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Changes in seagrass coverage in Cockburn Sound, Western Australia between 1967 and 1999

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Abstract

Changes in seagrass coverage in Cockburn Sound from 1967 to 1999 were assessed from aerial photographs using modern mapping methods with the aim of accurately determining the magnitude of change in hectares of seagrasses between 1967 and 1999 and to set up a baseline for future monitoring of seagrass loss in Cockburn Sound. Firstly, coverage and assemblages of seagrasses in Cockburn Sound were mapped using the best available aerial photographs from 1999, rectified to a common geodesic base with comprehensive groundtruth information, and with a semi-automated mapping algorithm. Then the same technique was used to map historical seagrass coverage in Cockburn Sound from aerial photographs taken in 1967, 1972, 1981 and 1994.

The seagrass coverage in Cockburn Sound has declined by 77% since 1967. Between 1967 and 1972, 1587 ha of seagrass, were lost from Cockburn Sound, mostly from shallow subtidal banks on the eastern and southern shores. By 1981, a further 602 ha had been lost. Since 1981, further seagrass losses (79 ha) have been restricted to a shallowing of the depth limit of seagrasses, localised losses associated with port maintenance and a sea urchin outbreak on inshore northern Garden Island. There has been no recovery of seagrasses on the eastern shelf of Cockburn Sound after nutrient loads were reduced in the 1980s, suggesting that this shallow shelf environment has been altered to an environment not suited for large-scale recolonisation by *Posidonia* species.

Keywords: Mapping; Aerial photography; Seagrass decline; *Posidonia* spp.; Australia

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1. Introduction

Large-scale losses of seagrass meadows associated with human impacts have occurred in Australia (Walker and McComb, 1992) and worldwide (Short and Wyllie-Echeverria, 1996). One of the most commonly cited cases of large-scale seagrass loss happened in Cockburn Sound, Western Australia following increased industrial discharge and expansion of port facilities (Cambridge, 1979; Cambridge and McComb, 1984; Hillman, 1986). Cambridge and McComb (1984) documented a loss of 3400 ha of seagrass meadows between 1969 and 1978, with most losses occurring before 1975. Their study has recently been criticised heavily by local marine industries and management agencies because unrectified aerial photographs were used, the mapping area was poorly defined, and the 1969 map of seagrass distribution in the eastern shelf of Cockburn Sound was mostly determined from field observations, as the aerial photography was of poor quality (Cambridge and McComb, 1984). This study redresses these limitations, focuses on the years of major historical loss and extends the work of Cambridge and McComb (1984) 20 years to the present day.

Cockburn Sound has historically been used for recreational boating and commercial fishing, but its relatively protected deep waters also provide an excellent anchorage, and in 1954 it was designated as an industrial harbour for the Perth-Fremantle region (Cambridge and McComb, 1984). Industrial development commenced with the establishment of an oil refinery in 1955, followed by the addition of iron, steel, alumina and nickel processing and refining plants, chemical and fertiliser production plants and a bulk grain terminal. In conjunction with the development of these heavy industries, wharves and groynes were built and channels dredged for shipping access. A wastewater treatment plant was commissioned in 1966 which discharged into the northern end of the Sound, while at the southern end of the Sound, a 2.5 km long causeway was constructed between 1971 and 1973 to connect Garden Island to the mainland (Hicks et al., 1973). This causeway is interrupted by two trestle bridges (one 305 m long and other 610 m long), through which limited exchange of water with the ocean occurs.

Industrial expansion resulted in a decline in seagrass coverage in Cockburn Sound from 4200 to 900 ha between 1954 and 1978, with most loss occurring between 1969 and 1975 (Cambridge and McComb, 1984). The Western Australian Government funded a 3 year study (1976–1979; Cambridge, 1979), which identified that the decline in seagrass coverage was linked to an increase in nitrogen loading in the Sound. Over 90% of the nitrogen contributed by industrial effluent and wastewater to the Sound came from two sources: the outlet shared by the CSBP fertiliser works and the Kwinana Nitrogen Company, and the outlet of the Woodman Point Wastewater Treatment Plant (Cambridge et al., 1986). The proposed mechanism for seagrass loss was that increased nitrogen levels led to enhanced growth of nuisance epiphytic algae and consequent shading and deterioration of the seagrasses (Cambridge et al., 1986).

