

METHODS

The initial plan for the surveys included all the inshore waters of the southern Great Barrier Reef region (referred to as the southern GBR) and extended south to include both Hervey and Moreton Bays, and the intervening coastline.

Unfortunately, the survey period was characterised by unseasonally poor weather, and suitable survey conditions were limited. For this reason, the survey coverage was incomplete, and focussed on known high quality dugong habitats at the expense of regions where few or no dugongs had been recorded previously. This resulted in the omission of the region between Cape Bedford and Innisfail, part of the coastline south of Mackay, including Broad Sound, much of the coast between Hervey Bay and Moreton Bay, and three of the six blocks in Moreton Bay. More specific details of the survey design and subsequent alterations are provided below.

Survey Methodology

The surveys were conducted in October–December 1999. The aerial survey method used was the strip transect technique detailed in Marsh and Sinclair (1989a, b). The reasons for adopting this survey methodology rather than the line-transect methodology (Buckland et al. 1993) were as follows: (1) we wished to use the same survey methods as the previous surveys in the time series to avoid confounding survey methodology with temporal change in dugong numbers; (2) a review of dugong survey methodology in 1997 by Professor Ken Pollock recommended that we retain the strip transect methodology.

Transects were flown in an east-west direction as this reduces the interference of glare with the observations. The exception to this was in the Hinchinbrook Channel where mountains make east-west flight dangerous. The transect positions and lengths were modelled on previous surveys of the region (see figure 1(a-g) for details of transect and block positions).

The survey altitude was 137 m and transects of 200 m width on the water surface were demarcated using fibreglass rods attached to artificial wing struts on each side of the aircraft. Tandem teams of observers on each side of the aircraft recorded their sightings independently onto separate tracks of an audio tape using a two-track tape recorder. These independent sightings were then used to develop survey-specific correction factors (see below). Each sighting was designated to the first (top), second, third or fourth (bottom) quarter of the transect to enable us to decide if simultaneous sightings by the tandem observers were of the same group of animals. Other large marine vertebrates (especially sea turtles and cetaceans) were also recorded during the survey.

Our intention was to survey the entire coastline from Cape Bedford in the north to Moreton Bay at the southern limit of the dugong's range, basing the survey design on those of previous surveys (Marsh et al. 1994a, 1995; Lanyon & Morrice 1997). The suitability of weather for aerial surveying leaves only a small window of opportunity, therefore we intended to use two aircraft flying concurrently with separate teams of observers. One team was to survey the region north of Shoalwater Bay, while the other surveyed the region south of Shoalwater Bay. Shoalwater Bay was surveyed separately two weeks prior to the main body of the survey (30 October - 1 November), as military activity prevented access at the desired time.

The region south of Shoalwater Bay including Hervey Bay and the Great Sandy Straits was surveyed under generally good conditions, and in general accordance with previous surveys from 13–20 November 1999. Poor weather occasionally caused delays in this

region. In particular, the survey block covering the region between Hervey Bay and Moreton Bay was truncated to allow our transfer to Brisbane in the hope of encountering sufficient good weather to complete the coverage of Moreton Bay. Part of Moreton Bay was surveyed in marginal conditions before the weather degenerated to levels unsatisfactory for aerial surveys. After waiting several days, the weather did not improve and the remainder of the Moreton Bay leg was cancelled due to the increasing costs of keeping an aircraft and six crew in Brisbane, with no prospects of completing the surveying. Consequently, blocks M2, M4 and M5 (table 1, figure 1g) were omitted.

