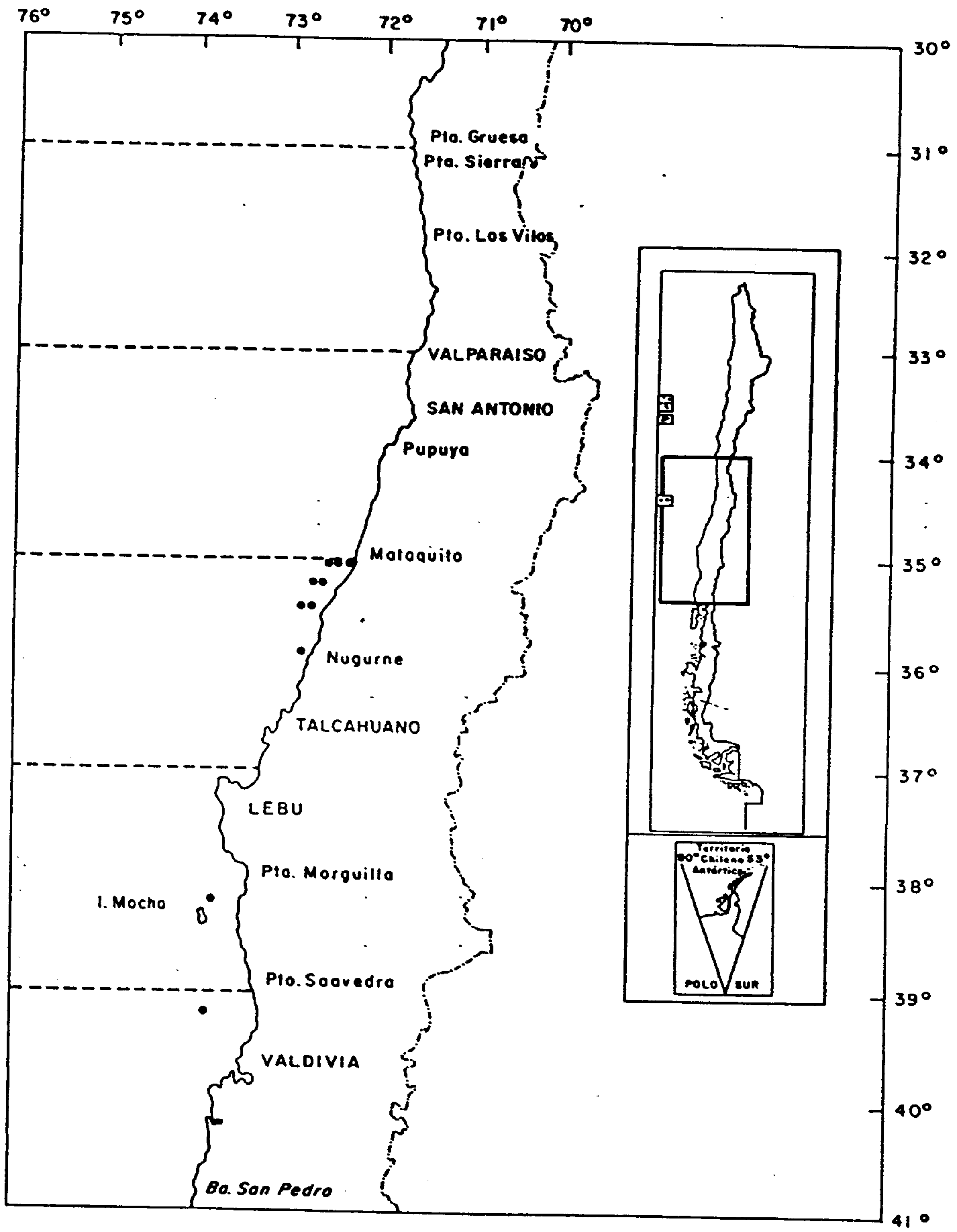


Figure 1: Map of area with sampling sites indicated by dots.

