An evaluation of community-based monitoring and what it can tell us about the distribution and status of seagrasses in Moreton Bay, Australia.

Paul Finn[1], Nicola Udy[2], Keira Price[1], Simon Baltais[3]

[1]Seagrass-Watch Moreton Bay, Queensland Conservation, 166 Ann Street, Brisbane, QLD 4000.

[2]Queensland Parks and Wildlife Service, Moreton Bay District Office, PO Box 402, Cleveland, QLD 4163.

[3]Wildlife Preservation Society of Queensland, Bayside Branch, PO Box 427, Capalaba QLD 4157.

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Correspondence to:

Paul Finn

c/- Queensland Parks and Wildlife Service

Moreton Bay District Office

PO Box 402, Cleveland, QLD. 4163

E-mail: Paul.Finn@epa.qld.gov.au

Abstract

The community-based Seagrass-Watch program was established in 1998 as an initiative of the Queensland Department of Primary Industries and Fisheries, and has operated in Moreton Bay since 2001. Seagrass-Watch aims to raise awareness of the condition and trends of near-shore seagrass ecosystems and provide an early warning of major coastal environmental changes.

Moreton Bay supports seven seagrass species with extensive meadows in certain locations, totalling 25,000 ha of seagrass habitat. Seagrass plays a critical role in supporting the ecological health of the Bay and is routinely monitored to determine its condition. The survey methods are well established, simple and scientifically rigorous. After considerable training, groups of volunteers adopt a site and conduct surveys three times per year. Seagrass condition is visually assessed at one to four sites nested within each of 20 locations (53 sites in total).

There are many advantages to volunteer-based data collection but the accuracy of the data is often considered questionable. This paper shows that the visual assessment of percentage seagrass cover by volunteers is highly correlated with that of professional scientists ($r=0.85$, $v=2423$, $P<0.001$). Thus seagrass data collected by volunteers in Moreton Bay is accurate enough to track its condition and distribution, and to add value to water quality data collected by the Ecosystem Health Monitoring Program.

Key words: locally-based assessment; eelgrass; dugong grass; water quality; conservation volunteers; South East Queensland.

Introduction

Community-based monitoring of environmental resources has become increasingly popular world-wide since the beginning of the 20th century (Evans *et al.* 2000; Pattenengill-Semmens and Semmens 2003; Gouveia *et al.* 2004; Danielsen *et al.* 2007), including that of seagrass habitats (McKenzie *et al*. 2000; Short *et al*. 2006). There are many advantages to this kind of data collection, including cost efficiency, coverage over large spatial scales, community involvement and education and multi-organisational engagement (Darwall and Dulvy 1996; Evans and Birchenough 2001; Fore *et al.* 2001; Sharpe and Conrad 2006; Danielsen *et al.* 2005). However, the accuracy and usefulness of scientific data collected by volunteers is often considered questionable (Darwall and Dulvy 1996; Foster-Smith and Evans 2003; Gouveia *et al.* 2004), sometimes justifiably (Uychiaoco *et al.* 2005). Danielsen *et al.* (2005) highlight the need for a greater number of comparative studies on the findings of volunteer- versus professionally-based monitoring.

Seagrass is a marine angiosperm evolved to cope with salinity, low and variable light, water movement and anoxic sediment (Touchette 2007a, b). Seagrass meadows are an important coastal habitat and are indicative of ecosystem health at the land-sea interface (Bostrom *et al.* 2006; McArthur and Boland 2006; Short *et al.* 2006, 2007). There are numerous natural and anthropogenic threats to seagrasses, and once lost, recovery is limited via both natural processes and restoration practises

(West *et al.* 1990; Lee Long *et al.* 2000; Campbell and McKenzie 2004; McLennan and Sumpton 2005; Orth *et al.* 2006). Seagrass is an excellent organism to monitor marine ecosystem health due to its widespread distribution, important ecological role, sessile nature, and the fact that it is integrative of environmental conditions and shows measurable and timely responses to impacts (Orth *et al.* 2006).

Seagrass-Watch (SGW) was established in 1998 as an initiative of the Queensland Department of Primary Industries (McKenzie *et al*. 2000) and is now the largest scientific, non-destructive, seagrass assessment and monitoring program in the world with 18 countries represented. There are currently 17 regions within Australia where SGW programs have been established and 14 of these are in Queensland. In Moreton Bay, SGW was established in 2001. Its success is owed to its simple but scientifically rigorous methods and in providing a wide range of associated and interesting activities for people to be involved with. SGW aims to raise awareness on the condition and trend of near-shore seagrass ecosystems and provide an early warning of major coastal environment changes. Analysing four years of recent data, this study aims to: (1) review the data accuracy and consistency; (2) explore what the data can tell us about the distribution of seagrasses in Moreton Bay; and (3) correlate seagrass percent cover with several water quality variables.