Water quality in Cockburn Sound has improved greatly since the late 1970s (Hillman, 1986; Hillman, unpublished data). The annual loading of nitrogen has decreased from 2000 t N per year in 1978 to less than 500 t N per year in 1997 (Hillman, unpublished data). The northeastern shore of Cockburn Sound still has high N levels from contaminated groundwater discharging into the sound. This contaminated groundwater contributed 70%

of the total nitrogen entering Cockburn Sound in 1995 (Department of Environmental Protection, 1996).

There has not been a reassessment of seagrass distribution in Cockburn Sound for the past 20 years since the work of Cambridge and McComb (1984). This paper redresses this by mapping seagrass coverage in 1981, 1994 and 1999 and revisits the period of maximum seagrass loss between 1967 and 1972. We map coverage of assemblages of seagrasses in Cockburn Sound using the best available aerial photographs from 1999, rectified to a common geodesic base with comprehensive groundtruth information (Kendrick et al., 2000). This is then compared to maps of historical seagrass coverage in Cockburn Sound constructed from historical aerial photographs taken in 1967, 1972, 1981 and 1994.

2. Methods

2.1. Mapping of seagrasses

To determine seagrass distribution, submerged vegetation was mapped from recent and historical aerial photography. Distribution of seagrass assemblages and reef were then determined in 1999 from towed underwater video. We define assemblages of seagrasses as multi-species assemblages dominated, or characterised, by single or multiple species as determined from their relative abundance in video footage. In Cockburn Sound, the seagrass species *Amphibolis antarctica*, *Amphibolis griffithii*, *Posidonia australis*, *Posidonia coriacea*, *Posidonia sinuosa*, *Halophila ovalis*, *Heterozostera tasmanica* and *Syringodium isoetifolium* were components of the seagrass assemblages. We did not map to single species, although a single species assemblage is composed of more than 70% of that species. Results from mapping of aerial photographs and underwater video footage were then combined in a GIS to create coverage maps of seagrass assemblages, reef and unvegetated sand. We describe our maps as coverage maps, rather than maps of seagrass cover to reduce the confusion between the area covered by a single species of seagrass and the area occupied by an assemblage of seagrasses than is dominated by one or a few species. This is not presence–absence mapping, as vegetated assemblages do not exclude all unvegetated habitat (see Section 2.6).

2.2. Study area and mapped regions

Cockburn Sound is a sheltered marine embayment 16 km long × 9 km wide, and consists of a deep central basin (17–22 m deep) surrounded by shallow platforms. The shallow platforms vary in width from 50 m to 3 km and are where seagrass meadows are found (Fig. 1). The seagrass mapping area was delineated as shallow platforms to a depth of 10 m and covered an area of approximately 3667 ha (Table 1). The mapped area of the present study is smaller than that used by Cambridge and McComb (1984), as they incorporated an undefined proportion of Parmelia Bank into their mapped area and never defined a depth limit for their study. The total area mapped by Cambridge and McComb (1984) was 4200 ha.

