Results of a combined hydroacoustic and midwater trawling survey of the Prince Edward Island group

D.G.M. Miller
Sea Fisheries Research Institute
Cape Town

A combined hydroacoustic and midwater trawling survey of the Prince Edward Island Group was completed in May-June 1980. The area was characterised by relatively low zooplankton abundance and biomass (0,001 – 2,625 mg dry weight/m³), thought to be the result of seasonal variation. Dominant species found were Parathemisto gaudichaudii, Sagitta gazellae *and* Gaimardia trapesina. *Both* P. gaudichaudii *and* S. gazellae *along with* Euphausia vallentini *were implicated in the diets of island-based predators in the region.*

'n Gekombineerde hidro-akoestiese en midwatertreil ondersoek van die Prins Edward-eilandgroep is gedurende Mei-Junie 1980 voltooi. Die gebied was gekenmerk deur 'n relatief lae voorkoms van soöplankton en biomassa (0,001 – 2,625 mg droë gewig/m³), gesien as die gevolg van seisoenale verandering. Parathemisto gaudichaudii, Sagitta gazellae *en* Gaimardia trapesina *was as dominante spesies gevind. Beide* P. gaudichaudii *en* S. gazellae, *tesame met* Euphausia vallentini, *is gebruik as aanduiding van die dieet van eilandgebonde roofdiere in die streek.*

Introduction

Distances between the land masses of the Southern Ocean are characteristically vast (Holdgate 1967). As a result oceanic islands form an integral part of the marine ecosystem (Knox 1960, El-Sayed 1977). Not only do they constitute accessible platforms for many land-breeding species (Knox 1960), they also provide a rich food resource in their nearshore waters (Anon 1978).

The islands of the Prince Edward group (46° 45′S, 37° 55′E) are frequented by many seabird and seal species, particularly during summer (Van Zinderen Bakker 1966, 1967, Skinner *et al.* 1978). To what extent these animals prey on nearshore plankton and micronekton in the region is largely unknown (Anon 1979). A joint hydroacoustic and midwater trawling survey was undertaken in an attempt to assess the abundance and distribution of potential food organisms in the coastal waters of the group.

Methods

The survey took place in May-June 1980 and formed part of the annual Marion Island Relief Voyage of the M.V. *SA Agulhas.*

Equipment

(a) *Detection of plankton*

A pre-calibrated 120 kHz echo-sounder (Simrad EKS 120) was used for the detection of organism concentrations. It was operated in conjunction with an echo-integrator (Simrad QM Mk. 1) and strip chart recorder unit (Hewlett-Packard HP 7702B). The apparatus gave a quantitative estimate of acoustic reflectivity along the survey path. An analogue record of scatterer conformations was also obtained.

(b) *Acoustic target identification*

Targets detected by the echo-sounder were to be collected for identification using an "aimed", opening/closing midwater trawl (RMT-8m² mouth), rigged with 5,1 mm anchovy mesh (Robertson *et al.* 1981). As a result of an observed scarcity of suitable acoustic targets, this fishing method was only employed on three occasions. A total of 14 hauls were fished obliquely. Seven of these were deployed into areas of light acoustic scatter. The net was shot closed, opened at the required depth and towed for 15 mins. prior to recovery while still open. A further seven hauls were shot "blind", taking no account of scatterer presence. The net was deployed to 50 m and fished obliquely. Towing speed during hauls was two knots.

(c) *Sampling of surface waters*

Surface waters (0-1 m) were fished using a standard neuston net fitted with 950 μ mesh (Cheng 1975). This was modified to prevent skipping by removal of the buoyancy floats and attachment of a 10 kg weight to the lower mouth bar. The net was shot daily at approximately six-hour intervals and towed for 15 mins. at two knots.

Survey strategy

The survey was divided into two parts. Initially a course was followed around both islands in the group (Prince Edward and Marion). The survey area extended as far as the 1 000 m depth contour offshore (Fig. 1). During the second half of the survey, the area between the two islands was covered extensively (Fig. 2). Survey speed was 10 knots except when hauling nets.

Data collection

(a) *Acoustic data*

The echo-sounder and integrator charts were annotated every 30 mins. Integrator readings were vetted by reference to the corresponding echo-chart record and the volume back-scattering strength/m³/30 min. interval was calculated using the following formula (after Urick 1975):

$$SV = 10\log D - 10\log R - A - SL - VR - 10\log T - 10\log I + C \quad (1)$$

where:

SV = Mean volume backscattering strength (dBm^{-3})
D = integrator deflection (mm)
R = width of depth channel integrated (m) (±5 – 100 m)
A = integrator gain (dB)
SL (source level) = 221 (dB ref. 1 Micro Pascal at 1 m)
VR (receiving sensitivity) = −104,7 (dB ref. 1V per Micro Pascal)

