The National Marine Biological Analytical Quality Control Scheme
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Macroalgae and Seagrass % Cover Component Report –
OMC RT04 2013

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ALGAL COMPONENT REPORT FROM THE CONTRACTOR SCHEME OPERATION – YEAR 4 - 2013

1 Introduction

To enable correct water quality classification and good management decision-making, quality control of biological data is a high priority. This extends through all biological elements including macroalgae and seagrass. Good quality control ensures consistency of data being reported for management purposes, and for macroalgae and marine angiosperms this has been driven primarily by the requirements of the Water Framework Directive. This QC scheme aims to facilitate improvements in biological assessment whilst maintaining the standard of marine biological data. The scheme should help to ensure consistency between analysts with improved confidence in ecological quality status.

The National Marine Biological Analytical Quality Control (NMBAQC) Scheme addresses several issues relating to macroalgae and seagrass data collection, this report focuses on two of these:

- The estimation of % cover
- The comparison of methodologies

This is the fourth year in which % cover estimations of macroalgae have been included as an element of the NMBAQC scheme and the second year for which seagrass has been assessed as a separate entity. This included a single exercise for macroalgae and one for seagrass both of which were split into three smaller modules based on methodology. The format followed that of previous years (RT01 – RT03). Test material was distributed to participating laboratories from which data forms were completed with macroalgae and seagrass % cover results and returned for analysis.

Twelve laboratories were issued test material. Eleven laboratories completed the % cover macroalgae/seagrass component of the NMBAQC scheme with a total of 32 participants, one laboratory failed to submit any results. Of those laboratories submitting results, ten were government organisations and one was a private consultancy. To ensure consistency between scheme years, each participating laboratory was assigned the same laboratory code as in previous years except where a laboratory was new to the scheme. Individual codes may, however, change slightly due to variations in individual participants. Due to the nature of the exercise there was no limit on the number of participants per lab.

Laboratories were able to complete the % cover test that best represented the methodology used within their laboratory to allow comparisons of methodology. However, the laboratories were encouraged to complete all three variations of both the macroalgae and seagrass exercise.

Currently this scheme does not specify a definite qualifying performance level, and NMBAQC ring tests may be treated as training exercises. However, certain targets have been applied to the assessment of the results based on Z-scores allowing “Pass” or “Fail” flags to be assigned accordingly; these may be used by competent monitoring authorities for internal monitoring of performance. These flags have no current bearing on the acceptability of data from such participating laboratories. Ring tests offer a means of assessing personal and laboratory performance from which continued training requirements may be identified or from which improvements in current field and laboratory procedures may be addressed.

1.1 Summary of Performance.

This report presents the findings of the macroalgae/seagrass component for the fourth year of operation within the National Marine Biological Analytical Quality Control (NMBAQC) Scheme. This component consisted of one macroalgae and one seagrass exercise which was subsequently split into three alternative means of assessment which may be considered as separate modules from which laboratories could complete one or more module.

The analytical procedures of the exercise remained consistent with previous rounds of the scheme (OMC RT01 – RT03). The results for the exercise are presented and discussed with comments provided on the overall participant performance.

Two sets of fifteen quadrat photographs consisting of various % covers of opportunist macroalgae and seagrass were used for the exercise. These sets of photographs were duplicated to produce the three separate modules incorporating the different assessment methods utilised by the various participating laboratories. The set of quadrat photos differed by the use of grid squares of varying quantities; open quadrat, 10 x 10 square grid and 5 x 5 square grid. Each photo represented natural levels of opportunist macroalgae and seagrass cover.

Results for % cover of both opportunist macroalgae and seagrass varied between participants and between the different methods used. A number of results deviated from the sample mean and from the % cover as calculated by image analysis. However deviation from the latter was more noticeable. There was a much higher range of results submitted for seagrass which appears to be more difficult to estimate % cover and may be attributed, in part, to its patchy nature. Although there was a slight preference for using method B (10 x 10 square grid) for the macroalgae this was not apparent with the seagrass. It was also noticed that method B for both macroalgae and seagrass resulted in the greatest number of 'Fails' due to overestimation of % cover.

2 Summary of Macroalgae Component

2.1 *Introduction*

There was one exercise for the assessment of % cover of macroalgae and one for seagrass, which took the form of three separate methodology options. This exercise is described in full below to include details of distribution and logistics, procedures for estimation of % cover, completion of test result forms and full analysis and comparison of final submitted results.