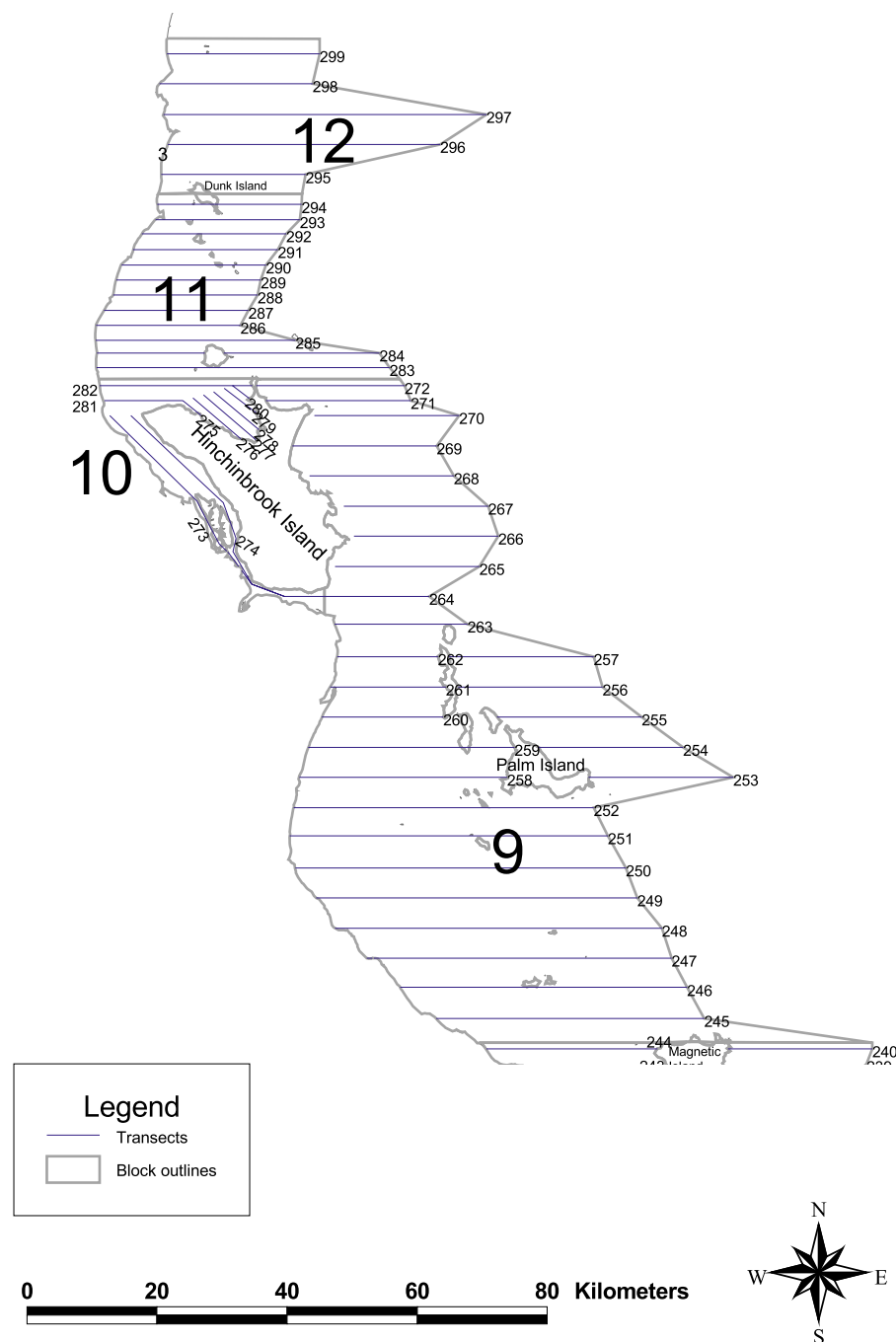


Figure 1a. Positions of blocks C9 to C12, and transects contained within, in the Central Section of the Great Barrier Reef region, from Innisfail to Magnetic Island

