Photoquadrat and Linear Point-intercept Methods for Assessing Benthic Cover Should Not be Used Interchangeably in Long-term Coral Reef Survey Programmes

El Método de Foto-quadrat y el Método Linear de Puntos de Intercepción No deben Usarse Intercambiablemente en los Programas de Monitoreo de la Cobertura Bentónica de Arrecifes Coralinos

La Méthode de Photo-quadrat et la Méthode Linéaire de Points d'Interception Ne Doivent pas être Utilisées de Manière Interchangeable dans les Programmes de Suivi de la Couverture Benthique des Récifs Coralliens

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EXTENDED ABSTRACT

Monitoring programmes are an important component in the conservation, management and sustainable use of coral reef ecosystems (McField and Kramer 2007) and have attracted much attention in recent years with the realization of regional- and global-scale changes in coral reef health (Jackson et al. 2014, Flower et al. 2017). One of the important issues that remains problematic when examining regional trends in reef health is the comparability of different survey methods typically used by reef scientists (Jackson et al. 2014). To address this, the newly re-activated Global Coral Reef Monitoring Network (GCRMN – Caribbean) has produced a set of guidelines for standardized biophysical monitoring of coral reefs (UNEP 2016). Scientists and managers throughout the Caribbean are now being encouraged to adopt the highly recommended methods in these guidelines (UNEP 2016). In this study, the performance of the photoquadrat (PQ) method, the GCRMN-Caribbean highly recommended method for estimating the cover of key taxa on the reef benthos, is compared against the linear-point-intercept (LPI) method utilized by the long-term Barbados Reef Survey Programme, in order to make an informed decision on whether or not the PQ protocol should be adopted.

Fifteen sites across the three typical reef types found in Barbados (bank, patch and fringing reefs) were surveyed in July -August 2017 using both survey methods concurrently in permanently established monitoring plots at each reef site. Comparisons between the two methods were made for:

i) Estimates of percent cover of the six major benthic categories (hard corals, sponges, gorgonians, macroalgae, encrusting coralline algae [ECA] and turf algae),
ii) Species diversity for four of the six major benthic categories (hard corals, sponges, gorgonians and macroalgae), and
iii) The time required to obtain data in a usable form.

At each site, the LPI method used ten 10 m transects (spaced 2 m apart across the 10 x 20 m plot) to record the benthos at point intercepts every 10 cm, resulting in approximately 1,200 data points per site. The PQ method used all eleven 10 m transect lines to take photographs every 2 m using a monopod or 60 x 90 cm photoquadrat, resulting in 66 photographs per site. The photographs were subsequently analysed with the coral point count (CPCe) software (Kohler and Gill 2006) using 25 randomly selected points per photograph to give 1,650 data points per reef site. For both methods, the data points (recording the taxa present) were used to calculate: (1) the mean percent abundance of each of the six major benthic categories; and (2) the number of species present for four major benthic categories per reef site.

At a coarse taxonomic resolution, the methods produced broadly similar results. For example, both methods assigned the same importance ranking (based on % cover) to major benthic categories across different reef types. However, at a more detailed level, the results differed considerably depending on the major benthic category, the reef type and the percent cover.

The PQ method generally detected slightly fewer species than the LPI method, largely because of the additional difficulty in identifying some taxa in the absence of *in situ* tactile and scale cues, as well as the limited resolution of photographs particularly in highly rugose reefs or deeper water with lower light levels. The photographs also did not allow the observer to identify species present in crevices, overhangs or heavy shadow.

With regard to benthic cover, there were differences between methods that depended on the identity of the major benthic category of interest, as well as on the reef type (i.e. showed a 'reef effect'). For example, the PQ method detected significantly lower percent cover of hard corals on all reef types than the LPI method (Paired Samples t-tests: $p < 0.05$ in all cases; Figure 1); significantly lower percent cover of sponges on bank and patch reefs but no significant difference on fringing reefs (Paired Samples t-tests: for bank reefs $p = 0.02$, for patch reefs $p = 0.03$, for fringing reefs $p = 0.12$; Figure 1);

and slightly lower, but significantly different, percent cover of macroalgae on patch reefs, but no significant difference on bank or fringing reefs (Paired Samples t-tests: for patch reefs p = 0.02; for bank and fringing reefs $p > 0.05$; Figure 1). In contrast, the PQ method detected higher percent cover than the LPI method across most reefs for gorgonians, ECA and turf algae (Figure 1), which was statistically significant for gorgonians on patch reefs ($p < 0.01$), for ECA on bank reefs ($p < 0.01$), and for turf algae on fringing and patch reefs ($p = 0.01$ and 0.03, respectively). Moreover, for some benthic categories, the magnitude of the difference between methods in estimates of percent cover increased, as the benthic category increased in overall abundance at a reef site (i.e. showed an 'abundance effect') (Figure 1). These differences in estimates between methods reflect the fact that the LPI method collects data in 3D by following the reef benthic profile, whilst the PQ method collects data in 2D from planar images. As such, the more physically complex the benthic substrate, the greater the difference will be between survey methods, in estimating percent benthic cover. For the gorgonians the difference between the methods is further magnified by the fact that gorgonians can overwhelm a photograph, but can be brushed aside by the diver when using the LPI method to determine benthic cover.

With regard to field data collection times, these were similar between PQ and LPI methods. However, analysis of the photographs to obtain data at a given taxonomic resolution took (on average) double the time needed for LPI data entry from the underwater slates to obtain equivalent data (Table 1).