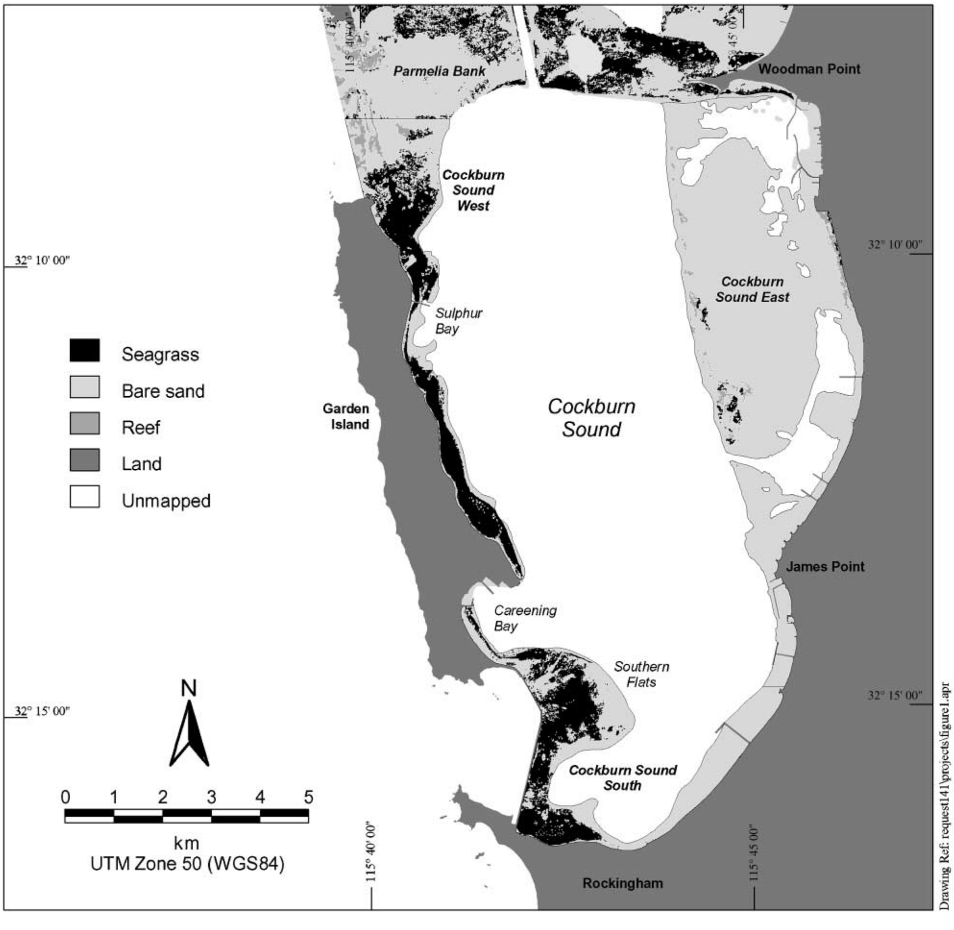

Fig. 1. Map of Cockburn Sound showing the extent of seagrass mapping bounded by the coastline and 10 m isobath, the three mapping regions (Cockburn Sound West, South and East), locations mentioned in the text, and the 1999 mapped distribution of seagrasses and reef.

Historical changes in seagrass coverage of Parmelia Bank have been recently published (Kendrick et al., 2000) so have not been included in this paper.

Coverage of all submerged vegetation was separately calculated for three regions called Cockburn Sound East, South and West (Fig. 1, Table 1). Cockburn Sound East encompassed most of the eastern bank from Woodmans Point to south of James Point. Cockburn Sound South contained the shallow bank near Rockingham, the southern sand flats and Careening Bay, Garden Island. Cockburn Sound West encompassed the western bank north of Careening Bay and shallow waters north of Garden Island. Benthic features are difficult to resolve from aerial photographs at depths greater than 10 m as seagrasses become sparsely distributed at these depths. Hence, the 10 m isobath and the coastline are used to delineate the mapping boundaries within each of these regions.

Table 1
Area of seagrass assemblages in 1999 for each mapped region (Cockburn East, South and West) and for Cockburn Sound in total

Mapping region	Mapping area (ha)	*Posidonia australis* (ha)	*Posidonia sinuosa* (ha)	*Posidonia sinuosa* and *Posidonia australis* (ha)	Total seagrass (ha)	Reef (ha)	Shallow bare sand (ha)
Cockburn Sound East	2138	0	13	0	13	25	2100
Cockburn Sound South	818	11	279	2	292	0	526
Cockburn Sound West	711	0	356	0	356	21	334
Total	3667	11	648	2	661	46	2960

Data area represented as area in hectares (ha).

2.3. Data sources

In 1999, flights to acquire aerial photographs were purpose-flown in late-February to early-March when conditions were optimal. These conditions included maximum seagrass leaf cover; maximum water clarity; minimum haze from the adjacent industrial zone; minimum turbidity from dredging, river outflow or industrial activities; minimum cloud cover; weak prevailing winds; and incident sun angle at 20–30°. Colour photography with a yellow lens filter was obtained at two altitudes. High altitude imagery was collected at 10,000 m (scale, 1:55,000) for accurate *ortho*-rectification. The resulting imagery was used as a rectification base for the low-altitude imagery that was obtained at an altitude of 3,800 m.

Mapping of the historical seagrass coverage in Cockburn Sound was conducted using rectified and mosaicked imagery obtained in: 1994 (majority of imagery obtained on 4 and 8 January 1994 and some on 6 January 1995); 1981 (imagery from 13 June 1981); 1972 (imagery from 2 May 1972); and 1967 (imagery from 20 March 1967).