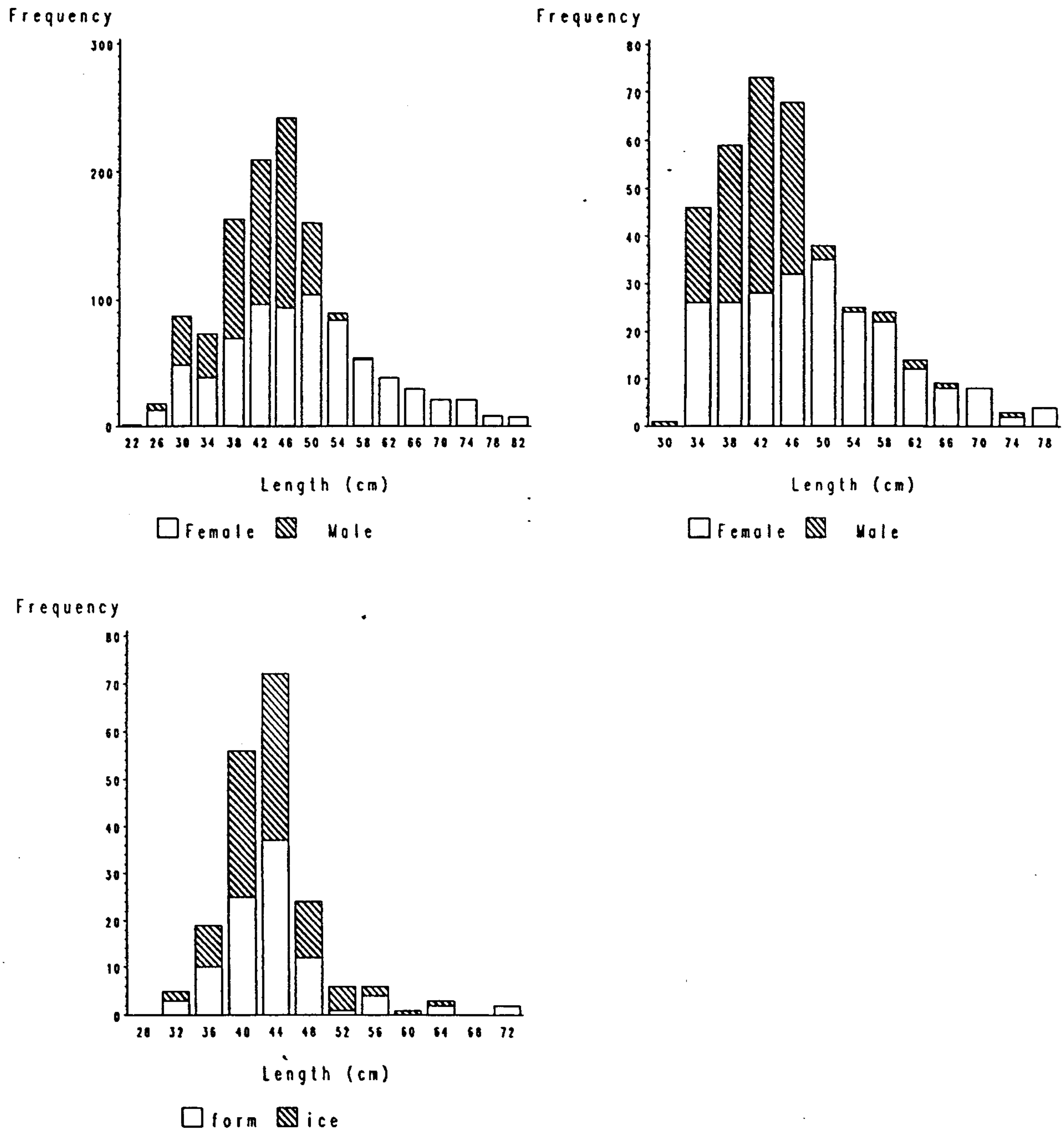


Figure 2: Frequency of sampled fish lengths for the sampling at sea (upper left), factory sampling (upper right), and the formalin-ice comparison (lower).

