

Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology[☆]

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Abstract

Photographic and video methods are frequently used to increase the efficiency of coral reef monitoring efforts. The random point count method is commonly used on still images or frame-grabbed video to estimate the community statistics of benthos. A matrix of randomly distributed points is overlaid on an image, and the species or substrate-type lying beneath each point is visually identified. Coral Point Count with Excel extensions (CPCe) is a standalone Visual Basic program which automates, facilitates, and speeds the random point count analysis process. CPCe includes automatic frame-image sequencing, single-click species/substrate labeling, auto-advancement of data point focus, zoom in/out, zoom hold, and specification of random point number, distribution type, and frame border location. Customization options include user-specified coral/substrate codes and data point shape, size, and color. CPCe can also perform image calibration and planar area and length calculation of benthic features. The ability to automatically generate analysis spreadsheets in Microsoft Excel based upon the supplied species/substrate codes is a significant feature. Data from individual frames can be combined to produce both inter- and intra-site comparisons. Spreadsheet contents include header information, statistical parameters of each species/substrate type (relative abundance, mean, standard deviation, standard error) and the calculation of the Shannon–Weaver diversity index for each species. Additional information can be found at <http://www.nova.edu/ocean/cpce/>.

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1. Introduction and rationale

Random point count methodology is commonly used in many population estimation applications,

e.g. forestry vegetation (Stoyan and Penttinen, 2000), tree canopy cover (Thomas and Winner, 2000), bird population and diversity (Ralph et al., 1995; Thompson III et al., 2002; Young and Hutto, 2002). It is also commonly used on frame-grabbed video or still images to estimate the population statistics of marine benthic communities (Carleton and Done, 1995). Previous methods included overlaying underwater photographic images with transparent sheets containing randomly positioned

[☆] Code available from server at <http://www.iamg.org/CGEditor/index.htm>

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points (Murdoch and Aronson, 1999). Later improvements to this method included the use of computer software to generate the random point patterns and to identify the underlying benthic features. PointCount99¹ is one such computer program.

Instead of requiring the counting of each specimen, the random point method relies on statistical power analysis to estimate the actual population using the random point samples as a proxy (Lenth, 2001). The technique consists of randomly distributing a number of points onto an underwater photographic image, and then visually identifying the features (e.g. coral, algae, rubble, etc.) lying under each point. The percentage of points overlying each benthic category is calculated, and statistics can be compiled to estimate the population of biota such as stony coral, sponges, macroalgae, etc. over a region of interest. Coral Point Count with Excel extensions (CPCe) was developed to increase the efficiency and ease of performing the large number of image analyses and feature identification required to provide meaningful population estimates. It includes many user-friendly design features, and provides a reliable means of data archiving. This paper describes the features and functionality of CPCe at the time of this writing, Version 3.3.

2. Overview

CPCe was designed specifically to quickly and efficiently calculate statistical coral coverage over a specified area. Underwater photographic frames are overlaid by a matrix of randomly distributed points, and the fauna/flora species or substrate type lying beneath each point is visually identified. The species code data for each frame is stored in a .cpc file which contains the image filename, point coordinates and the identified data codes. Data from individual frames can be combined to produce both inter- and intra-site comparisons via automatically generated Excel spreadsheets. The transect datasets can then be statistically analyzed to give quantitative population estimates over the area of interest. In addition, CPCe has the ability to measure both planar length and area of selected benthic features. This capability allows the statistical comparison

between video quadrat analyses and in situ measurements, and also to determine growth trends over time.

The primary features of CPCe are:

- automatic frame-image sequencing,
- single-click species/substrate labeling,
- auto-advancement of data point focus,
- multiple point data assignment,
- user-specified coral/substrate codes,
- variable random point number/distribution,
- image scaling and calibration,
- planar area analysis,
- batch data input and output,
- automatic Excel spreadsheet generation,
- adjustable frame border dimensions,
- color-coded category boxes,
- zoom in/out and zoom hold,
- hide/show random points on image,
- customizable data point shape/color,
- code file integrity checker,

A significant feature of CPCe is the ability to automatically generate analysis spreadsheets in Microsoft Excel based upon the supplied species/substrate codes. Individual image frames can be analyzed separately or multiple frames can be combined into a single transect datasheet containing header information, statistical parameters of each species/substrate type (relative abundance, mean and standard deviation), and the calculation of the Shannon–Weaver diversity index for each species.

3. CPCe operation

The basic operations of CPCe consist of specifying a digital image, defining a frame border, overlaying random points, identifying the coral species and/or substrate-type lying beneath each of the random points, and saving the data to file. After the images have been processed, the data can be automatically assembled into Excel spreadsheets for statistical analysis. CPCe was specifically designed to flow logically from one operation to the next, and to simplify and speed the processing effort. Each of these operations is detailed below.