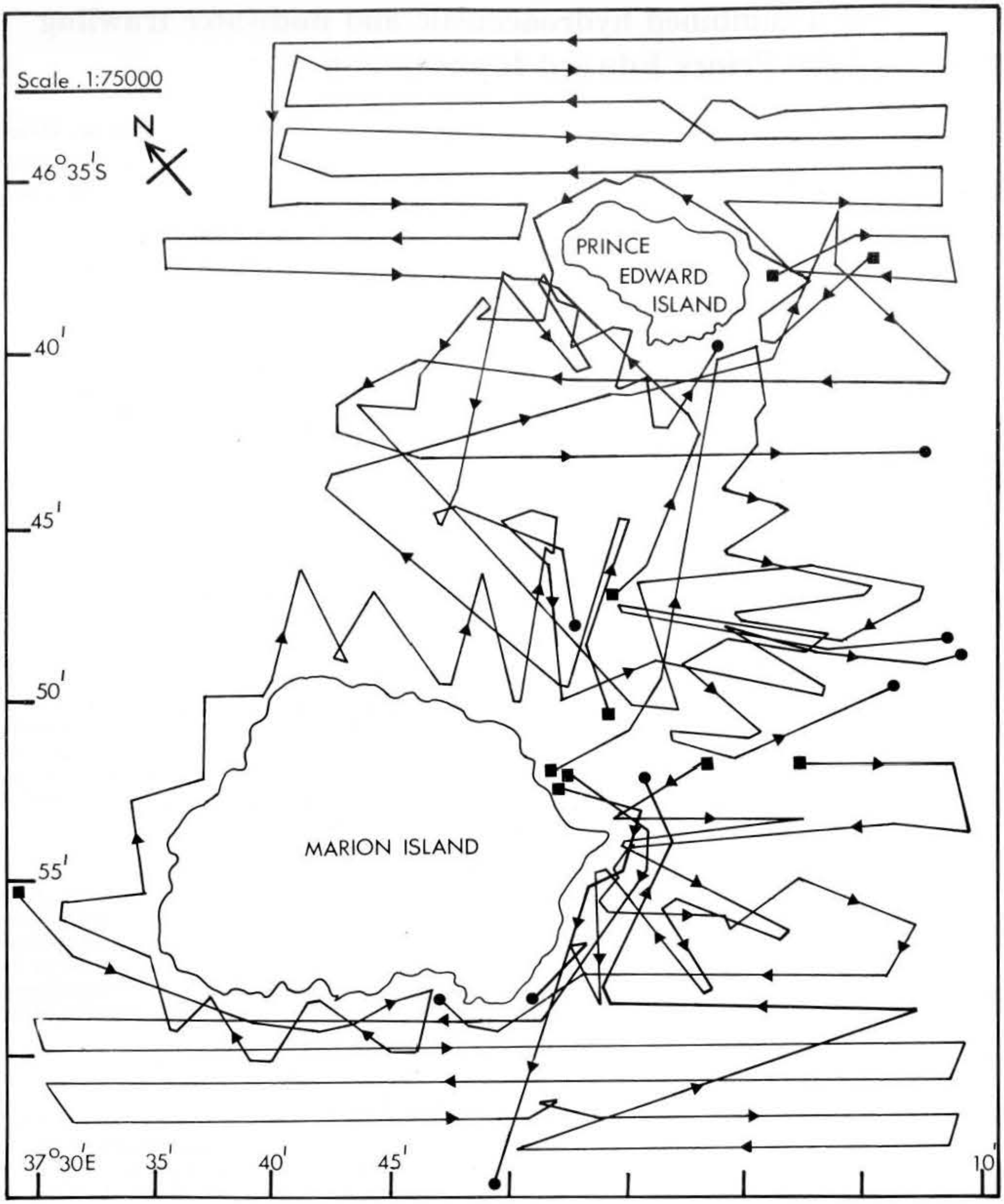


Fig. 1 (above). The first part of the survey cruise track.
■ – Start of survey leg
● – End of survey leg
→ – Direction of travel

T = pulse length (msec)
L = distance steamed during interval (nautical miles)
C (equipment constant incorporating, among others, transducer sensitivity) = 65,20.

Mean integrator deflection ($\bar{D}$) was calculated for one nautical mile and for all intervals:

$$\bar{D} = \sum_{i=1}^{n} Di \Big/ \sum_{i=1}^{n} Li \qquad (2)$$

Fig. 2 (opposite). The second part of the survey cruise track.
■ – Start of survey leg
● – End of survey leg
→ – Direction of travel

where:
Di = integrator deflection (mm) for interval i
Li = distance steamed (n. mile) during interval i
n = total number of intervals.

Mean volume backscattering strength for one nautical mile was then calculated using formula (1) and substituting $\bar{D}$ for D and letting L = 1.

In order to contour scatterer incidence within the survey area, mean volume backscattering strength was standardised to echo-integrator deflection per half-hourly recording interval.

(b) *Biological data*

Displacement volume of each catch was measured (Beers 1976). Catches were sorted and numbers of individual species counted. Wherever possible, displacement volumes of more dominant species were also measured. Respective catch counts and volumes were standardised to a set tow of one nautical mile. Biomass data were calculated from displacement volumes and a rough dry weight conversion of 12 mg/m*l* was used (Grindley & Lane 1979). These were expressed as a function of volume of water filtered (m^3) per haul by each net used.