2.4. Image geo-referencing and rectification

Images were initially rectified (Datum: WGS-84) using ERMapper-6.1 to a resolution of 2.0 m (Earth Resource Mapping, 2000). The images were initially scanned into three colour bands (red, green and blue). The red band of the colour images contained almost no information for marine benthic habitat, as red light was severely attenuated through the water column. The green band was better than the red, though images had low contrast due to atmospheric attenuation. The blue band provided the best contrast between vegetated and unvegetated habitats and therefore was the only band used for mapping. It was converted to 256 greyscales.

Rectified imagery was processed using Geographic Resources Analysis Support System (GRASS) GIS software (Neteler, 1998). GRASS is a raster-based GIS and the 2.0 m cell size and its spatial location (spatial integrity) was strictly maintained in rectified imagery. Also the same spatial integrity was kept consistent among the rectified imagery for the different years mapped (spatial consistency).

2.5. Automated mapping of submerged vegetation

A computerised, semi-automated, greyscale segmentation mapping method called Spann–Wilson segmentation (Spann and Wilson, 1985) was employed to map submerged vegetation. Spann–Wilson combines locally adaptive segmentation (local centroid) with pre-processing using multi-level quad-tree smoothing. The segmentation method was implemented using the Xite image-processing software (The University of Oslo, 1999). The size of the moving histogram window and the number of quad-tree smoothing levels were controlled by the operator, although for this exercise were set to 324 m^2 and 3–4. Spann–Wilson segmentation was very effective in defining the boundaries of seagrass meadows reefs and unvegetated sand from greyscale images. It reduced the original 256 greyscales from the aerial photographs to four greyscales. The operator then chose a greyscale which most closely coincided with the visually interpreted boundary between vegetated and unvegetated habitat.

2.6. Control rules for mapping

The vegetated areas were distinguished from the unvegetated areas as they had a distinct photo-tone of medium to dark grey. To enable consistent coverage mapping across the study area, a series of control rules were used (Kendrick et al., 2000). These control rules were as follows:

- Isolated vegetated patches less than 30 m^2 in area were not mapped.
- Vegetated patches, that were greater than 30 m^2 and less than 100 m^2 were mapped as separate patches when the distance between one patch and another was greater than the diameter of the patch.
- Vegetated patches, that were greater than 30 m^2 and less than 100 m^2 were mapped as a single meadow when the distance between one patch and another was less than the diameter of the patch. Unvegetated areas within the meadow with an area greater than 100 m^2 were mapped.
- Vegetated patches greater than 100 m^2 were mapped and the edges of these areas were traced accurately. Unvegetated regions within these patches with areas greater than 100 m^2 were mapped.

The control rules were applied automatically during mapping with control rules 2–4 processed during the Spann–Wilson segmentation step to a 324 m^2 moving window, and control rule 1 applied after the segmentation step to 1 km^2 areas using a PERL script.

2.7. Groundtruth surveys

Detailed groundtruth surveys were conducted between late-February and May 1999. These groundtruth surveys were undertaken using a differential GPS combined with diver-operated towed video (manta tow) and a downward-looking surface deployed (drop-down) video. Following the completion of the formal groundtruth surveys, a series of opportunistic dives were also undertaken to establish the assemblage type in specific areas of interest. A total of four manta tow transects (8 km in total) and 114 drop-down video locations were surveyed during the groundtruthing exercise.

The manta tow videos were analysed by pausing the video at 20 s intervals (corresponding with the differential GPS waypoints). At each of these video pauses the percent of the image each seagrass species and habitat type was recorded. For the drop-down videos, percent representation of species of seagrass and habitats was averaged across the total video footage obtained from each drop unless the species composition varied noticeably. If it was variable, the drop was sub-divided to more accurately represent the seagrass coverage.

Seagrass species recognised in the video footage were *A. antarctica*, *A. griffithii*, *P. australis*, *P. coriacea*, *P. sinuosa*, *H. ovalis*, *H. tasmanica* and *S. isoetifolium*. Habitats other than seagrasses that were recognised were limestone reef and unvegetated sand.

It was not possible to separate the species of *P. sinuosa* and *Posidonia angustifolia* from the video data, as this requires an examination of the rhizome fibres (Cambridge and Kuo, 1979). Groundtruth dives indicated that *P. sinuosa* was generally more common than *P. angustifolia* (greater than 90% except in the Cockburn Sound East region where *P. sinuosa* cover was approximately 70%). In the present mapping exercise, these two species were both mapped as the *P. sinuosa* assemblage.