3.1. Image and coral code file specification

The user specifies a digital image in the form of a .jpg, .gif, or .bmp file by selecting File-Open-Raw image file. Images smaller than the available screen

¹Dustan, P., Leard, J., Meier, O., Brill, M., Kosmyrin, V., 1999. PointCount99 software. University of Charleston, South Carolina, <http://www.cofc.edu/~coral/pc99/pc99.htm>.

area are expanded to fill the available space, while larger images are reduced in size to fit. A set of multiple image files can be specified at once and CPCe will process each file sequentially in alphabetical order. This eliminates the need to manually specify each image file for analysis, and allows the user to quickly switch back and forth between images.

3.2. Border designation

The user then specifies the rectangular region of the image to be covered with random points. The region border can be specified in one of four ways (Fig. 1). The first method is to click and drag to create a rectangular area on the digital image. The border can then be manually stretched and moved into the desired size and position. The second method is to use the entire image. Thirdly, the user can specify a border offset (in pixels) in the x - and y -direction independently. The border is then drawn on the image using the appropriate offsets from the image edges. Lastly, the user can specify the dimensions of the border region. For this method, the user must either specify the scaling resolution of the digital image, e.g. number of pixels per centimeter, or the image scaling can be calculated within CPCe (see Section 6: Program tools). After the image resolution is specified or calculated, a border of specific dimensions can be drawn and positioned.

3.3. Random point specification

The random points to be overlaid within the border perimeter can be specified in one of four

ways (Fig. 2). The first way is the simple random method where every pixel within the marked border boundary has an equal likelihood of being chosen for the position of the random points. The x - and y -coordinates of the random points are generated separately and are calculated as follows. The Visual Basic random number generator is initialized with the *Randomize* statement. An array *newrand* of size *numrand* is filled with random numbers in the range 0–1. A random element of array *newrand* is chosen and the corresponding random number chosen. The random numbers are then scaled to produce coordinates which lie within the specified bordered area. The chosen *newrand* element is then refilled with a new random number for the next iteration.

The second border specification type is the stratified random method. In this case, the bordered region is sub-divided into m rows and n columns, and each cell is populated with k random points lying within the cell borders, using the technique described for the simple random method. This reduces the potential clumping of the random points using the simple random method, and ensures that some random points are present in each image cell region. The total number of points is $m \times n \times k$.

The third and fourth border specification types allow the specification of a uniform grid over the bordered area. The third type asks for the number of points in the x - and y - direction and creates the corresponding matrix of point coordinates, fitting the points exactly within the border boundaries. In this case, the x -spacing of the grid points does not necessarily equal the y -spacing.

The fourth specification type dictates that the x -spacing of the points equals the y -spacing, and the user can specify the number of points in either the x - or y -direction. The number of points that will fit in the non-chosen direction (e.g. y -direction if the number of points in the x -direction is specified) is calculated, and the point grid is centered in the non-chosen direction.

In all the four methods, the maximum number of overlying points allowed is 500. After the point distribution method is specified, the random points are placed inside the bordered region of the image (Fig. 3).

3.4. Point data assignment

The random points are displayed and labeled either alphabetically or numerically. Data codes are

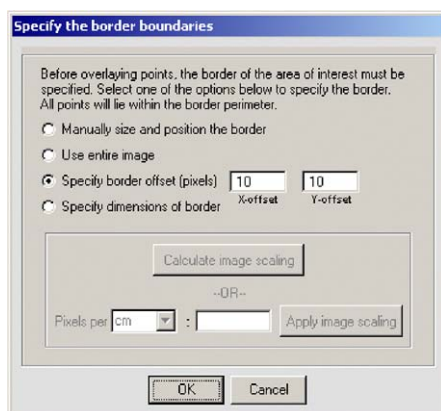


Fig. 1. Border boundary specification options.

