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Latitude versus local effects on echinoderm assemblages along the Victoria Land coast, Ross Sea, Antarctica

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Abstract: Data from two new cruises is used to assess whether latitude plays any role in influencing broad-scale spatial patterns in echinoderm assemblage composition along the Victoria Land coast and the Balleny Islands as a contribution to the Latitudinal Gradient Project. Our results indicate that a latitudinal gradient is influencing assemblage structure in subtle and non-linear ways. The Balleny Islands system is different from the Victoria Land coast, probably because of a different biogeographic origin and current oceanographic conditions. Along the Victoria Land coast, latitude related differences arise when taking into account benthic biodiversity at different spatial scales. Alpha diversity increases from north to south, but beta diversity shows the opposite trend, although not linearly, suggesting the different importance of the iceberg disturbance along the northern Victoria Land coast.

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Introduction

It is widely recognized that environmental variables can influence community structure over latitudinal scales (e.g. Arntz *et al.* 1997, Gray 2001 and references therein). However, the morphology of the Antarctic continent's coastline limits the application of latitudinal gradient studies, except for along the Antarctic Peninsula and the Ross Sea. The Victoria Land coast, delimiting the western side of the Ross Sea, represents a gradient extending from 72° to 78°S.

In the framework of the Latitudinal Gradient Project (LGP) along the Victoria Land coast, the aim of this study is to evaluate the distribution of asteroids, ophiuroids and echinoids and their diversity at different spatial scales. This is in order to address the LGP question regarding what aspects of and to what extent does ecosystem structure and function (diversity/complexity) change with latitude, and why (Howard-Williams *et al.* 2006). We have focused on echinoderms because these organisms often play important trophic roles in benthic communities, responding to spatial variation in primary production and detritus as well as functioning as predators operating at various trophic levels and impacting on habitat-structuring sponges (Dayton 1971, Dell 1972, Dayton *et al*. 1974, Cerrano *et al.* 2000). Echinoderms are also widely distributed across a range of seafloor habitats and they tend to be large organisms, facilitating efficient sampling with various types of sampling gear (Piepenburg *et al*. 1997). Moreover, studies in other areas of the Antarctic have indicated that station groupings defined by analysis of the echinoderm assemblage are a good indicator of polar megafaunal assemblage types (Piepenburg & von Juterzenka 1994, Piepenburg *et al*. 1997).

In the Ross Sea, information on the benthic communities has been largely derived from a few restricted shallow water areas of McMurdo Sound and Terra Nova Bay, near the permanent scientific installations (Dayton & Oliver 1977, Cattaneo-Vietti *et al*. 2000 and references therein, Thrush *et al.* in press), although, additional information is available from early ship-based sampling (e.g. Bullivant & Dearborn 1967, Dayton *et al*. 1974). In particular, species lists and descriptions of echinoderms are available from the *Southern Cross* 1898–1900 (Bell 1902), *Discovery* 1901–1904 (Bell 1908), *Nimrod* 1907–1909 Antarctic Expeditions (Koehler 1911) and other expeditions carried out between the years 1925–1936 aboard *Discovery*, *Discovery II*, and *William Scoresby* (Fisher 1940), from which Ross Sea echinoids and ophiuroids were described by Mortensen (1936). The most recent cruises performed in the area were the Trans-Antarctic (New Zealand) Expeditions of 1956–58 from HMNZS *Endeavour* and USS *Glacier* and two cruises of HMNZS *Endeavour* (1959 and 1960). Asteroids from these cruises are reported in Clark (1963) and ophiuroids in Fell (1961). Finally, there are data for echinoids from the NZOI Expedition 1964–1965 (McKnight 1976).

In this paper, we add to the information on echinoderm distribution from the Balleny Islands (68°S) to the central Victoria Land coast, reporting on recent samplings (summer 2004) conducted from the RVs *Italica* and *Tangaroa*. We evaluate whether latitude plays any role in

Table I. RV *Italica* station list: location, coordinates, sampling gear and depth are reported for sampling with Agassiz Trawl.

