Spatial distributions and temporal change in distributions of deep water seagrasses in the Great Barrier Reef region

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Background

The Great Barrier Reef World Heritage Area stretches 2,000 km along the northeastern coast of Australia covering 347,800 km^2 of seabed. It includes around 2,800 coral reefs that make up about 6% of the area. The shallow inter-reef and lagoon areas are more extensive and combined make up some 58% of the area, with the remainder being shelf slope and deep ocean. (Wachenfeld et al. 1998). The Great Barrier Reef Marine Park overlays the world heritage area and provides the legal basis for management which follows a multi use zoning strategy. There has been an enormous amount of research conducted on the coral systems of the Great Barrier Reef World Heritage Area but until recently little attention has been paid to the less accessible and less charismatic soft bottom inter-reef habitats. This is despite the fact that a major penaeid shrimp trawl fishery worth around 100 million Australian dollars per year and a scallop trawl fishery worth around 23 million Australian dollars operate in these inter reef waters (Williams 1997).

Early in the 1990s coastal management agencies recognised the value of seagrass meadows to coastal fisheries in the northern Australian region (Watson et al. 1993; Coles et al. 1993) and subsequent studies have reinforced the value of seagrasses as part of coastal ecosystems worldwide (Costanza et al. 1997). Seagrasses themselves are a functional grouping of vascular flowering plants, which can grow fully submerged and rooted in soft bottom estuarine and marine environments. Seagrass meadows are continuing to receive greater research attention because of the recognition of their importance in stabilising coastal sediments, providing food and shelter for diverse organisms, as a nursery ground for fish and invertebrates of commercial and artisanal fisheries importance, as carbon dioxide sinks and oxygen producers, and for nutrient trapping and recycling (Short et al. 2001). Seagrasses are rated the third most valuable ecosystem globally (on a per hectare basis) and the average global value for their nutrient cycling services and the raw product they provide has been estimated in 1994 US Dollars at $19,004 ha^{-1} yr^{-1} (Costanza et al. 1997). Seagrasses are also food for the endangered green sea turtle (Chelonia mydas) and dugong (*Dugong dugon*) (Lanyon et al. 1989), which are found throughout the GBR and used by traditional communities for food and ceremonial use. Seagrass systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities. Seagrasses slow water movement, causing suspended sediment to fall out, and thereby benefiting corals by reducing sediment loads in the water.

Mapping seagrass is simple and quick intertidally and down to depths where free-divers or SCUBA divers can reasonable operate. The effective limit for this is around fifteen metres below mean sea level. Deeper than this the logistics of diving and dive times makes meadow edge mapping expensive, time consuming and inaccurate. Incidental collections from trawl nets, from vessel anchors and taxonomic collections indicated that seagrass was present in the Great Barrier Reef lagoon at least to depths of thirty metres – well below the depth feasible with convention meadow edge mapping techniques.

Since 1994 two programs have surveyed the bottom seagrasses of the Great Barrier Reef region. Between 1994 and 1999 the Department of Primary Industries and Fisheries Queensland (QDPI&F) towed an epibenthic net and camera at 1,429 locations chosen from 10 depth zones on cross shelf transects set randomly within each 1 degree latitude (Coles et al 2000). Between 2003 and 2006 the CSIRO led Seabed Biodiversity project visited almost 1500 sites and towed an epibenthic sled and camera at 306 stations. The sampling approach of the Seabed Biodiversity project was a stratified representative weighted approach using biophysical variables, patterns and the scale at which management questions need to be resolved (Pitcher et al. 2006). From the point information derived from these surveys it is possible to develop probability maps of the extent and spatial configuration of likely seagrass meadows (Coles et al 2000). This report is a preliminary comparison of the distribution of seagrass from these surveys conducted nearly ten years apart.

Summary

Two data sets of seagrass surveys were analysed to assess spatial patterns and how they have changed over time. Presence-absence of five species of seagrass and pooled seagrass were modeled. The sampling intensity for the two data sets differed.The mean presence was much higher for Seabed Biodiversity data for all taxa. This survey conducted approx. ten years after the first survey involved a far more detailed pre-analysis of strata in the Great Barrier Reef World Heritage Area and the sampling intensity more focused on areas of complex bottom. Because of this it is not possible to use a comparison of the two data sets to estimate change in abundance over the ten year period. This study could only assess (1) the spatial variation of seagrass, and (2) how that spatial variation differed between the QDPI&F and Seabed Biodiversity surveys.

Statistical Modeling

The two data sets were combined for the analyses. The data were analysed in using logistic regression models with the response variables being SG, HS, HD, HO, HC, HT, (Seagrass all species, *Halophila spinulosa, H, decepiens, H. ovalis, H. capricorni*, and *H. tricostata*) and the explanatory variables being spatial trends and differences between surveys.

Four models were fitted to each response: (1) a constant, (2) Model 1 plus a term represent a mean difference between the two surveys, (3) Model 2 plus a single smooth surface (Wood 2004), and (4) Model 2 plus a separate surface for each survey. The Akaike Information Criteria (AIC) values with lowest value identifies the best model (Venables and Ripley 2002).

The models can be interpreted as follows, Model 1 fits the same probability of occurrence to all sites for both surveys; it is the baseline model against which we compare models that include terms that have a direct interpretations. Model 2 includes a term that accounts for the differing sampling intensities across QDPI&F and SB sampling. This adjustment is equivalent to assuming the mean presence-absence was the same for each taxa for the two surveys. Given the lack of information about sampling differences between QDPI&F and SB, we can only assess whether the distributions of the seagrasses has changed – not whether the mean presence has changed between surveys. Model 3 fits a single surface common to both QDPI&F and SB. Model 4 fits different surfaces for QDPI&F and SB, and if Model 4 is a better fit t then the spatial distributions differ for the two surveys. The changes in deviance for Models 1-4 (equivalent to sums of squares for linear models) quantifies the variation attributable to the different surveys and to space. In particular we can compare the magnitude of the spatial changes over the GBR with the difference between QDPI&F and SB.

In all analyses the spatial component of the models was based on relative distance across and along the reef rather than the usual latitude-longitude. Relative distance across and along the reef takes advantage of the natural boundaries of the GBR that affect many of the bio-physical processes of the reef, and thus one might expect that many spatial distributions of observed data would be best explained (and best predicted) in this coordinate system. This has been shown to be the case in numerous data analyses (unpublished data). The across-along coordinates are also particularly useful for graphical presentations of change and can be interpreted in more scientifically meaningful ways than latitude-longitude.

Relative distance across and along the reef are also more informative in the case of models that do not include interactions between across and along, having a particularly simple interpretation, whereas the equivalent latitude-longitude interactions have no simple interpretation.

Results

The mean presence-absence and SEMs (standard error of the mean) for the response variables SG, HS, HD, HO, HC, HT broken down by survey source (QDPI&F or SB) show much higher probabilities for SB than QDPI&F.

Table 1: Mean presence-absence and SEMs for response variables SG, HS, HD, HO, HC, HT broken down by survey – QDPI&F or SB.

	SG		**HS**		**HD**		**HO**		**HC**		**HT**	
	Mean	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**	**Mean**	**SEM**
QDPI&F	0.314	0.013	0.115	0.009	0.174	0.010	0.091	0.008	0.012	0.003	0.056	0.006
SB	0.851	0.018	0.562	0.026	0.485	0.026	0.337	0.024	0.093	0.015	0.088	0.015

The modeling (Table 2) shows strong spatial patterns that account for between 75-85% of the variation due to space and surveys adjusted for sampling intensity, i.e. from Table 2 the variation in rows three of Table 2 divided by the summed variation in rows three and four. The remaining 15-25% shows change in spatial distributions.