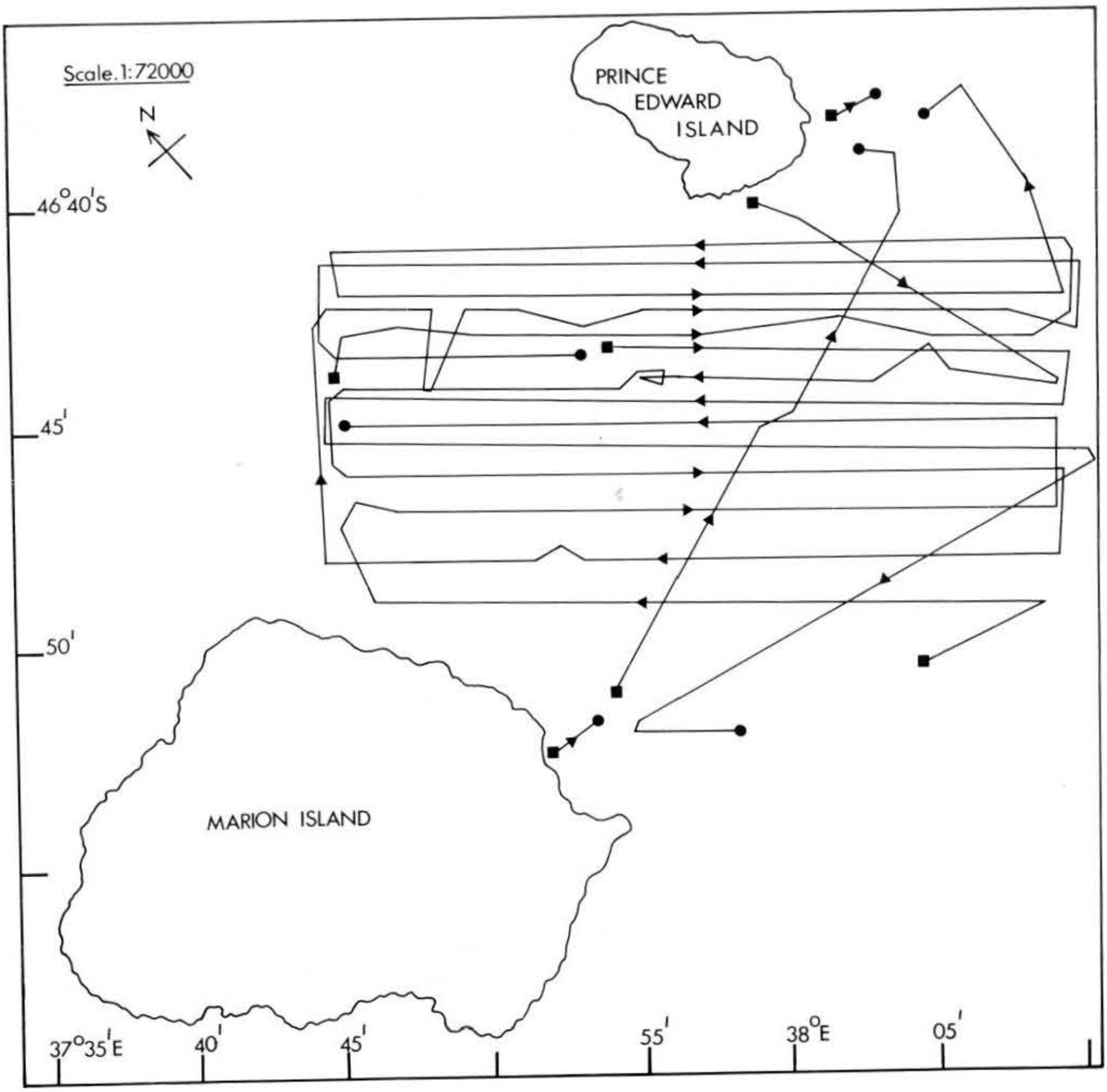
Results

Acoustics

Approximately 1 200 sq. mls. were surveyed acoustically and 1 010 nautical miles steamed. Reflectivity along the survey path was low (Fig. 3). A mean volume scattering strength of −94,84 dB for one nautical mile was recorded. The highest value observed was −81,61 dB and the predominant scatterer incidence was confined to the channel separating Prince Edward and Marion islands (Fig. 3). Correspondingly, few echoes were visible on the echo charts elsewhere in the region.