Station	Location	Lat. S	Long. E	Average depth (m)
A5	Cape Adare out	71°18.7'	170°25.5'	119
A4	Cape Adare out	71°18.4'	170°28.9'	230
A3	Cape Adare out	71°18.7'	170°33.5'	305
A2	Cape Adare out	71°17.3'	170°39.2'	421
A1	Cape Adare out	71°15.5'	170°42.2'	515
Hin5	Cape Hallett in	72°17.2'	170°17.9'	84
Hin4	Cape Hallett in	72°17.1'	170°14.0'	196
Hin3	Cape Hallett in	72°17.0'	170°13.1'	316
Hin2	Cape Hallett in	72°16.7'	170°09.8'	408
Hout5	Cape Hallett out	72°16.9'	170°17.0'	105
Hout 4bis	Cape Hallett out	72°18.5'	170°26.8'	235
Hout 4ter	Cape Hallett out	72°18.2'	170°26.0'	218
Hout 3	Cape Hallett out	72°17.5'	170°26.1'	246
Hout 3bis	Cape Hallett out	72°17.4'	170°26.4'	258
Hout 2	Cape Hallett out	72°16.3'	170°24.9'	337
Hout 2bis	Cape Hallett out	72°17.1'	170°29.9'	388
Hout2-dredge	Cape Hallett out	72°17.5'	170°29.4'	353
Hout 1	Cape Hallett out	72°15.5'	170°28.3'	537
C2	Coulman Island	73°22.7'	170°06.9'	410
C1	Coulman Island	73°24.5'	170°23.2'	474
R4	Cape Russell	74°50.0'	164°05.7'	208
R3	Cape Russell	74°49.3'	164°11.5'	330
R2	Cape Russell	74°49.0'	164°18.1'	364
TNB	Terra Nova Bay	74°43.2'	164°13.1'	366

influencing broad-scale spatial patterns in the assemblage composition and echinoderm diversity or if other constraints such as depth, oceanography or modification of sea bottom topography by iceberg scouring, are more important. The impact of iceberg scouring has been discussed in the last decade with regard to global warming processes and its effects in Antarctica have been documented, in particular with respect to the Weddell Sea and to a bipolar comparison (Lien *et al*. 1989, Gutt *et al.* 1996, Gutt & Starmans 1998, Gutt 2000, Starmans & Gutt 2002, Gutt & Piepeburg 2003).

Materials and methods

Samples were collected during the joint 19th Italian Antarctic Expedition aboard of RV *Italica* (February 2004) and NZ BioRoss Expedition (January–March 2004), aboard of the RV *Tangaroa*. Aboard *Italica*, samples were collected using an Agassiz Trawl (AGT) in 23 stations located along six transects between Cape Adare and Cape Russell (Table I), in a depth range between 84 and 537 m: Cape Adare (A), Cape Hallett in (Hin, the inner side of the Cape), Cape Hallett out (Hout, the outer side of the Cape), Coulman Island (C), Terra Nova Bay (TNB) and Cape Russell (R). The *Tangaroa* sampled between Balleny Islands and Cape Hallett. Samples were collected by Van Veen Grab (GVVL), Epibenthic Sledge (SEL), Rough Bottom Trawl (ORH) and Beam Trawl (BEAM). Five transects were completed between Cape Adare and Cape

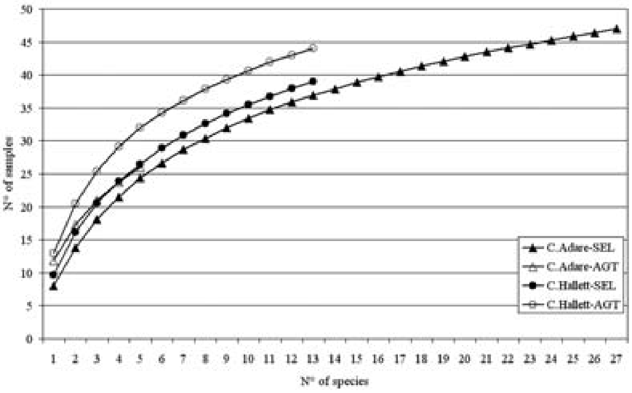

Fig. 1. Species area curves for Epibenthic Sledge (SEL) and Agassiz Trawl (AGT) samples collected in Cape Adare and Cape Hallett.

Hallett, in a depth range between 65 and 1538 m. Forty-four stations were sampled in the area of the Balleny Islands and nearby seamounts (Table II reports stations where echinoderms were found). In total 165 stations with echinoderms were sampled by *Tangaroa*. On both vessels, echinoderms, as well as all the other material, were sorted on board and preserved in 70° ethanol. Specimens were identified, relying mainly on Clark (1963) for sea stars, Fell (1961) for brittle stars and David *et al.* (2001) for sea urchins.

As different types of sampling devices were employed on the two vessels, we developed site-specific species-area curves to contrast the sampling efficiency of different gears. Based on this preliminary analysis, we have only analysed data derived from the AGT and SEL, which revealed similar sampling efficiencies when the gear was used in similar locations (Fig. 1).