The Figures 1-12 show the distribution and differences in seagrass distributions.

Table 2: Assessment of model fits for the six seagrass response variables. Four models were fitted to each response: (1) a constant, (2) Model 1 plus a term represent a mean difference between the two surveys, (3) Model 2 plus a single smooth surface, and (4) Model 2 plus a separate surface for each survey. The AIC measures with lowest value identifies the best model and is denoted by *.

	Model	Model DF	Deviance	Change DF	Change Deviance	AIC
SG	1	1747.0	2389.1			2391.1
	2	1746.0	2023.9	1.0	365.2	2027.9
	3	1720.0	1731.6	26.0	292.3	1787.6
	4	1706.5	1657.2	13.5	74.4	1740.3*
HS	1	1747.0	1804.5			1806.5
	2	1746.0	1496.6	1.0	307.9	1500.6
	3	1719.5	1203.9	26.5	292.7	1260.9
	4	1697.8	1106.0	21.7	97.8	1206.5*
HD	1	1747.0	1932.3			1934.3
	2	1746.0	1791.0	1.0	141.3	1795.0
	3	1719.8	1568.1	26.2	222.9	1624.5
	4	1703.8	1501.1	16.0	67.1	1589.4*
HO	1	1747.0	1441.9			1443.9
	2	1746.0	1318.7	1.0	123.2	1322.7
	3	1721.0	1109.2	25.0	209.5	1163.3
	4	1702.4	1063.1	18.5	46.1	1154.2*
HC	1	1747.0	468.0			470.0
	2	1746.0	416.1	1.0	51.9	420.1
	3	1732.2	345.1	13.8	71.0	376.7*
	4	1723.7	335.8	8.5	9.3	384.4
HT	1	1747.0	821.4			823.4
	2	1746.0	816.8	1.0	4.6	820.8
	3	1724.4	487.0	21.6	329.9	534.1
	4	1700.2	421.7	24.3	65.3	517.3*

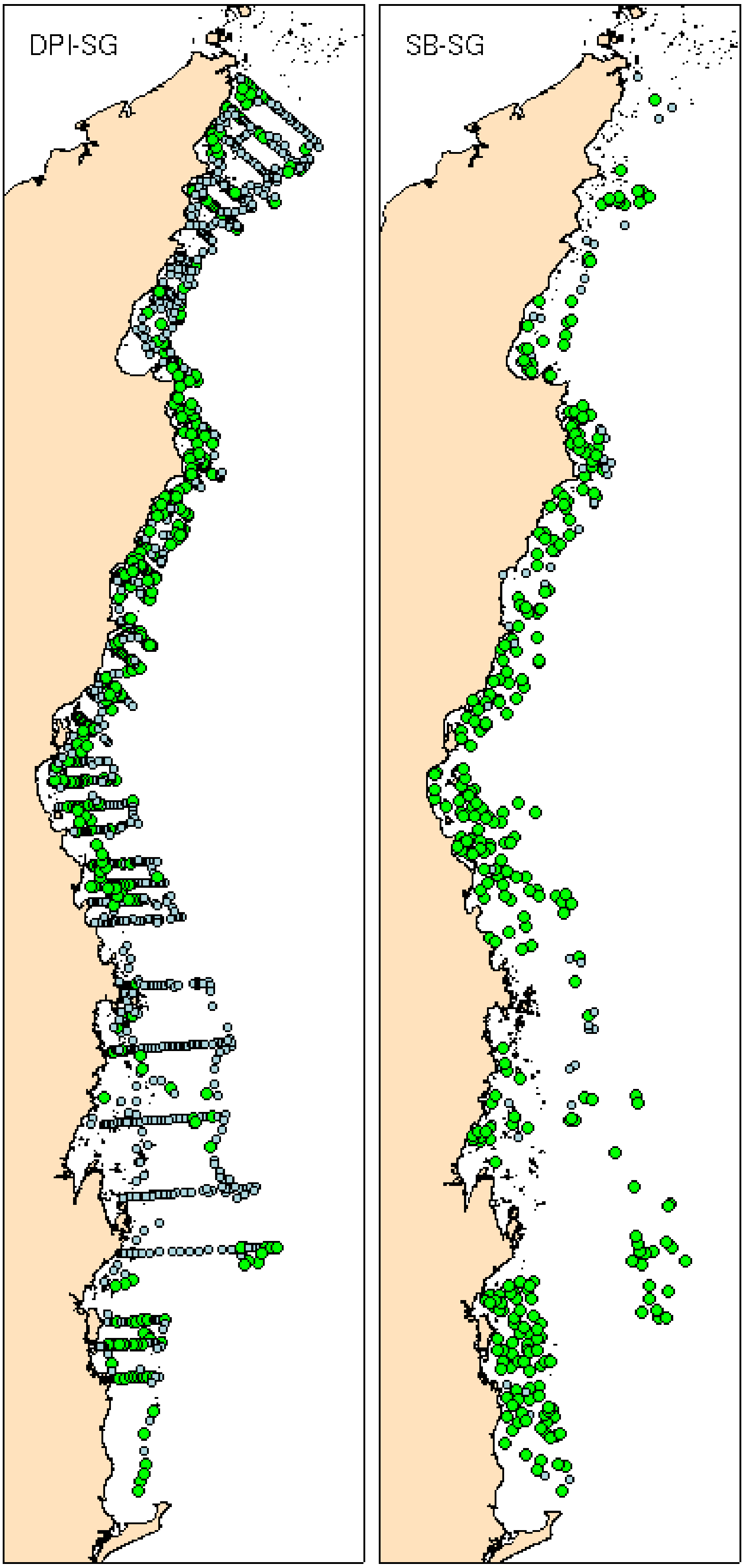

Figure 1: Presence (green) and absence (light blue) of seagrass on the GBR for survey conducted by QDPI&F (left) and the Seagrass Biodiversity Program (right).

