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An Assessment of Deep Water Shrimp Surveys In Angolan Waters

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ABSTRACT

Four surveys for deep water shrimp (*Parapenaeus longirostris* and *Aristeus varidens*) sponsored by the EU were carried out in Angolan waters in the period 1989 to 1991.

Estimates of fish abundance from stratified random trawl survey can be highly variable and modifications of the estimators and the survey design have been suggested to provide more precise estimates.

The sampling design and the precision of these surveys are evaluated in this work.

The present study showed that in general for the two species the sampling design with stratification performed better than a simple random survey. However, more precise estimates could be obtained if the sample were allocated proportional to the strata. For *P. Longirostris* more samples should be allocated in the 100-200

Introduction

Shrimp is one of the world's economically most valuable fishery resources and the present annual shrimp catch is estimated at around 1.8 million tones (Anon. 1993). Most of this comes from coastal Panaeid shrimp fisheries and the so-called deep-water shrimps contribute only 10% to the world catch.

The trawl fishery for deep- water shrimps is at the present economically most important fishery in Angola, but relatively little is Known about the shrimp stocks and their population dynamics. Fourteen deep-water shrimp species, representing nine families, occur in the commercial catch, but only the deep-water rose shrimp (*Parapenaeus longirostris*, Penaeidae) and the Striped red shrimp (*Aristeus varidens*, Aristeidae) are commercially important due their abundance (López-Abbélan & Cárdenas, 1990). The two species are living at different depths, with the former mainly found between 150 to 400m and the latter most common between 400 and 600m (Holthuis,1980).

The fishing takes place in the area between 5°S and 12°S (Figure 1 A and B) and has developed rapidly since commercial trawling started in 1967 (Dias & Machado, 1973). The first assessment on the Angolan deepwater shrimp, based on catch statistics from the Spanish trawlers was carried out by Rosado (1974). He reported that annual yields rose from around 1,200 to 8,000 tones in the period 1967 to 1972. Those catch figures emcompased a mixture of three species; *P. longriostris* , *A. varidens* and *Plesiopenaeus edwardsianus* (Scarlet shrimp).The same author reported that this increase in catch was accompanied with increase on effort from 11 to 54 vessels.

The Spanish fleet ceased to exploit the stock in 1977 and was replaced by a Cuban fleet, which fished until 1979 (Wysokinski, 1986).The reported catch was around 1,800 tones in 1977 and 200 tones in 1979. No information on effort is available for that period.

Strømme and Sætersdal (1991) reported that in 1985 the fishery was resumed with high effort, and presently the fishery is performed by licensed vessels from European Union (EU), mainly Spain. The catches were in order of about 9,000 tones per year until 1988 when it fell to 5,500 tones (Strømme and Sætersdal 1991).

The decline in the reported catch and the general lack of reliable comprehensive statistics, stresses the need for stock assessment in order to establish a sound management of the resources. From 1989 four research surveys, sponsored by the EU and conducted by commercial Spanish vessels, were carried out in the Angolan waters period 1989 to 1991 (López Abellãn & García- Talavera,1993).

The principal objective of these surveys were to describe the species composition, distribution and to estimate the abundance index (cpue) of the main species of shrimp.

López Abellán Cárdenas,1990 ,López Abellán & García-Talavera, (1992) used the stratified sampling design recommended by Saville (1977) to increase the precision of the mean cpue estimates for the Angolan shrimp research surveys. However, it is a recurrent discussion with trawl surveys how they are best designed and how the limited time and resources are best allocated, as the reliability of stock assessment results are greatly influenced by the precision of the survey abundance estimate (McConnaughey & Conquest, 1993; Smith & Gavaris, 1993). Smith & Gavaris (1993) reported that research on methods to improve the precision of abundance estimates from trawl surveys are mainly concentrated on two approaches: modification of the estimators and modification on the survey design.

For modifications of the estimators several statistical models have been suggested for, example the negative binomial (Houser and Dunn ,1967), the poisson (Brodie & Wells, 1985) and the Delta distribution (Pennington 1983, 1986). Most of this models are skewed probability distribution and they are chosen to reflect observed mean to variance relationship (Smith,1990).

Modifications on survey design are mainly based on revision of stratification criteria (Smith & Gavaris ,1993), changes in total sampling effort and the allocation of samples to the various strata (Vølstád *et al.*, 1994).Too small sample-size may lead to imprecise results, while too large may be a waste of limited resources (Dixon & Garret,1993).

Based on the above considerations the objective of this work is to review the sample design for the research surveys for deep-water shrimp carried out in Angolan waters in order to possibly improve the precision of the abundance estimates

Materials and Methods

This study is based on the data collected during the four EU sponsored research surveys carried out in Angolan waters from 1989 to 1990 (Table 1).The first survey was conducted with the commercial vessel " Pegado Terceiro", a 40.15 m rigged trawler. The others were carried out with commercial vessel " la Espanhola" a 36 m rigged trawler.The positions of the trawl stations are shown in the figure 1 A and B.

Table 1: Deep water shrimp surveys carried out in Angolan waters by the EU vessels

Surveys	Year	Month	Season
I	1989	March	Rain
II	1989	November	Dry
III	1990	November	Dry
IV	1991	July	Dry

Information on gear design can be found in López Abèllan & Càrdenas (1990) and López Abèllan & García-Talavera (1992).

Under normal operation, four hauls, each of about 30 minutes, were performed daily throughout the survey periods. In order to minimize the supposed influence of vertical migration the trawling was carried out during day-time only.

Survey design

A stratified random sampling design was used for the surveys. The fishing area was divided into two geographical regions: a northern between Cabinda and Ponta das Palmerinha (5°00'S and 9°05'S) and a southern between Ponta das Palmerinhas and Lobito (9°05'-12°20')(Fig 1 A and B). In the first survey each of regions were divided into nine depths strata. In the remaining surveys eight depths strata were used (Table 2 and 3) The stratification of the survey area was based on depth contours and previous available information on the distribution of *P. longirostris* and A.*varidens* (López Abèllan & Càrdenas (1990 and López Abèllan & García-Talavera 1992). No criterion was given for the allocation of hauls to strata.