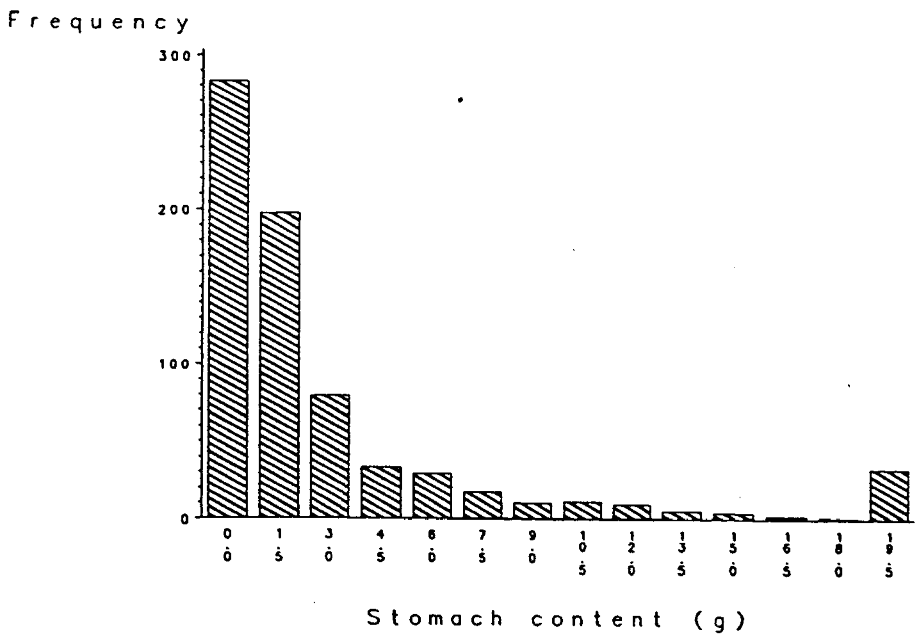
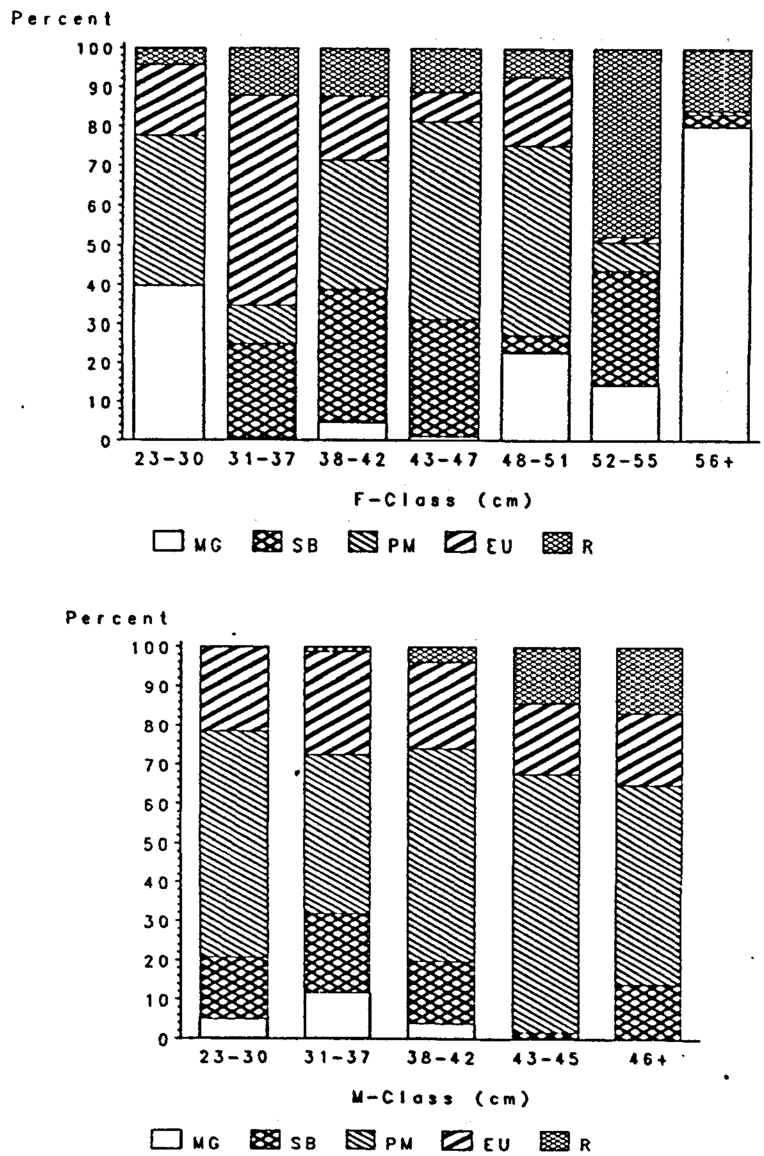
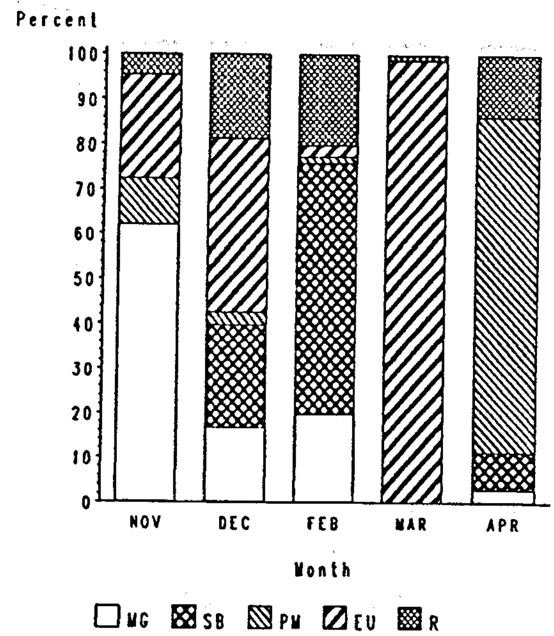