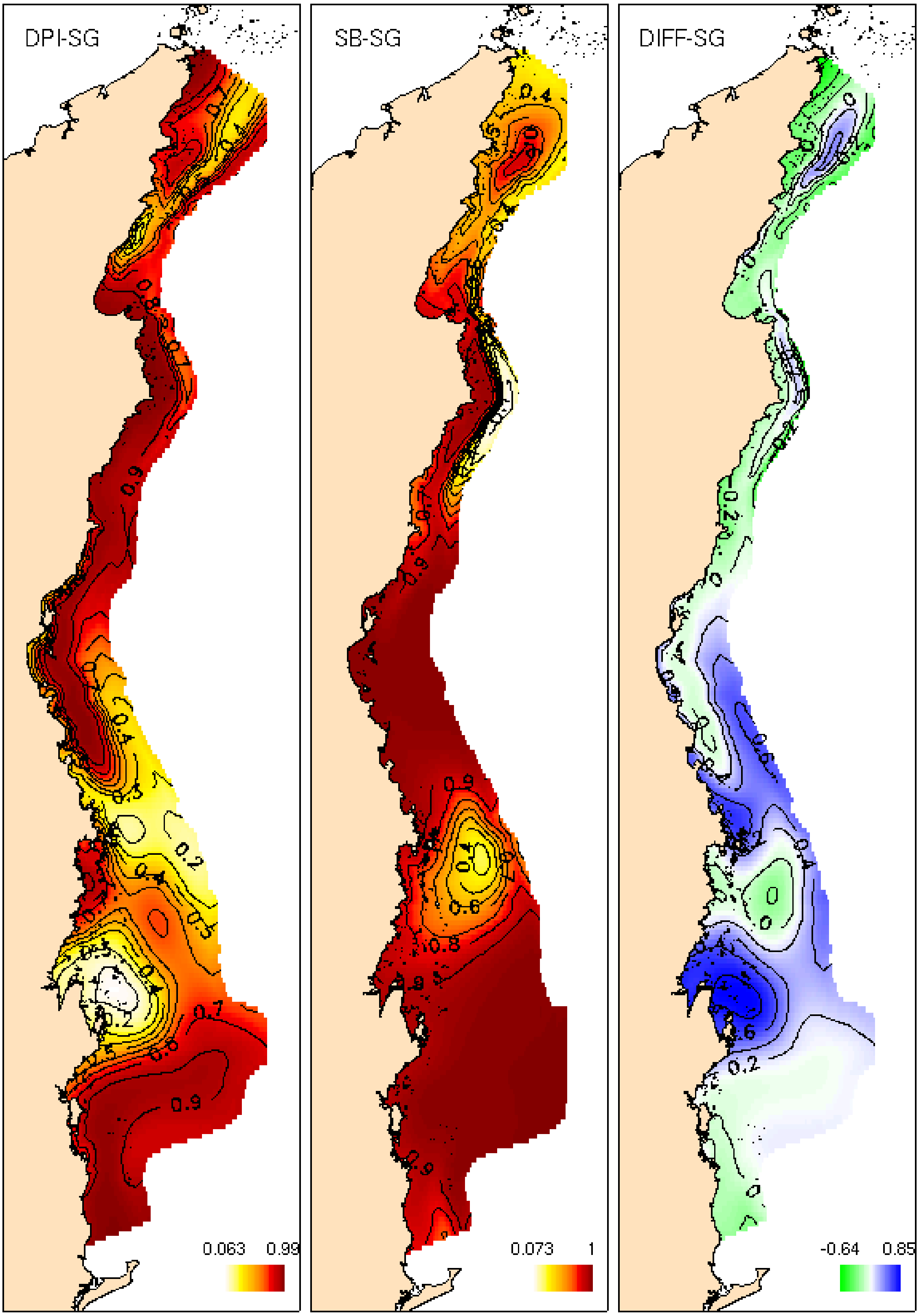

Figure 2: Modelled presence, absence and differences between seagrasses on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (centre).

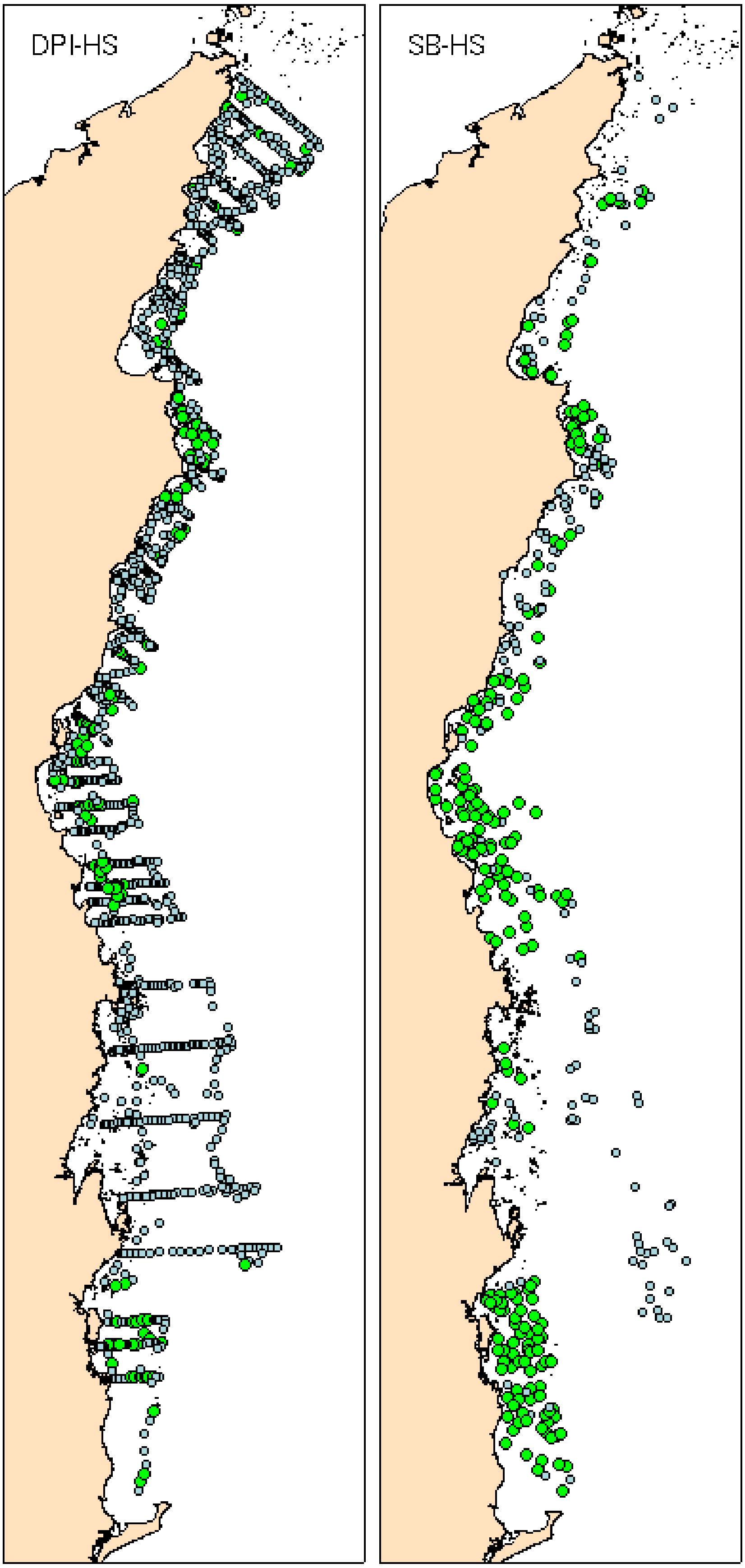

Figure 3: Presence (green) and absence (light blue) of HS on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