2.8. Mapping of seagrass assemblages and benthic habitats

The maps of the 1999 vegetated and unvegetated areas were combined with the groundtruth data using GRASS GIS to produce a benthic assemblage map. Within the mapped region, the seagrass assemblages *P. sinuosa*, mixed species *P. sinuosa* and *P. australis*, and *P. australis* were distinguished as these species were the dominants. Single species assemblages were defined when a single species had greater than 70% representation on videos and the *P. sinuosa* and *P. australis* assemblage was defined when *P. sinuosa* and *P. australis* were equally represented (representation of any one species could range between 30 and 70%). Shallow unvegetated sand (<10 m depth) and reef were also mapped.

Mapping of historical seagrass coverage in Cockburn Sound was conducted using rectified and mosaicked imagery obtained for 1967, 1972, 1981 and 1994. Coverage of all seagrass assemblages combined was calculated for the three regions within Cockburn Sound separately. The reef areas which were identified in the 1999 mapping exercise were transposed onto the historical images from Cockburn Sound, using the assumption that the size and location of these reef areas had not changed over the mapping period. Previous ground truth data were collected from a range of sources, including those of Cambridge (1979), Marsh and Devaney (1978) and Wilson et al. (1978), and used as an aid in interpreting historical seagrass coverage.

3. Results

3.1. Seagrass coverage in 1999

In 1999, seagrasses occupied an area of 661 ha (18%) of sandbanks less than 10 m in depth (3667 ha) in Cockburn Sound (Table 1, Fig. 1). Extensive seagrass meadows were found predominantly on the western margin of Cockburn Sound (Cockburn Sound West,

Table 1) and in the Southern Flats and western Rockingham regions (Cockburn Sound South, Table 1). The seagrass meadows in 1999 were predominantly composed of *P. sinuosa* assemblages with a small area on the Southern Flats dominated by assemblages of *P. australis* (Table 1). Besides these dominant species, small proportions of *A. antarctica*, *A. griffithii*, *P. coriacea*, *H. ovalis*, *H. tasmanica* and *S. isoetifolium* were observed.

3.2. Time course of seagrass loss

In 1967, seagrasses formed an almost continuous 2929 ha meadow, between 1 and 10 m depths, that fringed the eastern, southern and western margins of Cockburn Sound (Fig. 2). Between 1967 and 1981, all but a few isolated patches of seagrass were lost from Cockburn Sound East and the eastern margins of Cockburn Sound South (Figs. 2 and 3). Seagrass loss was broad-scale with 1587 ha of seagrasses disappearing between 1967 and 1972, and 602 ha between 1972 and 1981 (Fig. 3, Table 2). A further 79 ha of seagrasses have disappeared between 1981 and 1999, mostly from Cockburn Sound West, but the scale of loss was smaller and more localized.

In Cockburn Sound East, 1750 ha of seagrasses covered 82% of the shallow bank habitat in 1967, but by 1972 only 310 ha (14.5% coverage) survived and by 1981 only 14 ha (0.6% coverage) remained (Table 2, Fig. 3). In 1999, the few remnants of seagrasses in the Cockburn Sound East region are associated with relatively shallow waters along its western margin and have similar coverage to that of seagrasses in 1981.

In Cockburn Sound South, the area of shallow bank was only 38% of Cockburn Sound East. One hundred and six hectares of seagrass meadows were lost between 1967 and 1972, and a further 245 ha disappeared between 1972 and 1981 (Table 2). From 1981 to 1999, there has been a slight increase (9 ha) in seagrass coverage, associated with growth of seagrasses into sand blowouts on Southern Flats.

Seagrass loss in Cockburn Sound West has been less dramatic than Cockburn Sound East and South, but has continued up to the present day (Table 2). Forty-one hectares of seagrass meadows were lost between 1967 and 1972, a further 61 ha disappeared between 1972 and 1981, followed by 71 ha lost between 1981 and 1994, and 16 ha from 1994 and 1999 (Table 2). These losses are substantial, as Cockburn Sound West is only 33% of the area of Cockburn Sound East.