Biology

A total of 33 net hauls were completed (Fig. 3). Lists of the various fauna collected and respective catch counts are



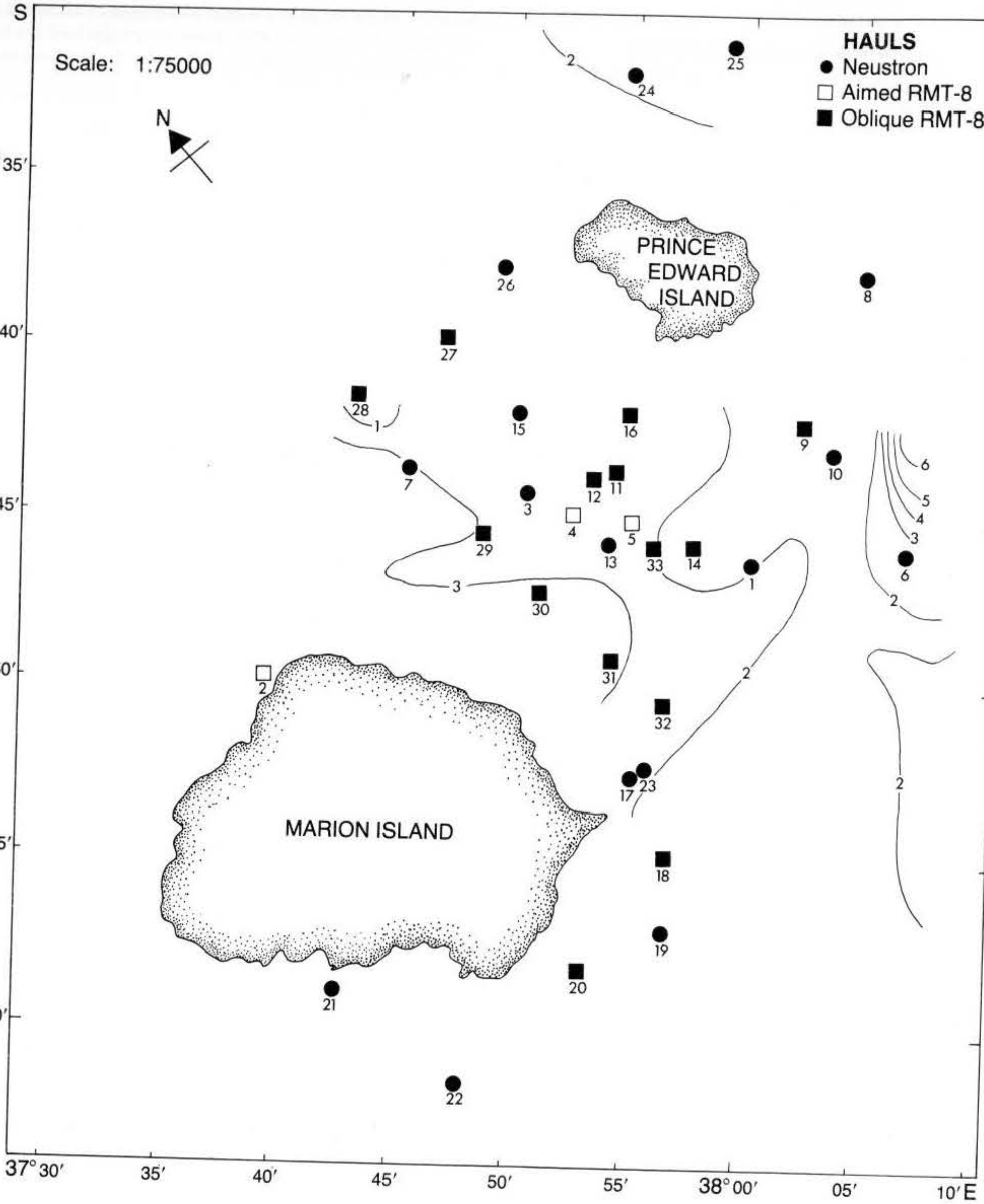


Fig. 3. Positions of various net stations and contour values for echo-integrator deflection in mm.

presented (Tables 1 and 2). No significant differences were observed between day or night catch count values for either RMT or neuston net ($P<0,01$). There was no difference between catches taken by the RMT during "blind" or "aimed" fishing ($P<0,01$) and catches with either fishing method were sparse. For purposes of further analysis, catch data were pooled for each net irrespective of time or method of fishing.

A scarcity of acoustic results precluded direct comparison of net catch with scatterer presence and no relationship between mean volume backscattering strength and catch or species was apparent. As a result it was not possible to estimate quantitatively the absolute abundance of various species collected. Catch counts and displacement volumes were used to assess the relative abundance of the 10 most common species captured by each net (Table 3). Results indicate domination of catches by relatively few species. By number 82,5 per cent (67,7% by volume) of the total RMT catch consisted of three species: *Parathemisto gaudichaudii*, *Sagitta gazellae* and *Sagitta maxima*, with *P. gaudichaudii* comprising 53,6 per cent of the total. Total neuston net catch was dominated (75,2% by number) by *Notothenia marionensis* (larvae), *Tomopteris* sp. and *Cyridaria* sp., with *N. marionensis* constituting 45,8 per cent of the total. A crude conversion of catch displacement volume to biomass in mg dry weight/m^3 of water sampled by both nets, gave very low values per haul (0,001 – 2,625 mg/m^3: mean 0,13 mg/m^3). Further examination of catch data indicated that catch composition could have been affected by single, large samples and as a result estimates of total catch numbers and volumes may have been biased (Tables 1 and 2). To further categorise specific abundance in the area, a faunal frequency analysis was done in which each sample was equally weighted (Fager 1957). The quantitative importance of a particular species was determined by ranking it from 1 to 10 by numerical abundance within each sample. A rank of 1 was given 10 points, a rank of 2 equalled 9 points . . . . and a rank of 10 was equivalent to 1 point. Thus a species being ranked first in all 17 RMT hauls would have had an index value of 170 points, the highest possible score. The results obtained (Table 4) with this method were different from those outlined earlier (Table 3). Both RMT and neuston net catches could now be shown to be dominated by *Parathemisto gaudichaudii, Gaimardia trapesina* and *Sagitta gazellae. Notothenia marionensis, Tomopteris* sp. and *Cyridaria* sp. were relegated further down the neuston catch rank order (Table 4), their original rankings having been the result of single large catches.