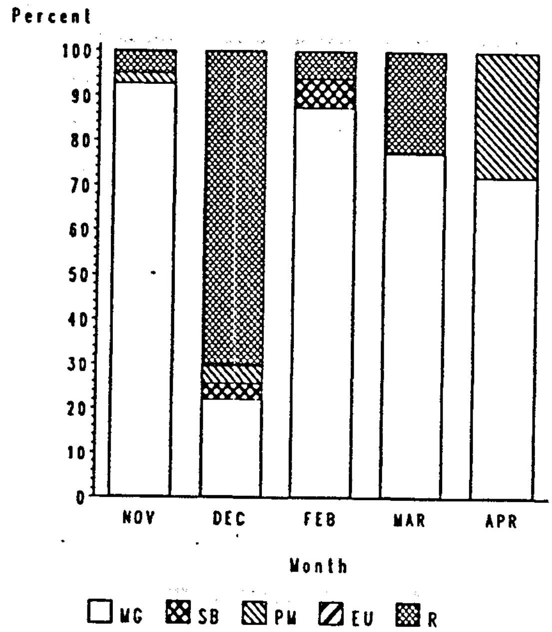
Figure 3: Frequency of the stomach content values excluding empty stomachs (511) and regurgitated stomachs (108). The last column is a sum of all values greater than 19g.