Table 2. Total number of hauls per depths stratum in the Northern region

	Survey							
	P.longirostris				*A.varidens*			
Depth/stratum	I	II	III	IV	I	II	III	IV
50-100	5	7	7	5				
100-200	3	7	7	6				
200-300	9	7	6	6				
300-400	6	5	4	8	6	-	4	
400-500	-	-	9	-	7	6	9	5
500-600	-	-	-	-	5	7	5	6
600-700	-	-	-	-	6	5	4	6
700-800	-	-	-	-	3	7	6	3

Table 3. Total number of hauls per depths stratum in the Southern region.

	Survey							
	P.longirostris				*A.varidens*			
Depth/stratum	I	II	III	IV	I	II	III	IV
50-100	4	9	7	6				
100-200	3	5	6	6				
200-300	5	4	7	6				
300-400	4	5	5	4	4	4	5	4
400-500	-	-	-	-	4	7	8	5
500-600	-	-	-	-	3	9	8	6
600-700	-	-	-	-	4	4	4	6
700-800	-	-	-	-	2	4	4	4

Estimators of relative abundance

Although the sample mean is an unbiased estimator of the population mean, studies have show that it is sensitive to extreme values (e.g. Pennington, 1983; McConnaughey & Conquest, 1993). Distributions of catch per standard tow are often highly skewed and the sample mean may not be an efficient estimator in such cases. Moreover, if sample sizes are small, the Central Limit Theorem cannot be invoked when confidence limits of the mean abundance are to be calculated (Sissenwine,1978). When evaluating trends in catch based on abundance indices, McConnaughey & Conquest (1993) recommended a comparison of several indices. A preliminary study of the catch data for Angolan shrimps showed an aggregated distribution with several zero-catches. It was therefore decided to model the catch rates of shrimps According to Delta distribution and compare the estimated mean for this distribution with that based on the arithmetic mean.

Design-based estimators

For a stratified random survey the stratified arithmetic mean is an unbiased estimator for the population mean (Cochran,1977):

$$\bar{y}_{st} = \sum_{h=1}^{L}\left(\frac{N_h}{N}\right)\bar{y}_h = \sum_{h=1}^{L}\left(\frac{A_h}{A}\right)\bar{y}_h = \sum_{h=1}^{L} W_h \bar{y}_h \qquad (1)$$

Where L is the number of strata, N_h is the number of sampling units (hauls) in stratum h, N is the total number of sampling units, and $\bar{y}_h$ is the sample mean cpue in stratum h. Because the sampling units are identically-sized area sections covered in a standard haul, the stratum weight for stratum h (w_h) is equal to the ratio of the area of stratum h to that of the total surveyed area.

An estimator of the variance of the stratified mean is:

$$Var(\bar{y}_{st}) = \sum_{h=1}^{L} W_h^2(1-f_h)\frac{s_h^2}{n_h} \approx \sum_{h=1}^{L} W_h^2 \frac{s_h^2}{n_h} \qquad (2)$$

Where n_h is the number of hauls in stratum h, $f_h = \frac{n_h}{N_h}$ is the finite population correction in stratum h, s_h^2 is the sample variance in the h, and w_h are defined for equation (1)

Model-based estimator

The delta distribution is a modification of the log-normal distribution to situations where zero observations are observed (Pennington, 1983). If the conditional distribution of stochastic variable X given X is not equal to zero is lognormal, then X is delta distributed. Unbiased estimators of the mean (c) and its variance for delta distribution are (Aitcheson, 1995; cited by Pennington, 1983).

$$c = \begin{cases} \frac{m}{n}\exp(\bar{y})\, G_m(\frac{s^2}{2}), & m > 1 \\ \frac{x_1}{n}, & m = 1 \\ 0, & m = 0 \end{cases} \qquad (3)$$

and

$$Var(c) = \begin{cases} \frac{m}{n}\exp(2\bar{y})\left\{\frac{m}{n}G_m^2(\frac{1}{2}s^2) - (\frac{m-1}{n-1})\, G_m(\frac{m-2}{m-1}s^2)\right\}, & m > 1 \\ (\frac{x_1}{n})^2, & m = 1 \\ 0, & m = 0 \end{cases} \qquad (4)$$

where n is the total number of observation (hauls), m is the number of non-zero observations: x_1, x_2 .....x_m are the non-zero observations, and $\bar{y}$ and s^2 are the mean and variance of the log-transformed non-zero observations G_m is an infinite series which is used to correct for bias in re-transformation from log to arithmetic scale.

One of assumptions for the applicability of the delta distribution is that the logaritmically transformed non-zero catches are normally distributed. In order to test this assumption the Kolmogorov & Smirov test for normality (Zar,1984) was applied to the log transformed cpue distributions for each species and survey.

Stratified survey design vs. simple random sampling

According to Cochran (1977), one way to evaluate the efficiency of a stratified random survey,is to compare its variance with that obtained for a simple random survey of the same size. Given the results of a stratified random sample, an estimate of a variance for simple random survey from the same population is (Sukhatme & Sukhatme, 1970; cited by Smith & Gavaris, 1993):

$$\hat{V}(\bar{y}_{ran}) = (\frac{N-n}{nN})\sum_{h=1}^{L} W_h s_h^2 + (\frac{N-n}{n(N-1)})\left\{\sum_{h=1}^{L} W_h(\bar{y}_h - \bar{y}_{st})^2 - \sum_{h=1}^{L} W_h(1-W_h)\frac{s_h^2}{n_h}\right\} \qquad (5)$$

where n is the total number of hauls, N_h is the total number of possible y_h is the mean in stratum h, $\bar{y}_{st}$ is the stratified mean is the sample variance in stratum h, and W_h is the stratum weight for stratum h as defined in equation (1).