In order to investigate the purported latitudinal trend, data were analysed in terms of multivariate analysis (MDS), using the package Primer6, from the Plymouth Marine Laboratory. Bray-Curtis (1957) similarity index was used on data standardized by total and square root transformed. Analysis of similarities (ANOSIM: Clarke 1993) was used to test latitude and/or depth effects. The levels of the factors analysed were Balleny Islands, Cape Adare, Possession Islands, Cape Hallett, Coulman Island and Terra Nova Bay (TNB and Cape Russell stations together) as much as latitude, and depth ranks 1 (451–550 m), 2 (351–450 m), 3 (251–350 m), 4 (151–250 m) and 5 (< 150 m). To assess changes in echinoderm assemblage composition relative to surrogate variables for broad-scale environmental drivers (latitude, longitude and depth), we used canonical correspondence analysis, and to factor-out differences between locations due to sampling gear/vessel we used partial canonical correspondence analysis (ter Braak 1986, 1988, ter Braak & Prentice 1988, Legendre & Legendre 1998). Analyses were performed using CANOCO (ter Braak 1987). In order to analyse in more detail the two

Table II. RV *Tangaroa* station list: location, coordinates, and depth are reported for sampling with an Epibenthic Sledge.

Station	Location	Lat. S	Long. E	Average depth (m)
209	Balleny Is.	67°34.3'	165°02.6'	671
213	Balleny Is.	67°26.2'	165°16.5'	1370
222	Balleny Is.	67°16.0'	164°31.3'	217
241	Balleny Is.	66°54.8'	163°13.7'	74
245	Balleny Is.	66°40.5'	162°45.4'	379
251	Balleny Is.	66°33.1'	163°00.2'	566
253	Balleny Is.	66°21.9'	162°34.5'	910
258	Balleny Is.	66°13.2'	162°28.9'	1538
264	Balleny Is.	66°06.7'	162°00.8'	1106
232	Balleny Seamount	67°25.2'	163°56.6'	107
233	Balleny Seamount	67°25.1'	163°54.9'	229
234	Balleny Seamount	67°26.8'	163°48.6'	502
266	Balleny Seamount	65°26.9'	160°55.5'	101
268	Balleny Seamount	65°29.5'	161°03.0'	763
274	Balleny Seamount	65°29.8'	160°56.7'	374
277	Balleny Seamount	65°24.5'	160°53.3'	115
132	Cape Adare in	71°38.9'	170°10.8'	167
133	Cape Adare in	71°38.7'	170°13.1'	251
96	Cape Adare out	71°11.3'	170°58.6'	728
98	Cape Adare out	71°11.5'	170°56.5'	614
101	Cape Adare out	71°12.1'	170°56.4'	568
103	Cape Adare out	71°14.4'	170°42.4'	551
105	Cape Adare out	71°15.5'	170°38.1'	466
108	Cape Adare out	71°16.3'	170°36.0'	403
112	Cape Adare out	71°17.6'	170°34.6'	349
116	Cape Adare out	71°17.9'	170°32.4'	314
124	Cape Adare out	71°18.6'	170°28.6'	224
126	Cape Adare out	71°18.6'	170°27.0'	160
128	Cape Adare out	71°19.6'	170°24.8'	89
130	Cape Adare out	71°19.8'	170°27.6'	123
134	Cape Adare out	71°38.5'	170°09.2'	65
160	Cape Adare out	71°27.8'	171°59.8'	701
165	Cape Adare out	71°28.2'	171°58.5'	672
169	Cape Adare out	71°28.8'	171°55.8'	605
178	Cape Adare out	71°31.9'	171°18.3'	347
182	Cape Adare out	71°31.6'	171°24.6'	384
184	Cape Adare out	71°30.0'	171°36.4'	486
188	Cape Adare out	71°32.9'	171°06.7'	283
190	Cape Adare out	71°34.8'	170°52.4'	230
193	Cape Adare out	71°36.1'	170°52.8'	227
195	Cape Adare out	71°37.3'	170°55.4'	245
197	Cape Adare out	71°37.2'	170°52.0'	205
206	Cape Adare out	71°09.9'	171°02.9'	958
8	Possession Is.	71°42.8'	171°49.6'	539
13	Possession Is.	71°42.6'	171°49.6'	534
15	Possession Is.	71°43.7'	171°44.1'	452
17	Possession Is.	71°44.4'	171°39.3'	421
22	Possession Is.	71°48.0'	170°56.5'	166
25	Possession Is.	71°47.9'	170°56.0'	134
33	Possession Is.	71°45.3'	171°25.0'	280
35	Possession Is.	71°46.1'	171°06.6'	240
39	Possession Is.	71°45.3'	171°08.9'	250
140	Possession Is.	72°00.8'	170°46.5'	236
143	Possession Is.	72°01.4'	170°48.2'	320
145	Possession Is.	72°01.9'	170°54.3'	275
148	Possession Is.	72°08.0'	171°26.9'	393
150	Possession Is.	71°58.8'	171°58.1'	471
152	Possession Is.	71°59.7'	172°08.1'	505
154	Possession Is.	72°00.1'	172°13.3'	561
157	Possession Is.	71°59.1'	172°10.7'	728
48	Cape Hallett out	72°19.0'	170°21.7'	131
52	Cape Hallett out	72°20.2'	170°23.7'	154
54	Cape Hallett out	72°19.5'	170°25.7'	203
59	Cape Hallett out	72°19.6'	170°27.5'	234
63	Cape Hallett out	72°19.3'	170°28.7'	298
65	Cape Hallett out	72°20.1'	170°30.0'	323
70	Cape Hallett out	72°03.0'	173°19.2'	755
72	Cape Hallett out	72°03.7'	173°14.7'	621
74	Cape Hallett out	72°04.4'	173°08.2'	538
78	Cape Hallett out	72°07.0'	172°41.9'	496
82	Cape Hallett out	72°03.6'	172°54.2'	527
83	Cape Hallett out	72°04.4'	173°08.0'	540
82	Cape Hallett out	72°03.6'	172°54.2'	527
83	Cape Hallett out	72°04.4'	173°08.0'	540
91	Cape Hallett out	72°16.6'	171°26.9'	412