We conclude that all factors of interest to reef monitoring (benthic category, reef type, abundance of benthic cover) have measurable and inconsistent effects on the difference between methods in estimates. As such the two methods are not easily comparable and we therefore warn against transition between these two methods in long-term reef survey programmes. Furthermore, the PQ method

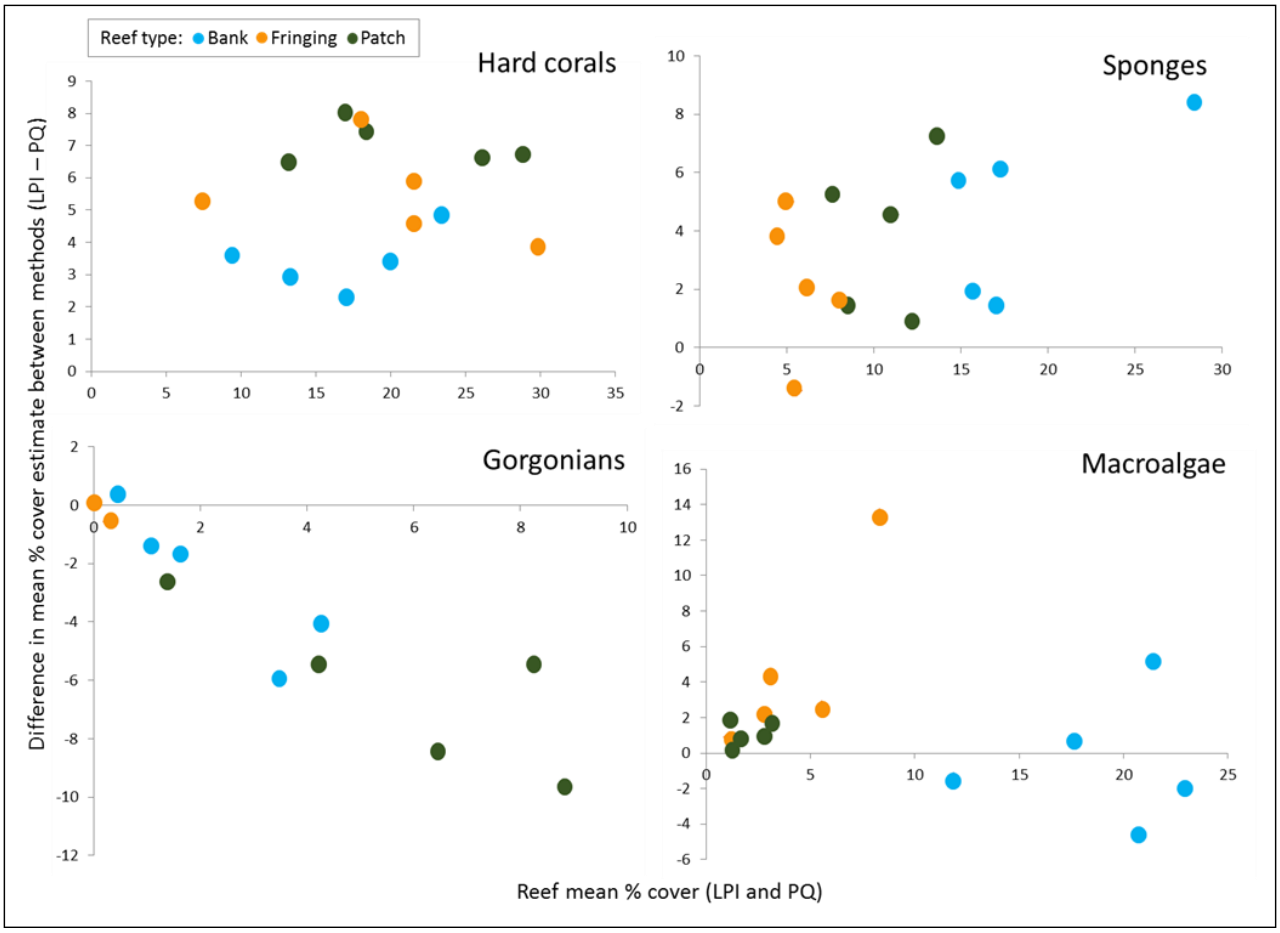

Figure 1. Comparison of estimates of cover by each of four major benthic categories obtained by the LPI and PQ methods at each of the 15 reef sites. Data are shown as the difference in mean % cover at each reef site estimated by the two methods (as LPI estimate - PQ estimate) and are plotted against the reef overall mean estimate of cover (based on both methods) to show abundance effects. Note that for gorgonians, they were present on only one of the five fringing reefs.

does not save any field time, requires more expensive resources (e.g. underwater cameras) and double the time for data entry, albeit recognized that the PQ method provides a permanent visual record of reef quadrats that could be used for investigating other aspects of reef ecology.

KEYWORDS: Coral reefs, survey methods, photoquadrats

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Table 1. Summary of mean time taken for underwater data collection and subsequent data entry into a taxonomic-level database by the photoquadrat (PQ) and the linear point-intercept (LPI) coral reef survey methods per reef site. Data are shown by reef type and across all reefs. Data entry shows time needed by one person. PQ data entry includes downloading, labelling and editing photographs and analysis in the CPCe software to obtain taxonomic data points. LPI data entry includes transcribing from the underwater slates into an electronic database.

Reef Type	Dive Time per diver (min)		Data Entry (min)	
	PQ	LPI	PQ	LPI
Bank	92	102	340	180
Patch	93	105	234	120
Fringing	89	89	220	100
All Reefs	**91**	**99**	**265**	**133**