2.2 *Description*

This exercise examined the participants' ability to accurately estimate various levels of opportunist macroalgae and seagrass % cover. The exercise is able to determine the level of inter-laboratory variation and the degree of deviation from % cover estimations as calculated using image analysis software. It identifies areas of significant error, problematic coverage or mis-use of grid squares for aiding with estimations.

Three sets of 15 representative macroalgae and seagrass quadrat photos were distributed to each participating laboratory in January 2013. Participating laboratories were required to estimate the % cover of the opportunist macroalgae and seagrass using one or more of the methodologies provided. The nature of the photos was consistent with those provided for RT03 with the two overlying grid systems. Opportunist algae consisted of species of Ulva (previous known as Enteromorpha) and seagrass was identified as *Zostera noltii*.

2.3 *Logistics*

The test material was distributed on CD to each laboratory. Each disc contained the six tests, description of methods and data submission forms. Participants were given a month to complete the test and return the results, this was later extended to six weeks due to late subscriptions. There were no restrictions on the number of participants per laboratory.

Email has been the primary means of communication for all participating laboratories subsequent to the initial postal distribution of test material.

2.4 Preparation of the Samples

In order to assess the accuracy of determining % cover of opportunist macroalgae and seagrass, photographs were taken of quadrats overlying varying degrees of algae cover. In total 15 representative photographs of both macroalgae and seagrass were taken by Wells Marine for the purpose of this exercise. Each photograph was ground truthed at the time of collection with additional drawings of areal coverage produced on a grid scale to ensure % cover could be accurately determined subsequent to field analysis and during image analysis.

The two sets of 15 photographs were adapted to produce three tests of each component that utilised different methods of % cover estimation.

2.4.1 Method A

Method A was an open quadrat, this method allowed the analyst to estimate the percent cover in a $0.25m^2$ quadrat without visual obstruction or assistance from gridlines. A general estimation is conducted looking solely at the total area within the quadrat that is clearly covered by the opportunist macroalgae or seagrass.

2.4.2 Method B

Method B consisted of a 9 x 9 crosshair quadrat. This method splits the quadrat into 100 squares. The crosshair referred to the point at which the lines cross and within a 9 x 9 grid amounts to a total of 81 crosshairs. The method of cover estimation was achieved by recording the presence or absence of algae/seagrass under each of the crosshair points. Where present this was recorded as 1 and absence was recorded as 0. The number of cross hairs with algae/seagrass present was divided by 81, and then multiplied by 100 to give a percentage.

2.4.3 Method C

Method C split the $0.25m^2$ quadrat into 25 squares with each square representing 4% of the total quadrat. The percent cover was estimated by counting the number of squares, to the nearest half square, that were covered by macroalgae/seagrass. Completely covered squares were counted as one each. Between 50% and 100% cover in individual squares was estimated to the nearest quarter and these portions were summed. For quadrats with sparse macroalgae cover (i.e. always < 50% cover per square) the participants accumulated the small portions of algal coverage (totalling to the nearest half square). The number of squares was divided by 25 and then multiplied by 100 to give a percentage.

2.5 Quadrat image analysis

An image analysis programme called ImageJ was used to achieve a more precise measurement of % cover which could be compared with the traditional means of assessment. The photographs were opened within the ImageJ program which distinguishes contrasts in colour/tone and is therefore able to compare the colour of the macroalgae against the background substrate. Prior to analysis the images were modified within photoshop to ensure a substantial colour contrast and enable the program to pick up the differences. ImageJ converts the colour image to a greyscale which is later changed into binary form to highlight the thresholds. The entire quadrat is calibrated against a known measurement scale from which the highlighted area can be spatially analysed. A percent cover is calculated using the area of macroalgae cover against the area of the quadrat as calibrated in ImageJ. These percentages were used as a comparison against the skilled eye estimations as submitted by the participants.

A full, impartial image analysis comparison was sought as part of the QC exercise. This was previously attempted using GIS but it was thought that this method did not provide a fully independent analysis of % cover. ImageJ is thought to be less subjective providing a more accurate analysis based on colour/tone contrast. Image analysis has been conducted to demonstrate how the comparisons would work, but may require further modification and discussion as to its applicability and accuracy, therefore cannot be taken as a finite measure of % cover.