Victoria Land locations with the larger number of samples (Cape Hallett out and Cape Adare out), an MDS was performed on two randomly selected samples for each depth range at each location. Permutational multivariate analysis of variance (PERMANOVA: Anderson 2001) was performed on these data to test for location and depth effects.

In addition, all the samples were analysed in terms of diversity at different spatial scales. In particular, we analysed α-diversity (within-habitat diversity) by way of $\ln_2$ based Shannon-Weaver diversity (Shannon & Weaver 1949), measured at the single sample level and averaged among depth levels in each area. The estimation of ß-diversity (between-habitat diversity: Whittaker 1972) was based on averaged Bray-Curtis similarity among samples from the same area along the depth gradient (Starmans & Gutt 2002, Hewitt *et al*. 2005).

Results

A total of 14 376 specimens were found belonging to 84 different echinoderm taxa, 37 asteroids, 29 ophiuroids, and 18 echinoids (Table III).

The canonical correspondence analysis performed on untransformed data, down-weighted for rare species, revealed that latitude was highly correlated (r = -0.71) with first ordination axis, while depth and gear type were correlated with the second and third axes respectively. Partialing out depth and gear indicated that latitude was a significant predictor (P = 0.0020 first axis) of echinoderm assemblage structure. However, it is important to note that overall only 16% of the variability in the data could be constrained by the first four axes of the ordination. Inspection of outliers in the ordination indicated that the importance of latitude was driven mainly by data collected from the Balleny Islands. Thus we repeated this set of

Table III. List of asteroid, ophiuroid and echinoid species found in the *Italica* and *Tangaroa* joint cruises (2004). The total specimen numbers for each species are also reported, as well the information relative to if the species is found only in the Balleny Islands (B), or along the Victoria Land (V) and if the species is a new record for the study area (*B or *V).