An estimator for difference between the variance of the sample mean based on simple random sampling and stratified random is (Sukhatme & Sukhatme, 1970; cited by Smith & Gavaris 1993).

$$\hat{V}(\bar{y}_{ran}) - \hat{V}(\bar{y}_{st}) = \overbrace{\sum_{h=1}^{L}(\frac{1}{n} - \frac{W_h}{n_h})W_h\, s_h^2}^{a} + \overbrace{(\frac{N-n}{n(N-1)})\left\{\sum_{h=1}^{L} W_h(\bar{y}_h - \bar{y}_{st})^2 - \sum_{h=1}^{L} W_h(1-W_h)\frac{s_h^2}{n_h}\right\}}^{b} \qquad (6)$$

Using this formula it is possible to separate the variance of the sample mean from random sampling into two components. The first term (a) of the equation refers to the variance component due to the allocation scheme. The second term (b) is variance component due to stratification scheme.

According to Smith & Gavaris (1993) the percentage gain or loss in precision between a stratified design versus a random design can be expressed in terms the relative efficiency:

$$RE = \frac{\left[\hat{V}(\bar{y}_{ran}) - \hat{V}(\bar{y}_{st})\right]\cdot 100}{\hat{V}(\bar{y}_{ran})} \qquad (7)$$

RESULTS

Estimations of abundance and variance

The general trend in the cpue whether using the delta distribution or arithmetic mean is that for both species, the stocks have fluctuated (Table 4 and 5). However, a higher fluctuation amplitude is found within a year (survey I and II in 1989).

Table 4. Arithmetic mean $\bar{Y}(st)$ and delta distribution (C) estimates of the stratified cpue (Kg/h), the variance (V), and coefficient of Variation (CV) for *P. longirostris* by region and surveys.

		Arithmetic			Delta Distribution		
Survey	Region	$\bar{Y}$(st)	V(st)	CV(%)	C	V(C)	CV(%)
I	Northern	7.76	12.6	46	6.68	2.67	24
	Southern	24.64	101.07	41	39.47	292.28	43
	Total	14.02	18.91	31	21.30	33.69	27
II	Northern	16.43	15.63	24	16.43	2.67	10
	Southern	62.47	63.21	39	63.21	303.72	28
	Total	33.51	88.72	28	33.50	29.43	16
III	Northern	8.77	4.80	25	8.90	4.14	23
	Southern	33.42	37.29	18	33.76	64.74	24
	Total	17.91	7.03	15	21.02	11.54	16
IV	Northen	7.78	3.08	23	7.89	2.12	18
	Southern	23.48	29.81	23	23.62	36.40	26
	Total	13.60	5.32	17	15.38	5.57	15

Table 5. Arithmetic mean $\bar{Y}(st)$ and delta distribution (C) estimates of the stratified cpue (Kg/h), the variance (V), and coefficient of Variation (CV) for *A. varidens* by region and surveys.

		Arithmetic			Delta Distribution		
Survey	Region	$\bar{Y}(st)$	V(st)	CV(%)	C	V(C)	CV(%)
I	Northern	10.83	6.57	25	7.87	2.29	22
	Southern	12.36	4.69	18	10.02	4.52	18
	Total	11.35	3.42	16	8.29	2.54	19
II	Northern	17.21	9.31	18	13.18	5.14	18
	Southern	19.17	5.20	12	14.81	6.21	12
	Total	18.87	4.68	11	14.27	2.99	12
III	Northern	15.64	3.32	12	11.66	2.66	14
	Southern	20.50	9.50	15	15.05	6.88	17
	Total	17.28	2.54	9	13.39	2.49	12
IV	Northern	9.24	3.18	19	6.90	1.86	20
	Southern	18.18	5.70	13	13.27	6.03	19
	Total	12.24	2.04	12	10.45	2.07	12

For *P.longirostris* the ordinary log transformed (y= ln (x+1)) catch distribution is highly skewed to the right (Fig 2). When zero catches were removed, the log transformed data (y=ln (x)) were closer to normal distribution (Fig 2), supporting the applicability of the delta distribution. Also for *A. varidens* the results (fig 3) show that after log transformation of non- zero catches, the distribution approaches normal. Although the distribution of non-zero catches was not normal (P<0.01) for the surveys carried out in March 1989 and November 1990, the degree of skewness is less than compared with that of zero catches included.

A comparison of the precision of the survey estimate from two approaches (based on the coefficient of variation) showed no consistent difference for *P.longirostris* (Table 4). For *A.varidens*, however, a general increase in the coefficient of variation was observed with Delta distribution approach (Table 5).

Stratified random survey vs. simple random survey

For *P. longirostris* the results show (Table 6) showed that the stratification scheme used in the first two surveys resulted in negative relative efficiency,thus in these surveys a simple random design would performed better. However, for the last two surveys the result of the stratification was in a gain in the precision relative to a simple random survey.

For *A. varidens* (Table 7) the stratification scheme for the three first surveys performed better than a simple random survey. However, for the last survey carried out in 1991, a simple random design could have performed better than stratified random survey.

Table 6. Stratified mean cpue ($\bar{Y}_{(st)}$) for *P.longirostris* by surveys and regions, its variance ($V_{(st)}$) and teh variance ($V_{(ran)}$) of a simple random survey. The relative efficiency (%RE) is the gain or loss in precision of the employed stratified design compared with a simple random design.

Survey	Region	$\bar{Y}_{(st)}$	$V_{(st)}$	$V_{(ran)}$	%RE
I	Northern	7.76	12.67	10.28	-23.25
	Southern	24.64	101.07	63.66	-58.78
	Total	14.02	18.91	14.16	-33.60
II	Northern	16.43	15.63	17.17	8.97
	Southern	62.47	599.76	356.22	-68.37
	Total	33.51	88.72	75.37	-17.71
III	Northern	8.77	4.80	5.88	20.83
	Southern	33.42	37.29	48.10	22.46
	Total	17.91	7.03	12.77	44.95
IV	Northern	7.78	3.08	3.28	6.06
	Southern	23.48	29.81	44.61	38.18
	Total	13.60	5.32	10.26	48.17

Table 7. Stratified mean cpue ($Y_{(st)}$) for *A.varidens* by surveys and regions, its variance ($V_{(st)}$) and the variance ($V_{(ran)}$) of a simple random survey. The relative efficiency (%RE) is the gain or loss in precision of the employed stratified design compared with a simple random design.

