Spatial Configuration of Eelgrass in Studland Bay: a Reappraisal of Report NECR111_part_2

by M.J.Simons, October 2013

Summary

The imagery used in report NECR111 part 2 is examined in detail to test claims about the extent and "fragmentation" of the eelgrass in a historical series. The basis for the claim of a declining area trend in the most recent (2008) image is the classification of large areas of an earlier image as showing "sparse seagrass", although it is noted that another page in the same report shows those areas as sand. Close examination of the aerial images showed the areas to be sand, possibly mis-classified because of the blue-green colour of the water above the sand. On this basis, the trend in area is actually increasing.

One computer-derived metric (out of five) showed an implausibly low value for "Core Area" of the eelgrass, leading to claims of recent "fragmentation". Close examination to pixel level of the images showed no evidence of high levels of fragmentation, indeed the 2008 images show greatest eelgrass area and least fragmentation in the whole historical series. Evidence is given that the low "Core Area" value arose from a system artefact, and that the computer analysis was simply measuring the speckle pattern of image noise, and not the configuration of the eelgrass at all. We conclude that claims of declining area and increasing fragmentation are spurious and invalid.

Introduction

This report examines aspects of the report by JACKSON, E.L., GRIFFITHS, C.A., COLLINS,K. & DURKIN, O., 2013, *A guide to assessing and managing anthropogenic impact on marine angiosperm habitat - Part 2: Studland Bay vulnerability assessment*. Natural England Commissioned Reports, Number 111, referred to hereafter as NECR111. **(1)**

It is a wide-ranging work which examines many aspects of the seagrass *Zostera marina,* or eelgrass, habitat in Studland Bay.One particular aspect which has caught the attention of some conservationists is a claim that the eelgrass habitat is undergoing increasing fragmentation. To cite from the Executive Summary, pp iv and v,

"**despite having the largest area of dense seagrass, 2008 shows a low total coverage of seagrass and the lowest total core area, an indication of the increase in fragmentation of the seagrass within the core area and a trend now moving towards a degrading habitat.**"

It is the purpose of the current paper to examine the truth or otherwise of that statement.

Methodology

The author is grateful to C. A. Griffiths for providing copies of the original aerial images and the corresponding "classified" images of the moorings area, as used in NECR111. This followed a Freedom of Information Request through Natural England.

The approach is straightforward. A number of conclusions in The Report come from relatively complex computer operations on the original data. Here, we simply examine the images at appropriate magnifications to see if they are indeed compatible with the derived computed metrics. This is done against the author's background in imaging science acquired during his extensive professional career in the Kodak Research Laboratories. In addition, questions are raised about the fundamental validity of some of the processing steps in NECR111.

Issue 1: "2008 shows a low total coverage of seagrass"

This claim comes from the following text and figure in NECR111, p.58:

"1.115 Figure gives the area (ha) of each seabed type within the mooring area for the different years examined. According to this analysis, dense seagrass was at its highest in 2008 (19ha), although total seagrass (including sparse seagrass cover) was greatest in 1997 (27ha), when coverage in the area appears to be purely seagrass (i.e. no bare patches of sand). Comparisons should be made with caution however as the aerial photographs differed in terms of quality and the classification was not ground truthed."

This is reproduced as Figure 1, below.