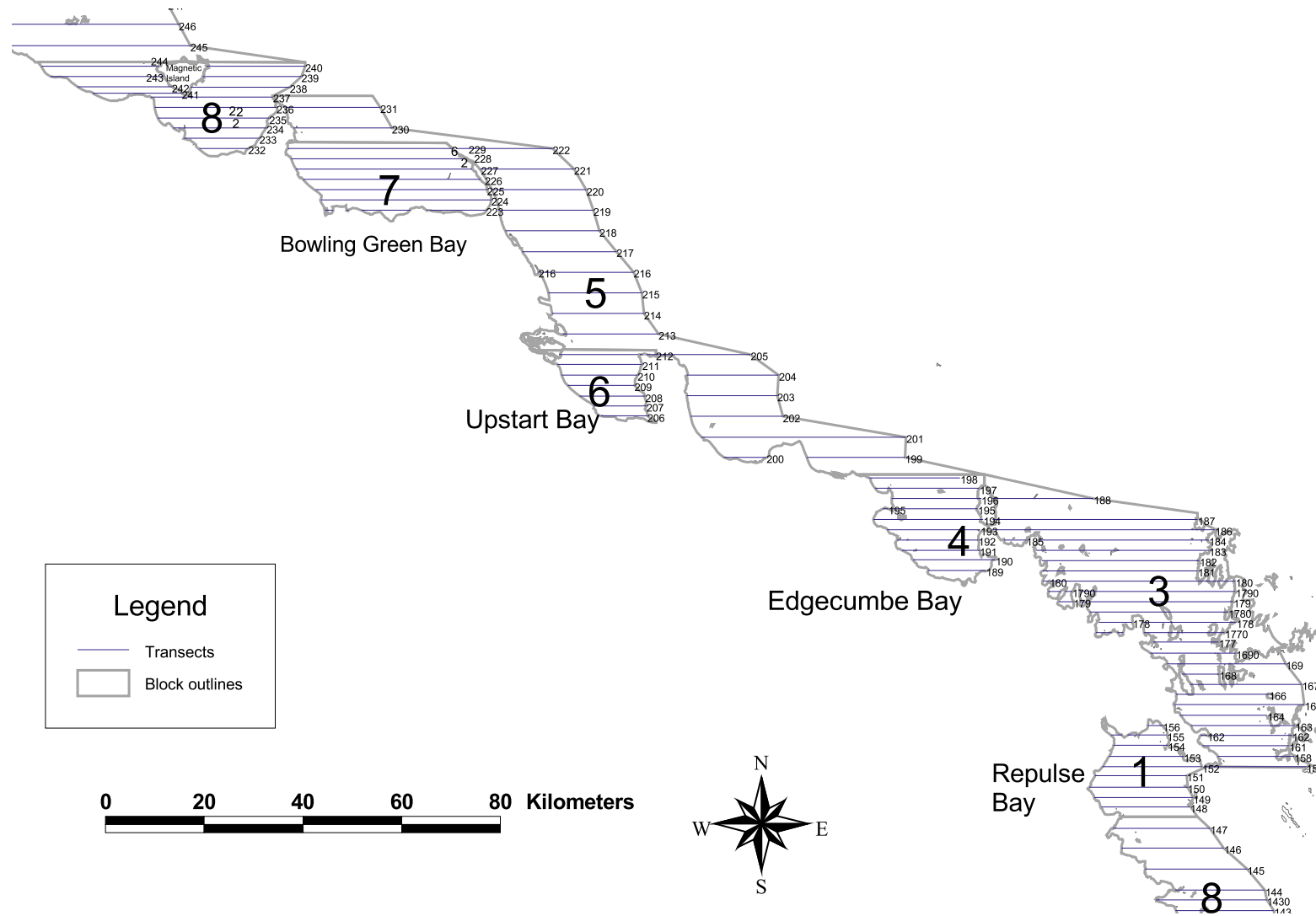


Figure 1b. Positions of blocks C1 to C8, and transects contained within, in the Central Section of the Great Barrier Reef region, from Cleveland Bay to Repulse Bay