Survey	Region	$Y_{(st)}$	$V_{(st)}$	$V_{(ran)}$	%RE
I	Northern	10.83	6.57	11.91	44.85
	Southern	12.36	4.69	5.94	21.04
	Total	11.35	3.42	5.59	38.75
II	Northern	17.21	9.31	16.71	41.28
	Southern	19.17	5.20	11.13	53.32
	Total	18.87	4.68	7.44	37.05
III	Northern	15.64	3.32	4.51	26.32
	Southern	20.50	9.50	9.62	1.29
	Total	17.28	2.54	3.16	19.80
IV	Northern	9.24	3.18	1.87	-70.18
	Southern	18.18	5.70	4.49	-26.98
	Total	12.24	2.04	1.76	-16.10

The decomposition of the variance components (Fig 4), shows that for *P.longirostris* the stratum component contributes positively to an increase in the precision of the stratified random survey. Although the allocation component is negative in most of surveys, there is an improvement in this component from March 1989 to July 1991 (from -60% to + 5%). when the total area was considered.

For *A.varidens* (fig 5) the decomposition of the gain in precision shows that the two components contribute positively to an increase in the precision in most surveys. However, for last survey a negative contribution from the stratum and allocation component is observed when the two regions are considered separately.

Discussion

Quality of data

Gunderson (1993) listed some of the underlying that must fulfilled in bottom trawl surveys to get reliable estimates of abundance indices: 1) The entire population of the target species is within the survey area at the time is being conducted. 2) The target species should be completely vulnerable to the employed sampling gear with no gear avoidance or size selectivity.

The first assumption was not fulfilled because all the experimental surveys covered the area where the commercial fleet operate only. According to Hilborn & Walters (1992),the current distribution of the commercial fishing activity should never be used for deciding spatial boundaries of experimental abundance surveys. In addition, the surveys covered the area down to Lobito only but *P.longirostris* has been recorded southward of Lobito by R/V " Dr Fridtjof Nansen " (Anon., 1989). Both *P. longirostris* and *A. varidens* are also found in the northern part of Namibian waters (Bianchi *et al.*, 1993). This source of bias is difficult to reduce, however, because from Lobito southward the slope is to steep and rugged for any random deep water trawling (Strømme and Sætersdal 1991)

Another problem that affects the analysis of trawl survey data is the vertical distribution or migration (Parsons & Frechette, 1989). No study on vertical distribution of deep-water shrimps has been carried out in Angolan waters. Therefore, as an attempt to reduce this potential source of bias all hauls were performed during daylight only. However, making all hauls during daylight could affect the availability to the gear and underestimate the abundance of *A. varidens*. This species is Known to burrow into the bottom substrate during the day and better catch rates are generally obtained at night (Bianchi *et al.*, 1993).

Improving the precision of the estimates

As mentioned in the introduction, the research on methods to improve the precision of the abundance is based on modification of the estimators and on modification on the survey design.

The modifications of estimators tried in this study, show that in terms of relative precision, there was little evidence that the conventional arithmetic mean was less adequate than using the Delta distribution (Table 4 and 5). According to Volstad *et al.* (1994) this could be due to a low variability in the log transformed non-zeroes catches. Pennington (1983) pointed out that only if the variance of the transformed (ln (x)) data is high, the delta distribution would be substantially more efficient, since arithmetic mean is very sensitive to extreme values catches, particularly when the sample size is too small (McConnaughey & Conquest, 1993).

Survey designs

The assessment of the survey design showed that, in general for the two species, a positive contribution from the stratification was observed (Fig 4 and 5). Although the strata were defined in the same way every year,a negative contribution from this component was observed in 1991 for *A. varidens*. This could be interpreted as the variance within the stratum exceeded the variance between the strata in that year (Gavaris & Smith, 1987), meaning that the strata were not homogenous enough to reduce the variance within the stratum (Gunderson, 1993).

For *P.longirostris*, an increased improvement in the allocation component was observed from the first survey to the last survey (Table 6). The improvement was obtained by change in the sample allocation. The large negative contribution from the allocation of samples in the first two surveys was caused by the number of hauls allocated to the strata 100-200 m and 200-300m. Few hauls were allocated to these strata, which according to the present results, are the strata with highest abundance. For *A. varidens* a positive contribution from the allocation component was observed in all surveys except for 1991 (fig 5). This is related with sampling intensity, where more stations were given to the strata with a higher variance or could be related with distribution pattern of the species.

Conclusions and Recommendations

From the present study it is possible to conclude that in general for two species of shrimp, the sampling design with stratification performed better then a simple random survey, particularly when the total area is considered. However, more precise estimates could be obtained for *P. longirostris* if the samples were allocated according to the variance within each stratum. For *P.longirostris* more samples should be allocated in the 100-200 and 200-300 depth strata. For *A. varidens* an allocation scheme should be based on proportional allocation with the size of the strata.