Methods

Seagrasses in Moreton Bay

Moreton Bay extends north east and south east of the City of Brisbane, in South East Queensland (27° 20’ 01” S, 153° 17’ 35” E). At 300,177 ha, it is one of the largest estuarine bays in Australia, enclosed on its western side by the mainland and on its eastern side by two of the largest sand islands in the world (Moreton and North Stradbroke Islands) (Blackman and Craven, 1999). Moreton Bay extends approximately 132 km along the coast in a north-south direction and reaches a maximum width and depth of 40 km and 40 m respectively (Blackman and Craven, 1999). Salinity is highest on the eastern side of the Bay because the western side receives an input of freshwater from coastal drainage (Young, 1978). The majority of this drainage comes from the Coomera, Logan, Brisbane, Pine and Caboolture rivers (Blackman and Craven, 1999). Moreton Bay contains a complex system of intertidal flats totalling 23,000 ha at low tide (Blackman and Craven, 1999). Substrate types within the Bay are diverse and have been broadly categorised into sand, coral, sandy mud, and mud (Young, 1978). Moreton Bay supports seven seagrass species in four broad environments (river/estuarine, coastal, deep water and reef) totalling about 25,000 ha and they occur both sub-tidally and inter-tidally (Hyland *et al.*, 1989; Blackman and Craven, 1999). In Moreton Bay, SGW is primarily concerned with intertidal areas of the coastal environment.

Volunteers and seagrass surveys

Detailed descriptions of the methods are reported in McKenzie *et al.* (2000 and 2001). Briefly, volunteers head along three 50 m long transects, 25 m apart, running perpendicular to the shoreline and assess the seagrass within a half meter squared quadrat every 5 m, making a total of 33 samples per site (50 x 50 m area). SGW in Moreton Bay began with a pilot study (six sites within two locations) in May 2001 and has since expanded to 53 sites within 20 locations (Figure 1). Teams of two to four people adopt a site and conduct surveys within three distinct monitoring periods per year: autumn (March-April), winter (July-August) and summer (November-December).

About 150 volunteers have been trained in the methods required for scientifically rigorous assessment of seagrass meadows through formal lectures in a class-room style venue and on site field training. The volunteers ranged in ages from 13 to 68 and represent a diverse cross-section of the community, including tradespeople, engineers, housewives, school teachers, fishers, boaties, retirees, high school and university students, biologists and ecologists. Many are involved with local conservation groups. Volunteers monitor in all weather conditions and only abort if conditions become a problem for the accuracy of data collection. Surveys involve identifying local species of seagrass, *Lyngbya*, macroalgae and invertebrates, visually assessing the percent seagrass cover (assisted by photographic guides), using a compass/GPS, photography, and identifying the presence of dugong feeding trails and other impacts. Ongoing training in the form of refresher lectures and field exercises ensures that teams are collecting the same information to similar standards. The volunteers work closely with experienced scientists, whom carry out all data management and analyses.

The data undergoes several quality assurance and quality control procedures. Nine of the 33 quadrats (27 %) sampled by volunteers during each monitoring session are photographed and later scored by a professional trainer. This allows an independent check on how closely the visual estimates of percent seagrass cover that volunteers collect match with those of the trainer.

Data analysis

Pearson's correlation coefficient was used to determine the correspondence between the seagrass percent cover estimates of the volunteers' and professional trainers', and thus how accurate and consistent the data collected by volunteers is. To look at distributional changes in seagrass percent cover over time, we compared means and standard errors in four different sections of the Bay (north, south, east and west). Seagrass-Watch data over four years (i.e. 12 monitoring periods from March-April 2003 to November-December 2006) was compared with Ecosystem Health Monitoring Program (EHMP) water quality data, collected monthly from 2000-2007. Groups of EHMP sites were associated with groups of adjacent SGW sites. The minimum and maximum distances between SGW and EHMP sites within groupings were ## and ## m respectively. Data records of EHMP water quality variables across the 20 locations ranged from 78 to 503, representing the number of different days where measurements were taken. A correlation matrix was used to reduce the number of water quality variables used in analyses down to five that were not highly correlated with each other: secchi depth, oxygen saturation, total nitrogen, water temperature and the ecosystem health index (EHI) value. The EHI is the proportion of the waterway's area that complies with established water quality objectives. To assess the broadscale correspondence between seagrass condition and water quality, we used an all-subsets multiple regression (Quinn and Keough 2002) of seagrass percent cover against the five water quality variables across 20 locations, using SAS (SAS Institute Inc. 1999).