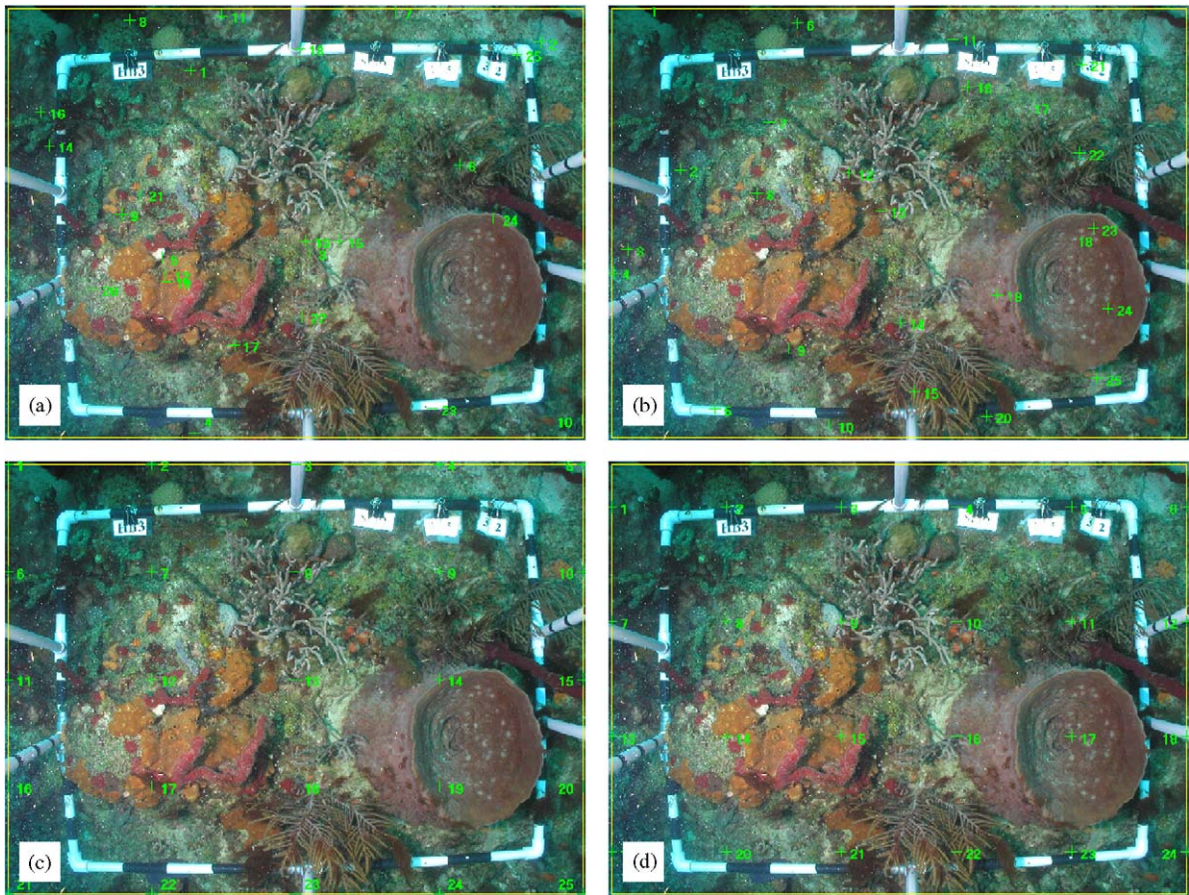


Fig. 2. Random point specification types: (a) simple random; (b) stratified random; (c) uniform grid; and (d) equally spaced grid.

assigned by clicking the point label in the point codes box on the right side of the screen and then the appropriate species code identifier at the bottom of the screen (Fig. 3). A sample species code file, *shallow_coral_codes.txt*, is supplied with CPCe and contains common corals from the Caribbean region; however, a user can create a customized file with data types most appropriate for a specific analysis. The appendix provides details for creating a customized code file. The full name of the species or substrate corresponding to the displayed code can be seen by allowing the cursor to hover over the code box. After clicking on the appropriate code box, the corresponding coral code is inserted in the point data table. Only data codes existing in the code file may be entered for each point. The NOTES column is used to further classify the data points pertaining to disease, bleaching, etc. Points that have been assigned data then change color to give a

visual representation of points still requiring identification. If the number of random points is greater than the number of data entry boxes that can be shown on the screen at once, arrow buttons are provided to scroll up or down through the data point set.

3.5. Saving the data

At any time during the analysis, the data points can be saved to a .cpc data file. The .cpc file contains the image filename, the name of the file containing the species code identifiers, the coordinates of the border boundaries, the number of overlying points, the coordinates of the overlying points, and the assigned code data for each point. By saving to a .cpc file, the image and point data can be retrieved at a later time for further analysis and/or modification.