Discussion

The acoustic results indicate low scatterer abundance throughout the survey area (Fig. 3). Both the mean volume backscattering strength for one nautical mile (−94,84 dB) and peak value (−81,61 dB) were considerably lower than values obtained by similar surveys in the San Pedro Basin (−70,54 dB) (Pieper 1979) and in a sector of Indian Ocean adjacent to the Antarctic continent (−77,40 dB) (Anon 1982). Although relatively higher scatterer incidence was indicated in the channel between Marion and Prince Edward islands, it must be concluded that plankton abundance in the Prince Edward region was low at the time of the survey. Further substance is given to the acoustic result by the rather poor net catches, particularly with the RMT (Tables 1 to 3).

Low plankton incidence results from a number of complex causes and environmental changes (Hart 1942, El-Sayed 1970, El-Sayed *et al.* 1980). It is most probable that the observed results were indicative of seasonal fluctuations of abundance. The survey took place during winter, when marked variations in primary productivity (El-Sayed 1967) and zooplankton abundance (Foxton 1956, 1962) characterise the Southern Ocean. For this reason low plankton abundance at the Prince Edward islands during the survey would be expected.

The above conclusion is substantiated by the fact that many of the land-based predators in the region are known to migrate away from the islands during the winter (Williams *et al.* 1975, 1978, Condy 1978, 1979). Presumably they leave in the absence of sufficient food, to exploit richer feeding grounds elsewhere.

Most species collected are typical sub-Antarctic surface water fauna (Mackintosh 1934, Baker 1954, 1965). The amphipod *Parathemisto gaudichaudii* is widely distributed throughout the Southern Ocean (Kane 1966, Thurston 1972) and has been shown to form large swarms close to South Georgia (Mackintosh 1934, Kane 1966). The chaetognath *Sagitta gazellae* is common in sub-Antarctic surface waters having a circumpolar distribution (David 1958, 1962). In contrast, *Sagitta maxima* is rarely found close to the surface (David 1962) although it is endemic to the sub-Antarctic region. The presence of this species in the relatively shallow waters of the survey area requires explanation.

Some deepwater and Antarctic species may be introduced

Table 1
Number of individuals per haul, standardised to one nautical mile tow — RMT

	Haul																	
Species	2	4	5	9	11	12	14	16	18	20	27	28	29	30	31	32	33	Total
COELENTERATA																		
Obelia geniculata Hyman							1			2								3
CHORDATA																		
Salpa fusiformis Cuvier							1			1								2
CHAETOGNATHA																		
Sagitta gazellae Ritter – Záhony					8		2			73		7			8	3		101
Sagitta maxima Conant	2					11				3					9	52		77
MOLLUSCA																		
Gaimardia trapesina Dell					2	1	1			5			1		2	10		22
Clione limacina (antarctica) Van der Spöel				3			1						15			4		23
Spongiobranchia australis d'Orbigny							3									2		5
Clio pyramidata (antarctica) Van der Spöel																1		1
Endopteuthidae sp.													1					1
CRUSTACEA																		
Parathemisto gaudichaudii Guerin	63			1						20		210	32			4		330
Aytloella magellanica Stebbing										2								2
Calanus propinquus Brady															3			3
Euphausia vallentini Stebbing										3								3
Euphausia sp (L)																		
PISCES																		
Notothenia marionensis Nybelin					5	17							18					40
Harpagifer sp.													1					1
Notothenia macrocephla Gunther													2					2
Total individuals captured	65			4	15	29	9			109		217	70		22	76		616
Time of haul (GMT + 3)	15.30	16.20	12.00	15.00	15.42	20.54	03.12	10.12	15.20	09.12	10.00	11.00	13.00	14.00	15.00	16.00		

Table 2
Number of individuals per haul, standardised to one nautical mile tow — neuston net