Results

There was a strong positive correlation between the seagrass cover estimates of the volunteers' and professional trainers' (r=0.85, v=2423, $P<0.001$). In the majority of cases (84 %, Figure 2), the visual estimation of seagrass percent cover made by the volunteers' and independently by the trainers' were less than 19 % different.

We recorded all seven seagrass species known to be present in Moreton Bay but *Zostera muelleri capricorni* and *Halophila ovalis* were by far the most dominant and wide spread (Table 1). *Halophila spinulosa* tends to occur only at those sites that do not completely dry out at low tide (Fisherman Islands and Moreton and Amity Banks; Table 1).

There appears to be a decline in seagrass cover from November-December 2004 to March-April 2007 (Figure 3), particularly in the north section, however some of the sample sizes are small and further monitoring and analyses are required to understand this trend.

In an all-subsets multiple regression the EHI value contributed the most to the explained variance in percent seagrass cover, which was a negligible 8 % ($r^2=0.08$,

Table 2). Although the explained variance increased gradually with the addition of subsequent water quality variables (secchi depth, total nitrogen, oxygen and water temperature), the model became consistently less efficient (most efficient models are those with relatively low BIC values) and explained a maximum of only 15 % of the variation in seagrass cover among locations (r^2=0.15, Table 2).

Discussion

Quality of the data and value of the volunteers

The data collected by volunteers in this program are generally very accurate. For the majority of cases, the visual estimates of seagrass percent cover by volunteers and professional trainers were almost identical. This is encouraging, particularly as the potential sources of error are numerous. Although photographs are scored consistently by the same trainer, they are supplied by many different volunteers. Photographic quality can be poor and mix-ups may lead to photographs misrepresenting the actual sample assessed. Considering only 5.2 % of cases were greater than 50 % different between volunteer and professional trainer, the number of errors seem minimal. In the 0.45 % of cases where the visual estimates of seagrass percent cover were 80-100 % different between volunteer and professional trainer, differences are likely to be due to administrative errors rather than actual discrepancies. This level of consistency between volunteers and professional scientists is not always achieved. Uychiaoco *et al.* (2005) found no significant correlation between the abundance estimates of major fish species between volunteers and biologists in the Philippines. However the results of some other studies have shown a qualitative equivalence between the data collected by volunteers and professionals (Darwall and Dulvy 1996; Fore *et al.* 2001; Foster-Smith and Evans 2003; Bell 2007).

We have established that the volunteer-collected data is relatively consistent and accurate, and as such it can have a monetary value placed on it. The data used in this paper came from a total of 350 surveys, involving an average of 3 volunteers for 3 hours each. A conservative (at $15/volunteer hour) estimate of the cost of this data (in person hours only) is $47,250. SGW volunteers also regularly cover areas where management agencies visit rarely or not at all and allowed numerous sites to be surveyed simultaneously.

Danielsen *et al.* (2005) express uncertainty as to the sustainability of locally-based monitoring over the long term and concern that these programs need to be as simple and locally appropriate as possible. SGW in Moreton Bay has been steadily growing for seven years, with several volunteer teams remaining unchanged for this entire time. We feel there are several reasons why SGW has worked so well in Moreton Bay. First, volunteers feel a sense of ownership for their site and we provide a website where the data is freely available to them and management agencies (http://www.qccqld.org.au/seagrass/monitoring/index.htm). We endeavour to provide interesting avenues for related topics by organising a seminar series on local wildlife and environmental processes involved with seagrass habitat. Another popular activity is our night time spotlighting expeditions which also increase the general natural history skills of participants.

SGW methods are simple, but scientifically rigorous, and with approximately half a day of training, volunteers could produce reliable data. Although initial training is done with large groups (10-30 people) in the classroom and/or in the field, individual teams (2-4 people) who wish to adopt a site are trained at their focal site. We feel both of these training practises are essential. The initial stage in large groups weeds out those who are not really interested and the more personalised training in small groups is necessary to ensure a complete understanding of the scientific methods.

Distribution and status of seagrasses in Moreton Bay

Since SGW commenced, the distribution of seagrass in Moreton Bay appears to have remained relatively stable. Although there may have been some minor distributional shifts within seagrass meadows, no site has gone from supporting seagrass to being completely devoid or vice versa. We are currently using GPS mapping techniques to gain greater accuracy in detecting these minor distributional shifts.

However, there has been a decline in seagrass percent cover over time, particularly in the north section. There is cause to keep a cautious eye on seagrass meadows in the north section of the Bay as *Zostera muelleri capricorni* is the dominant species at most sites and has been shown in other areas to be relatively resilient and stable through time (Michael Rasheed pers. comm.). This is also an area where the macro-algae *Caulerpa taxifolia* has been encroaching on some sites.