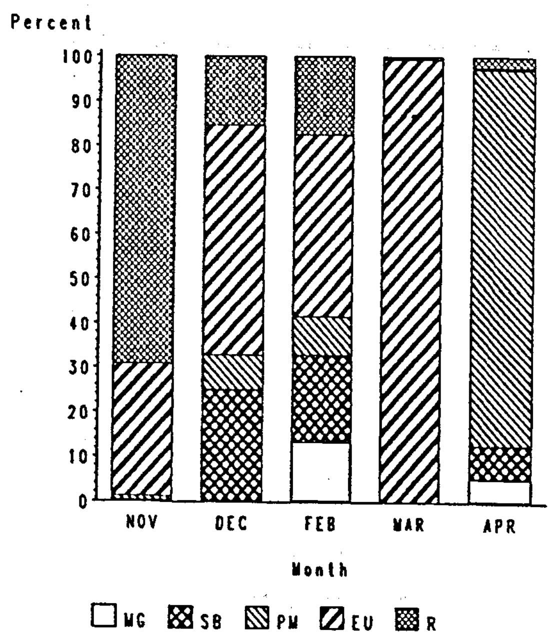


Mg: Merluccius gayi gayi
Pm: Pleuroncodes monodon
Sb: Strangomera bentincki
Eu: Euphausia mucronata
R : other items

Figure 4: Food composition per length class for females (upper) and males (lower).







Mg: _Merluccius gayi gayi_
Sb: _Strangomera bentincki_
Pm: _Pleuroncodes monodon_
Eu: _Euphausia mucronata_
R : other items

Figure 5: Food composition by month for females 23-55cm (upper left), females 56+cm (upper right), and males (lower).