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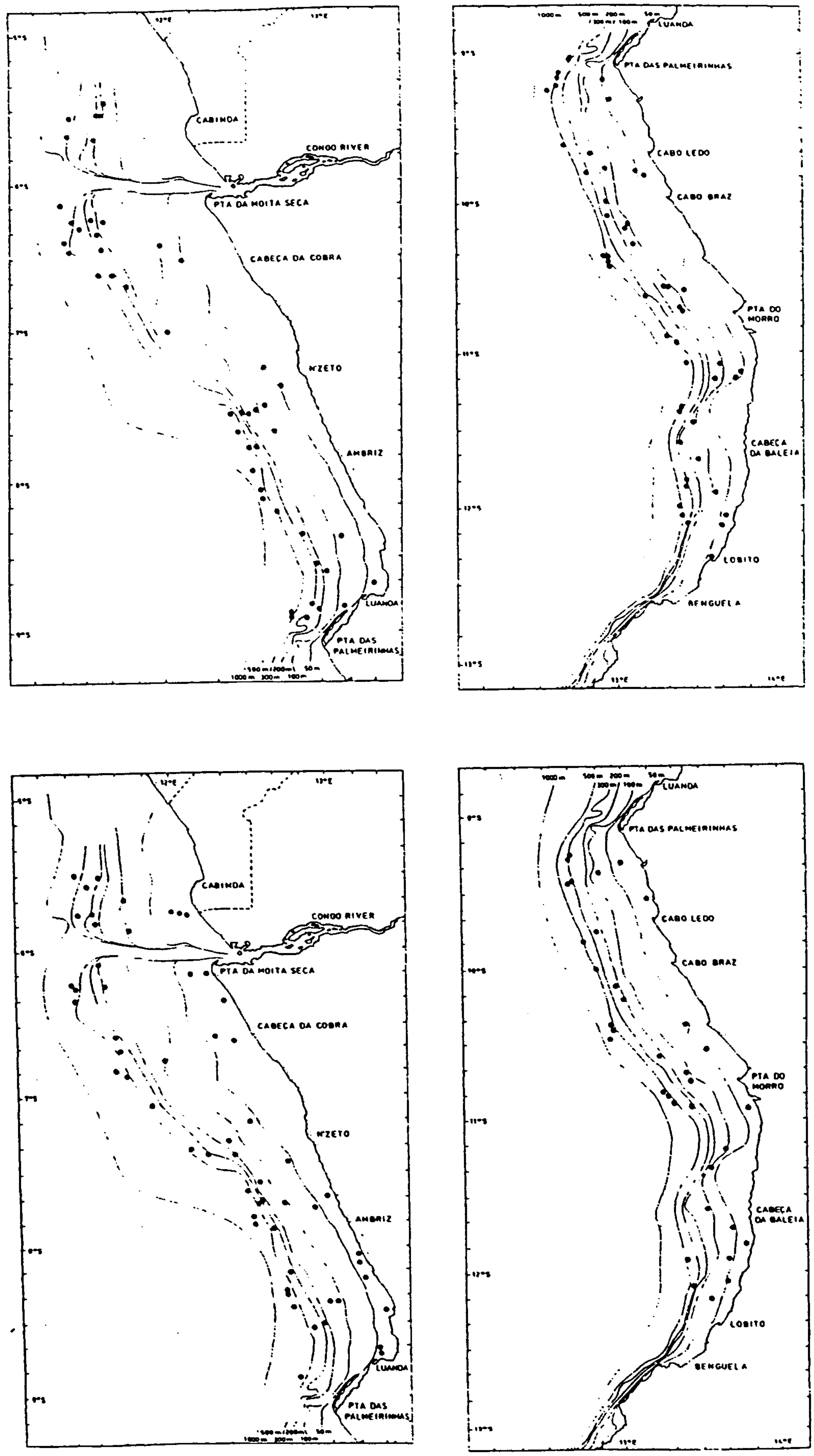

Figure 1 A: Position of the trawl stations. Upper panel March 1989, lower panel November 1989.