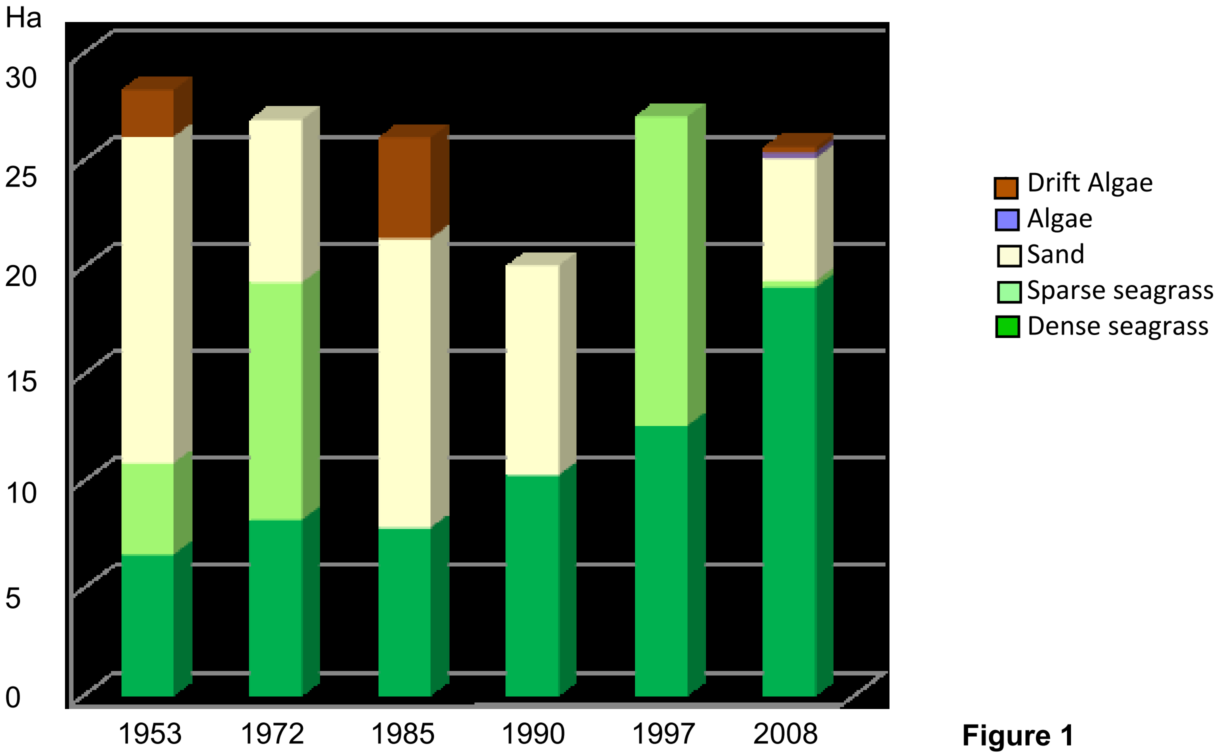


Figure 1

In NECR111 the areas of dense seagrass, sparse seagrass, sand, etc. were calculated from a classification process in which each class was identified by its spectral properties (i.e. colour). NECR111 does not follow normal scientific convention by detailing the process in enough detail that others can replicate it, indeed detail is sparse. We quote from p.4:

"In addition, seven photographs taken in 2008 were selected for analysis of the extent and configuration of seagrass in the entire bay. Image analysis involved classifying habitats (by grouping image pixels with similar spectral properties). This unsupervised classification was then ground truthed using a drop down camera and towed video during March 2012."

An accuracy assessment for eight photographs covering the Bay is given on p. 48 of NECR111. In three cases the accuracy estimate was in the range 0 - 20%, in one case 21 - 40%, one case 41 - 60%, two cases 61 - 80%, and in just one case 81 - 100%.

These are low confidence figures by any standards. The process appears to have been calibrated on the basis of the 2008 photographs. However the 1997 image varies substantially from the 2008 images in ways discussed below, and the spectral properties of any particular class are likely to be substantially different. The accuracy will be lower, indeed it is questionable if the process is valid at all for the images from before 2008, and even more so for the images from 1985, 1972 and 1953 which are black and white and can contain no spectral data.

The 2008 images were captured by digital camera with a relatively small field of view, requiring eight fields to cover the Bay. The 1997 image was on colour reversal film, subsequently digitised by scanning, and the one wide field covered most of the Bay. The resolution of the images varied, and was estimated by observing the finest detail visible in each case (subjects above water). The 2008 finest resolution was estimated at 0.2 m, and the 1997 image at 1 m .

It is important to note that the spectral responses of the two imaging systems will differ. In the case of a digital camera the spectral responses of the sensor are defined by the colour filter array on the sensor chip and the spectral responses of the output image by the image processing employed. In the case of film, the sensor's spectral response is determined by the sensitising dyes in the film moderated by filter layers, and the output image by the spectral curves of the image dyes which are then read by a scanner and subject to image processing. It would not be safe to assume that the ratios of the r,g and b (red, green, blue) outputs from a given r,g,b input would be exactly the same for the two systems, so it would not be safe to assume that the classification results, which rely on the exact r,g,b ratios, would be the same either. Further, the actual images for the two years are very different beyond the difference in resolution: the 2008 image has low colour saturation and image contrast, the 1997 image has high saturation and contrast. This is shown in Figure 2, in which similar fields of view from the two images are compared. The only adjustment to the images as received are cropping and re-sizing, and adjustment of resolution to an appropriate file size.