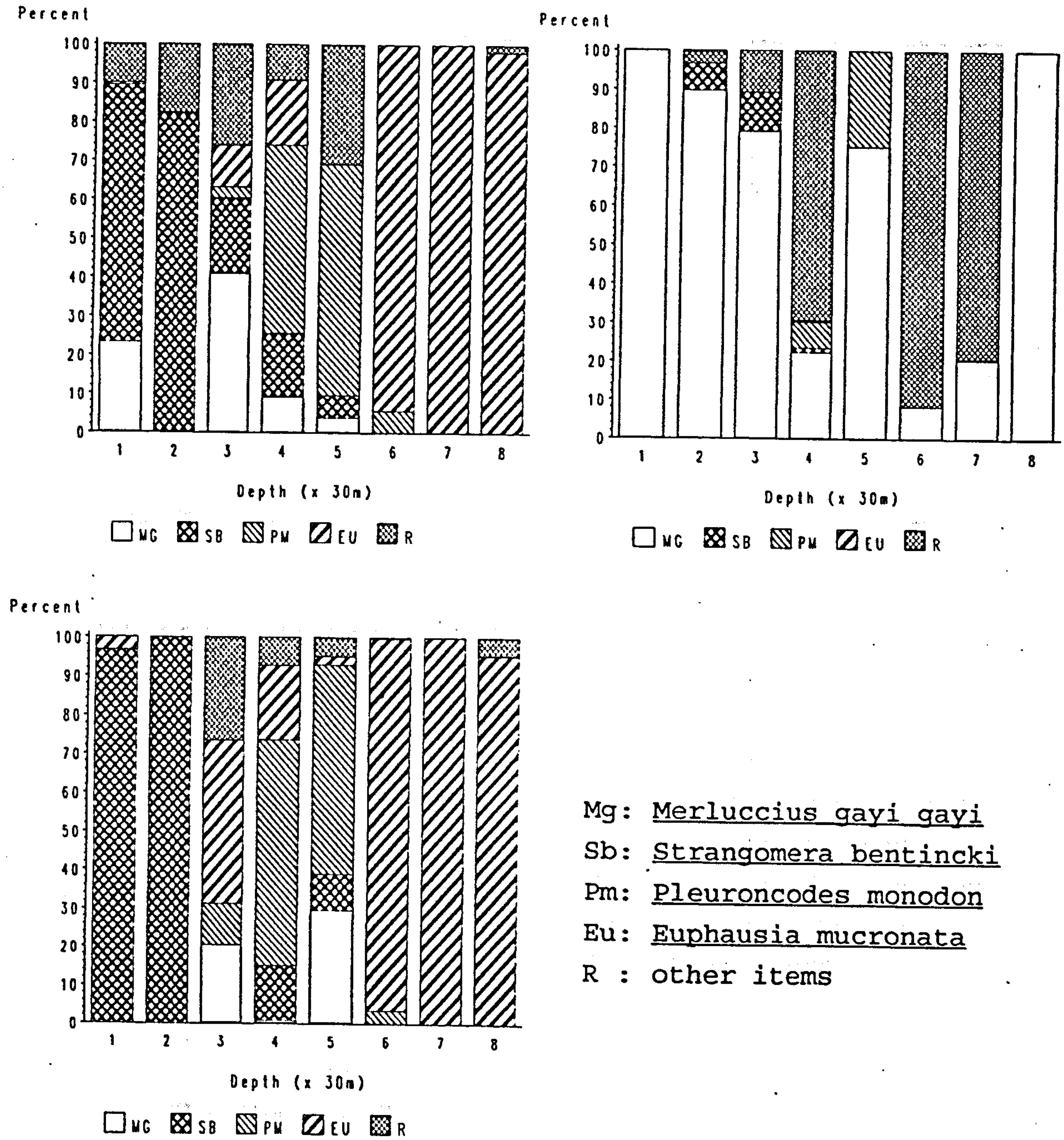


Figure 6: Food composition by depth for females 23-55cm (upper left), females 56+cm (upper right), and males (lower).