Class	Family	Species	Numbers of specimens	Exclusive	New record
Asteroidea	Asteridae	*Diplasterias brucei* (Koehler, 1908)	217		
		Lysasterias adeliae (Koehler, 1920)	20		
		Lysasterias sp.	28		
		Notasterias armata Koehler, 1911	139		
		Notasterias stolophora Fisher, 1940	109		
		Pedicellaster hypernotius Sladen, 1861	89	V	
		Psalidaster mordax Fisher, 1940	46	V	
		Saliasterias brachiata Koehler, 1920	11	V	
	Astropectinidae	*Bathybiaster loripes obesus* Sladen, 1889	116		
		Bathybiaster sp.	1	B	
		Leptychaster flexuosus Koehler, 1920	2		
		Macroptychaster accrescens (Koehler, 1920)	16		
		Psilaster charcoti (Koehler, 1906)	125		
	Benthopectinidae	*Luidiaster gerlachei* (Ludwig, 1903)	26		
	Goniasteridae	*Pergamaster triseriatus* H.E.S. Clark, 1962	35	V	
	Odontasteridae	*Acodontaster capitatus* (Koehler, 1912)	4		
		Acodontaster conspicuus Koehler, 1920	35		
		Acodontaster sp.	1		
		Odontaster meridionalis (Smith, 1876)	61		
		Odontaster validus Koehler, 1906	154		
	Poranidae	*Porania antarctica glabra* Sladen, 1889	138		
		Porania sp.	10	B	
	Asterinidae	*Kampylaster incurvatus* (Koehler, 1920)	7	V	
	Echinasteridae	*Perknaster densus* Sladen, 1889	5	V	
		Perknaster fuscus antarcticus (Koehler, 1906)	25		
		Perknaster sladeni (Perrier, 1891)	4	V	
		Perknaster sp.	5	V	
	Korethrasteridae	*Peribolaster macleani* Koehler, 1920	44	V	
		Peribolaster powelli H.E.S. Clark, 1961	27	V	
		Peribolaster spp.	30	V	
	Pterasteridae	*Pteraster* sp.	11		
		Pteraster stellifer Sladen, 1882	24		
	Solasteridae	*Crossaster canopous* H.E.S. Clark, 1961	14		
		Cuenotaster involutus (Koehler, 1912)	2	V	
		Lophaster gaini Koehler, 1912	20		
		Myoraster antarcticus (Koehler, 1912)	113	V	
		Paralophaster sp.	1	V	
Ophiuroidea	Gorgonocephalidae	*Astrochlamys bruneus* Koehler, 1912	59		
		Astrohamma tuberculatum (Koehler, 1923)	17		
		Astrotoma agassizii Lyman, 1875	146		
		Gorgonocephalus chilensis (Philippi, 1858)	12	B	
	Amphiuridae	*Amphiura algida* Koehler, 1911	164		
		Amphiura belgicae Koehler, 1900	64		
		Amphiura spp	287		
	Ophiacanthidae	*Glaciacantha jason* Fell, 1961	186		
		Ophiacantha antarctica Koehler, 1900	1646		
		Ophiacantha pentactis Mortensen, 1936	375		
		Ophiacantha sp.	4	V	
		Ophiacantha vivipara Ljungman, 1870	1543		
		Ophiosparte gigas Koehler, 1922	4	B	
	Ophiodermatidae	*Toporkovia antarctica* (Lyman, 1882)	443		
	Ophiolepidinae	*Ophioceres incipiens* Koehler, 1922	1241		
	Ophioleucidae	*Ophiopyren regularis* Koehler, 1922	17		
	Ophiuridae	*Ophiocten megaloplax* Koehler, 1900	8	V	
		Ophionotus victoriae Bell, 1902	1055		
		Ophiosteira antarctica Bell, 1902	109		*B
		Ophiosteira bullivanti Fell, 1961	15	V	
		Ophiosteira echinulata Koehler, 1922	342	V	
		Ophiosteira sp.	2	V	

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Table III. (continued) List of asteroid, ophiuroid and echinoid species found in the *Italica* and *Tangaroa* joint cruises (2004). The total specimen numbers for each species are also reported, as well the information relative to if the species is found only in the Balleny Islands (B), or along the Victoria Land (V) and if the species is a new record for the study area (*B or *V).

Class	Family	Species	Specimen number	Exclusive	New record
		Ophiura ambigua (Lyman, 1878)	24		
		Ophiura spp	44		
		Ophiuroglypha carinifera (Koehler, 1901)	93		
		Ophiuroglypha sp.	12		
		Ophiurolepis gelida (Koehler, 1900)	1316		
		Ophiurolepis spp	2211		
		Ophioperla koehleri (Bell, 1908)	23	B	
Echinoidea	Echinidae	*Sterechinus antarcticus* Koehler, 1901	205		
		Sterechinus neumayeri (Meissner, 1900)	767		
	Cidaridae	*Ctenocidaris* spp juv	106		
		Ctenocidaris gigantea (H.L. Clark, 1925)	12	V	
		Ctenocidaris rugosa (Koehler, 1926)	33	V	*V
		Ctenocidaris perrieri (Koehler, 1910)	10		
		Ctenocidaris spinosa (Koehler, 1926)	24		*V*B
		Aporocidaris milleri (A. Agassiz, 1898)	8		
		Austrocidaris canaliculata (A. Agassiz, 1863)	1	V	*V
		Notocidaris sp	2	V	
		Notocidaris platyacantha (H.L. Clark, 1925)	2		
		Cidaridae spp	3		
	Schizasteridae	*Abatus shackletoni* Kohler, 1926	10	V	
		Abatus cavernosus (Philippi, 1845)	1	V	
		Abatus elongatus (Koehler, 1908)	3	V	
		Abatus nimrodi (Koehler, 1911)	5	V	
		Abatus philippii Lovén	1	V	
		Abatus spp	6	V	

analyses omitting the Balleny Islands data, and with the restricted dataset the PCCA did not reveal a significant effect of latitude ($P = 0.3538$).