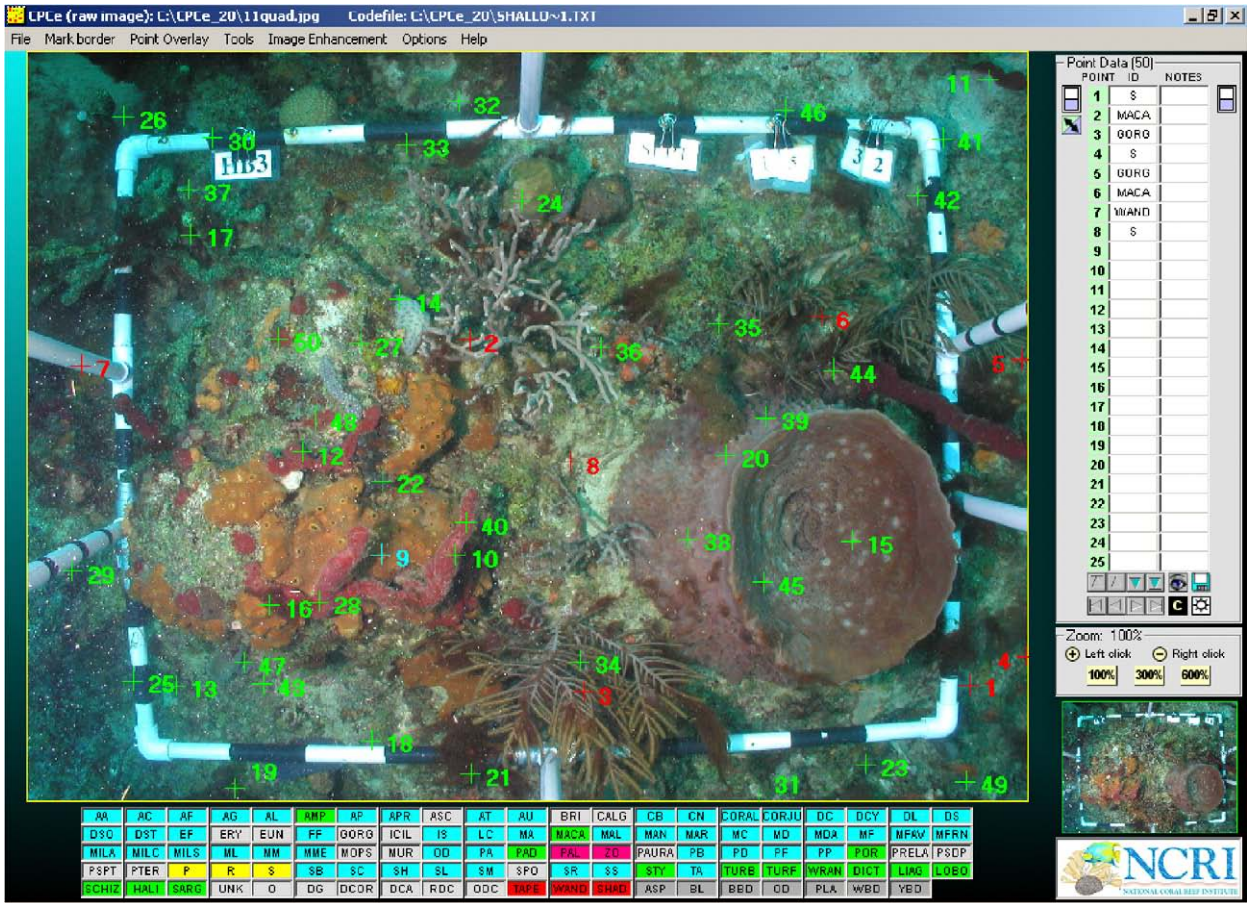


Fig. 3. Screenshot of image with overlying random points. Available coral codes are shown underneath image. Data entry area is on right.

3.6. Excel spreadsheet creation

The data from one or more .cpc files can be combined in various ways to produce Excel spreadsheets. Individual frames can be analyzed to provide intra-site comparisons. Alternatively, multiple image frames can be grouped together for single transect evaluation. Additionally, multiple transects can be analyzed together as a single site or sampling station. To perform these analyses, the user specifies one or more .cpc files to process, and the corresponding Excel spreadsheets are created. The coral categories and classes specified in the data code file are inserted automatically into the spreadsheet. For each transect, two Excel worksheets are created—one containing basic statistical analyses of the data such as point frequency, percentage, Shannon–Weaver diversity index for both species and category group (Fig. 4a), and another

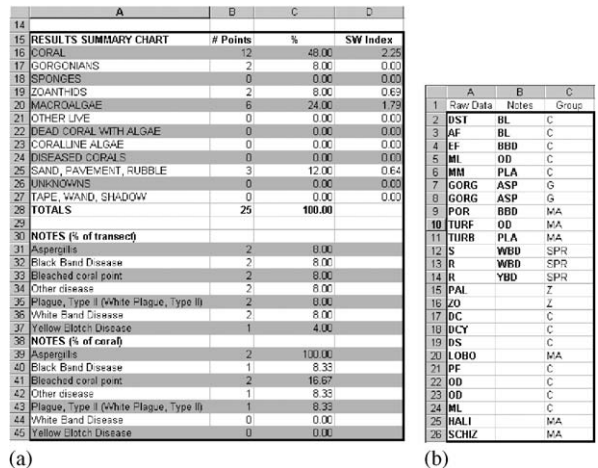


Fig. 4. Example Excel spreadsheets generated by CPCe showing: (a) point frequency, percentage, and Shannon–Weaver diversity index and (b) raw point code data of a single frame.