2.6 *Analysis and Data Submissions*

A prepared results sheet was distributed with the exercise instructions to standardise the format in which the results were submitted. Each participant had the option of completing the test which most represented their own procedures but all participants were encouraged to complete all three tests of both macroalgae and seagrass to enable a comparison of methodologies and levels of accuracy achieved within each.

For each test the participant had to estimate the % cover of opportunist macroalgae/seagrass species only, excluding any additional species that were present within the quadrat and that were not considered to be either of these types of species. The assessment included a large degree of variation in % cover to represent the full range experienced within the field.

Spreadsheet based forms were distributed with the test material to standardise the format in which the results were submitted. These results will be retained and stored appropriately.

2.7 *Confidentiality*

To preserve the confidentiality of participating laboratories, each participant is allocated a four digit laboratory code from which they can identify their results. These codes are randomly assigned. The initial letters (MA) refer to the scheme this is followed by the scheme year which refers to the year in which the NMBAQC scheme original commenced, the final two digits represent the laboratory. For those laboratories where multiple submissions were provided the four digit code is followed by a letter allocated to each participant of that laboratory. For example, participant c from laboratory twelve in scheme year twenty will be recorded as MA2012c.

2.8 *Results*

The results have been analysed using a number of different approaches to compare the results between participants, between the three different methods of estimation and to compare against ImageJ calculated % cover estimations for both macroalgae and seagrass.

2.8.1 General Comments

In total twelve laboratories signed up for the % cover component of the macroalgae/seagrass element for RT04. Eleven laboratories returned data; one laboratory did not supply data or communicate their abstention. Of those laboratories that did submit data 18 completed method A, 24 completed method B and 11 completed method C for the macroalgae component. For the seagrass component 22 completed method A, 14 completed method B and 11 completed method C. Seven participants completed all three macroalgae and seagrass methods. The results have been collated and represented in various formats to enable full comparisons between participants and against % cover as calculated by the image analysis.

Details of each participating laboratory performance were distributed in the macroalgae OMC RT04 Bulletin Report and the seagrass OMC RT04 Bulletin Report, which represent a summary of the results for RT04. The Bulletin provides 'Pass' and 'Fail' flags to each data set to highlight deviation from sample mean and actual results. Values of Z-scores were used to apply the 'Pass' and 'Fail' assessment.

Z-scores, calculated to indicate the level of deviation of % cover, used the following formula:

$$Z = \frac{X - \mu}{\delta}$$

x is a raw score to be standardized;

μ is the mean of the population;

σ is the standard deviation of the population.

Z-scores were calculated using the mean % cover and the image analysis % cover. A Z-score value of greater than +/- 2.0 was considered to be outside an acceptable limit of deviation from the mean. This value is considered standard practice and was used assign a 'Fail' or 'Pass' flag on the data.

2.8.2 Macroalgae Results from Participating Laboratories

2.8.2.1 Test A Results (open quadrat)

Test A consisted of 18 participants and was the second most popular of the three methods. The range of results per quadrat varied considerably with the largest range of results produced for quadrat 1, with a range of 40% from 8% to 48%. Quadrats 2 and 8 also had a range of 35% with between 25% and 60% cover and 40% and 75% cover recorded respectively. The smallest range was for quadrat 11 from 3% to 11%, the remaining quadrats had % cover ranges of between 15 and 28. Z-scores calculated against the population mean resulted in four laboratories failing just one quadrat and one laboratory failing 8 quadrats. In total there was a 95% pass rate for test A when using Z-scores derived from the mean.

The deviation from % cover as calculated using ImageJ was much greater than seen when using the population mean. Most participants showed an average % cover deviation from image analysis % cover ranging between 3.67% and 12.28%. The pass rate was equally much lower using Z-scores derived from image analysis estimates of % cover with 15 out of 18 labs failing at least one quadrat. The overall pass rate was lower at 87%. Mean % cover for quadrats 3 and 9 showed the highest degree of deviation from % cover as calculated from image analysis.

2.8.2.2 Test B Results (9 x 9 crosshairs quadrat)

Test B had the greatest number of participants with 24. As with test A there was a greater degree of correlation of % cover against population mean compared with the image analysis. A total of 62% of labs (15 out of the 24) consistently produced Z-scores of less than 2.0, which is regarded as a 'pass'. The remaining 9 labs failed between 1 and 3 quadrats. The largest range of % covers per quadrat was a range of 30.9% cover recorded in quadrats 6 and 14. The lowest range of % cover estimates was for quadrats 3 and 4 differing considerably from the results seen in test A.