MDS ordination applied on the total dataset does not show any clear latitudinal gradient (Fig. 2). In fact, the ANOSIM performed on the latitude groups (Global R = 0.214; significance level = 0.1%) does not show any significant clustering of stations according to latitude. Only the Balleny Islands are significantly different relative to the whole set of data from the Ross Sea (ANOSIM: Global R = 0.567; significance level = 0.1%).

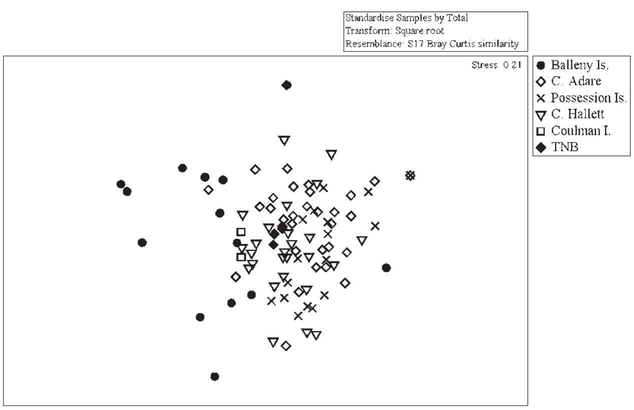

Fig. 2. MDS ordination of sampling stations according to latitude

As the latitudinal hypothesis was not strongly supported along the Victoria Land coast, data from Cape Adare and Cape Hallett were analysed to assess locational effects. The dataset used in this analysis was comprised of data mainly from the *Italica* cruise, although three samples collected from the *Tangaroa* (Cape Adare In) were also used. The more detailed analysis of Cape Hallett out and Cape Adare out locations is plotted in Fig. 3. PERMANOVA (2 Fixed, Crossed factors: Location, Depth) results are reported in

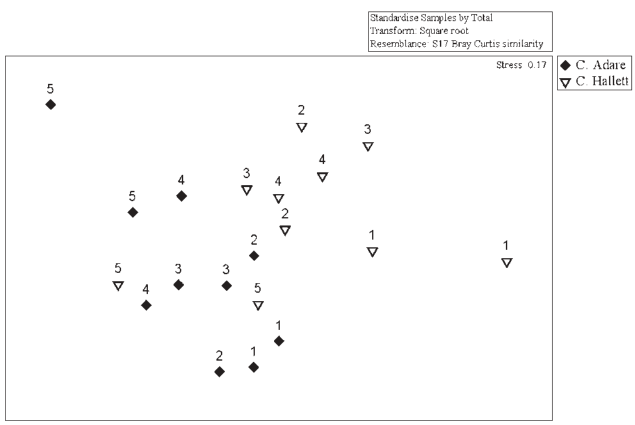

Fig. 3. MDS ordination of Cape Adare out and Cape Hallett out selected stations, according to depth rank (1 = 451–550 m, 2 = 351–450 m, 3 = 251–350 m, 4 = 151–250 m, 5 = < 150 m).

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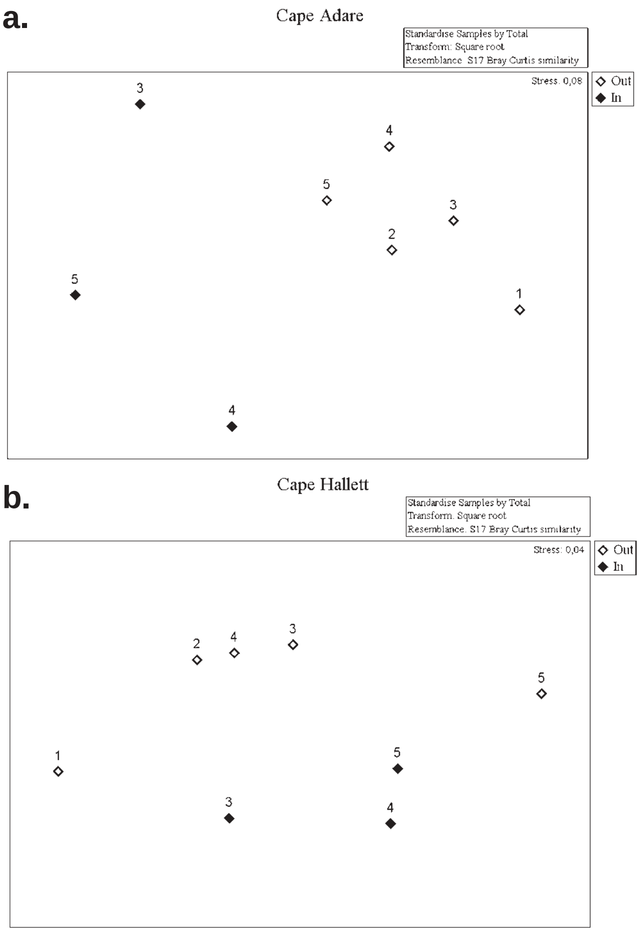

Fig. 4. MDS ordination of **a.** Cape Adare, and **b.** Cape Hallett, in and out samples, according to depth rank (1 = 451–550 m, 2 = 351–450 m, 3 = 251–350 m, 4 = 151–250 m, 5 = < 150 m).