Comparison with Ecosystem Health Monitoring Program water quality data

There appears to be no strong correlation between percent seagrass cover and any of the water quality variables used. Interestingly, the eastern section of the Bay, where water quality is generally better, does not always support the greatest coverage of seagrass but it is the most diverse. It would be erroneous to infer that water quality has no effect on seagrass, considering the evidence to the contrary (Udy and Dennison 1997; Lee *et al.* 2007), rather for some other reason the two data sets just do not match up. The lack of correlation may be explained by spatial and temporal differences in sampling. The minimum distance between SGW and EHMP sites in this study was ## m and some sites were ## m apart. In terms of secchi depth for example, Moreton Bay SGW monitors intertidal seagrass which sees no light attenuation for 6-8 hours a day. EHMP water quality sampling sites were further off shore and outside of the intertidal zone. Measures of water quality are relatively discreet and reflect the particular characteristic at the precise time of sampling. Water quality measures are also greatly affected by localised and pulsed events. On the other hand, seagrass is integrative of environmental conditions over approximately two weeks and less affected by pulsed events (Orth *et al.* 2006, Len McKenzie pers. comm.), and therefore offers an ecosystem health measure that is more indicative of chronic rather than acute impacts.

The results suggest that EHMP water quality data is a poor surrogate for seagrass condition and therefore provides good evidence that both programs are necessary to provide a complete picture of the ecological health of Moreton Bay. At present EHMP support Moreton Bay SGW financially and use our data in the creation of their annual report cards on ecosystem health.

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References

Bell, J.J. (2007). The use of volunteers for conducting sponge biodiversity assessments and monitoring using a morphological approach on Indo-Pacific coral reefs. Aquatic Conservation: Marine and Freshwater Ecosystems 17: 133-145.

Blackman, J.G. and Craven, S.A. (1999). Moreton Bay. Pp. 329-332 in Characteristics of important wetlands in Queensland. Eds J.G. Blackman, T.W. Perry, G.I. Ford, S.A. Craven, S.J. Gardiner and R.J. De Lai. Environmental Protection Agency, Queensland.

Bostrom, C., Jackson, E.L. and Simenstad, C.A. (2006). Seagrass landscapes and their effects on associated fauna: A review. Estuarine, Coastal and Shelf Science 68: 383-403.

Campbell, S.J. and McKenzie, L.J. (2004). Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. Estuarine, Coastal and Shelf Science 60: 477-490.

Danielsen, F., Burgess, N.D. and Balmford, A. (2005). Monitoring matters: examining the potential of locally based approaches. Biodiversity and Conservation 14: 2507-2542.

Danielsen, F., Mendoza, M.M., Tagtag, A., Alviola, P.A., Balete, D.S., Jensen, A.E., Enghoff, M. and Poulsen, M.K. (2007). Increasing conservation management action by involving local people in natural resource monitoring. Ambio 36: 566-570.

Darwall, W.R.T. and Dulvy, N.K. (1996). An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania – a case study. Biological Conservation 78: 223-231.

Evans, S.M. and Birchenough, A.C. (2001). Community based management of the environment: lessons from the past and options for the future. Aquatic Conservation: Marine and Freshwater Ecosystems 11: 137-147.

Evans, S.M., Birchenough, A.C. and Fletcher, H. (2000). The value and validity of community-based research: TBT contamination of the North Sea. Marine Pollution Bulletin 40: 220-225.

Fore, L.S., Paulsen, K. and O'Laughlin, K. (2001). Assessing the performance of volunteers in monitoring streams. Freshwater Biology 46: 109-123.

Foster-Smith, J. and Evans, S.M. (2003). The value of marine ecological data collected by volunteers. Biological Conservation 113: 199-213.

Gouveia, C., Fonseca, A., Camara, A. and Ferreira, F. (2004). Promoting the use of environmental data collected by concerned citizens through information and communication technologies. Journal of Environmental Management 71: 135-154.

Hyland, S.J., Courtney, A.J. and Butler, C.T. (1989). Distribution of seagrass in the Moreton Bay region from Coolangatta to Noosa. QDPI, Brisbane.

Lee, K.-S., Park, S.R. and Kim, Y.K. (2007). Effects of irradiance, temperature, and nutrients on growth dynamics of seagrasses: A review. Journal of Experimental Marine Biology and Ecology 350: 144-175.

Lee Long, W.J., Coles, R.G. and McKenzie, L.J. (2000). Issues for seagrass conservation management in Queensland. Pacific Conservation Biology 5: 321-28.

McArthur, L.C. and Boland, J.W. (2006). The economic contribution of seagrass to secondary production in South Australia. Ecological Modelling 196: 163-172.

McKenzie, L. J., Campbell, S. J. and Roder, C. A. (2001). Seagrass-Watch: Manual for mapping and monitoring seagrass resources by community (citizen) volunteers. (QFS, NFC, Cairns) 94pp.