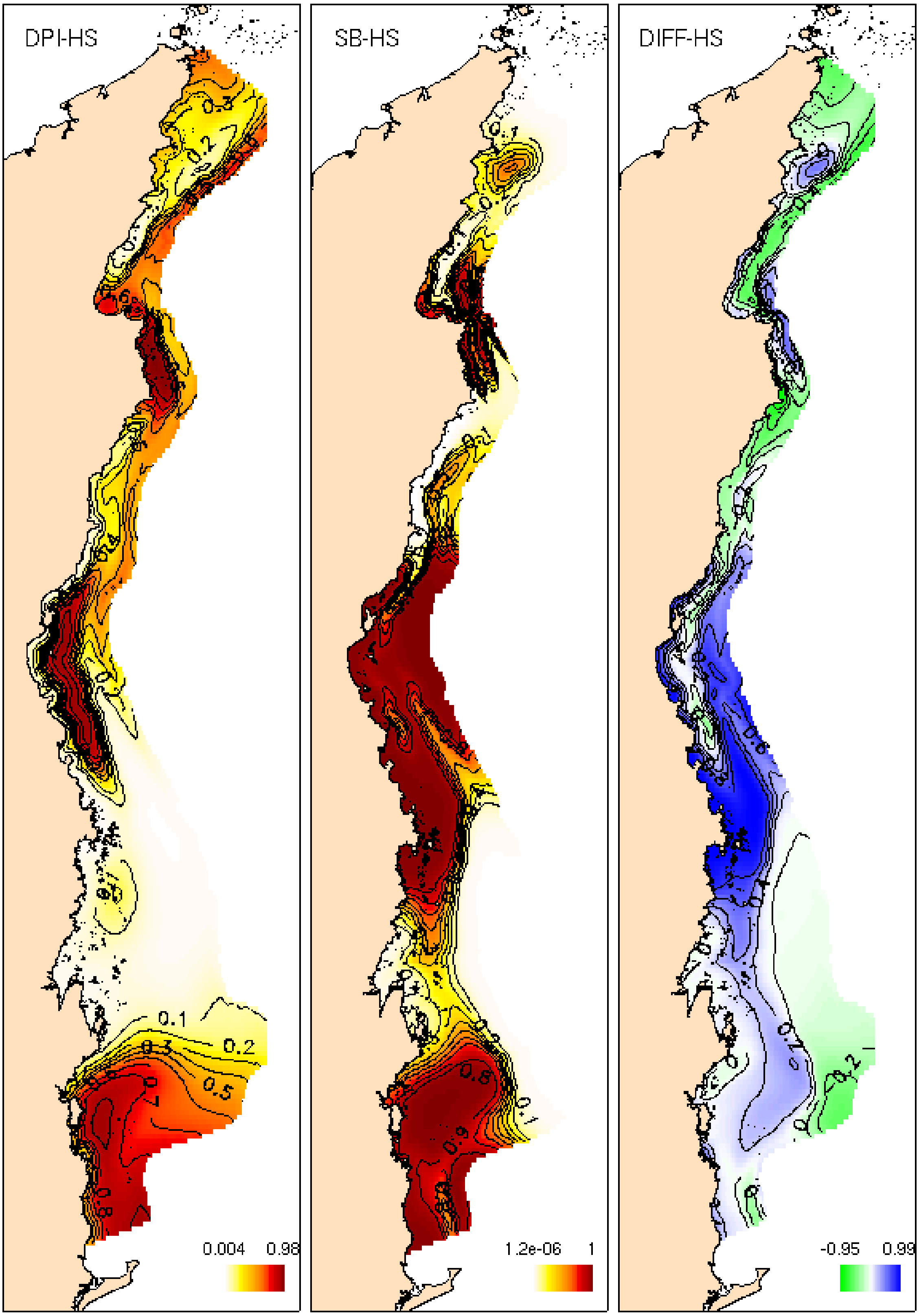

Figure 4: Modelled presence, absence and differences between HS on the GBR survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (centre).

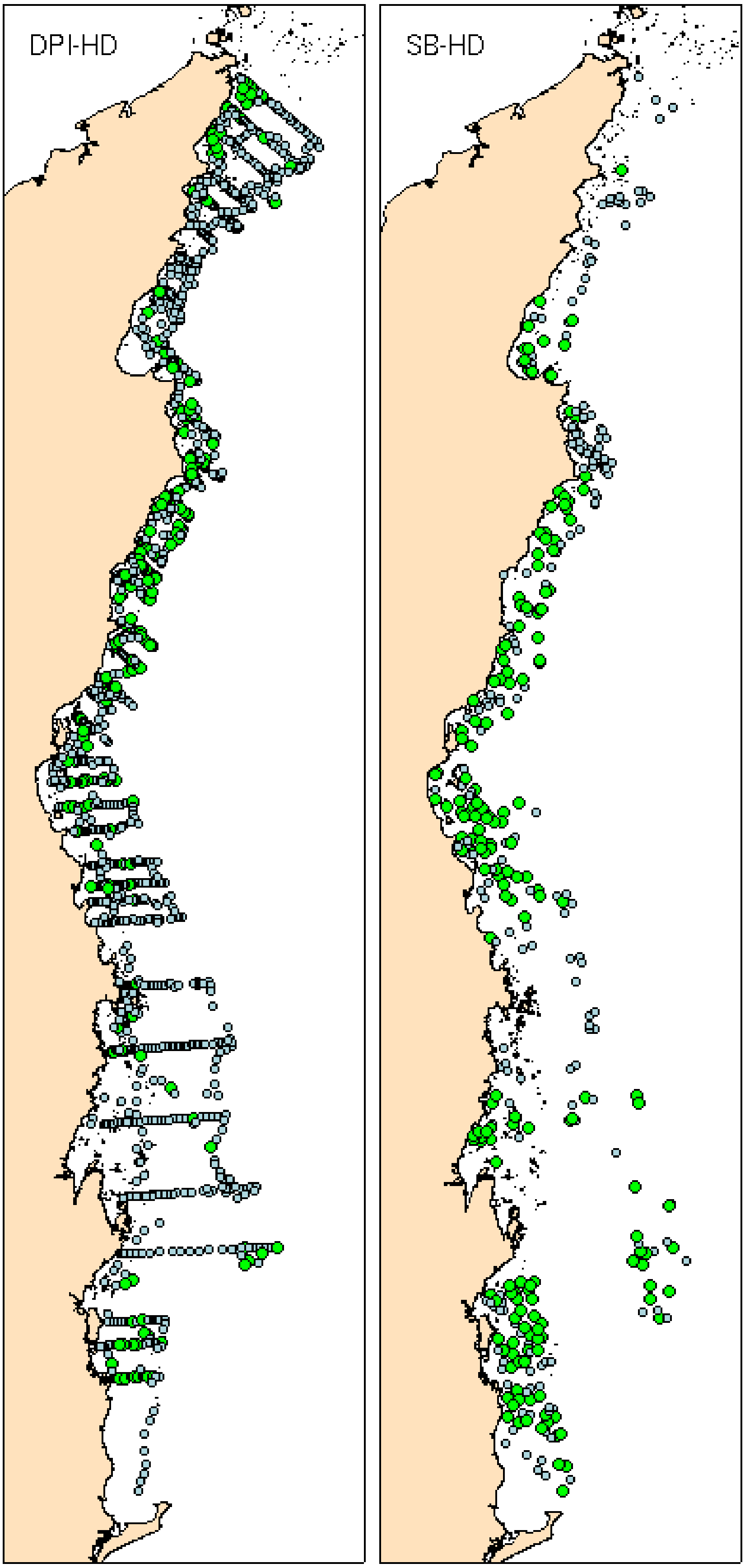

Figure 5: Presence (green) and absence (light blue) of HD on the GBR survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