	A	B	C	D	E	F	G	H	I	J
5										
6	TRANSECT NAME	transect1	transect2	transect3	transect4					
7	Number of frames	1	1	1	1					
8	Total points	25	25	25	25					
9	Total points (minus tape+wand+shadow)	25	25	25	25					
10	MAJOR CATEGORY (% of transect)						MEAN	STD. DEV.	STD. ERROR	
11	CORAL	48.00	24.00	16.00	48.00		34.00	16.49	8.25	
12	GORGONIANS	8.00	20.00	40.00	8.00		19.00	15.10	7.55	
13	SPONGES	0.00	4.00	0.00	0.00		1.00	2.00	1.00	
14	ZOANTHIDS	8.00	20.00	0.00	0.00		7.00	9.45	4.73	
15	MACROALGAE	24.00	28.00	20.00	28.00		25.00	3.83	1.91	
16	OTHER LIVE	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
17	DEAD CORAL WITH ALGAE	0.00	4.00	20.00	8.00		8.00	8.64	4.32	
18	CORALLINE ALGAE	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
19	DISEASED CORALS	0.00	0.00	4.00	4.00		2.00	2.31	1.15	
20	SAND, PAVEMENT, RUBBLE	12.00	0.00	0.00	4.00		4.00	5.66	2.83	
21	UNKNOWN	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
22	TAPE, WAND, SHADOW	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
23	Sum (excluding tape+shadow+wand)	100.00	100.00	100.00	100.00					
24										
25	SUBCATEGORIES (% of transect)						MEAN	STD. DEV.	STD. ERROR	
26	CORAL									
27	Acropora cervicornis	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
28	Acropora palmata	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
29	Acropora prolifera	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
30	Agaricia agaricites	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
31	Agaricia fragilis	4.00	0.00	0.00	0.00		1.00	2.00	1.00	
32	Agaricia grahamae	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
33	Agaricia tenuifolia	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
34	Agaricia undata	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
35	Agaricia lamarcki	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
36	Colpophyllia breviserialis	0.00	0.00	0.00	0.00		0.00	0.00	0.00	
37	Colpophyllia natans	0.00	0.00	0.00	4.00		1.00	2.00	1.00	
38		0.00	0.00	0.00	0.00		0.00	0.00	0.00	

Fig. 5. Example Excel spreadsheet showing data summary for four individual transects.

containing the raw point code data (Fig. 4b). This second worksheet provides an archival record for the point code data.

Additional transects can be appended to existing Excel spreadsheets. A separate data summary worksheet is created in each workbook which contains statistics among transects including mean, standard deviation, and standard error of category groups (Fig. 5).

4. Program controls

In the design of CPCe, an emphasis was placed on having the necessary tools accessible on a single screen window, while maximizing the screen area allocated to the analysis image. Additionally, CPCe was designed to be a self-contained program,

requiring only Microsoft Excel for automated data analysis.

There are several program controls designed to increase the efficiency of assigning the data point codes (Fig. 6). In order to better view the underlying image features, all of the data points can be temporarily hidden. Isolation mode can be used to show only the current point instead of all random points. Groups of points can be assigned with a single click. Point groups are selected by using the typical shift-click or ctrl-click combinations. Clicking on the data code box assigns that code to all selected points. The data of the currently selected points can be cleared by clicking on the ‘Clear selected points’ icon. Additionally, all points having a blank ID field or blank Notes field can be selected at once, and filled with a single data code with one click.

The image can be zoomed in or out by left-clicking or right-clicking on the image, respectively, with the zoom level increasing or decreasing by 50% with each click. If the ‘Maintain zoom’ option is checked in the Options menu, the current zoom level is maintained when moving among data points. Buttons are provided to zoom to 100%, 300%, and 600% with a single click. When the image is zoomed in, a border designating the visible region relative to

the entire image is shown on an inset image at the lower right of the screen.

5. Image enhancement

CPCe includes the capability of basic image enhancement within the program. The brightness, sharpness, and contrast of a selected area of the image can be adjusted to aid in species identification (Fig. 7). This is very useful on indistinct object edges when trying to determine random point position. Since it is rarely necessary to enhance an entire image, the image enhancement is performed on only a user-selected subset of the image to speed the creation of the enhanced area display.

To enhance an area of the image, the user selects the desired area by clicking and dragging. The type and strength of image enhancement (brightness, sharpness, and contrast) desired is then specified, and the modified image area is displayed. The brightness and sharpen filters are accumulative, whereas the contrast filter is not.

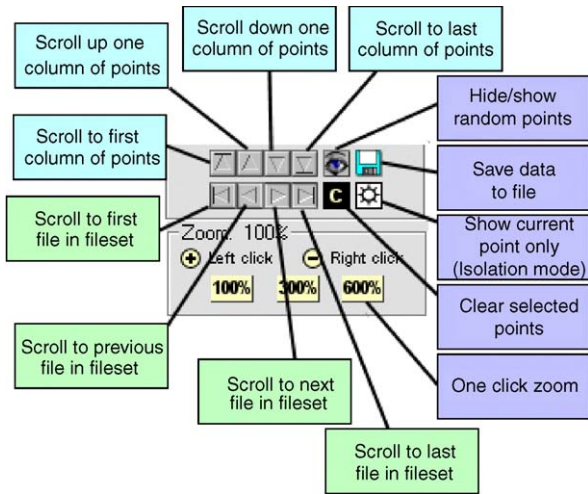


Fig. 6. CPCe program controls.