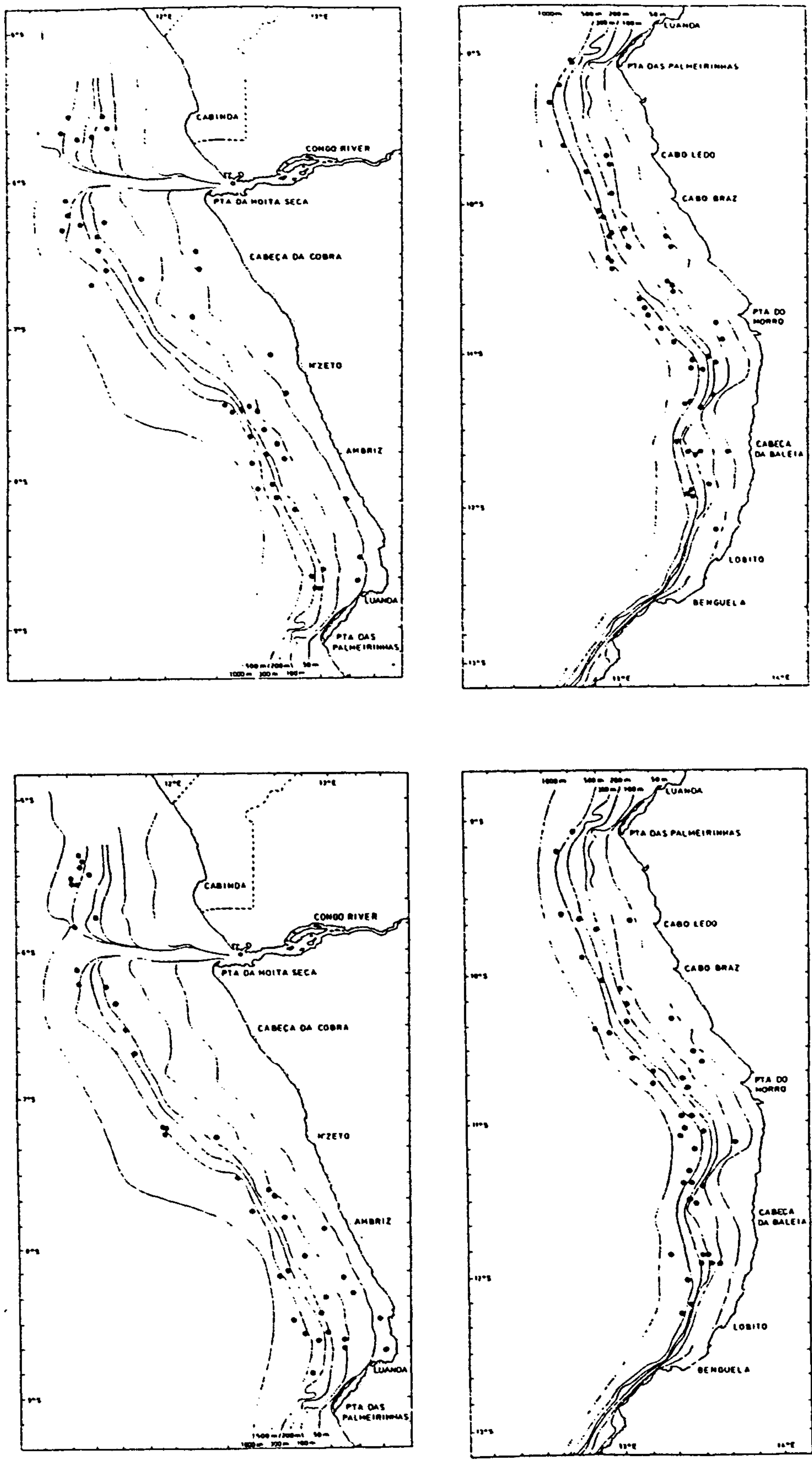

Figure 1 B. Position of the trawl stations. Upper panel Novvember 1990, lower panel July 1991

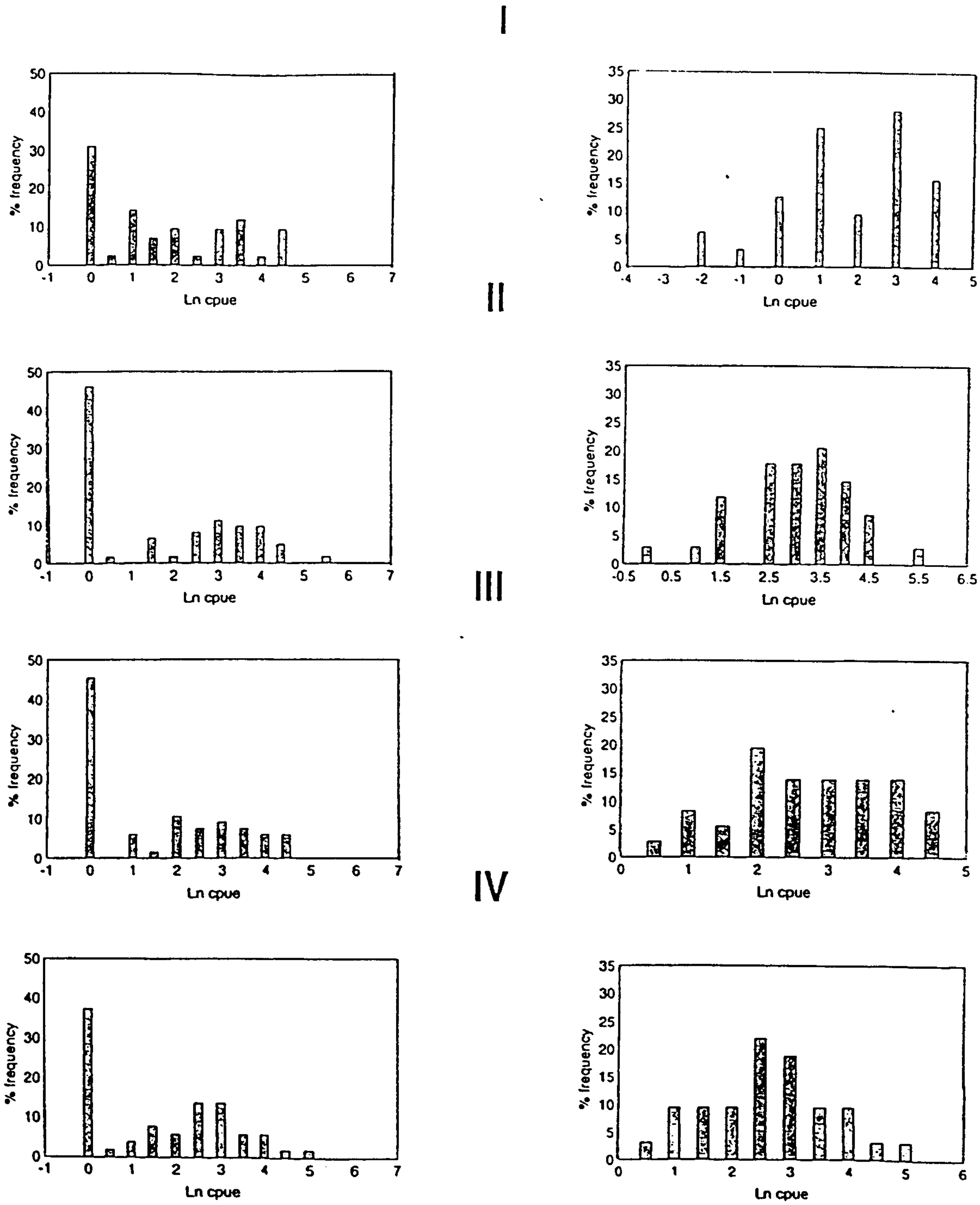

Figure 2. log transformed catch per unit effort data for *P. longirostris*. The left panel shows the distribution when zero-catches are included (Ln(x+1)) and the right when the zero-catches are excluded (delta - distribution)