McKenzie, L. J., Lee Long, W. J., Coles, R. G., and Roder, C. A. (2000). Seagrass-Watch: Community based monitoring of seagrass resources. Biol. Mar. Medit. 7: 393-396.

Mclennan, M. and Sumpton, W. (2005). The distribution of seagrasses and the viability of seagrass transplanting in the Broadwater, Gold Coast, Queensland. Proceedings of the Royal Society of Queensland 112: 31-38.

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck Jr., K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M. and Williams, S.L. (2006). A Global Crisis for Seagrass Ecosystems. BioScience. 56: 987-996.

Pattengill-Semmens, C.V. and Semmens, B.X. (2003). Conservation and management applications of the reef volunteer fish monitoring program. Environmental Monitoring and Assessment 81: 43-50.

Quinn, G.P. and Keough, M.J. (2002). Experimental Design and Data Analysis for Biologists. Cambridge University Press, Melbourne.

SAS Institute Inc. (1999). The sas System for Windows, Release 8. SAS Institute Inc., New York.

Sharpe, A. and Conrad, C. (2006). Community Based Ecological monitoring in Nova Scotia: Challenges and opportunities. Environmental Monitoring and Assessment 113: 395-409.

Short, F., Carruthers, T., Dennison, W., and Waycott, M. (2007). Global seagrass distribution and diversity: A bioregional model. Journal of Experimental Marine Biology and Ecology 350: 3-20.

Short, F. T., Koch, E. W., Creed, J. C., Magalhaes, K. M., Fernandez, E. and Gaeckle, J. L. (2006). SeagrassNet monitoring across the Americas: case studies of seagrass decline. Marine Ecology 27: 277-289.

Touchette, B.W. (2007a). The biology and ecology of seagrasses. Journal of Experimental Marine Biology and Ecology 350: 1-2.

Touchette, B.W. (2007b). Seagrass-salinity interactions: Physiological mechanisms used by submersed marine angiosperms for a life at sea. Journal of Experimental Marine Biology and Ecology 350: 194-215.

Udy, J.W. and Dennison, W.C. (1997). Growth and physiological responses of three seagrass species to elevated sediment nutrients in Moreton Bay, Australia. Journal of Experimental Marine Biology and Ecology 217: 253-277.

Uychiaoco, A.J., Arceo, H.O., Green, S.J., De La Cruz, M.T., Gaite, P.A. and Alino, P.M. (2005). Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodiversity and Conservation 14: 2775-2794.

West, R.J., Jacobs, N.E. and Roberts, D.E. (1990). Experimental transplanting of seagrasses in Botany Bay, Australia. Marine Pollution Bulletin 21: 197-203.

Young, P.C. (1978). Moreton Bay, Queensland: a nursery area for juvenile penaeid prawns. Australian Journal of Freshwater Research 29: 55-75.

Table 1. The average percent seagrass cover and composition for 20 locations within Moreton Bay (SGWMB Data) and corresponding water quality data (EHMP Data) used in statistical analyses. Also shows the amount of SGWMB data collected for each location in terms of the number of sites included and surveys conducted. Ranked from highest to lowest average percent seagrass cover.