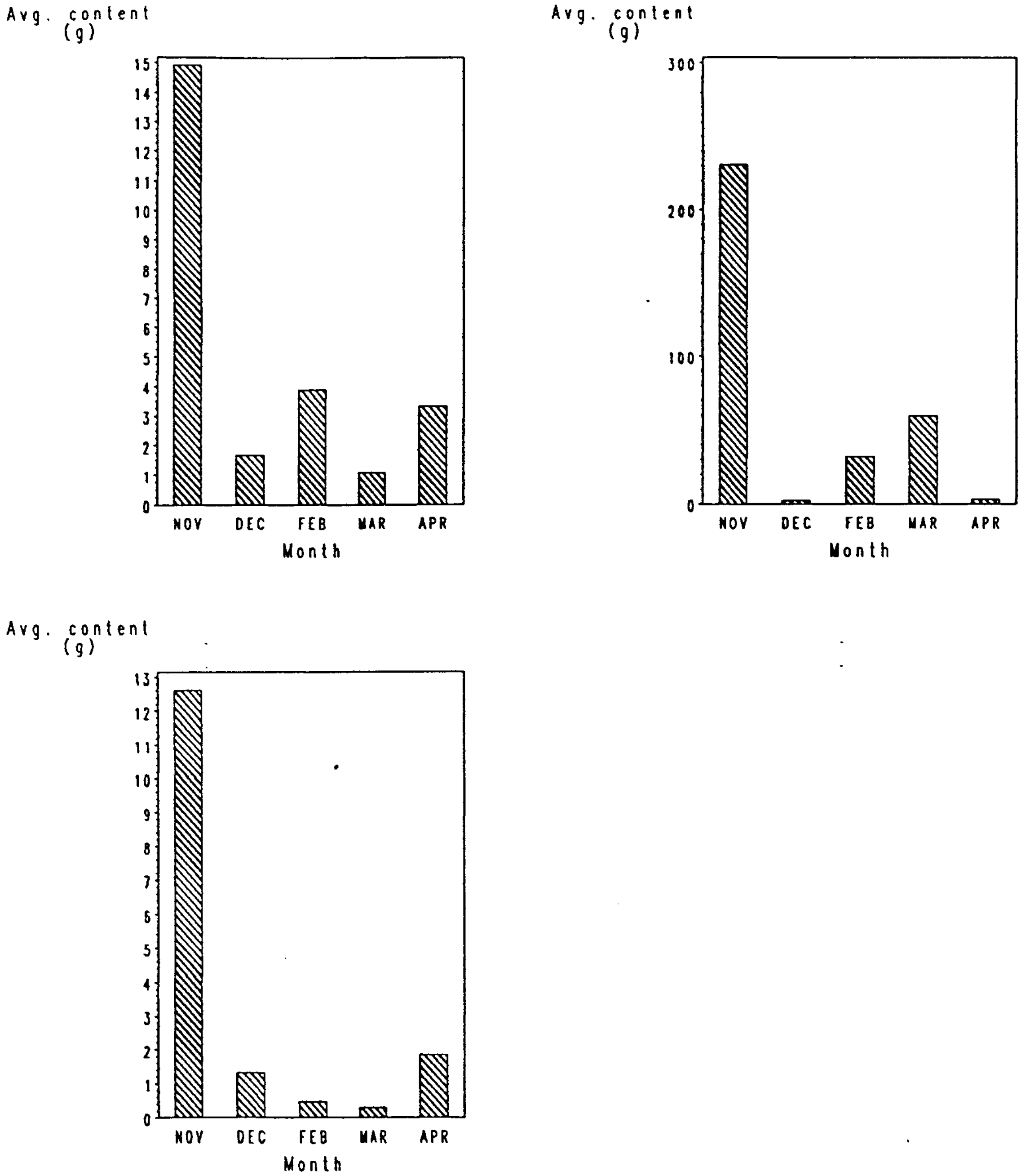


Figure 7: The average stomach content including the corrected factory samples (Nov) for females 23-55cm (upper left), females 56+cm (upper right), and males (lower).

Species	Agegroup	Cruise 1	Cruise 2	Cruise 3	Cruise 1+2	Cruise 1+3	Cruise 2+3	Cruise 1+2+3
Cod	2	0.94	0.86	0.98	0.91	0.99	0.95	0.98
	3	0.01	0.60	0.37	0.55	0.25	0.95	0.85
	4	0.91	0.69	0.54	0.77	0.79	0.80	0.78
	5	0.00	0.04	0.88	0.04	0.85	0.79	0.87
	6	0.42	0.48	0.02	0.41	0.30	0.33	0.54
	7	0.10	0.20	0.20	0.20	0.16	0.24	0.15
Haddock	2	0.53	0.71	0.07	0.73	0.22	0.26	0.49
	3	0.44	0.82	0.59	0.86	0.75	0.74	0.84
	4	0.57	0.88	0.59	0.77	0.58	0.86	0.73
	5	0.91	0.98	0.85	0.93	0.90	0.95	0.96
	6	0.96	0.93	0.97	0.98	0.98	0.99	0.98
	7	0.63	0.58	0.81	0.61	0.69	0.70	0.62
Saithe	3	0.37	0.05	0.01	0.24	0.19	0.06	0.27
	4	0.01	0.63	0.02	0.00	0.00	0.34	0.34
	5	0.88	0.80	0.85	0.87	0.91	0.94	0.92
	6	0.44	0.24	0.00	0.61	0.24	0.26	0.71
	7	0.83	0.32	0.15	0.90	0.79	0.32	0.84
	8	0.63	0.15	0.50	0.33	0.71	0.36	0.38

Table 7: Correlation (r^2) between VPA estimates and stratified indices from groundfish surveys 1983 - 1988 for various cruise combinations (original stratification).

Species	Agegroup	No stratification	Original stratification	restratified
Cod	2	0.98	0.98	0.99
	3	0.65	0.85	0.84
	4	0.76	0.78	0.70
	5	0.96	0.87	0.91
	6	0.72	0.54	0.84
	7	0.02	0.15	0.01
Haddock	2	0.50	0.49	0.44
	3	0.70	0.84	0.74
	4	0.72	0.73	0.70
	5	0.97	0.96	0.98
	6	0.96	0.98	0.96
	7	0.61	0.62	0.62
Saithe	3	0.38	0.27	0.58
	4	0.11	0.34	0.10
	5	0.90	0.92	0.87
	6	0.63	0.71	0.30
	7	0.85	0.84	0.87
	8	0.53	0.38	0.31

Table 8: Correlation (r^2) between VPA estimates and stratified indices from groundfish surveys 1983 - 1988 for various stratification schemes (all cruises combined).