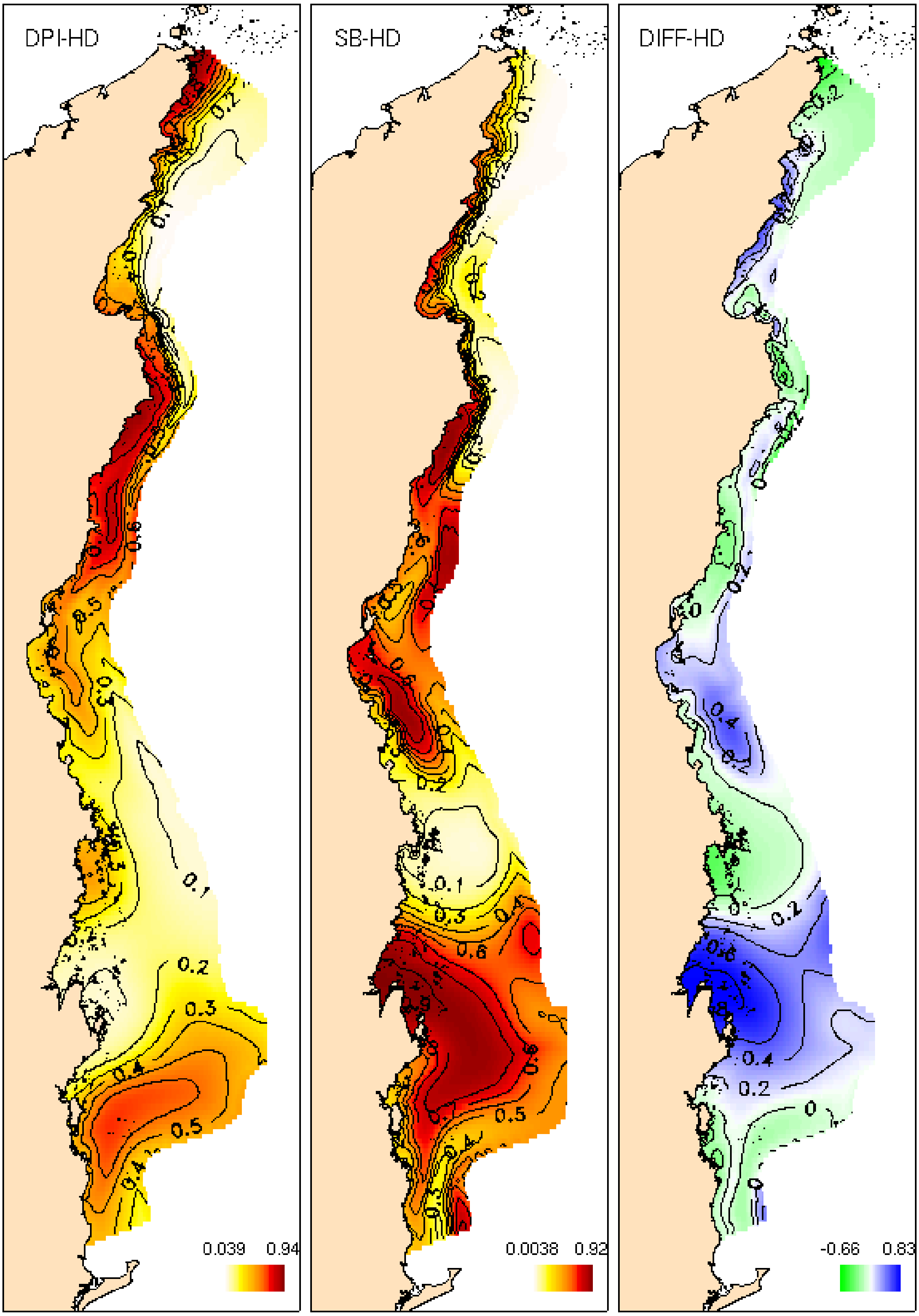

Figure 6: Modelled presence, absence and differences of HD on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

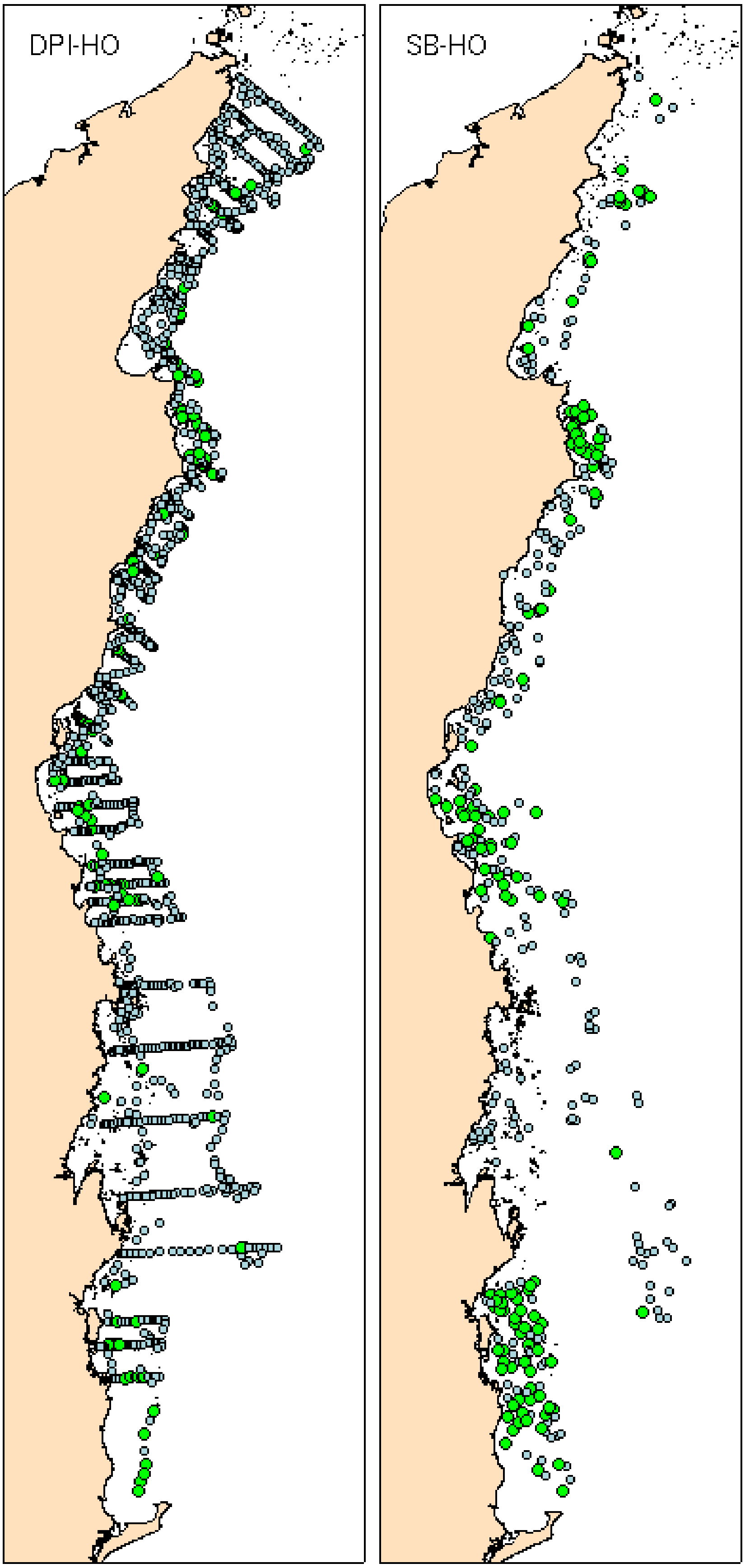

Figure 7: Presence (green) and absence (light blue) of HO on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