Table 2
Change in seagrass coverage in Cockburn Sound for 1967, 1972, 1981, 1994 and 1999

Seagrass coverage											
Region	Mapping area (ha)	1967		1972		1981		1994		1999	
		ha	%	ha	%	ha	%	ha	%	ha	%
Cockburn East	2139	1750	81.8	310	14.5	14	0.6	26	1.2	13	0.6
Cockburn South	818	634	77.5	528	64.6	283	34.6	291	35.6	292	35.7
Cockburn West	710	545	76.8	504	71.0	443	62.4	372	52.4	356	50.1
Total	3667	2929	79.9	1342	36.6	740	20.2	690	18.8	661	18.0

Data are presented as area in ha and as % of mapping area for each mapped region (Cockburn East, South and West) and for Cockburn Sound in total.

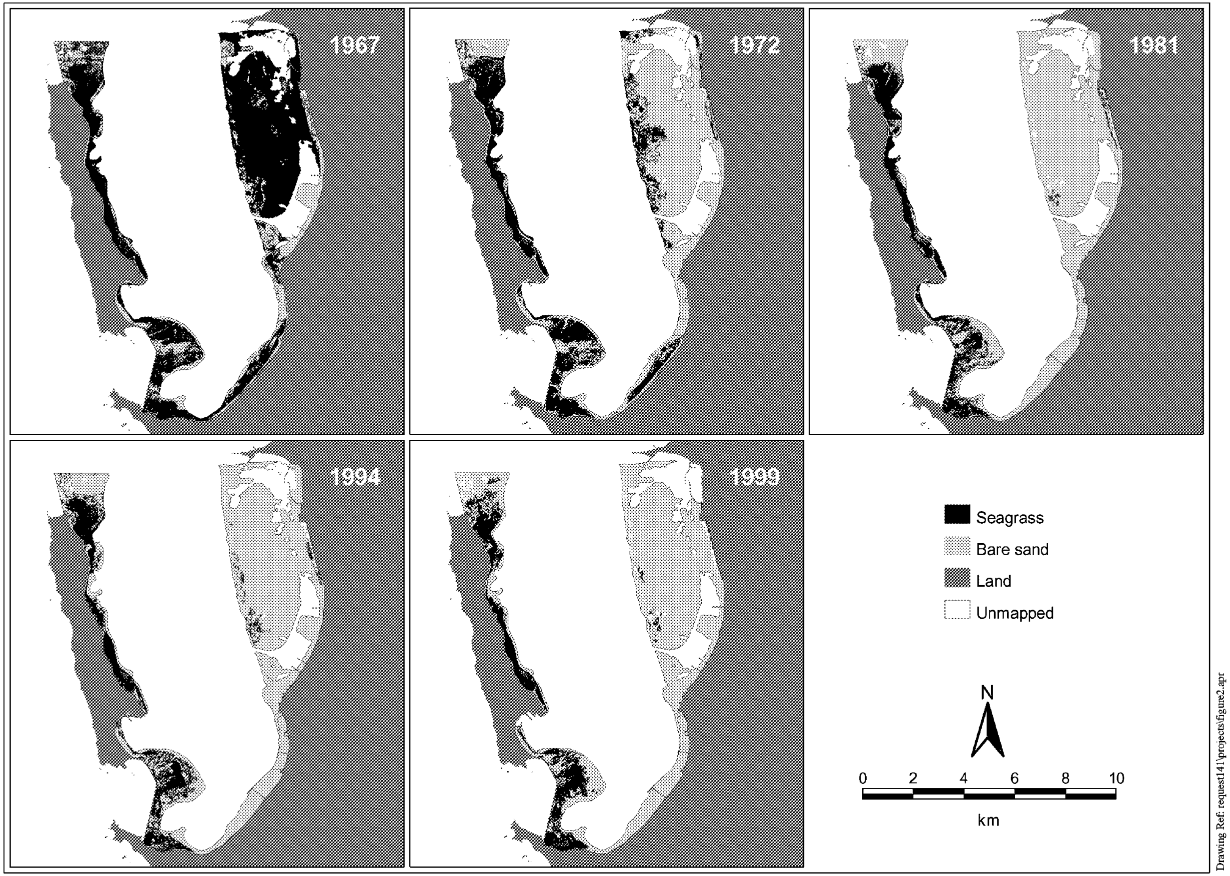

Fig. 2. Distribution of seagrasses in Cockburn Sound in 1967, 1972, 1981, 1994 and 1999.