					SGWMB data								EHMP data				
Location	Locode	Section of the bay	No. sites	No. surveys	avg % Zostera	avg % Ovalis	avg % Spinulosa	avg % Halodule	avg % Cymodocea	avg % Syringodium	avg % Decipiens	avg % Seagrass Cover	Secchi depth (m)	Oxygen saturation (%)	Temperature (deg C)	Nitrogen (as total N, mg/L)	Ecosystem Health Index (EHI) value
north Pumicestone Passage	NPP	north	1	5	45.1	3.4	0	0	0	0	0	48.5	1.39	99.60	23.47	0.22	0.25
Victoria Point	VTP	west	3	32	43.3	3.8	0	0	0	0	0	47.1	1.97	104.57	22.76	0.16	0.75
Lota/Thorneside	LOT	west	3	20	36.6	6.8	0	0	0	0	0	43.4	1.40	99.48	22.50	9.21	0.75
Fisherman Islands	FIS	west	3	13	38.8	3.0	0.8	0	0	0	0	42.6	1.69	107.06	21.95	0.37	0.75
Wynnum	WYN	west	4	37	31.3	6.8	0	0	0	0	0	38.1	1.50	103.43	22.68	0.17	0.75
southern Bay Islands	SBI	south	4	12	28.5	8.8	0	0.1	0.7	0	0	38.1	1.65	100.98	22.62	0.16	0.75
south Pumicestone Passage	SPP	north	4	43	35.1	2.9	0	0	0	0	0	38.0	2.18	97.54	22.80	0.17	1.00
Moreton Island	MIS	east	2	16	23.8	3.8	0	9.3	0	0.1	0	37.0	4.52	108.43	22.63	0.12	1.00
Amity Banks	AMB	east	3	5	10.0	1.7	2.3	0.6	8.4	13.4	0	36.5	3.77	102.47	22.80	0.12	1.00
WellingtonPoint	WLP	west	4	39	33.4	2.9	0	0	0	0	0	36.2	2.03	100.29	22.39	0.16	1.00
north Deception Bay	NDB	north	2	10	29.0	4.9	0	0	0	0	0	33.9	2.20	102.31	22.83	0.18	0.75
North Stradbroke Island south	NSN	east	2	8	27.3	4.2	0	0	0	0	0	31.4	2.59	100.77	22.64	0.14	0.75
North Stradbroke Island north	NSS	east	3	17	27.3	2.9	0	0.5	0.1	0.1	0	30.9	3.77	102.47	22.80	0.12	1.00
Ormiston	ORM	west	4	22	22.8	5.2	0	0	0	0	0	28.1	1.23	91.42	23.69	21.47	0.75
Peel Island	PIS	east	4	13	18.1	4.3	0	1.8	0	2.4	0.8	27.4	3.56	99.91	22.62	0.14	1.00
Moreton Banks	MTB	east	3	3	12.3	2.2	3.2	0	0	1.5	0	19.1	4.52	101.57	22.43	0.13	1.00
Cleveland	CLE	west	2	14	14.7	1.3	0	0	0	0	0	16.0	1.69	101.94	22.74	0.16	0.75
Macleay Island	MCI	south	2	5	9.7	3.5	0	0	0	0	0	13.2	2.52	101.15	22.59	0.15	0.75
south Deception Bay	SDB	west	1	3	0	0	0	0	0	0	0	0	1.05	107.62	23.30	0.25	0.50
Bramble Bay	BRB	west	3	33	0	0	0	0	0	0	0	0	1.28	101.71	22.83	8.69	0.25

Table 2. Selected results of an all-subsets multiple regression comparing percent seagrass cover (dependant variable) with five water quality characteristics across 20 locations (see Table 1). This table shows the best models for each number of predictors based on the adjusted r^2 (Adj r^2), Mallow's Cp (Cp), Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC) for each model.

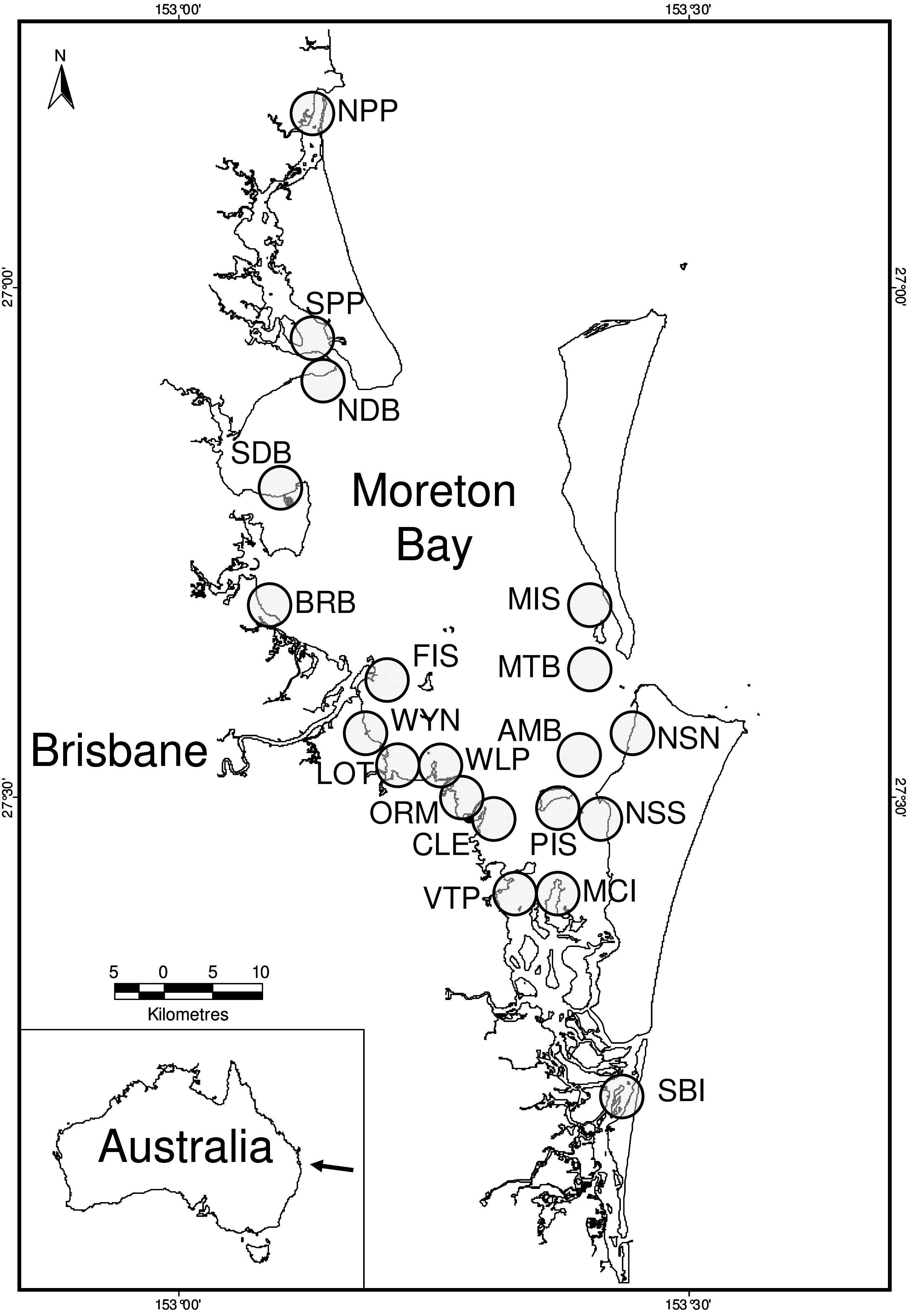
No. of predictors	Model	r^2	Adj r^2	C_p	AIC	BIC
1	ehi value	0.08	0.03	-0.85	106.9	110.0
2	secchi depth + ehi value	0.11	0.01	0.57	108.1	112.1
3	secchi depth + total nitrogen + ehi value	0.13	0.03	2.29	109.8	114.6
4	secchi depth + oxygen + total nitrogen + ehi value	0.15	0.08	4.04	111.4	117.3
5	secchi depth + oxygen + water temperature + total nitrogen + ehi value	0.15	0.16	6.00	113.3	120.1