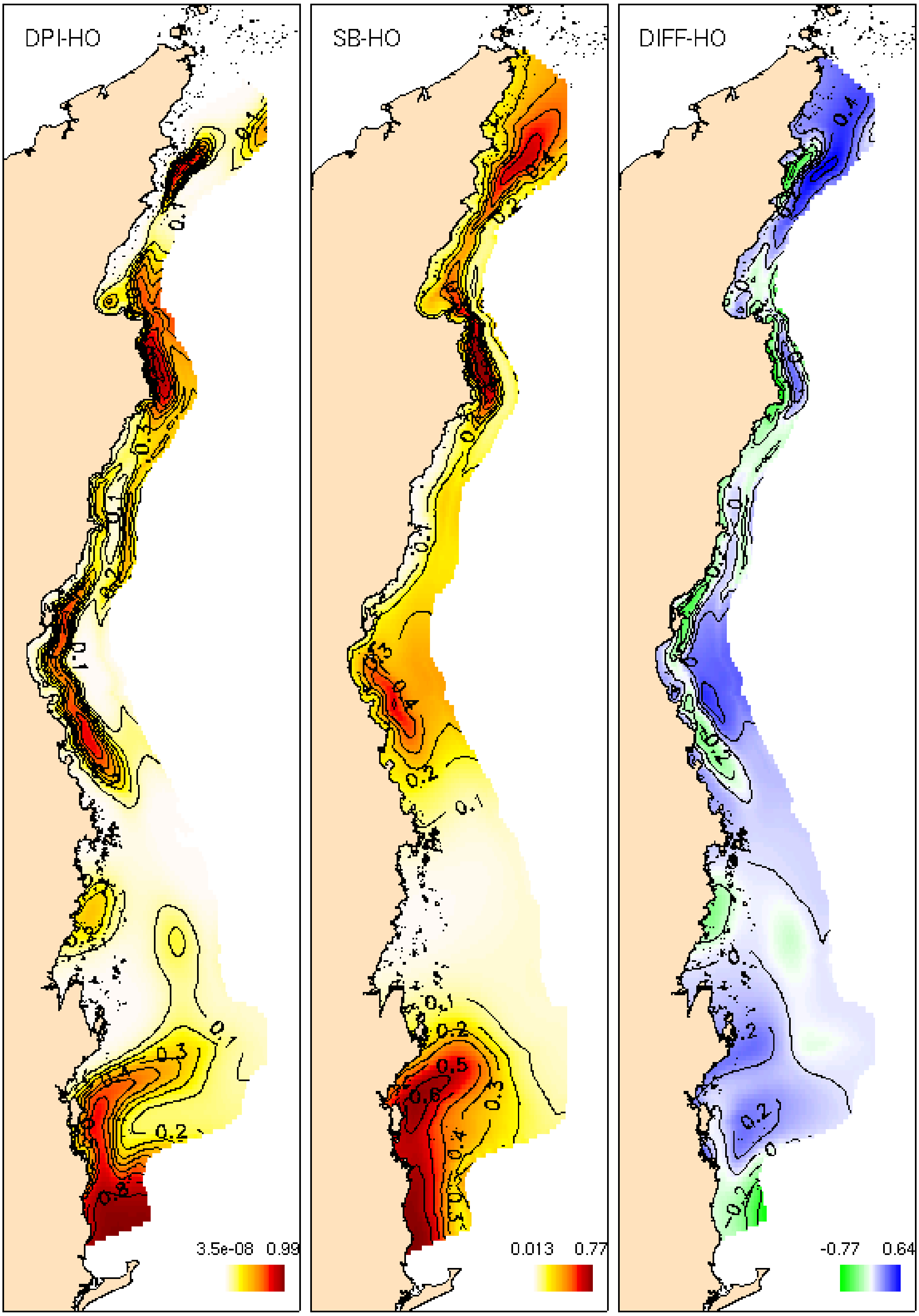

Figure 8: Modelled presence, absence and differences of HO on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (centre).

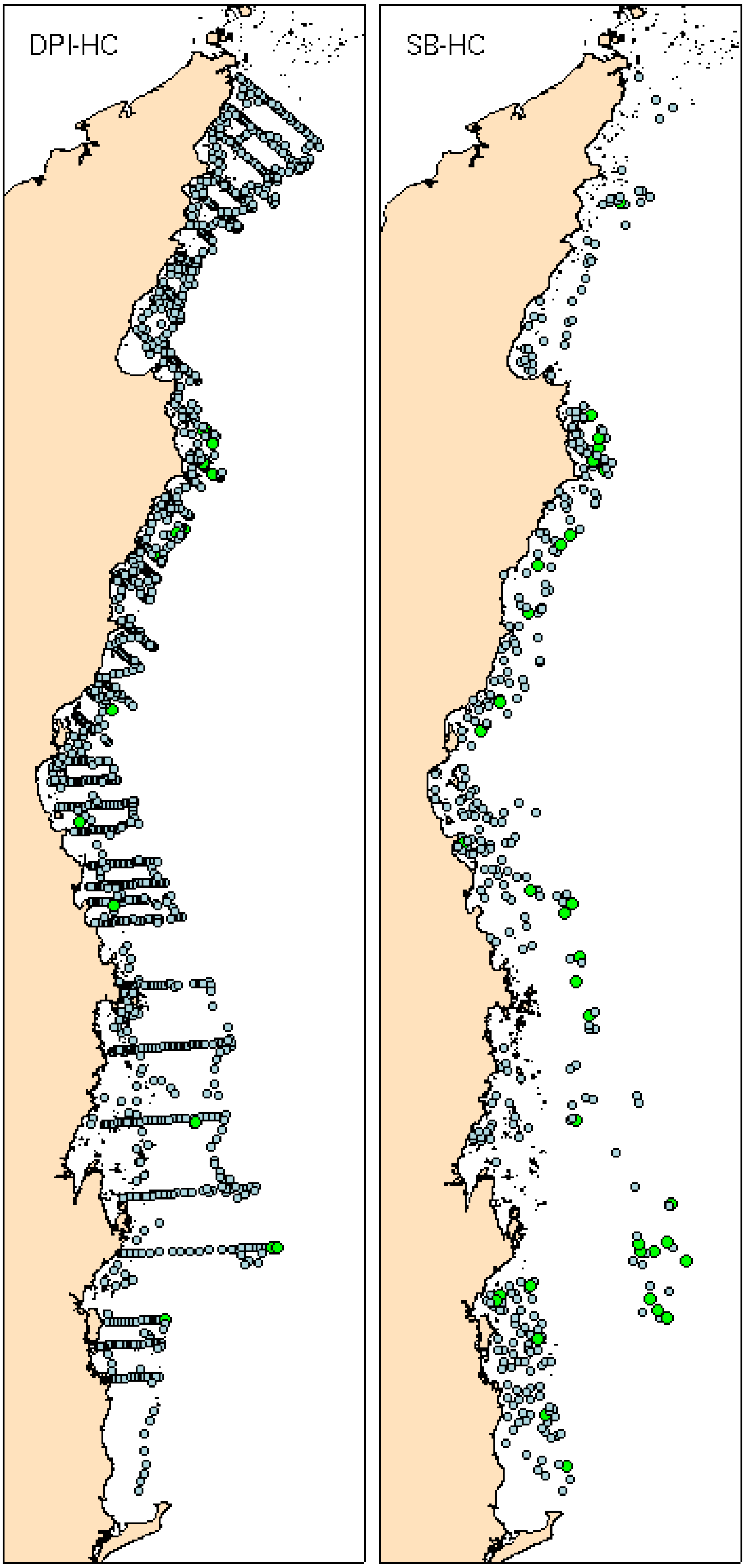

Figure 9: Presence (green) and absence (light blue) of HC on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