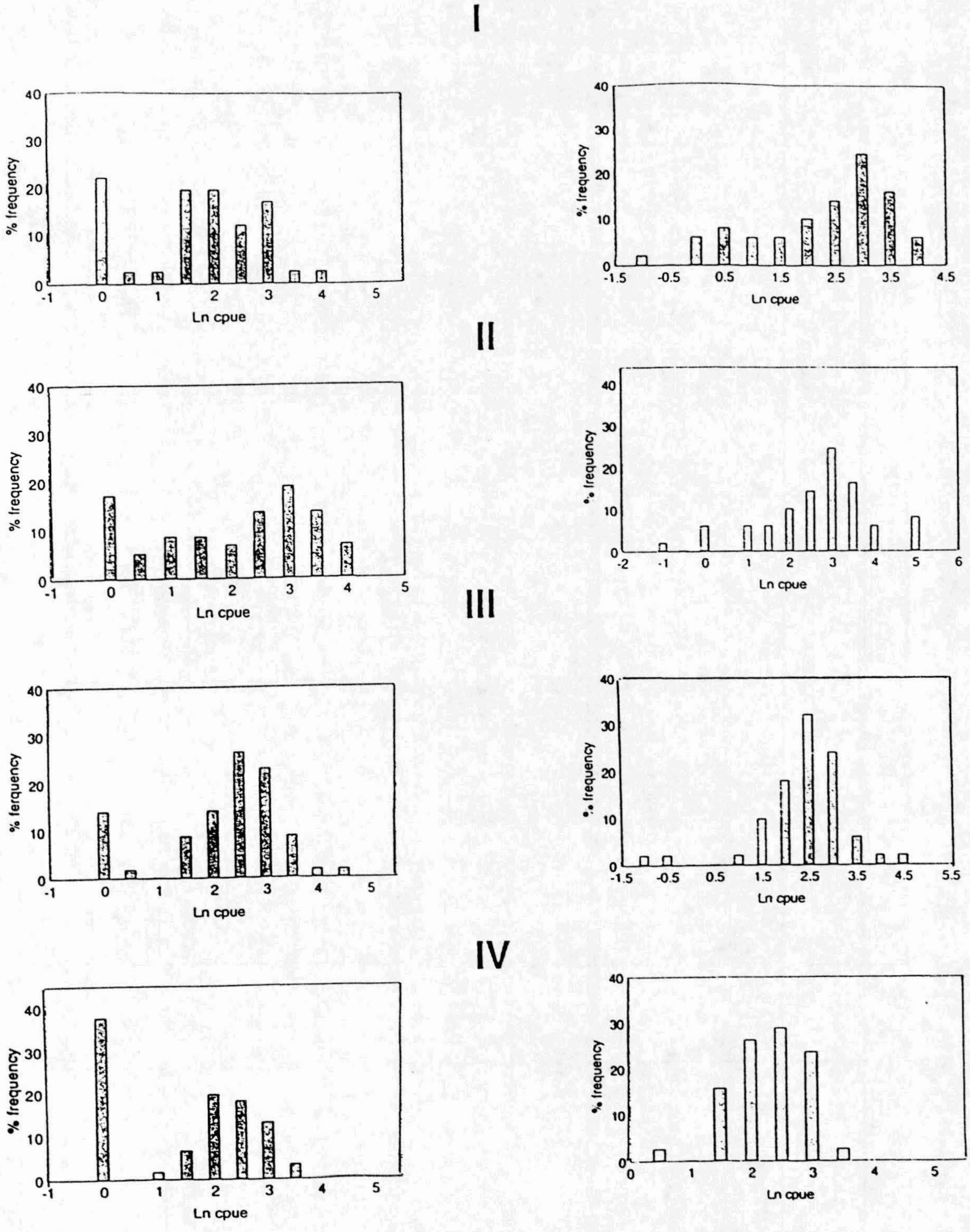

Figure 3. log transformed catch per unit effort data for *A. varidens*. The left panel shows the distribution when zero-catches are included (Ln(x+1)) and the right when the zero-catches are excluded (delta - distribution)