Figure 2

Left, 2008 image

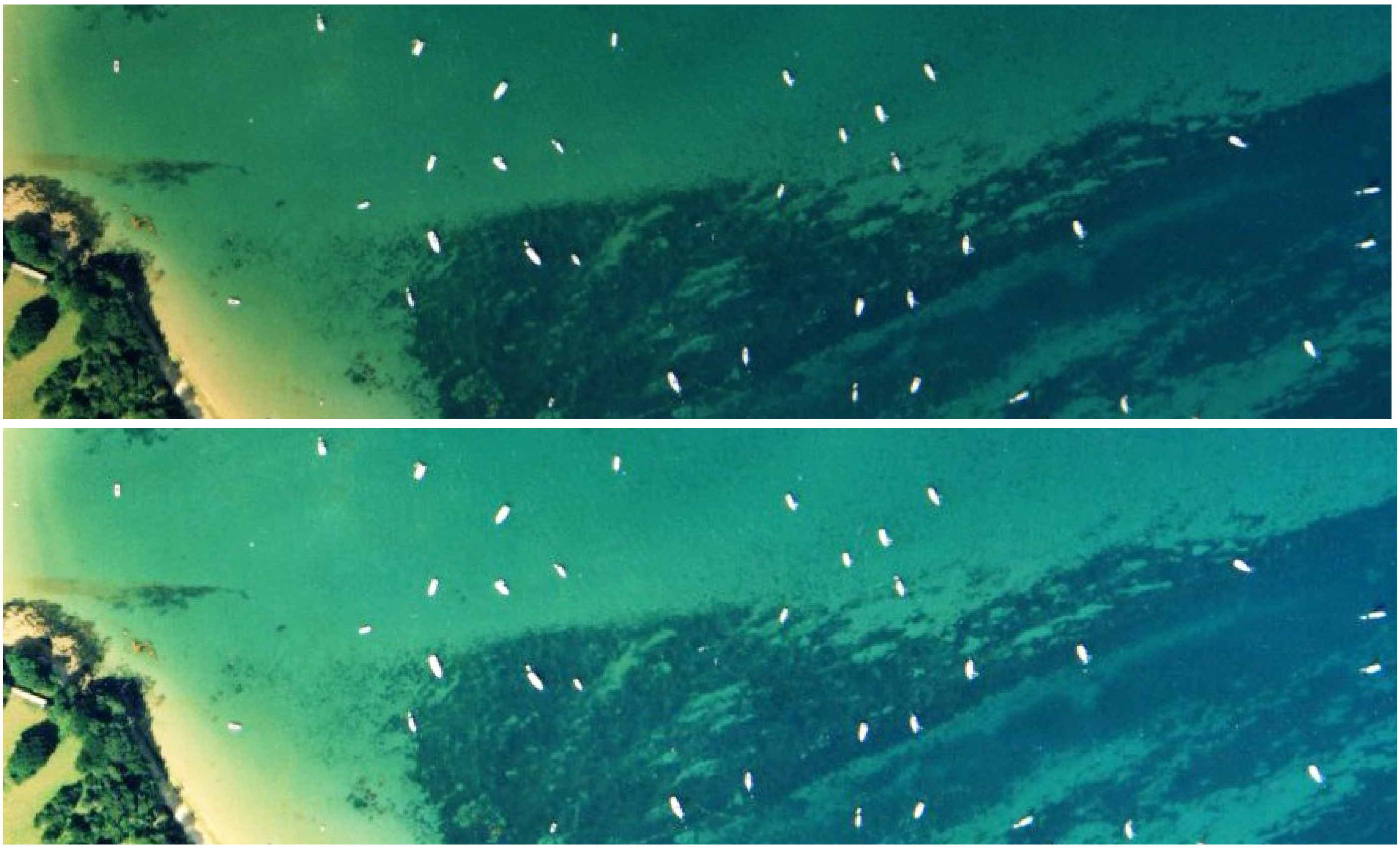
Right, 1997 image

Clearly the two images differ widely. If the trees in the left foreground were to be classified on the basis of their apparent spectral properties, one would conclude that they must be entirely different species.

It is also worth noting that the 2008 image appears to have substantially greater eelgrass cover.

To explore this issue further, Figure 3 shows the top edge of the dense eelgrass field in the 1997 image in greater detail, both at the native image brightness and with increased brightness to reveal more detail.

Figure 3



To the untutored, and indeed the tutored, eye, these images would seem to show Redend Point at the left, a strip of sandy beach, and a sandy bottom shelving out to sea. There are areas of dense eelgrass, with sandy gaps running diagonally up and to the right, and round the edges are wispy areas of sparse eel-grass. And boats, of course.

However, NECR111 explicitly reports on p.58, both in the text and in their fig. 36 (our Fig. 1) that there is no sandy bottom at all in the 1997 aerial image, everything in the area considered which is not dense seagrass being classified as sparse seagrass, leading to a an unusual and unlikely configuration of eelgrass in which there are no unvegetated patches at all.

The explanation of this apparent conflict would seem to lie in two factors. Firstly, the 2007 imaging system is producing more saturated (more intense) colours than the 2008 one. Second, NECR111 appears to ignore the need for water column correction. It is widely known that water attenuates red light more than green light more than blue light, so with increasing depth the colour of objects becomes increasingly green-blue. In the case of aerial photography, the light makes a double passage from surface to seabed and back again, so the effect is doubled. Further, these effects may be increased by suspended matter in the water - if micro algae are present, the water will give an enhanced green colour with depth. Such effects are discussed for example in a UNESCO document on “The Acquisition, Correction and Calibration of Remotely Sensed Data” **(2)**, and water column correction was used by Jackson et al in a study of eelgrass in the Scillies **(3)**. The images in Figure 3 clearly show the water column effect in action, the sand being yellow on the beach and appearing greener in hue as the water gets deeper.