	Haul																
Species	1	3	6	7	8	10	13	15	17	19	21	22	23	24	25	26	Total
COELENTERATA																	
Obelia geniculata Hyman															2		2
CHORDATA																	
Salpa fusiformis Cuvier					1				1								2
Salpa thompsoni Foxton		1															1
CHAETOGNATHA																	
Sagitta gazellae Ritter — Záhony	49	9							41	8		41		82		24	254
Sagitta maxima Conant		3							86					8			97
MOLLUSCA																	
Gaimardia trapesina Dell	3	7			2				2				4	6	7	2	33
Spongiobranchia australis d'Orbigny																2	2
Clio pyramidata (antarctica) Van der Spöel			2						2								4
Endopteuthidae sp					2					1							3
ANNELIDA																	
Tomopteris sp.							82					1010					1092
CRUSTACEA																	
Parathemisto gaudichaudii Guèrin	2	2	1	253	33	6		1	22		2	4	1		4	2	333
Phoronima sedentaria Forsk			1														1
Aytloella magellanica Stebbing	1																1
Oradarea ocellata Thurston							2					4					6
Rhinocalanus gigas Brady										11		7		5		8	31
Calanus propinquus Brady	3									4	17	9			5		38
Cyridaria sp.					352												352
Euphausia vallentini Stebbing	10				28				34	252		2				9	335
Euphausia longirostris Hansen								1		21		2				24	48
Euphausia sp (L)					20												20
Hippolytidae sp.								5		26							31
Jassa falcata Sexton								1									1
PISCES																	
Notothenia marionensis Nybelin		3			2180								26			46	2255
Harpagifer sp.						3											3
Total individuals captured	68	25	4	253	2598	9	84	8	188	323	19	1079	31	101	18	117	4925
Time of haul (GMT + 2)	20.12	14.24	20.12	02.06	08.24	14.00	20.00	04.00	08.18	10.12	20.54	02.06	08.12	20.24	02.00	08.05	

into the Prince Edward region by upwelled water in the lee of the islands (Grindley & Lane 1979). It is possible that a similar phenomenon could account for the presence of *S. maxima* in the survey area. To date, comprehensive hydrological data are lacking for the Prince Edward region (El-Sayed 1979). It would thus be rather premature to conclude that oceanic upwelling is important in determining the incidence of specific deepwater fauna. Nevertheless future research should take into consideration the possible influence of such oceanographic phenomena on plankton distribution in the region.

The faunal composition of trawl samples varied little (Table 3) despite obvious differences in sampling strategy of the different nets. Six of the 10 most common species were caught by both RMT and neuston net. The three most abundant catch organisms caught by the neuston net did however differ from the RMT catch, when catch count or displacement volume was used to assess abundance (Table 3). Catch biomass levels were considerably lower than previous values for the region (Grindley & Lane 1979) and with the exception of *Notothenia marionensis* collected by the neuston net (1,44 mg/m^3) biomass of individual species was less than 1 mg/m^3.

On elimination of the bias caused by large samples of single species, observed differences in the faunal composition of the respective net catches disappeared (Table 4). *Parathemisto gaudichaudii, Sagitta gazellae* and *Gaimardia trapesina* now dominated catches by both nets. These species not only occurred most often, but also dominated single catches more frequently (Table 4) than other plankters. Not only does this suggest that these species were most frequently abundant in the Prince Edward area, but also that some of the other species found (*Notothenia marionensis* and *Cyridaria* sp. in particular) were patchily distributed (Cushing 1962). There is considerable need for further sampling in the area in order to investigate possible effects of patchiness on the distribution of the various faunal elements (Wiebe & Holland 1968).

At the moment there is no way of assessing whether frequency of occurrence or numerical abundance of plankton in individual patches is of more benefit to island-based predators. For example, a single large uni-species swarm (i.e. *Notothenia marionensis:* Neuston Haul 18) may be more accessible to scavenging predators and hence more important to their diet than another species occurring more frequently but in less overall numbers (i.e. *Parathemisto gaudichaudii*). Of the more common species collected during the survey, *P. gaudichaudii* and *Euphausia vallentini* have been shown to form large surface aggregations, making them easily accessible to bird predators (Kane 1966, Mauchline & Fisher 1969). Along with *S. gazellae,* these two species have been suggested as important items in the diets of many marine animals (Hart 1942, Mauchline & Fisher 1969). Both *P. gaudichaudii* and *E. vallentini* have been found in the stomach contents of rock-

Table 3

The structure of RMT and Neuston net catches. The 10 most common species captured by each net are listed according to numerical abundance. The totals given (column 3) are the sum of the numbers of individuals of the given species in all samples taken with each net. Columns 4-8 list respectively the per cent composition by number, the rank order by number, the displacement volume, the per cent composition by volume and the rank order by volume for each species.