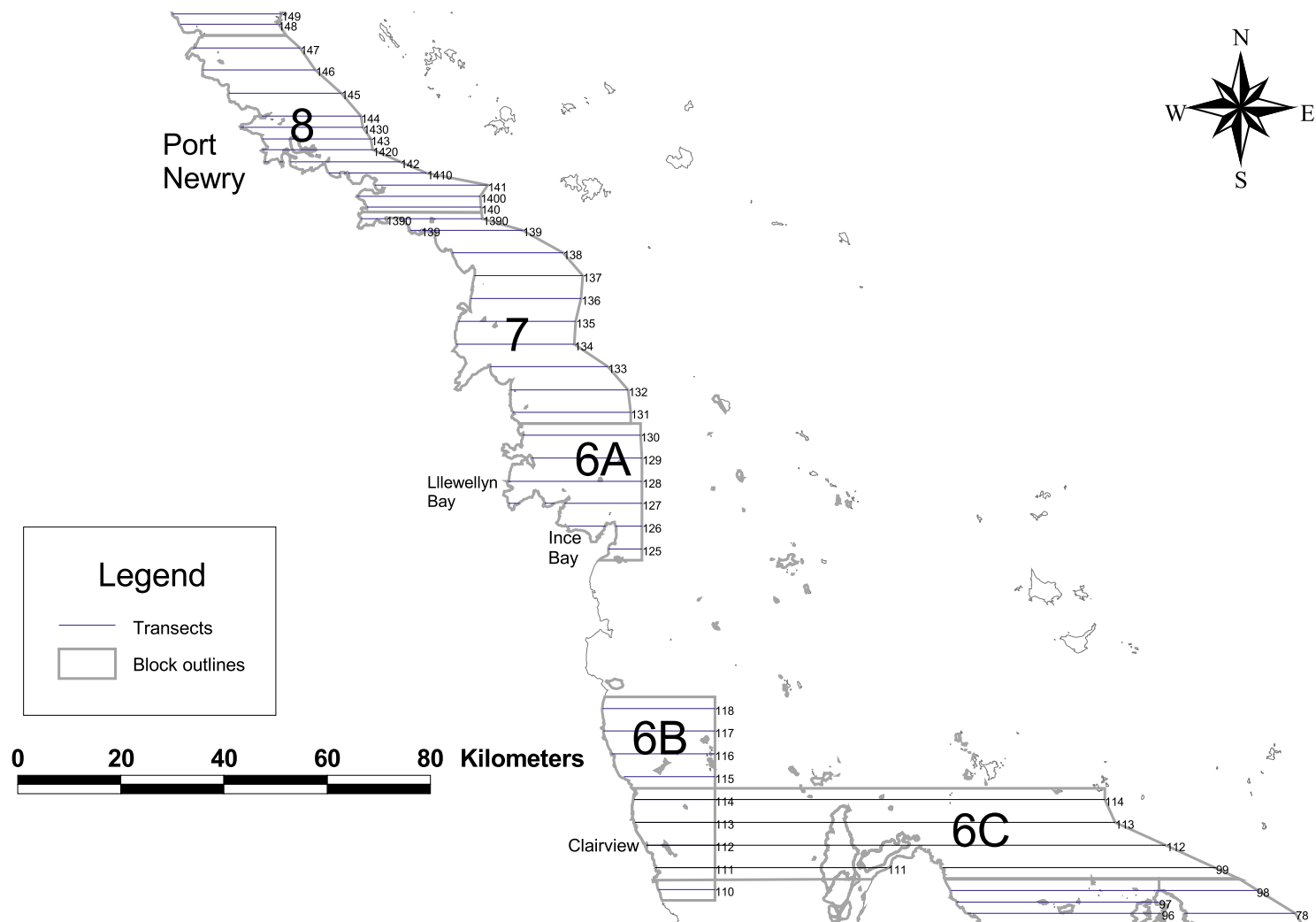


Figure 1c. Positions of blocks S6 to S8, and transects contained within, in the Southern Section of the Great Barrier Reef region, from the Newry Region to Clairview

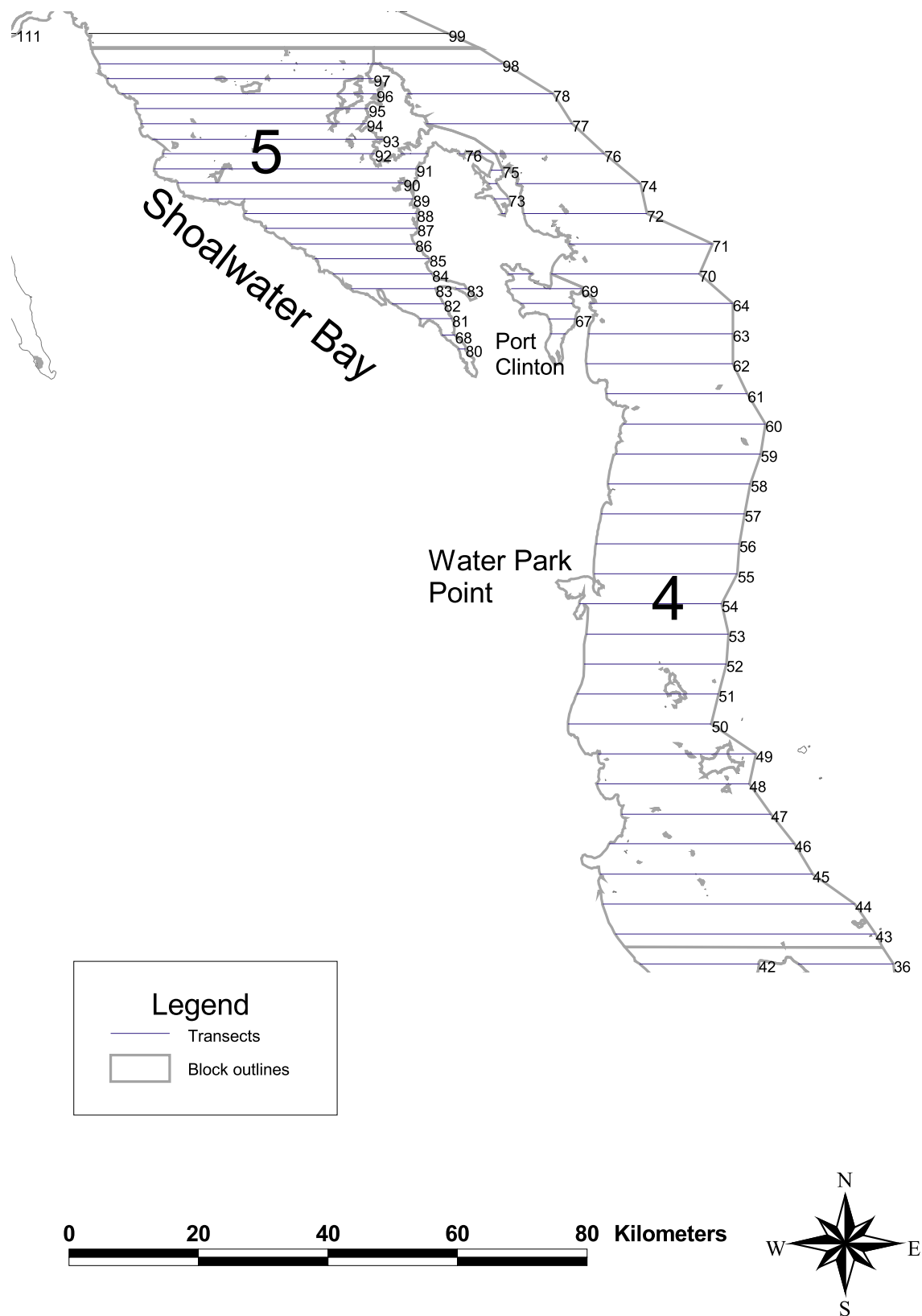


Figure 1d. Positions of blocks S4 and S5, and transects contained within, in the Southern Section of the Great Barrier Reef region, from Shoalwater Bay to the northern end of Curtis Island