Figure legends

Figure 1. Map of Moreton Bay showing the 20 locations where site(s) are situated, see also Table 1.

Figure 2. Percent records (0.5 m^2 quadrats) against each of five categories of percent difference in the visual estimation of seagrass percent cover between volunteer and professional trainer, for all photographs that were able to be validated (n=2425) since the Seagrass-Watch program commenced.

Figure 3. The percent seagrass cover (means and standard errors shown) for particular sections of Moreton Bay (north, south, east and west) for eight monitoring periods from November-December 2004 to March-April 2007. The number of sites monitored within each section during each monitoring period appears above the bars.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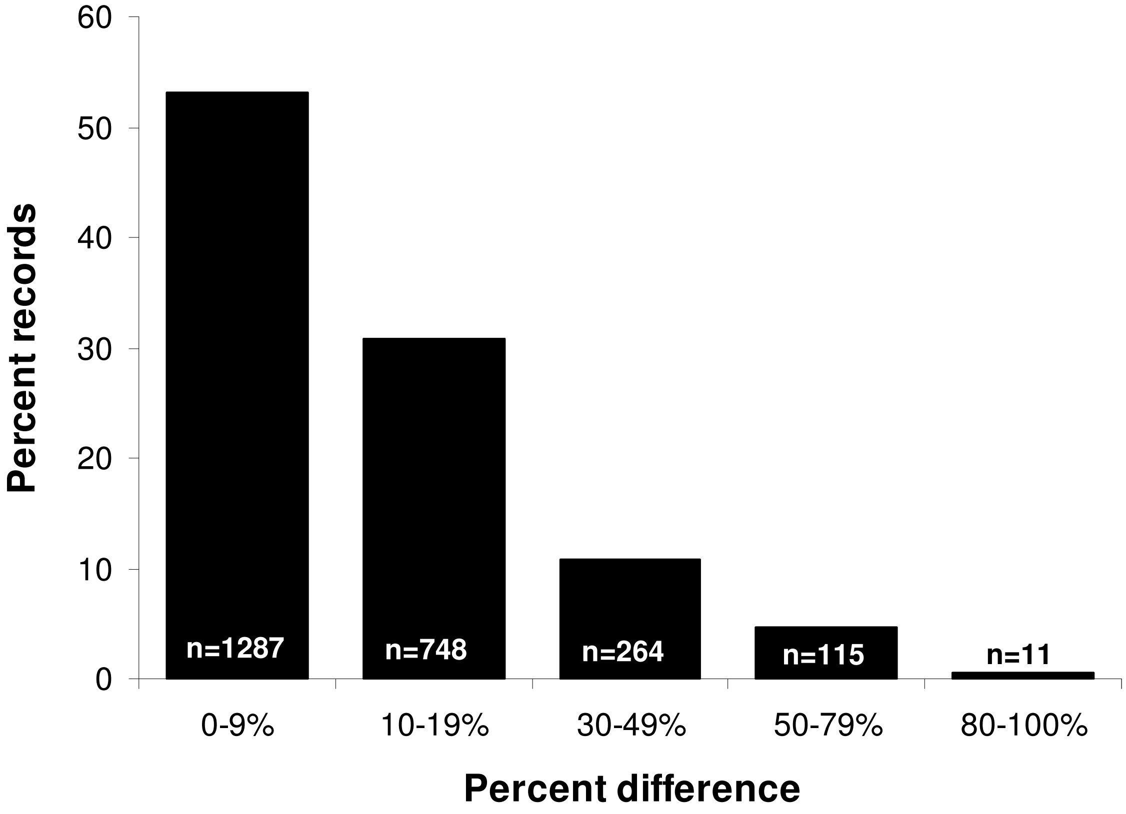