Consistent with test A, test B also showed a higher degree of deviation from the image analysis results compared with the population mean, with all 24 laboratories failing at least two quadrats and an overall pass rate of only 64% compared with a pass rate of 96% using Z-score from the population mean. Laboratory MA2018b had the greatest number of 'fails', a total of 11 for comparisons against % cover from ImageJ. Method Balso resulted in the highest level of deviation from % cover as calculated by ImageJ.

2.8.2.3 Test C Results (5 x 5 gridded quadrat)

A total of 11 participants opted to complete Test C using the 25 square method with varying levels of deviation from the population mean. This was the least popular of the estimation methods. The results verified that as with the other two test methods there was a higher degree of deviation when comparing results against the image analysis % cover as opposed to population mean.

The average range of percent covers per quadrat was 18% with quadrat 10 producing the highest range of 39%. Only two laboratories failed at least one quadrat using Z-scores from the mean with between 1 and 4 failures and an overall pass rate of 97%. There were also more 'Fails' using Z-score from image analysis with between 1 and 9 'Fails' per lab with only two lab receiving no 'Fails', and an overall pass rate of 82%.

2.8.3 Seagrass Results from Participating Laboratories

2.8.3.1 Test A Results (open quadrat)

Test A had the greatest number of participants with a total of 22 participants opting to complete the open quadrat method, resulting in varying levels of deviation from the population mean. The range of results submitted per quadrat varied more considerably than with the macroalgae test. The largest range was for quadrat 12 with % cover estimates ranging from 20% to 70%, other quadrats had similarly large ranges of between 40 and 45 for quadrats 2, 6, 8, 9, 10 and between 30 and 35 for quadrats 1, 3, 4 and 15. The smallest range was for quadrat 14 from 1% to 10%. Z-scores calculated against the population mean resulted in four laboratories failing between 1 and 5 quadrats. In total there was a 97% pass rate for test A when using Z-scores derived from the mean.

When comparing results against % cover as calculated using ImageJ, the number of 'Fails' per laboratory was greater with a total number of 41 'Fails' (88% pass rate) distributed over 13 of the 22 labs. The average deviation of results from ImageJ % cover per lab ranged from 4.01 to 18.63. Quadrat 10 appeared to be the most problematic, with the greatest number of 'Fails', 11 in total, and the greatest mean deviation from ImageJ % cover of 17.17.

2.8.3.2 Test B Results (9 x 9 crosshairs quadrat)

Test B consisted of 14 participants. This test followed the same trend as the other tests for both macroalgae and seagrass with comparisons against image analysis resulting in a greater number of failures using the Z-score than when comparing against mean % cover. The range of % cover values showed the same level of variation as described for test A with a 10 quadrats having % cover ranges in the order of between 30% and 52% indicating a high level of discrepancy between labs. Quadrat 15 had the largest range of between 28% and 80%. Comparing against mean % covers resulted in a total of 8 'Fails' distributed between 4 labs with a pass rate of 97%. In comparison the total number of

'Fails' using ImageJ was much higher at 42 and was distributed among 11 laboratories. Three labs had 100% pass rate. The overall pass rates using ImageJ was 83%. The level of deviation was also quite high at 10.89 twice as much as seen in test A.

2.8.3.3 Test C Results (5 x 5 gridded quadrat)

Test C had the least number of participants with only 11 choosing to use the 25 squared quadrat method to estimate % cover. These results were also more consistent between the two methods of comparison with population mean resulting in a pass rate of 95% and image analysis resulting in a pass rate of 95% indicating a greater level of consistency than with any other test. The range of results for each quadrat was not as high as seen with the other two methods however due to a particularly lower % cover for quadrat 7 from one lab this had a range from 10% to 98%. Quadrats 5 and 14 had the lowest ranges; this was also found when using the other two methods of % cover estimation (tests A and B).

Four laboratories failed at least one quadrat using Z-scores from the mean with each of these resulting in between 1 and 5 failures. The majority of 'Fails' could be attributed to one laboratory. There were also more 'Fails' using Z-score from image analysis with a total of 14 'Fails', seven of which were attributed to a single lab. Test C had the lower level of deviation from % covers as calculated from image analysis.