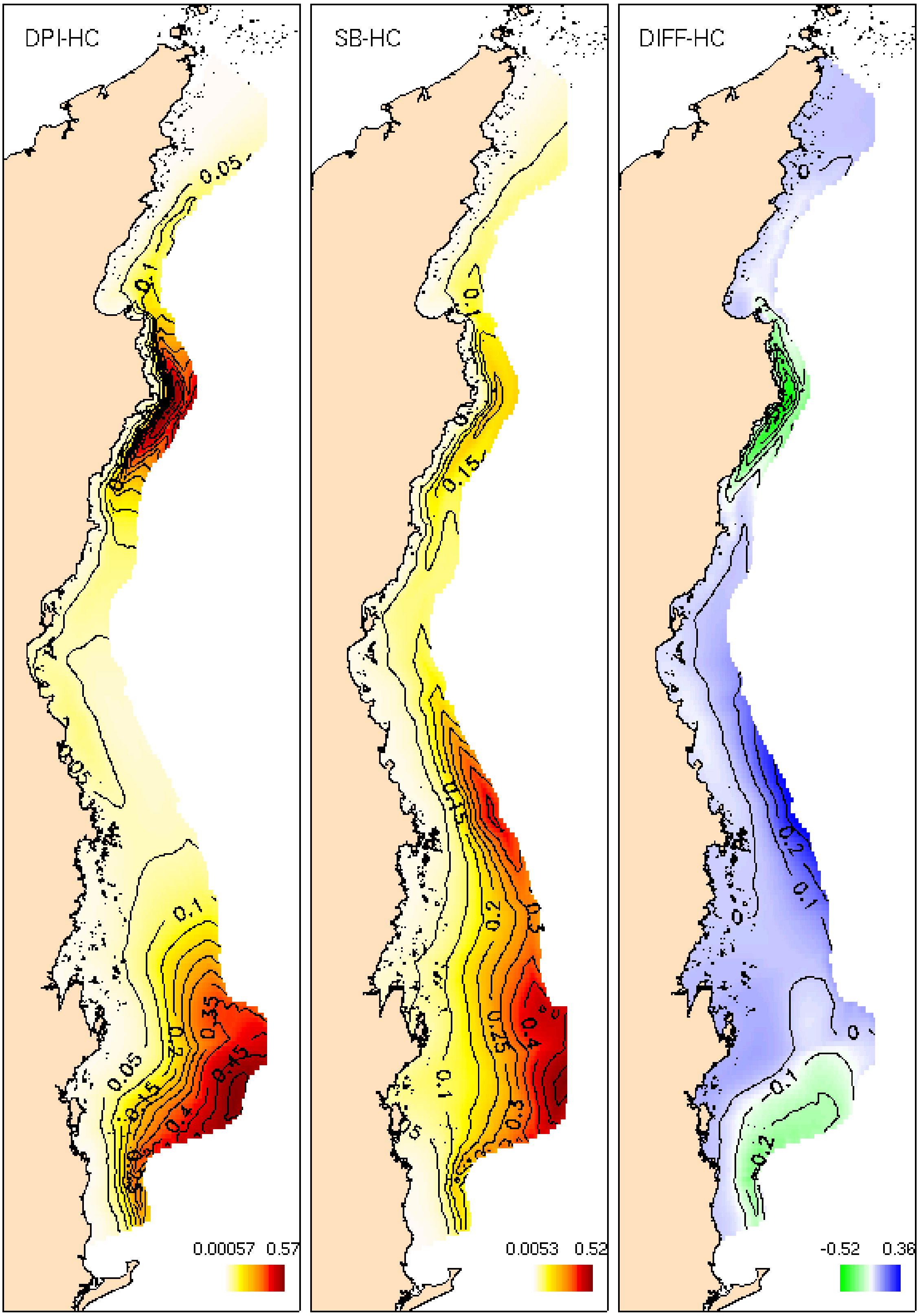

Figure 10: Modelled presence, absences and differences of HC on the GBR survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (centre).

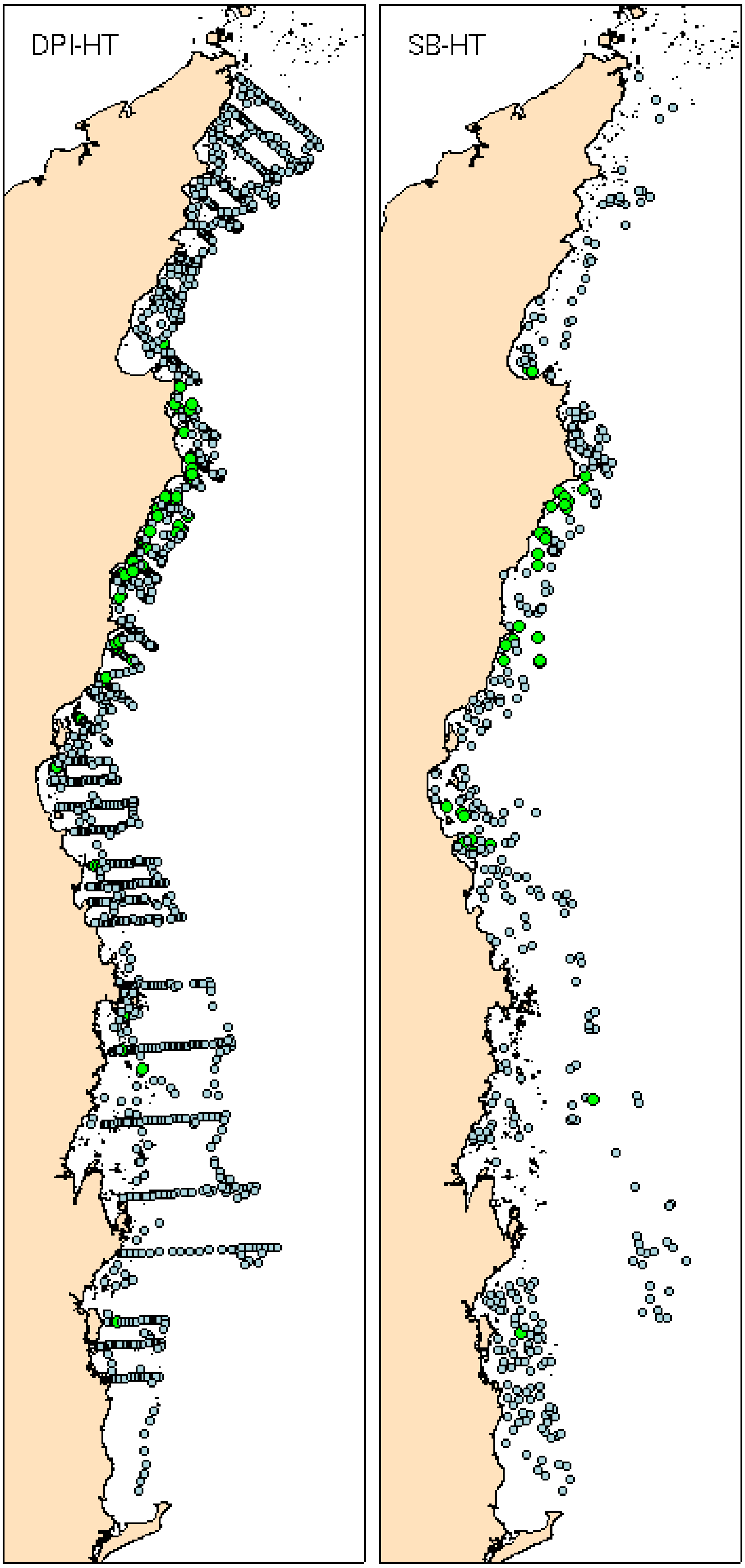

Figure 11: Presence (green) and absence (light blue) of HT on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (right).