6. Program tools

Several program tools are provided to perform tasks such as area measurements and various data integrity checks.

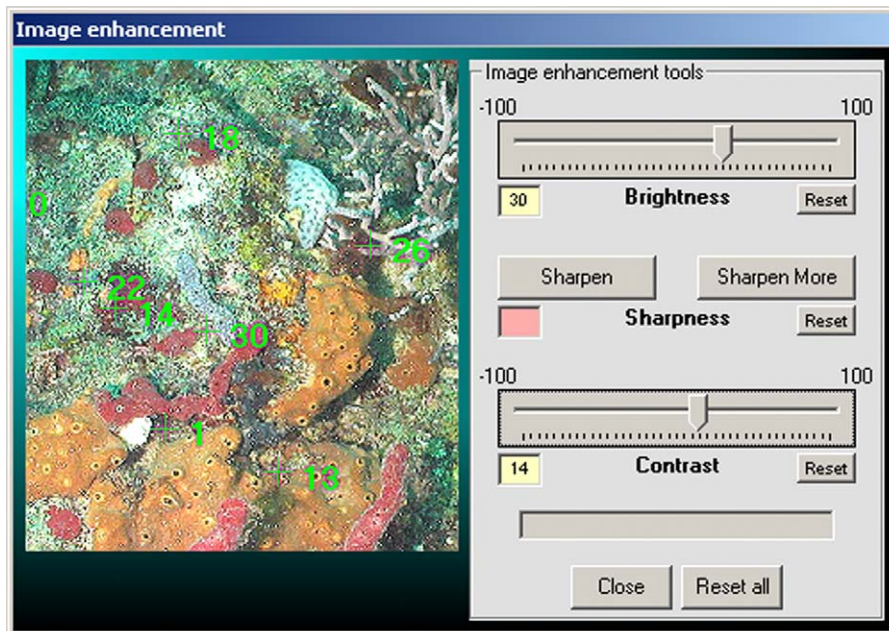


Fig. 7. Image enhancement interface.

6.1. Image calibration and planar area analysis

CPCe includes the ability to calibrate an image and to calculate a planar area or length of a displayed object. This is useful to document the size and area of bottom features, and to aid in the investigation of growth trends of a coral colony over time.

The first step in area or length analysis is to determine the scaling resolution of the image, e.g. number of pixels per centimeter. To determine the scaling, an image is selected, and two points that are a known distance apart are marked on the image (Fig. 8). The user enters the distance spanned by the points, and the scaling resolution is calculated.

Once the image calibration is known, areas and lengths on the image can be determined. To calculate a length, points at the beginning and end of a linear segment are clicked, and the distance between them is calculated and displayed. To calculate an area, a trace is performed by left-clicking the mouse, moving the mouse around the periphery of the desired area, and then right-clicking the mouse which connects the first and last points and closes the path. The area of the enclosed region is calculated and displayed. Other features include the ability to temporarily stop a trace, and to erase partial traces. Once an area is traced, the user can toggle between having the area filled or

outlined by pressing shift-right-click. Instructions to access these capabilities are displayed on the right side of the screen. An example of traced and calculated areas is seen in Fig. 9.

The image including the traced area(s) can be saved to an image (.bmp) file, either with or without the area information labels. Also, the traced area(s) information can be saved to an .ara file which can be retrieved for later re-analysis in CPCe.

6.2. Data check and species search in .cpc files

This option searches a selected set of .cpc files for unassigned points or the occurrence of a specified species code. It provides the ability to identify frames with incomplete data entries, and to locate frames containing possibly misidentified species. This is very useful for analysis involving large numbers of image frames as it eliminates the need to manually inspect each data file to ensure complete data point assignments.

6.3. Change code file/image file directory location

This option changes the directory location of either the coral code file or image file in a selected set of .cpc files. This allows the user to move the code or image files into other folder locations post-analysis.