2.9 Discussion

The % cover of opportunist algae in a ¼ m^2 quadrat is usually estimated based on a skilled eye observation using either an open quadrat or gridded quadrat with +/- 5% agreement. It is highly unlikely that this method of % cover estimation is 100% accurate due to the subjectivity of individuals. OMC RT04 has used the population mean and an image analysis method to calculate a more precise % cover for comparison with individual participants' records. There are difficulties in obtaining 100% accuracy for % cover of opportunist algae or seagrass; however using the image analysis method should provide a lesser degree of subjectivity than skilled eye estimation. The ImageJ program is able to select areas of cover based on the colouration, identifying by depth of colour. Each of the quadrat photographs is enhanced prior to analysis using photoshop to ensure maximum contrast between algae and substrate by selecting the areas of algal coverage and in this instance converting to a black and white scale. Once the two distinct colours have been identified within the ImageJ program it is able to calculate the total area covered thus reducing the degree of subjectivity experienced with skilled eye evaluations. During this fourth round of the macroalgae scheme photographs were also ground truthed against actual presence of algae within the field to ensure the area of algae could be accurately identified within each quadrat thereby ensuring full calibration of the photographs.

Z-scores were used to establish a level of acceptance for results submitted by participants. These z-scores used both the mean % cover per quadrat and the % cover as calculated by ImageJ. The results could then be compared between laboratories and between method of cover estimation for both macroalgae and seagrass. The results generally show a higher level of consistency between participants when comparing with the population mean. This was apparent across all tests for both macroalgae and seagrass. In conjunction with this there were a greater number of Z-scores failures when comparing the image analysis % cover with the population mean of the quadrats. This is consistent with previous years. This indicates either a lack of accuracy in % cover estimations or inaccurate % cover results produced using ImageJ. The benefit of comparing participants' results against the mean is that it fully represents the range of results submitted and this is not the case for the ImageJ results. However the image analysis represents a less subjective % cover value.

The overall range of results submitted is still highly variable with some quadrat results ranging in excess of 80% indicating a high degree of participant error. For some laboratories this was more noticeable than others, Lab MA2010 produced the largest deviation from both mean and image analysis for seagrass quadrat 7 (test C). Since the % cover estimation was so far from the actual cover it is questionable whether this was an unintentional mistake especially as other results from this lab showed little deviation. The level of success rate for individual laboratories was also not consistent between tests with the greatest number of 'Fails' for each test being attributed to different labs. This provides further evidence that different methods of % cover estimation provide varying levels of success for the different participating labs, making it difficult to conclude which method is the best in terms of producing the most accurate result. It seems this is highly dependent upon the lab.

The degree of deviation from the image analysis % cover value depended significantly upon the quadrat. Some quadrats were more problematic than others and this was consistent with the range of % cover and could be partly attributed to the more patchy coverage of opportunist algae in some quadrats which is much harder to accurately estimate. It is evident, as in previous years, that those quadrats with a mid percent cover from between 25% and 75% generally resulted in a higher levels of deviation (Figures 1 and 2) with less consistency between labs. Those quadrats with either a very high or low percent cover appeared much easier to accurately estimate total cover. This was consistent across both seagrass and macroalgae. This trend was most significant within the seagrass tests.