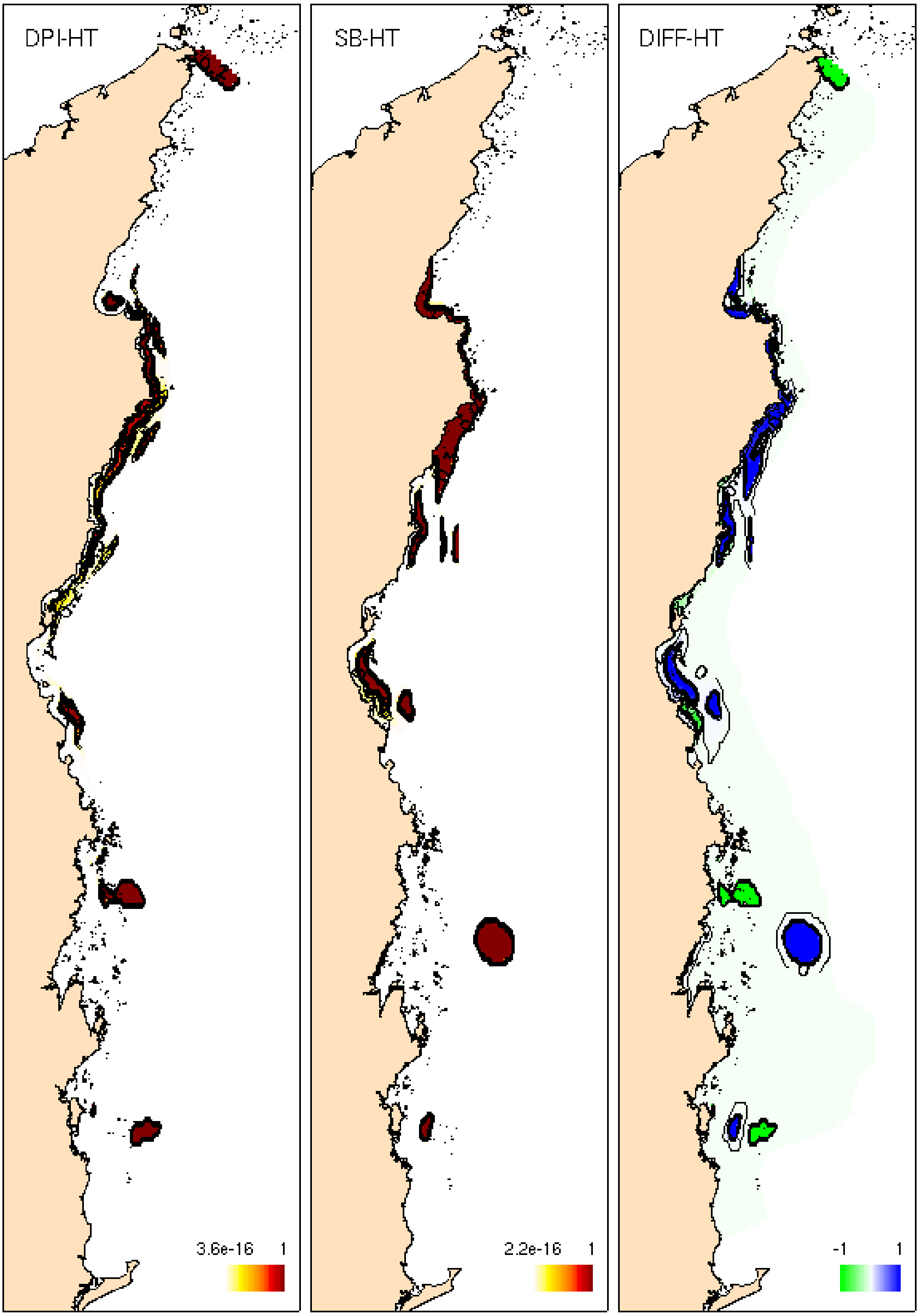

Figure 12: Modelled presence, absence and differences between HT on the GBR for survey conducted by QDPI&F (left) and the Seabed Biodiversity Program (centre).

Discussion

This report summarises a preliminary analysis of changes in seagrass distribution over the scale of the whole of the Great Barrier Reef World Heritage Area. Although similar numbers of sites were visited in both surveys fundamental differences in approach evident in the sample location (Figure 1) limit the amount of information that can be obtained from a comparison.

The comparison does show that ten years after the first survey large areas of the inter-reef waters of the Great Barrier Reef World Heritage Area are still populated with seagrass meadows. There is no evidence to suggest seagrasses have been lost from any region in the ten year period. Highest probabilities of finding seagrasses are in the central wet tropics from Princess Charlotte Bay to Upstart Bay and in the south offshore from Gladstone. There is a region south of Mackay of high tidal velocities where seagrasses are least likely to be found. These general patterns are present in the data from both surveys suggesting that these large spatial scale patterns are stable over time.

Most seagrass in deep water are of the genus *Halophila* (Coles et al 2000). The least common species HT and HC are the most clumped with HT in particular mostly limited in distribution to the central wet tropics. The small colonizing species HD and HO are widely distributed through the GBR apart from the region to the south of Mackay. HS is a larger plant with a non leaf replacing di-meristematic growth strategy (as has HT) enabling it to develop large leaf surface. It can form extensive deep water meadows and can be found in offshore areas at depths of sixty metres or more.

In July 2004 The Great Barrier Reef Marine Park Authority introduced a new zoning plan that was developed in part from biological information on the nature of the seafloor. This biological information was used to establish bioregions each of which is represented and protected in the new plan. The 1994-1999 seagrass data set was a key data set used to establish the interreef bioregions. Our analysis is the first attempt to establish whether the spatial distribution of this key habitat type is consistent through time or highly variable. The results suggest that seagrass meadows in the deep water of the Great Barrier Reef World Heritage Area have only a 15-25 % variation in spatial extent after ten years – a remarkably small change for a biological system. The designers of the new zoning plan can be reassured that spatial decisions to protect seagrass based on the 1994-1999 data set are likely to remain relevant over long time scales.

References

Coles, RG, Lee Long, WJ, Watson, RA, and Derbyshire, KJ (1993). Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research.* 44, 193-210.

Coles RG, Lee Long WJ, McKenzie LJ, Roelofs AJ and De'ath G (2000) Stratification of seagrasses in the Great Barrier Reef World Heritage Area, Northeastern Australia, and the implications for management. *Biol. Mar. Medit*. 7(2): 345-348.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil RV, Paruelo J, Raskin RG, Sutton P and van der Belt M. (1997). The Value of the world's ecosystem services and natural capital. *Nature* 387(15): 253-260.

Lanyon JM, Limpus CJ and Marsh H. (1989). Dugongs and turtles: grazers in the seagrass system. In: Biology of Seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. (AWD Larkum, AJ McComb and SA Shepherd eds). (Elsevier: Amsterdam, New York). Pp 610-34.

Pitcher R, Doherty P, Arnold P, Hooper J, and Gribble N (2006) Seabed Biodiversity on the Continental Shelf of the Great Barrier Reef World Heritage Area. Final report to the CRC Reef Research Centre C1.1.2/FIRDC project 2003/021/NOO Contract 2004/015 277pp.

Venables, WN. and Ripley, BD (2002) Modern Applied Statistics with S. Fourth edition. Springer.

Wachenfeld, DR., Oliver, JK. Morrissey, JI (Eds) (1998). State of the Great Barrier Reef World Heritage Area 1998. Great Barrier Reef Marine Park Authority, Townsville. 139pp.

Watson, RA., Coles, RG., and Lee Long, WJ (1993). Simulation estimates of annual yield and landed value for commercial penaeid prawns from a tropical seagrass habitat, northern Queensland, Australia. *Australian Journal of Marine and Freshwater Research*. 44(1), 211-220.

Williams LE (1997). Queensland's Fisheries Resources, Current condition and trends 1998-1995. Queensland Department of Primary Industries Information Series QI97007 101pp.

Wood, SN (2004) Stable and efficient multiple smoothing parameter estimation for generalized additive models. *Journal of the American Statistical Association*. 99:673-686