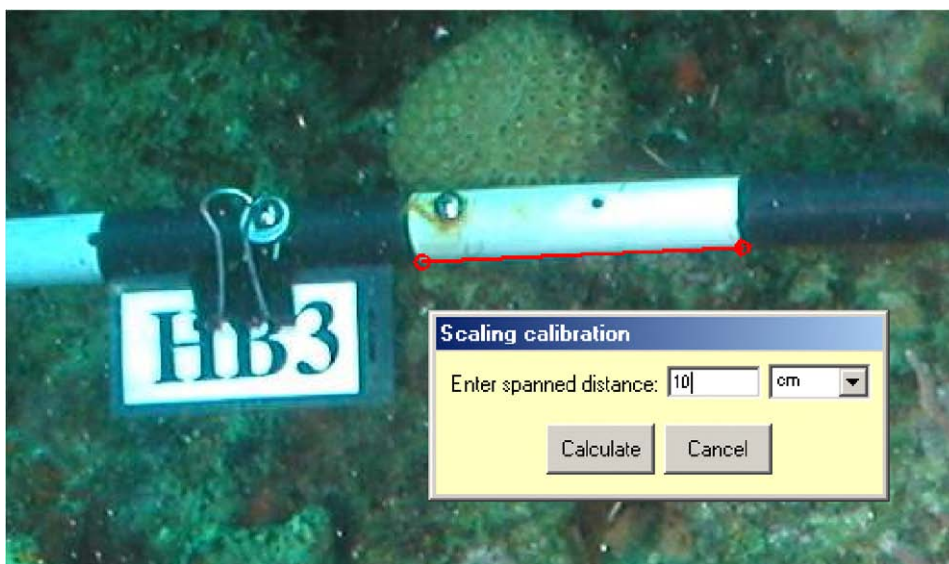


Fig. 8. Screenshot of image scaling and calibration process.

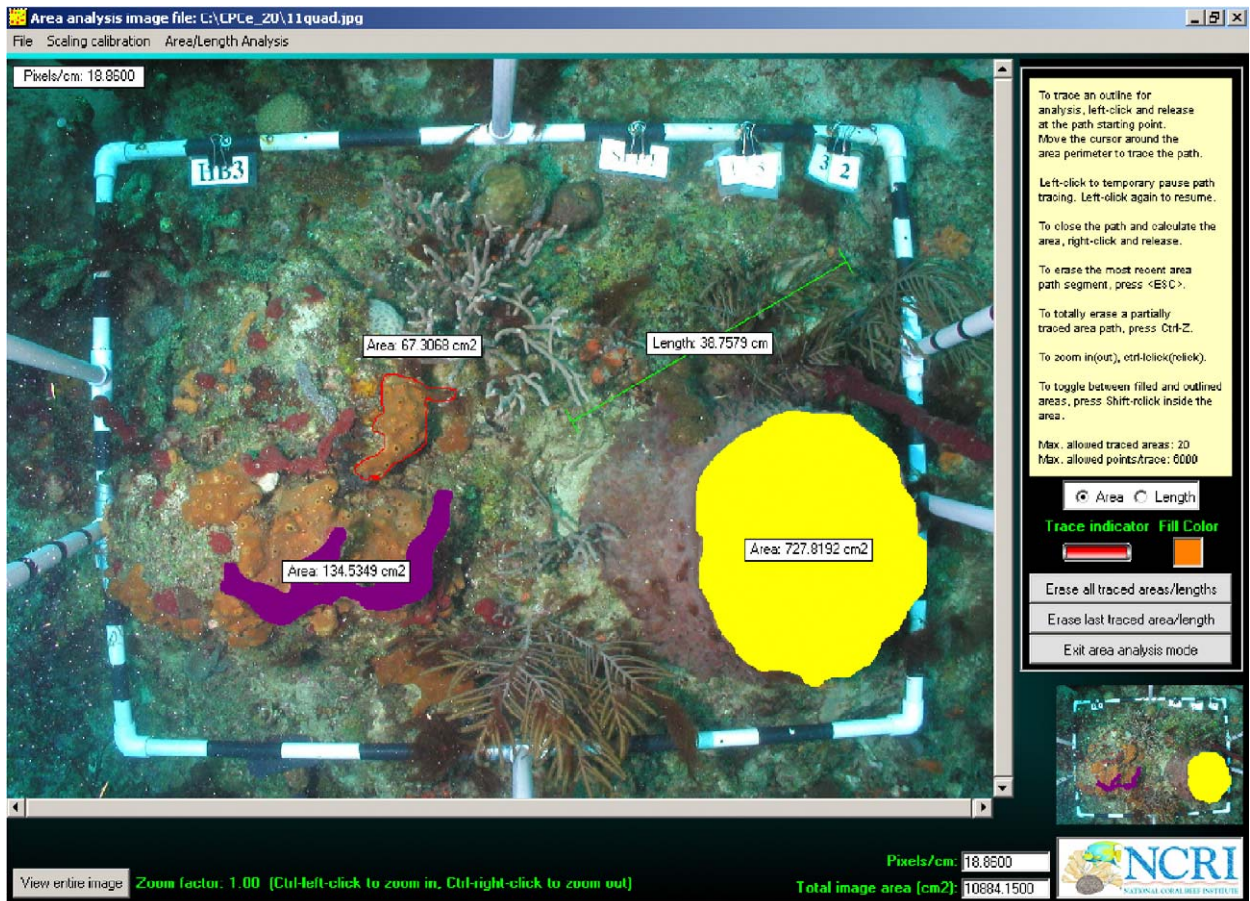


Fig. 9. Screenshot showing traced areas and lengths, outlined area, and movable text boxes. Areas of traced regions can be saved as bitmapped images.