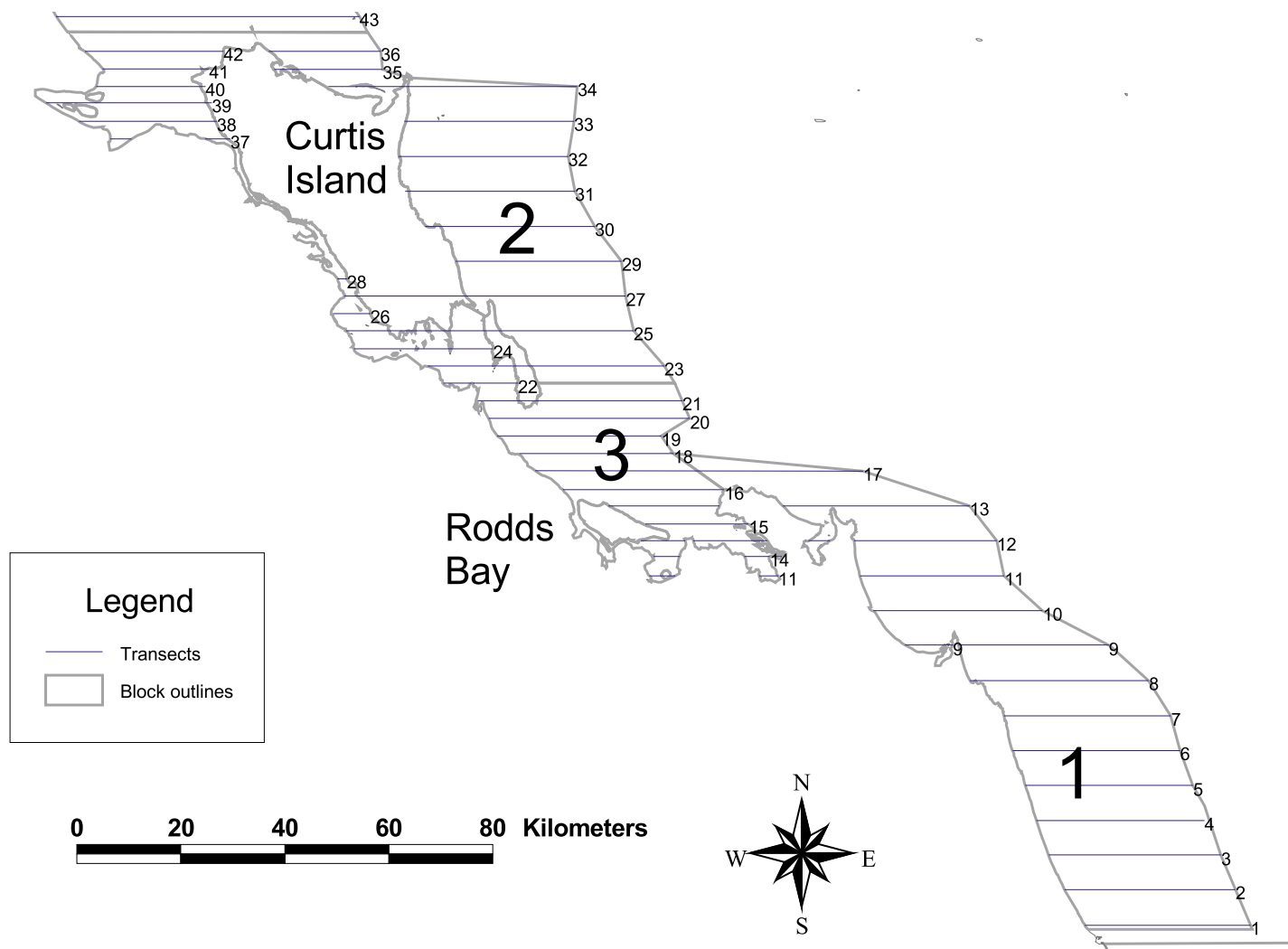


Figure 1e. Positions of blocks S1 to S3, and transects contained within, in the Southern Section of the Great Barrier Reef region, from Curtis Island to Baffle Creek