Net	Species	No.	% Fauna by No.	Rank by No.	Dis. vol. (ml)	% by Vol.	Rank by Vol.
RMT	*Parathemisto gaudichaudii*	330	53,6	1	24,2	51,7	1
	Sagitta gazellae	101	16,4	2	5,1	10,9	2
	Sagitta maxima	77	12,5	3	2,4	5,1	4
	Notothenia marionensis	40	6,5	4	2,5	5,3	3
	Clione limacina	23	3,7	5	1,8	3,8	6
	Gaimardia trapesina	22	3,6	6	2,3	4,9	5
	Spongiobranchia australis	5	0,8	7	0,8	1,7	8
	Obelia geniculata	3	0,4	8	0,6	1,2	9
	Calanus propinquus	3	0,4	9	0,5	1,1	10
	Euphausia vallentini	3	0,4	10	1,0	2,1	7
Neuston	*Notothenia marionensis*	2255	45,8	1	113,3	58,0	1
	Tomopteris sp.	1092	22,2	2	21,3	10,9	2
	Cyridaria sp.	353	7,2	3	11,3	5,7	5
	Euphausia vallentini	335	6,8	4	12,6	6,5	4
	Parathemisto gaudichaudii	333	6,7	5	14,3	7,3	3
	Sagitta gazellae	254	5,2	6	8,2	4,2	6
	Sagitta maxima	97	2,0	7	2,7	1,4	7
	Euphausia longirostris	48	1,0	8	2,2	1,1	8
	Calanus propinquus	38	1,8	9	1,7	0,9	10
	Gaimardia trapesina	33	0,7	10	1,9	1,0	9

Table 4

Faunal frequency evaluation of catches by RMT and Neuston net.

Net	Species	Frequency (/x hauls)	Rank by Index	Dominance frequency 1	2	3	4	5	6	7	8	9	10	Biol. Index Value
RMT	*Parathemisto gaudichaudii*	6/17	1	3	2	1	-	-	-	-	-	-	—	56
	Gaimardia trapesina	7/17	2	-	1	4	1	1	-	-	-	-	—	54
	Sagitta gazellae	6/17	3	2	3	-	-	-	1	-	-	-	—	53
	Sagitta maxima	5/17	4	2	2	-	1	-	-	-	-	-	—	39
	Clione limacina	4/17	5	1	-	2	1	-	-	-	-	-	—	32
	Notothenia marionensis	3/17	6	1	2	-	-	-	-	-	-	-	—	28
	Spongiobranchia australis	2/17	7	1	-	-	-	1	-	-	-	-	—	16
	Obelia geniculata	2/17	8	-	-	1	-	1	-	-	-	-	—	14
	Euphausia vallentini	1/17	9	1	-	-	-	-	-	-	-	-	—	10
	Calanus propinquus	1/17	10	-	-	1	-	-	-	-	-	-	—	8
Neuston	*Parathemisto gaudichaudii*	13/16	1	2	2	4	2	1	2	-	-	-	—	100
	Sagitta gazellae	7/16	2	3	3	-	-	-	-	-	-	-	—	63
	Gaimardia trapesina	8/16	3	1	2	2	-	3	-	-	-	-	—	62
	Euphausia vallentini	6/16	4	1	1	1	2	-	-	1	-	-	—	45
	Calanus propinquus	5/16	5	1	1	2	-	-	1	-	-	-	—	40
	Notothenia marionensis	4/16	6	3	-	1	-	-	-	-	-	-	—	38
	Euphausia longirostris	4/16	7	-	1	2	-	-	1	-	-	-	—	29
	Sagitta maxima	3/16	8	1	1	1	-	-	-	-	-	-	—	27
	Tomopteris sp.	2/16	9	2	-	-	-	-	-	-	-	-	—	20
	Cyridaria sp.	1/16	10	1	-	-	-	-	-	-	-	-	—	10

hopper penguins (*Eudyptes chrysocome*) collected on Marion Island (Miller unpubl. data).

Concentration of species in large surface swarms would effectively exclude them from acoustic detection resulting in erroneous estimates of abundance. For this reason, future surveys of this nature must supplement acoustic data collection with adequate net sampling of surface waters. Furthermore, in the light of the present results, consideration must be given to effects of both seasonal and hydrological variation on the distribution and abundance of fauna found in the Prince Edward Island region.

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References

ANON. 1978. Ecology of a sub-Antarctic island: 15 years on. *S. Afr. J. Sci.* 74: 451-452.

ANON. 1979. The Southern Ocean — South African co-operative research programme. *S.A. Nat. Sci. Prog. Rept.* 38:1-23.

ANON. 1982. Report of *ad hoc* working group on krill abundance: Post FIBEX data interpretation workshop, Hamburg 1981. 55 pp.

BAKER, A. de C. 1954. The circumpolar continuity of Antarctic plankton species. *Discovery Rep.* 27:201-218.

BAKER, A. de C. 1965. The latitudinal distribution of *Euphausia* species in the surface waters of the Indian Ocean. *Discovery Rep.* 33:309-334.

BEERS, J.R. 1976. Determination of zooplankton biomass: Volumetric methods. *UNESCO Monogr. Oceanogr. Meth.* 4:54-60.

CHENG, L. 1975. Marine pleuston — Animals at the sea-air interface. *Oceanogr. Mar. Biol. Ann. Rev.* 13:181-212.

CONDY, P.R. 1978. The distribution, abundance and annual cycle of fur seals (*Arctocephalus* spp.) on the Prince Edward islands. *S. Afr. J. Wildl. Res.* 8:159-168.

CONDY, P.R. 1979. The annual cycle of the southern elephant seal *Mirounga leonina* (Linn.) at Marion Island. *S. Afr. J. Zool.* 14:95-102.