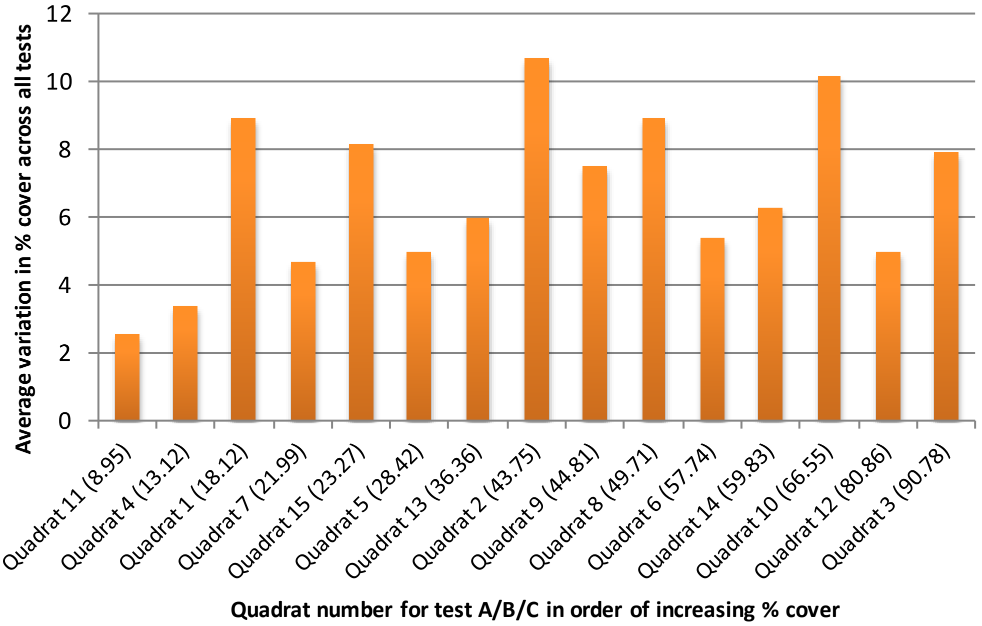

Figure 1: Average deviation from % cover of macroalgae as estimated using ImageJ

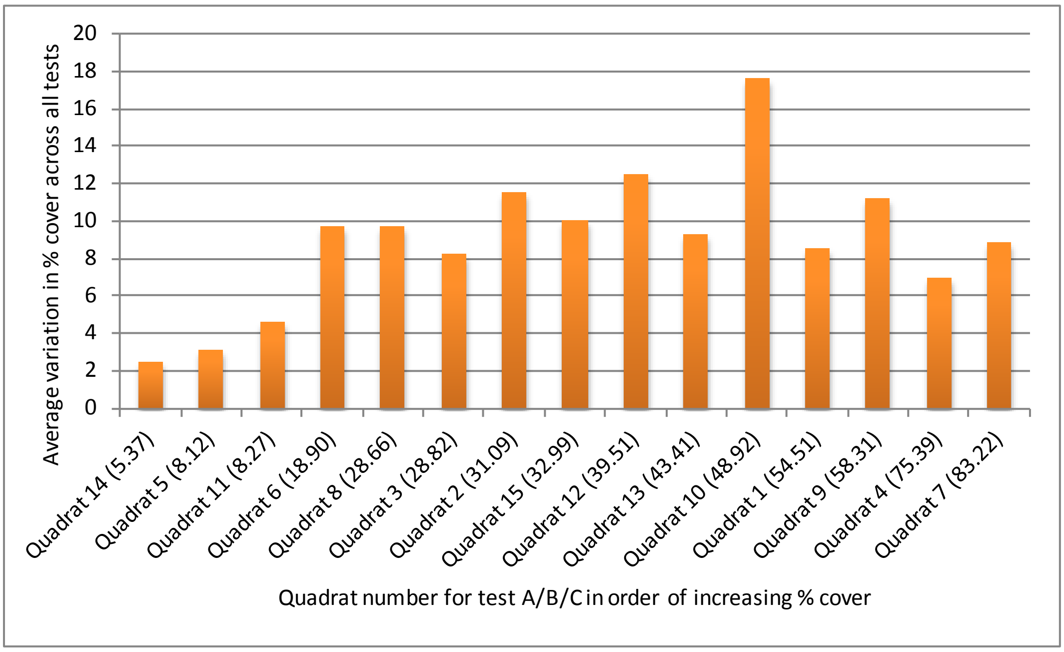

Figure 2: Average deviation from % cover of seagrass as estimated using ImageJ

There was some difference between method of estimation used. The seagrass showed fewer 'Fails' in test C when comparing against Z-scores from ImageJ, but this was not apparent when comparing Z-scores from population mean which was more consistent across tests. In contrast test A produced the most favourable results for macroalgae when comparing Z-scores from ImageJ. There was little difference in the levels of pass rate and number of 'Fails' between tests using Z-scores from the population mean. In general the pass rate using Z-scores against image analysis showed a much higher number of 'Fails' in Test B this was evident for both seagrass and macroalgae. Comparing the average % covers across all quadrats for each of the tests (Table 1) shows that test B results in a higher % cover than for the other two tests. This suggests that this method is over estimating the actual % cover. This is also seen in the level of deviation from the image analysis results which again is much higher compared with the other methods of % cover estimation.

Table 1: Mean % cover and deviation from image analysis % cover for tests A, B and C for Macroalgae and Seagrass.