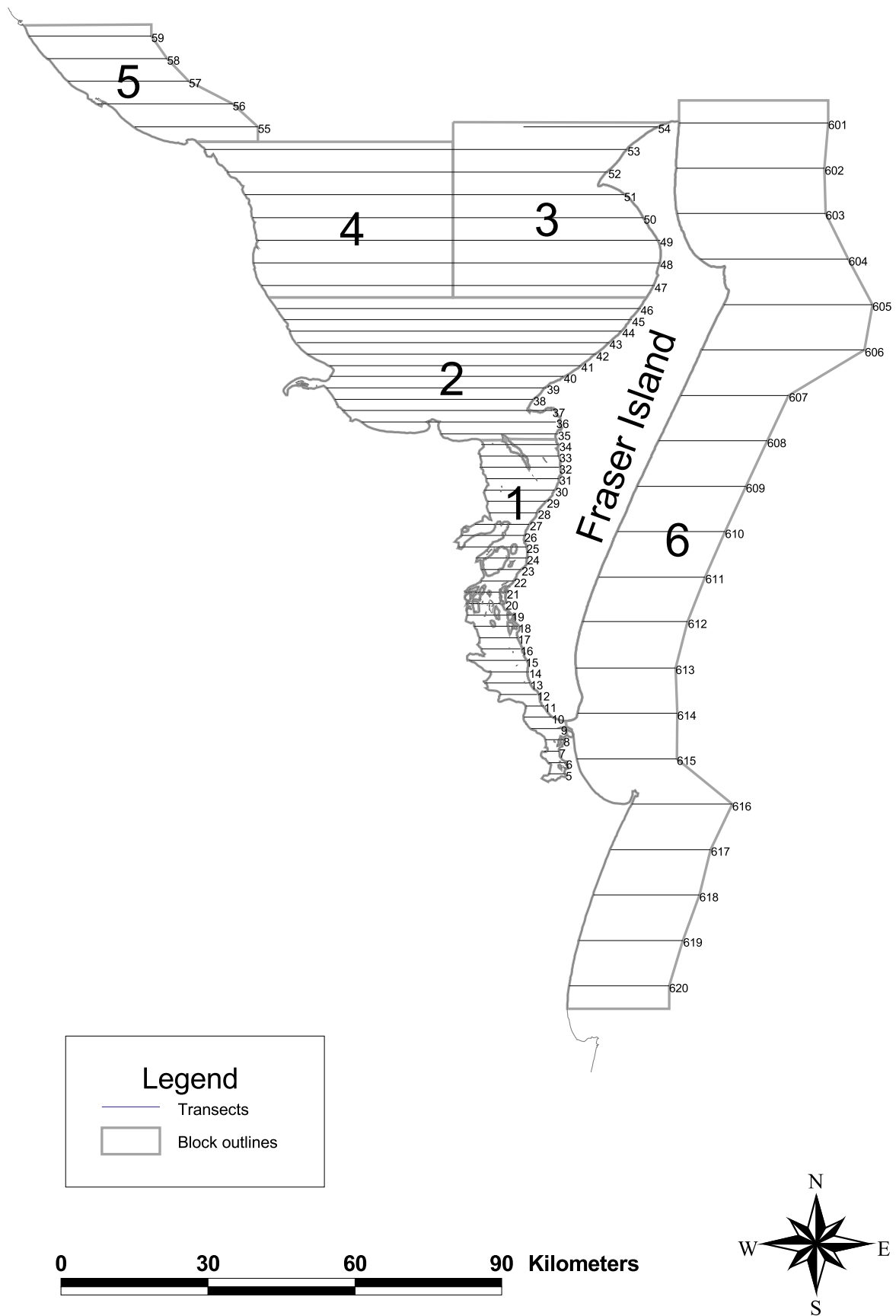


Figure 1f. Positions of blocks H1 to H5, and transects contained within, in the Hervey Bay/Great Sandy Straits region