CUSHING, D.H. 1962. Patchiness. *Rapp. P. -v. Réun. Cons. perm. int. Explor. Mer.* 153:152-164.

DAVID, P.M. 1958. The distribution of the Chaetognatha of the Southern Ocean. *Discovery Rep.* 29:119-228.

DAVID, P.M. 1962. The distribution of Antarctic chaetognaths. In: Biologie Antarctique, eds R. Carrick, M. Holdgate and J. Prevost. Herman, Paris. pp. 253-256.

EL-SAYED, S.Z. (ed) 1977. Biological investigations of marine Antarctic systems and stocks. *Rept. SCOR. W.G.* 54:1-79.

EL-SAYED, S.Z. 1967. On the productivity of the southwest Antlantic Ocean and the waters of the Antarctic peninsula. In: Biology of the Antarctic Seas. *Antarc. Res. Serv.* 3 (11):15-47.

EL-SAYED, S.Z. 1970. On the productivity of the Southern Ocean. In: Antarctic Ecology, ed. M.W. Holdgate. Academic Press, London. pp 118-135.

EL-SAYED, S.Z. 1979. Réchèrches sur la productivité primaire au cours de la campagne MD.08. *CNFRA* 44:79-82.

EL-SAYED, S.Z., TEES, C., WARNER, R., WEBER, L. & MEYER, M. 1980. Seasonal variability in biological productivity of the Scotia Sea and Southwest Atlantic. *Antarct. J. U.S.* 14:161-162.

EVERSON, I. 1977. The living resources of the Southern Ocean. *FAO GLO/SO/77/1.* 1-156.

FAGER, E.W. 1957. Determination and analysis of recurrent groups. *Ecol.* 38:586-595.

FOXTON, P. 1956. The distribution of the standing crop of zooplankton in the Southern Ocean. *Discovery Rep.* 28:191-236.

FOXTON, P. 1962. Seasonal variation in the plankton of Antarctic waters. In: Biologie Antarctique, eds R. Carrick, M. Holdgate and J. Prevost. Herman, Paris. pp 311-318.

GRINDLEY, J.R. & LANE, S.B. 1979. Zooplankton around Marion and Prince Edward islands. *CNFRA* 44:111-125.

HART, T.J. 1942. Phytoplankton periodicity in Antarctic surface waters. *Discovery Rep.* 21:261-356.

HOLDGATE, M.W. 1967. The Antarctic ecosystem. *Phils. Trans. R. Soc. Lond.* 252:353-383.

KANE, J.E. 1966. The distribution of *Parathemisto gaudichaudii* (Guèr) with observation on its life history in the 0° to 20°E sector of the Southern Ocean. *Discovery Rep.* 34:163-198.

KNOX, G.A. 1960. Littoral ecology and biogeography of the southern ocean. *Proc. Roy. Soc. Ser. B.* 152:577-624.

MACKINTOSH, N.A. 1934. Distribution of macroplankton in the Atlantic sector of the Antarctic. *Discovery Rep.* 9:65-160.

MAUCHLINE, J. & FISHER, L.R. 1969. The biology of Euphausiids. *Adv. Mar. Biol.* 7:454 p.

PIEPER, R.E. 1979. Euphausiid distribution and biomass determined acoustically at 102 kHz. *Deep Sea Res.* 26:687-702.

ROBERTSON, A.A., ALEXANDER, D.G.W. & MILLER, D.G.M. 1981. Modified collapsible opening and closing midwater trawls (RMT-8 and RMT-2). *Fish. Bull. S. Afr.* 14:103-113.

SKINNER, J.D., CONDY, P.R., VAN AARDE, R.J., BESTER, M.N. & ROBINSON, T.J. 1978. The mammals of Marion Island; a review. *S. Afr. J. Antarct. Res.* 8:35-38.

THURSTON, M.H. 1972. The crustacean Amphipoda of Signy Island, South Orkney Islands. *Br. Antarct. Surv. Sci. Rep.* 71:1-127.

URICK, R. 1975. Principles of underwater sound. 2nd Edition. McGraw-Hill. pp 190-194.

VAN ZINDEREN BAKKER, E.M. (Jr) 1966. Bird studies on Marion and Prince Edward islands. *News Bull. Zool. Soc. S. Afr.* 7:5.

VAN ZINDEREN BAKKER, E.M. (Jr) 1967. Observations on animal life on Marion and Prince Edward islands. *S. Afr. J. Sci.* 63:242-246.

WIEBE, P.H. & HOLLAND, W.R. 1968. Plankton patchiness: effects of repeated net tows. *Limnol. Oceanogr.* 13:315-321.

WILLIAMS, A.J., BURGER, A.E., BERRUTI, A. & SIEGFRIED, W.R. 1975. Ornithological research on Marion Island, 1974-1975. *S. Afr. J. Antarct. Res.* 5:48-50.

WILLIAMS, A.J., BURGER, A.E. & BERRUTI, A. 1978. Mineral and energy contribution of carcasses of selected species of seabirds to the Marion Island terrestrial ecosystem. *S. Afr. J. Antarct. Res.* 8:53-59.