	Test A		Test B		Test C	
	Mean % cover	Deviation from image analysis	Mean % cover	Deviation from image analysis	Mean % cover	Deviation from image analysis
Macroalgae	42.0	4.5	49.8	7.6	41.8	4.2
Seagrass	42.86	5.16	48.59	10.89	38.7	3.8

The preferred test method differed between macroalgae and seagrass, with a range of participant numbers for all 6 tests although test B for the macroalgae component had the greatest number of participants, consistent with year nineteen (OMC RT03). Most noticeable was the lower number of laboratories acquiring at least one 'Fail' for the seagrass quadrat than for the macroalgae quadrat and there was a greater level of agreement between participants' results and ImageJ results. There is no real explanation for this; it is possible ImageJ responds better to the seagrass cover then macroalgae cover. However, the range of results was also much high for seagrass than for macroalgae, indicating a higher degree of variability between participants. Seagrass is a lot patchier than macroalgae and can be much harder to estimate % cover, therefore the higher range of results contributing to an overall higher standard deviation would lessen the risk of achieving a 'Fail', based on the Z-scores.

3 Conclusions and Recommendations

1. There is evidently still a high degree of error between tests as well as between participants and this may prompt the need for a specific workshop whereby methods may be discussed and possibly % cover estimations compared in the field. It is not possible from the current ring test to conclude which % cover estimation method provides the most accurate results, however it is evident through the number of participants that Test B is the most favoured method for macroalgae and Test A for seagrass.

2. The image analysis method used during RT04 is considered more objective than skilled eye estimation and likely to produce a more accurate results, RT04 also incorporated ground truthing to pick up subtleties of variations in cover within the defined affected area. However, this method is still under development and will continue to undergo improvements prior to the next round of tests. Despite this round incorporating a fully classified and ground truthed image analysis method with more accurate results it is recommended at this time that participants should use the Z-scores derived from comparisons with the mean if they are required for internal quality reports.

3. During this fourth cycle of the macroalgae % cover exercise all participating submitted results within the designated timescale. All laboratories should continue to submit results within the requested deadlines as detailed at the beginning of the exercise. In subsequent years reminders will continue to be distributed prior to the completion of the exercise.

4. There are still some issues over the timing of the test and there are suggestions that the time allowed for completion of the test should be extended to accommodate increased workloads. Although this is still the most appropriate time of year to complete the tests, a longer time scale within which to complete the exercises would allow more laboratories to complete all three methodologies for both the seagrass and macroalgae. Consideration will be given to extending the time period to six weeks to ensure ample time for completion.

5. It is accepted that during field sampling it may be possible to estimate % cover of opportunist algae with a higher degree of accuracy. The nature of the photographs can produce difficulties when assessing the density of the algae and the presence of some shadows and the grids can hinder this further. In subsequent test consideration will still remain over the collection and selection of photographs for the exercise. However, it is to be noted that many seagrass beds remain waterlogged regardless of tidal height. It is equally accepted that sometimes it is difficult to accurately count algal cover when obscured under cross hairs, this would not be an issue in the field, but cannot be prevented within the test, therefore it remains important to include the open quadrat test method for a full view of the quadrat. Thought will be given to making the grid lines sharper or thinner. There was no comment this year over the range of % covers included in the test so it is assumed that these were more acceptable.

6. This year there was good approval on the current methods of estimation used and the descriptions provided, therefore no further methods will be considered at this time for future tests. The methods that are currently included within the ring test were those considered to be most frequently used. It is agreed that where laboratories use alternative methods such as subtidal quadrat % cover estimations these methods may not accurately represent their commonly used procedures. However, by completing all three methods for both seagrass and macroalgae it is still possible to compare results with other laboratories in order gauge the level of accuracy.

7. As many laboratories take quadrat photos whilst estimating % cover for in house quality control, it has been suggested that a reverse ring test could be included in the % cover component. This would enable laboratories to submit their own quadrat photos for analysis. This still remains to be discussed for inclusion in future ring tests.

If anyone has further thoughts on this, or disagrees with any of the interpretation, please pass forward your comments to Dr Emma Wells (emma@wellsmarine.org) or Dr Clare Scanlan (clare.scanlan@sepa.org.uk). This ring test is now in its fourth year and although it has general approval we are still very happy to receive feedback particularly suggestions on how it may be improved.