Table IV: the two locations are different, although a small interaction effect between location and depth is detectable (not confirmed by the Monte Carlo procedure). The clustering of inner and outer stations separately is evident in the Cape Adare plot (MDS Fig. 4a, ANOSIM: Global R = 0.877; significance level = 1.8%). Cape Hallett in and out stations are also differentiated in the MDS plot (Fig. 4b), but the ANOSIM statistic is not significant (Global R = 0.087; significance level = 37.5%), because of the low number of samples and the larger dispersion of outer stations.

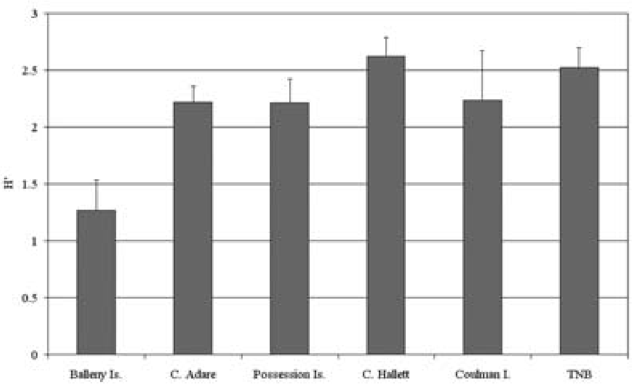

Fig. 5. Alpha diversity (within-habitat) distribution in the study area, measured by Shannon Weaver diversity (avg + standard error).

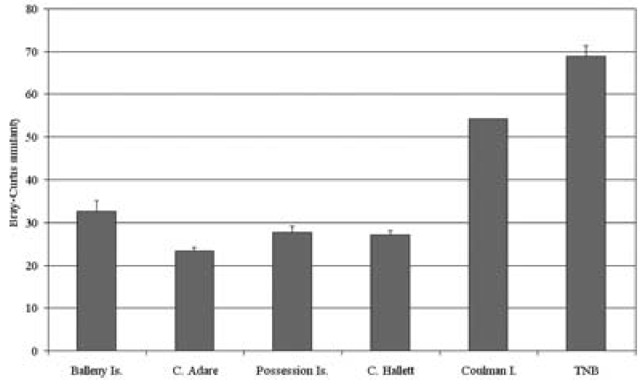

Fig. 6. Beta diversity (between-habitat) distribution in the study area, measured by Bray-Curtis similarity index among stations from the same location (avg + standard error).

The univariate diversity analysis revealed some interesting contrasts between α and β diversity (Figs 5 & 6). Alpha diversity, measured by the Shannon-Weaver index, demonstrates a significant positive relationship with latitude (log transformed) (P = 0.0150, r^2 = 0.81), indicating that average within location diversity is increasing to the south (Fig. 5). In contrast, ß-diversity, measured by Bray-Curtis similarity, does not reveal a significant relationship with latitude (log transformed) (P = 0.7530). However, Fig. 6, indicates a step trend of increasing similarity (i.e. low β-diversity) at the two southernmost locations (Coulman Island and TNB). The more species rich stations at the two southernmost locations are the most similar.

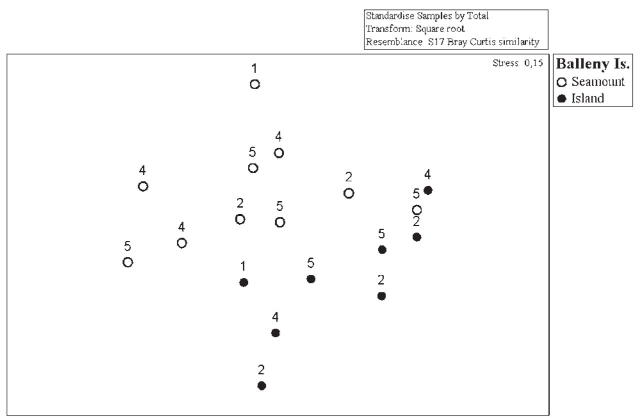

Fig. 7. MDS ordination of Balleny Island stations (only sledge samples) shallower than 500 m depth (1 = 451–550 m, 2 = 351–450 m, 3 = 251–350 m, 4 = 151–250 m, 5 = < 150 m). Island: samples collected near the islands; Seamount: samples collected in the nearby seamounts.