6.4. Code file check

This option finds any obvious errors in a user-customized species code file such as incorrect syntax, missing required category fields, and duplicate species codes.

7. Program options

There are several user-customizable program options available. CPCe uses a configuration file to hold the current setting of the various settings and options. Each setting/option change is written to the configuration file, and the current setting/option configuration is recalled each time the program starts. The program options are listed below.

7.1. Data point graphical parameters

This option customizes the shape, size, and color of the data point objects. The available shapes are circle, circle with crosshairs, box, triangle, crosshairs, all either filled (solid) or outlined. The colors of unassigned points, assigned points, the current focus point, and the frame border can also be specified, which makes it easier to determine which points remain to be identified. Also, the size of the font in the coral code boxes can be specified.

7.2. Color-coded code category boxes

This option allows the user to specify custom colors for each of the species and substrate code categories appearing under the analysis image. This helps in quickly finding a particular code box when using many codes. Blank boxes can also be inserted

in the coral code file to separate the coral codes for enhanced visual recognition.

7.3. Specify coral code file

The user can specify different data code files for individual analyses.

7.4. Letters/numbers

The user has the option of using either numbers or letters to identify the data points on the image.

7.5. Maintain zoom

If this option in the control box is checked, the current zoom level is maintained after assigning each data point.

7.6. Auto-advance and auto-follow

If the auto-advance option is checked, after a point is assigned a category, the next point in sequence becomes the current point, and the cursor is positioned at the corresponding data entry label. This eliminates the need to manually click each data point before assigning it a category value.

If the auto-follow option is checked, and maintain zoom is checked, the image shifts to center the current point in the display area, while maintaining the same zoom level.

8. Summary

Coral Point Count with Excel extensions (CPCe) is a standalone Visual Basic program which automates the random point count method for the statistical analysis of marine benthic communities. Features such as group point selection, auto-follow, auto-advance, isolation mode, batch processing of both input and output datasets, and image enhancement are specifically designed to speed the analysis of photo-quadrats. In order to ensure data integrity, the data are saved separately in .cpc format which can then be automatically assembled into Microsoft Excel spreadsheets. By saving the individual .cpc files, the resultant Excel spreadsheets can be easily regenerated at any time. CPCe also provides the capability to perform planar area and length analyses on individual coral colonies and other benthic features.

CPCe is continually updated, and the authors are receptive to suggestions from other researchers. The features described in this paper are found in the current version of CPCe, Version 3.3. CPCe is being made available free of charge to interested researchers affiliated with scientific institutions. More information, as well as instructions for downloading the software, can be found at <http://www.nova.edu/ocean/cpce/index.html>.

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Appendix A. Coral code file creation

A coral code file is an ASCII text file containing general coral categories and individual codes and species identifiers. The format of the coral code file is as follows:

```
The number of general coral categories
For each coral category: "category symbol",
"category name"
For each coral type: "coral code", "coral
description", "category name"
NOTES, NOTES, NOTES (this line separates
the coral names from the notes descriptors).
For each notes descriptor: "notes code",
"description", "NA" (not applicable)
```

Example:

```

4
"C","Coral"
"G","Gorgonians"
"S","Sponges"
"TWS","Tape, wand, shadow"
"AA","Agaricia agaricites","C"
"AC","Acropora cervicornis","C"
"AF","Agaricia fragilis","C"
"SPO","Sponge","S"
"SR","Siderastrea radians","C"
"PRELA","Plexaurella","G"
"PSDP","Pseudoplexaura","G"
"PSPT","Pseudopterogorgia","G"
"TAPE","Tape","TWS"
"WAND","Wand","TWS"
"SHAD","Shadow","TWS"
NOTES,NOTES,NOTES
"ASP","Aspergillis","NA"
"BL","Bleached coral point","NA"
"BBD","Black Band Disease","NA"
"OD","Other disease","NA"
"PLA","Plague, Type II (White Plague, Type II)","NA"
"WBD","White Band Disease","NA"
"YBD","Yellow Blotch Disease","NA"

```

Due to the requirements of the associated Excel spreadsheets, the category TWS (Tape, wand, shadow) must be included as one of the coral categories, as well as the category "Coral". Additionally, every category must contain at least one member.

Blank boxes can be inserted within the coral code list to separate groups of coral codes. This is done by entering "Blank", "Blank", "Blank". These boxes appear solid black on the screen.

Appendix B. Supplementary material

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.cageo.2005.11.009](https://doi.org/10.1016/j.cageo.2005.11.009)

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