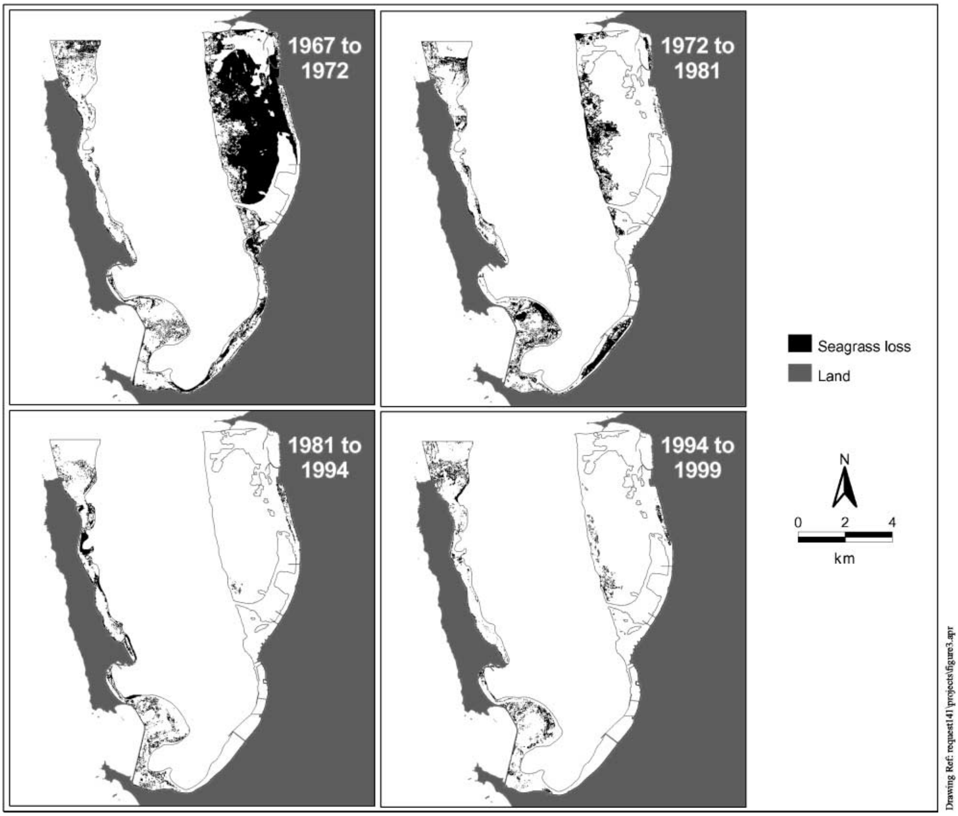

Fig. 3. Mapped losses of seagrasses between 1967 and 1972, 1972 and 1981, 1981 and 1994 and 1994 and 1999.

4. Discussion

Historical seagrass loss in Cockburn Sound has been re-assessed from 1967 to 1999 using modern semi-automated mapping techniques on a common geodesic mapping base. Broad-scale seagrass loss of 2087 ha occurred in Cockburn Sound between 1967 and 1981, with the greatest area lost from the eastern and southern banks. Losses continued between 1981 and 1999 at much reduced spatial scales and mainly on the western margins (total of 79 ha between 1981 and 1999), reflecting more localised impacts, like port developments at Careening and Sulphur Bays, and urchin outbreaks on north eastern Garden Island. Little regeneration of seagrass meadows has occurred on the eastern and southern banks over the two decades since seagrass decline, inferring that the shallow nearshore environment is altered in some critical way that is counter to seagrass recolonisation.

The time course of seagrass decline in Cockburn Sound between 1967 and 1981 is similar to that described between 1969 and 1978 by Cambridge and McComb (1984) and Hillman (1986). The loss of seagrasses from the shallow subtidal bank along the eastern shores of Cockburn Sound between 1967 and 1972 was extremely rapid in relation to the lifespan of the dominant seagrass species, *P. sinuosa*. Despite *P. sinuosa* being a dominant and widespread temperate seagrass, colonisation from seedlings and rhizome spread onto unvegetated areas is extremely slow (probably on the order of tens of years) (Kirkman and Kuo, 1990; Kirkman, 1998). The historical decline in seagrasses in Cockburn Sound is specific to the Sound and the dominant seagrass species *P. sinuosa*. Over a similar 30 years period (1965–1995) seagrasses have expanded their distribution by 529 ha on Parmelia and Success Banks, despite losses caused by shellsand mining and pollution (Kendrick et al., 2000). Parmelia and Success Banks are shallow sand banks immediately north of Cockburn Sound. Seagrass expansion has been predominantly in *P. coriacea* and *A. griffithii* assemblages (Kendrick et al., 1999).