60
50
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20
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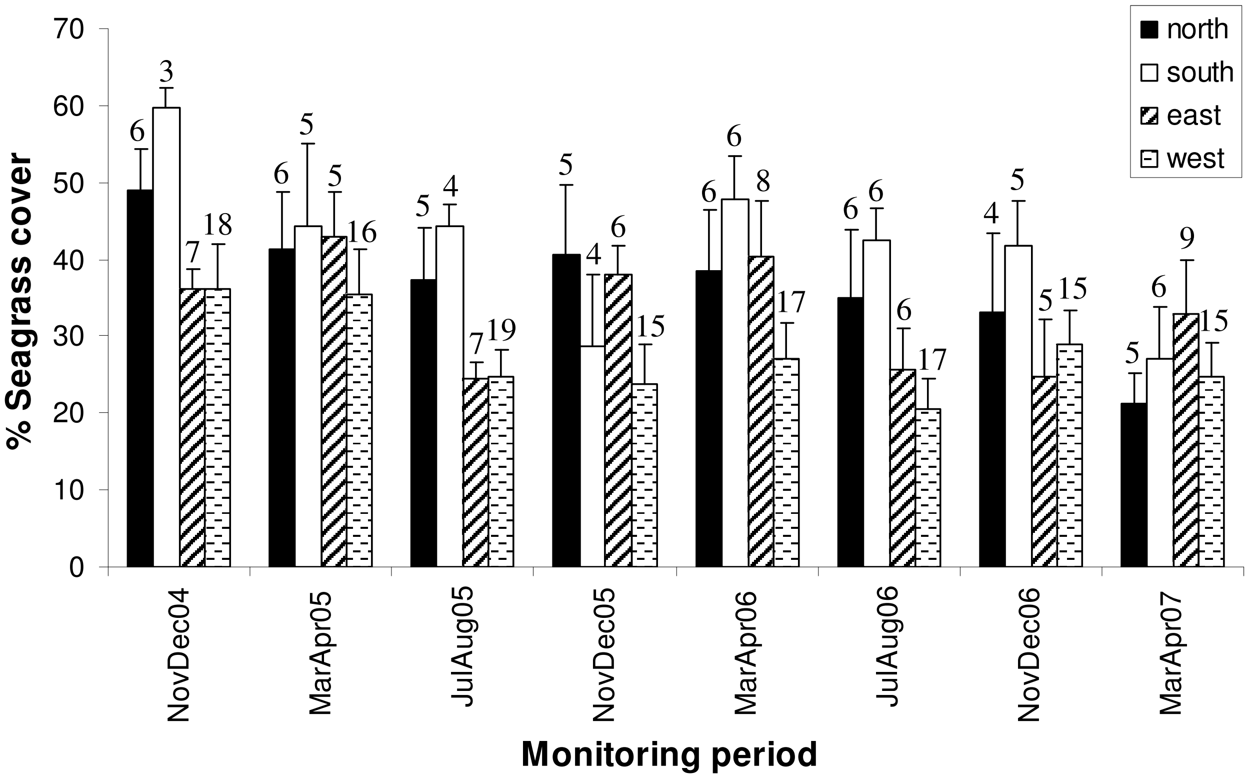
Percent records
n=1287
n=748
n=264
n=115
n=11
0-9%
10-19%
30-49%
50-79%
80-100%
Percent difference



% Seagrass cover
Monitoring period
north
south
east
west
70
60
50
40
30
20
10
0
NovDec04
MarApr05
JulAug05
NovDec05
MarApr06
JulAug06
NovDec06
MarApr07
6
3
7
18
6
5
5
16
5
4
7
19
5
4
6
15
6
6
8
17
6
6
6
17
4
5
5
15
5
6
9
15