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Table IV. PERMANOVA results regarding location and depth effects between the outer sides of Cape Adare and Cape Hallet. Data were transformed to square root, standardized by row (sample) sums. Analysis based on Bray-Curtis dissimilarities. Unrestricted permutation of raw data using correct permutable units. No. of permutations used = 9999.

Source	df	SS	MS	F	P (perm)	P (MC)
Location	1	5814.7763	5814.7763	2.7304	0.0020	0.0116
Depth	4	11496.0943	2874.0236	1.3495	0.0803	0.1366
Lo X De	4	12300.5053	3075.1263	1.4440	0.0407	0.0916
Residual	10	21296.1695	2129.6170			
Total	19	50907.5454				

As a particularly high ß-diversity value (i.e. low similarity) was observed for the Balleny Islands area, a more detailed analysis has been performed on the data from stations sampled by sledge, shallower than 500 m (similar to locations of the Victoria Land coast). The MDS ordination clearly separates "island" and "seamount" samples (Fig. 7: ANOSIM: Global R = 0.331; significance level = 0.4 %). Average similarity within the island group is 31.37%, while average similarity within seamounts is 28.16%. Dissimilarity between the two groups is 77.75%. Differences among islands and seamounts are due to the larger abundance of ophiuroids in the latter (especially *Ophionotus victoriae* and *Ophioceres incipiens*, totally absent in the "island" samples).

Discussion and conclusions

The data collected during the *Italica* and *Tangaroa* joint cruises increased our knowledge of the echinoderm assemblages of the Ross Sea. Four of the species found are new for the study area (Table III) and others show a larger bathymetric distribution than previously known. Particularly relevant is the confirmed absence of cidarids from the Terra Nova Bay area, while many cidarid species are reported for the Northern Victoria Land and for the McMurdo Sound area (Chiantore *et al*. 2005).

Our results indicate that a latitudinal gradient, if it is operating, is influencing assemblage structure in subtle and non-linear ways as indicated by the different patterns apparent when α-, ß-diversity or multivariate assemblage structure are used as response variables. From our multivariate analysis it would appear that the Balleny Islands system is separate from the Victoria Land coast, probably because of a different biogeographic origin (Dawson 1970) and current oceanographic conditions. Yet, in a more detailed view, differences arise in the comparison between relatively close locations that are subject to similar oceanographic conditions and seasonal variations in light as indicated by our comparison between Cape Adare and Cape Hallett. Moreover, differences are found in the comparison between inner and outer sides of the two capes. The compared location do not differ in the species composition, but in species depth distribution and abundance, stressing the role of local factors (sea bottom morphology, hydrographic features,…) in affecting abundance patterns. It was not possible to correlate echinoderm assemblages and sediment features, as only data from the *Italica* stations were available. Yet, preliminary analyses relating sediment grain size and echinoderm assemblages did not show any significant relationship. In addition, sediments were patchily distributed, without any latitudinal or depth trend.

Latitude related differences arise when taking into account benthic biodiversity at different spatial scales. Alpha diversity increases from north to south, but ß-diversity shows the opposite trend, although it is non-linear. It is well known that old, undisturbed communities, such as the hexactinellid sponge communities reported for McMurdo Sound (Dayton *et al*. 1974), Terra Nova Bay (Cattaneo-Vietti *et al.* 2000), and the Weddell Sea (Gutt *et al.* 1996), are rich in species, but display a low degree of patchiness, so α-diversity is high, while ß-diversity is lower, whereas the opposite pattern may be apparent in areas where disturbance creates patchiness. Importantly, we need to be able to characterize the spatial extent and frequency of disturbance, as well as the recovery rate, in order to characterize how trends in α- and ß-diversity are influenced by disturbance.

One of the best known causes of disturbance, resulting in increased ß-diversity is iceberg scouring (Gutt 2000, Starmans & Gutt 2002, Gutt & Piepenburg 2003, Teixido *et al.* 2004). A recent review from Thrush *et al*. (in press) illustrates how iceberg disturbance increases in the northern sector of the Victoria Land coast, because of hydrographic constraints that force icebergs to move closer to the coastline. In addition, high occurrence of iceberg scours is evident from the multibeam surveys carried out during the last two cruises. Consequently, we could assume that the observed diversity patterns are due to different iceberg disturbance, increasing from south to north. The diversity pattern observed for the Balleny Islands may be due, instead, to the higher habitat complexity (= habitat heterogeneity) and the particularly favourable oceanographic conditions, that make these islands a possible settling area for the larvae dispersed by the Antarctic Circumpolar Current, as it has been described for Bouvet Island (Gutt *et al.* 2005).

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