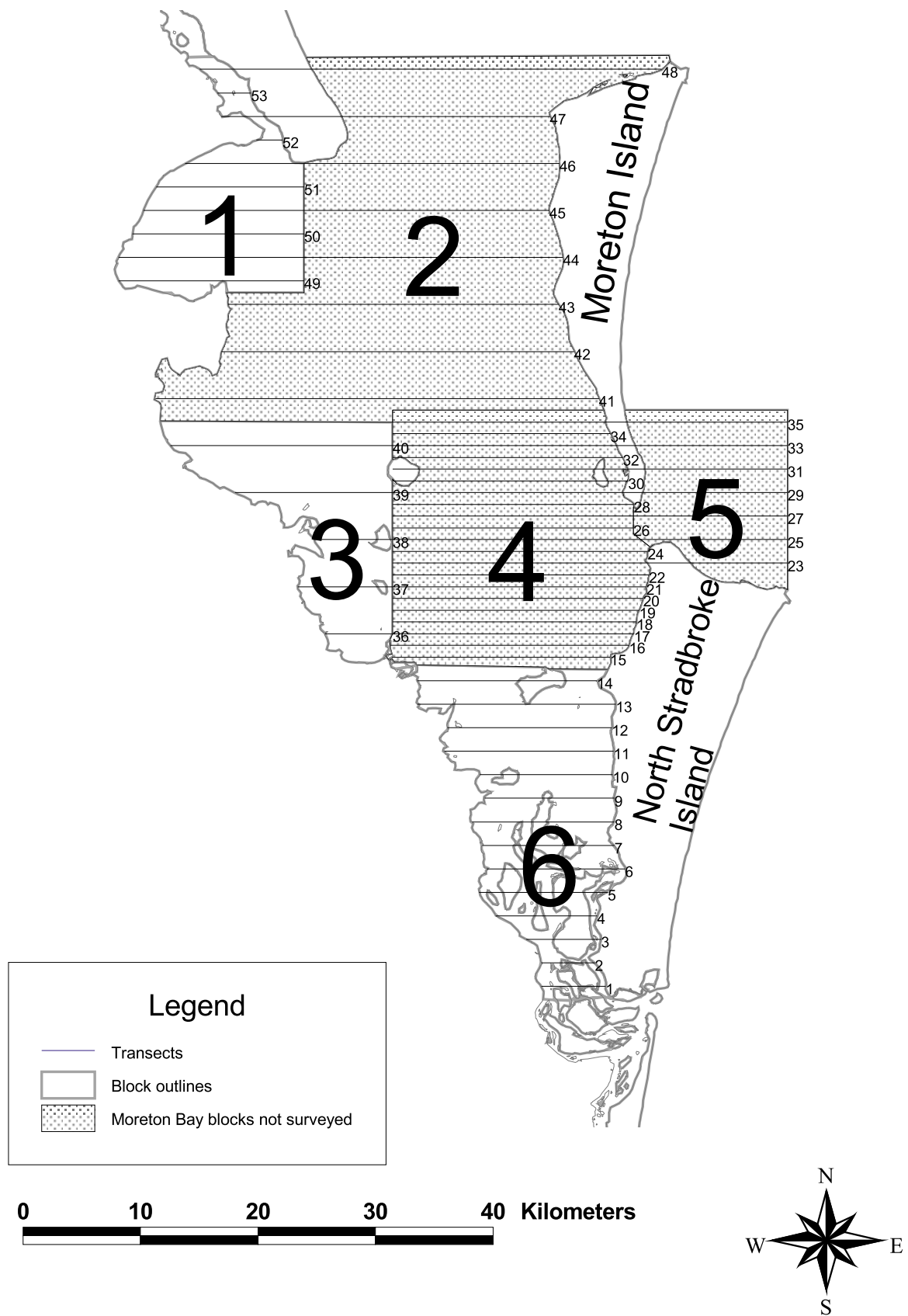


Figure 1g. Positions of blocks M1-M6, and transects contained within, in Moreton Bay

Table 1. Modification of the survey design¹ from previous surveys, mainly as a result of poor weather conditions encountered during the surveys.

Region	Block	Modification detail
Central GBR	Block C12 – abbreviated	only transects 295–299 flown transects 298, 299 truncated to 12 nautical miles
	Block C2 omitted (outside Whitsundays)	
	Block C3 – transects added	four extra transects added interspaced between transects 169 and 180
Southern	Block S6 – abbreviated, split into two blocks	transects 100–109, 119–124 omitted transects 125–130 truncated at 143°32' – new block S6A transects 110–118 truncated at 149°40' – new block S6B - A portion of this block (block S6C) was also surveyed during the Shoalwater Bay leg. It overlaps with block S6B
	Block S7	transects 135 truncated to 131 truncated to 12 nautical miles
	Block S8	Extra transects included between transects 139 and 143
Hervey Bay	Block H6	New block on east coast of Fraser Is and extending south to mainland ²
Moreton Bay	Blocks M2, M4 and M5 omitted	

¹See figure 1(a-g) for positions of blocks and transects

²Added as per contract with QPWS

Poor weather also meant that the northern team was only able to survey the region from Innisfail south to Cape Upstart, from 14–17 November 1999. The transects from Innisfail to Cape Bedford were omitted from the survey. The region between Cape Upstart and Shoalwater Bay (referred to as the Whitsunday leg) was surveyed between 10 and 12 December 1999. Again, poor weather was a limiting factor, and parts of this section also had to be omitted to enable the region to be adequately sampled within logistical limitations. Small sections of the coast where dugongs have not previously been seen were omitted, as was the block on the eastern side of the Whitsunday Islands. Transects were shortened in some blocks so that effort could be focussed on areas of potentially good dugong habitat. Details of changes to the previous survey designs are provided in table 1. Weather conditions encountered during this and previous surveys of the region are summarised in table 2. The areas of the survey blocks and the intensity of the survey coverage are shown in table 3.

Correction Factors

Estimates of dugong abundance were obtained by correcting sightings for perception bias and availability bias *sensu* Marsh and Sinclair (1989a). Perception bias occurs when animals are visible in the survey transect but missed by observers. A correction factor used to account for this bias is calculated using a modified Mark-Recapture model that is based on the proportion of animals seen by one or other, or both, observers (Marsh and Sinclair 1989a). Perception correction factors were calculated for each tandem team of observers. Unfortunately, the composition of some teams varied between survey legs because of the logistical difficulties described above and separate perception correction factors were calculated for each pair of observers.

Availability bias is corrected for by standardising the proportion of animals classified as 'at the surface' against the corresponding proportion in an earlier survey over very clear shallow water over white sand which enabled all animals in the survey area to be seen (Marsh & Sinclair 1989a). This approach makes the untested assumption that a constant proportion of animals is at the surface across all survey conditions. Availability correction factors were also estimated separately for different legs of the survey.