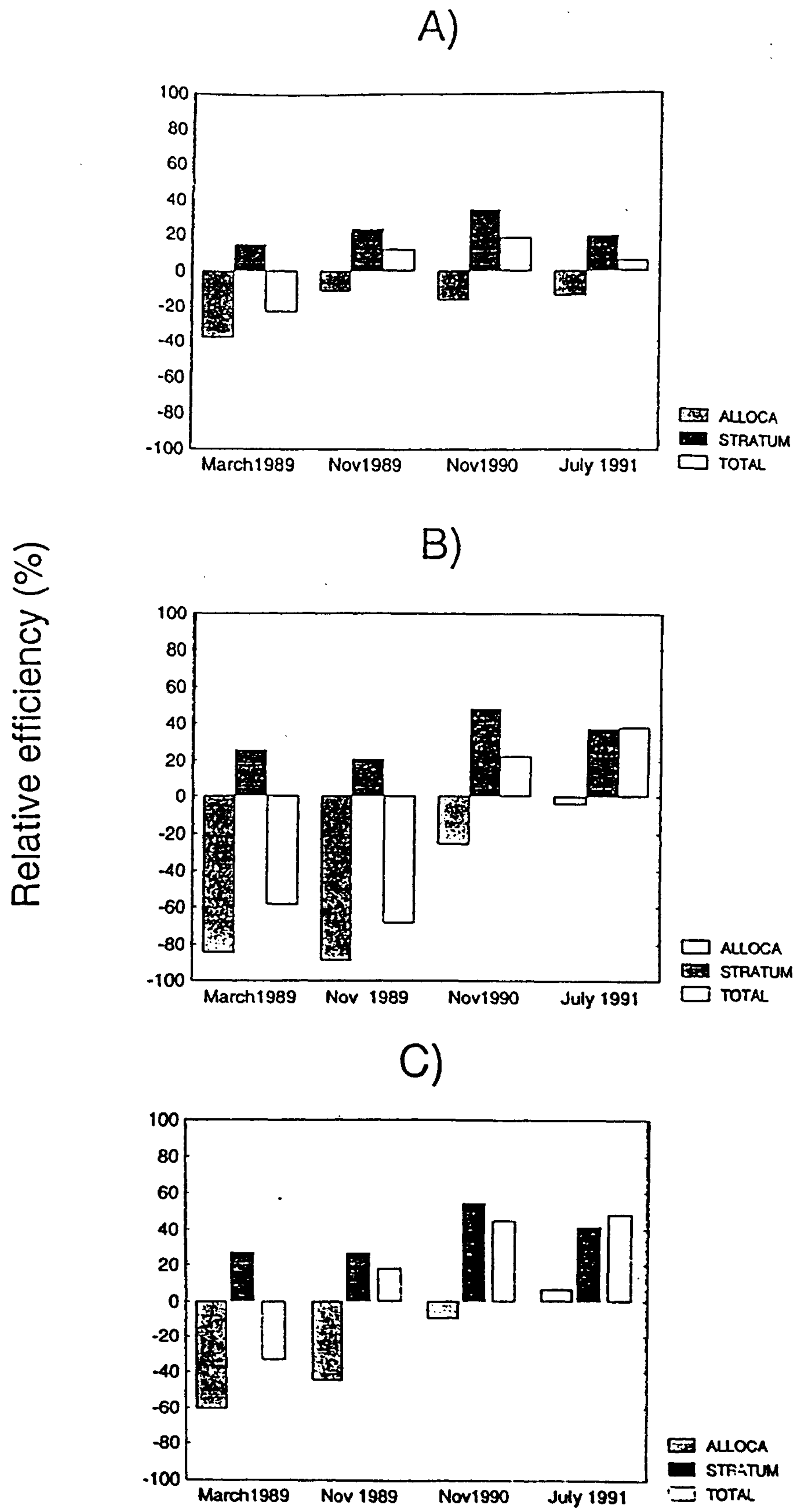

Figure 4. Gain or loss in precision (percentage) from allocation and stratum components of the stratified random survey in comparison with a sample random survey for the *P. longirostris* data. A) Northern B) southern C) total area

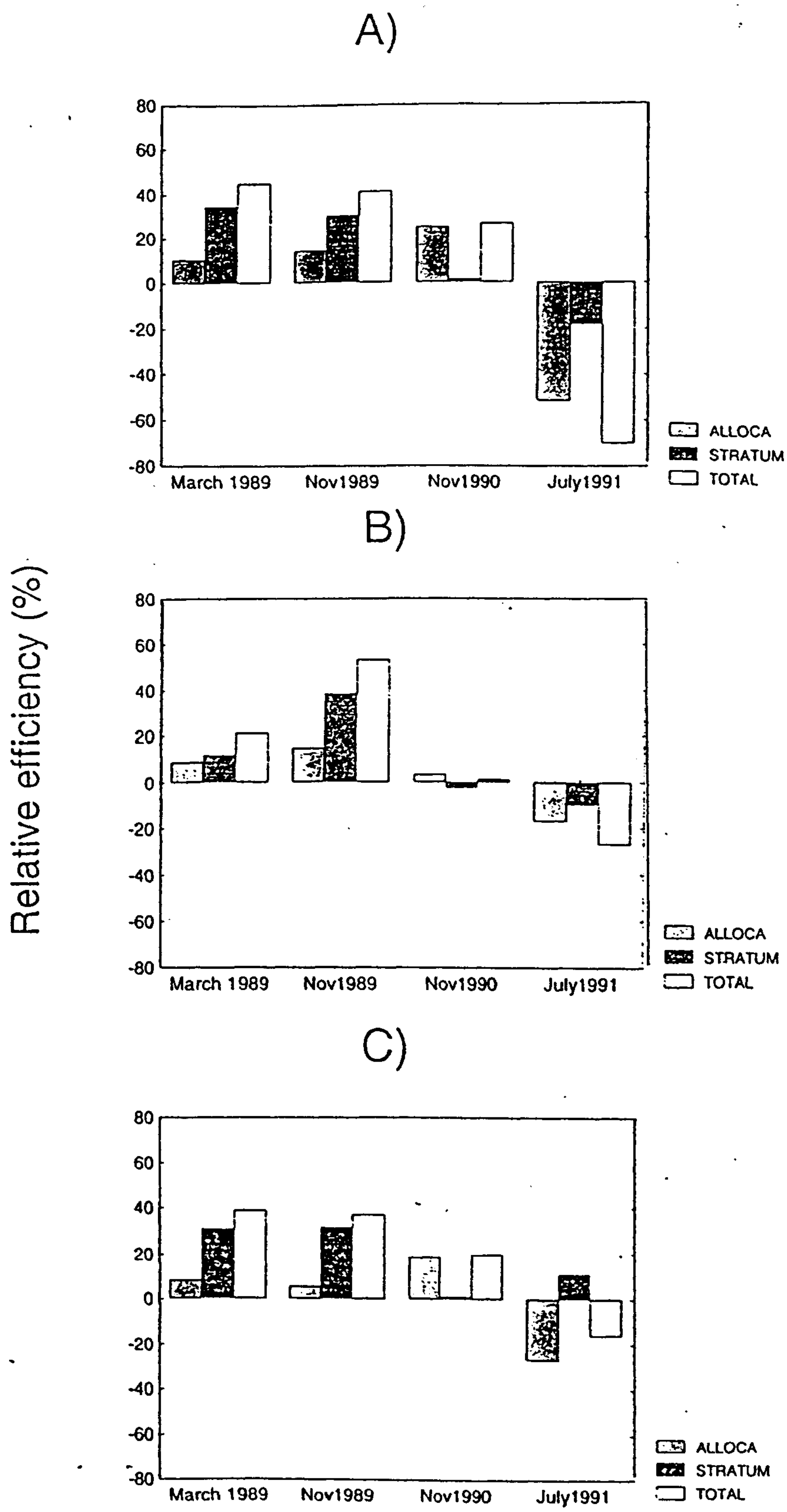

Figure 5. Gain or loss in precision (percentage) from allocation and stratum components of the stratified random survey in comparison with a sample random survey for the *A. varidens* data. A) Northern B) southern C) total area