The major disappearance of seagrasses recorded between 1967 and 1972 has been attributed to shading of seagrass leaves by excessive growth of epiphytic algae, following nitrogen enrichment of Cockburn Sound. (Cambridge et al., 1986). This hypothesis is supported by subsequent studies of epiphyte shading (Silberstein et al., 1986), in situ manipulation of shading levels (Gordon et al., 1994), and photosynthesis-irradiance studies (Masini et al., 1995; Department of Environmental Protection, 1996). One thousand and four hundred and 40 ha of seagrasses disappeared in 5 years (1967–1972) on Cockburn Sound East, and tended to overshadow more localised losses and reduction in seagrass depth limits. These localised losses were attributable to other causes like turbidity, the result of scallop dredging, harbour construction, dredge spoil dumping, and increased phytoplankton concentrations, overgrazing by sea urchins and direct removal of seagrass by channel dredging, boat moorings and anchor drag (Cambridge and McComb, 1984).

Losses of seagrasses in the southern region of Cockburn Sound were greatest between 1972 and 1981. Losses started on the southeastern shore between 1967 and 1972 and continued westward between 1972 and 1981. The Garden Island causeway, which was constructed between 1971 and 1973, appeared responsible for seagrasses disappearing from the Southern Flats (Hicks et al., 1973). Since the construction of the causeway, water exchange and passage of ocean swells between the Indian Ocean and Cockburn Sound has been greatly reduced (Cambridge et al., 1986). There have also been some increases in seagrass coverage associated with the filling by seagrasses of crescentic sand blowouts within meadows. These blowouts were described by Cambridge (1975), but in 1999 were continuous seagrass meadow. Major seagrass losses from the shallow subtidal banks on the western shores of Cockburn Sound also occurred between 1972 and 1982, including a shallowing of the maximum depth where seagrasses were found, and seagrasses lost by Australian Navy Port Developments in Careening (1972–1974) and Sulphur (1976–1978) Bays (Cambridge and McComb, 1984).

Losses on Southern Flats and western Cockburn Sound after 1981 were small-scale and included continued retreat of seagrass meadows into shallower water, and loss of seagrasses caused by maintenance dredging, jetty building, and sea urchin grazing. Losses of seagrasses from sea urchin grazing are generally well reported, but the effects are restricted in area when compared to the more insidious and large-scale losses of seagrasses due to increased light attenuation. For example, only 3 ha of shallow *P. sinuosa* meadows north of Sulphur Bay disappeared between 1981 and 1994 as a result of an invasion by the grazing urchins *Heliocidaris erythrogramma* and *Temnopleuris michaelsenii* in 1991 (Bancroft, 1992). Similar localised loss of seagrass meadows due to invasions by *T. michaelsenii* have previously been reported near Rockingham in 1972, Careening Bay in 1973, Woodman Point in 1976 and further south in Warnbro Sound in 1978 (Cambridge et al., 1986).

In conclusion, we have successfully mapped the distribution of seagrasses in Cockburn Sound for the years, 1967, 1978, 1981, 1994 and 1999, to a common geodesic base, and the seagrass coverage calculated for these years are now directly comparable. We have confirmed the extent of major loss in seagrasses in the 1970s as described by Cambridge and McComb (1984). Between 1967 and 1972, 46% of seagrass coverage, or 1587 ha of seagrasses, were lost from Cockburn Sound, mostly from the shallow subtidal banks on the eastern and southern shores. By 1981, a further 602 ha had been lost from Cockburn Sound. Therefore, by 1981, 75% of total seagrass coverage in Cockburn Sound recorded from 1967 was lost. Since 1981, further seagrass losses (79 ha) has been restricted to a shallowing of the depth limit of seagrasses, localised losses associated with port maintenance and a sea urchin outbreak. That there has been no recovery of seagrasses on the eastern shelf of Cockburn Sound during two decades since nutrient loads were reduced in the 1980s, suggests that the shallow shelf environment has been altered to an environment not suited for the recolonisation of *Posidonia* species. This contrasts with Success Bank, 8 km north, where 529 ha of shallow bank have been colonised by *P. coriacea* and *A. griffithii* between 1965 and 1995 (Kendrick et al., 2000). This study now forms an accurate baseline of seagrass change between 1967 and 1999, for further monitoring and management of seagrasses in Cockburn Sound.

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