Population Estimation

Dugong abundance was estimated separately for each block in the survey area. As transects varied in length, and hence area, the Ratio Method was used to estimate density, population and associated errors (Jolly 1969; Caughley & Grigg 1981). The estimated standard errors incorporate the errors associated with the correction factors described above (Marsh & Sinclair 1989a).

Statistical Analysis

Differences in dugong density between this and previous surveys of the same region were tested using linear mixed effects models estimated by restricted maximum likelihood (REML). The (fixed) year effect was tested against the random year*block variation using density averaged across all transects within blocks (in this model the mean square error is equivalent to the year*block variation). The initial models also included Beaufort Sea State as a fixed factor, but its effect was found to be weak and was omitted from the final models.

Two analyses were conducted. The first compared the densities of dugongs in the blocks in the Great Barrier Reef Marine Park only for four surveys in 1987, 1992, 1994 and 1999. The second analysis also included Hervey Bay, but used data from 1994 and 1999 when the two areas were surveyed together for the first time. Data were $\ln(x+0.01)$ transformed to stabilise variances.

Table 2. Weather conditions encountered during the survey in comparison to previous surveys of the same areas

	SGBR Northern Sector¹	SGBR Whitsunday Sector²	SGBR Shoalwater Bay Sector³	SGBR Southern Sector⁴	Southern GBR All sectors			Hervey Bay				Moreton Bay
Year of survey	1999	1999	1999	1999	1994	1992	1986–87	1999	1994	1993	1988	1999
Wind speed (km.h ⁻¹)	< 10	< 10	< 10	< 10	< 15	< 37	< 37	< 10	< 10	< 20	< 28	< 10
Cloud cover (oktas)	0–3	0–6	0–6	0–6	0–5	0–5	0–4	0	1–3	1–4	1–6	0–3
Minimum cloud height	3000	2500	2000	1500	2000– 5000	2500	300	-	2000– 5000	460-1800	610-2400	3500
Beaufort sea state (range)	1.45 (0–4)	1.55 (0–3)	1.87(0–4)	1.95 (0–3)	1.87 (0–4)	1.0 (0–4)	1.0 (0–3)	1.67 (0–4)	1.94 (1–3)	1.2 (0–3)	2.1 (0–4)	0.87 (0–3)
Glare ⁵												
North	0.67	1.10	0.53	1.76	1.44			1.92	0.92			1.42
South	0.70	1.32	1.08	1.85	1.29			1.86	1.08			1.23
Overall	0.69	1.21	0.80	1.80	1.36	2	2	1.89		1.4	0.9 (0-3)	1.32
Visibility (km)	> 20	> 20	> 20	> 10	> 15	N/A	> 20	> 30	> 20	N/A		> 20

¹Innisfail to Upstart Bay - Blocks C6–C12, C5 transects 213–231 (figure 1a, b)²Cape Upstart to Clairview - Blocks S6A, B - S8, C1–C4, C5 transects 199–205 (figure 1b, c)³Shoalwater Bay to approximately Great Keppel Island - Blocks S4, S5, S6C (figure 1c, d)⁴Curtis Island to southern limit of GBRMP (approximately Baffle Creek) - Blocks S1–3 (figure 1e)⁵Values for Beaufort sea state and glare are the mean of the modes for each transect.⁶The scale for glare is: 0 - no glare, 1 - up to 25% of field of view affected by glare, 2 - 25–50% affected, 3 - > 50%

Table 3. Areas of survey blocks and sampling intensities

Block	Area (km ²)	Sampling intensity (%)
	1999 (1994 if different) ¹	1999 (1994 if different) ¹
Southern section of SGBR		
S1	1390	9.57
S2	836	9.79
S3	1021	16.34
S4	3242	9.45 (11.4)
S5	1347	15.8
S6	Not done (6498)	Not done (8.4)
S6A	508	8.96
S6B	661	8.68
S6C	1633	8.55
S7	957 (1567)	9.37
S8	796	14.59 (9.36)
Central section of SGBR		
C1	371	16.4
C2		Not surveyed
C3	1733	17.05 (13.2)
C4	466	17.02
C5	2087	7.98
C6	244	18.03
C7	579	18.59
C8	620	18.83
C9	3829	8.66
C10	288	20.04
C11	756	16.95
C12A	713	8.59
Hervey Bay		
H1	517	18.87
H2	1414	15.17
H3	1232	8.07
H4	1246	8.20
H5	546	8.36
H6 ²	4090	4.3
Moreton Bay ²		
M1	166	19.86
M3	188	10.05
M6	226	24.30

¹In some blocks transects were added or modified leading to differences in the estimates of the area of the block and sampling intensity. See table 1 and figure 1a-g for details of these changes.

²Not surveyed in 1994.