We conclude that the images do show extensive areas of sand whose apparent colour is modified by the water column effect enhanced by the high contrast and saturation of the imaging film, and that the “classification” in NECR111 has mistakenly identified the apparent colour of the sand as sparse seagrass.

We therefore conclude that the statement on p v of NECR111 that the 2008 image “shows a low total coverage of seagrass” is erroneous, and the claimed high total coverage in 1997 results from mis-identifying sand as sparse seagrass.

Bizzarely, our view is supported on p. 52 of the same NECR111, in fig. 32, which clearly identifies the areas between the dense seagrass as sand, not sparse seagrass. The classification maps for 1997 and 2008 used in NECR111 fig. 32 are reproduced here as Figure 4. The label and the colour coding unmistakably identify yellow areas as sand.

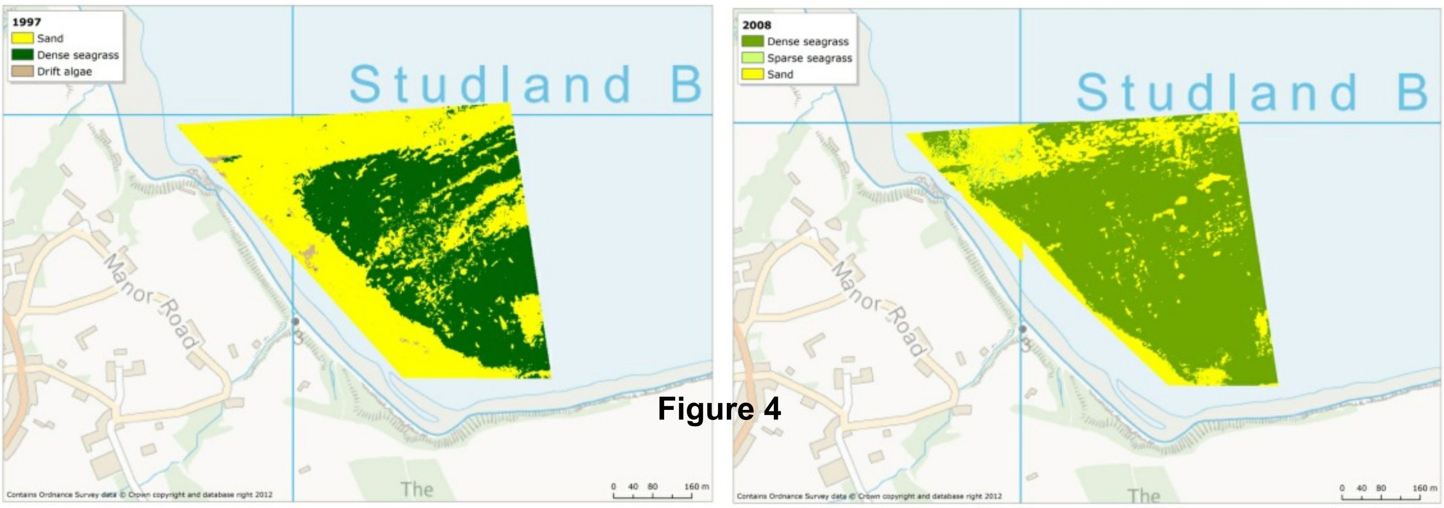


Figure 4

The fact that different pages, pp 52 and 58, of the same report, NECR111, identify the same (yellow) areas first as sand, then as sparse seagrass, raises serious questions over the integrity of the report and the classifications used. In view of this, and of the clear aerial photographic evidence, we conclude that the 2008 imagery in fact shows the **greatest** total area of seagrass in the historic series, and that its description as “**a low total coverage of seagrass**” on p v of the Executive Summary of NECR111 is seriously in error and positively misleading.

(Note: while the bar for the earlier1972 aerial image in Figure 1 reports a substantial amount of sparse seagrass, and hence a similar total area to 2008, examination of the low resolution black-and-white aerial image employed suggests there is not adequate information in the image to make such an assessment, i.e. that it is sparse seagrass rather than sand, with any confidence whatsoever. The image presents no evidence that the lighter-coloured areas of seabed are anything other than sand).

Issue 2: "2008 Shows the Lowest Core Area

" - an indication of the increase in fragmentation of the seagrass within the core area and a trend now moving towards a degrading habitat."

NECR111 states that a number of spatial configuration metrics were measured using FRAGSTATS software on the dense seagrass class metric. They are as shown below, in Figure 4. Four out of five show 2008 as having the highest level of aggregation. One, Total Core Area, shows 2008 as being the *least* aggregated, or as the text suggests, the most fragmented.

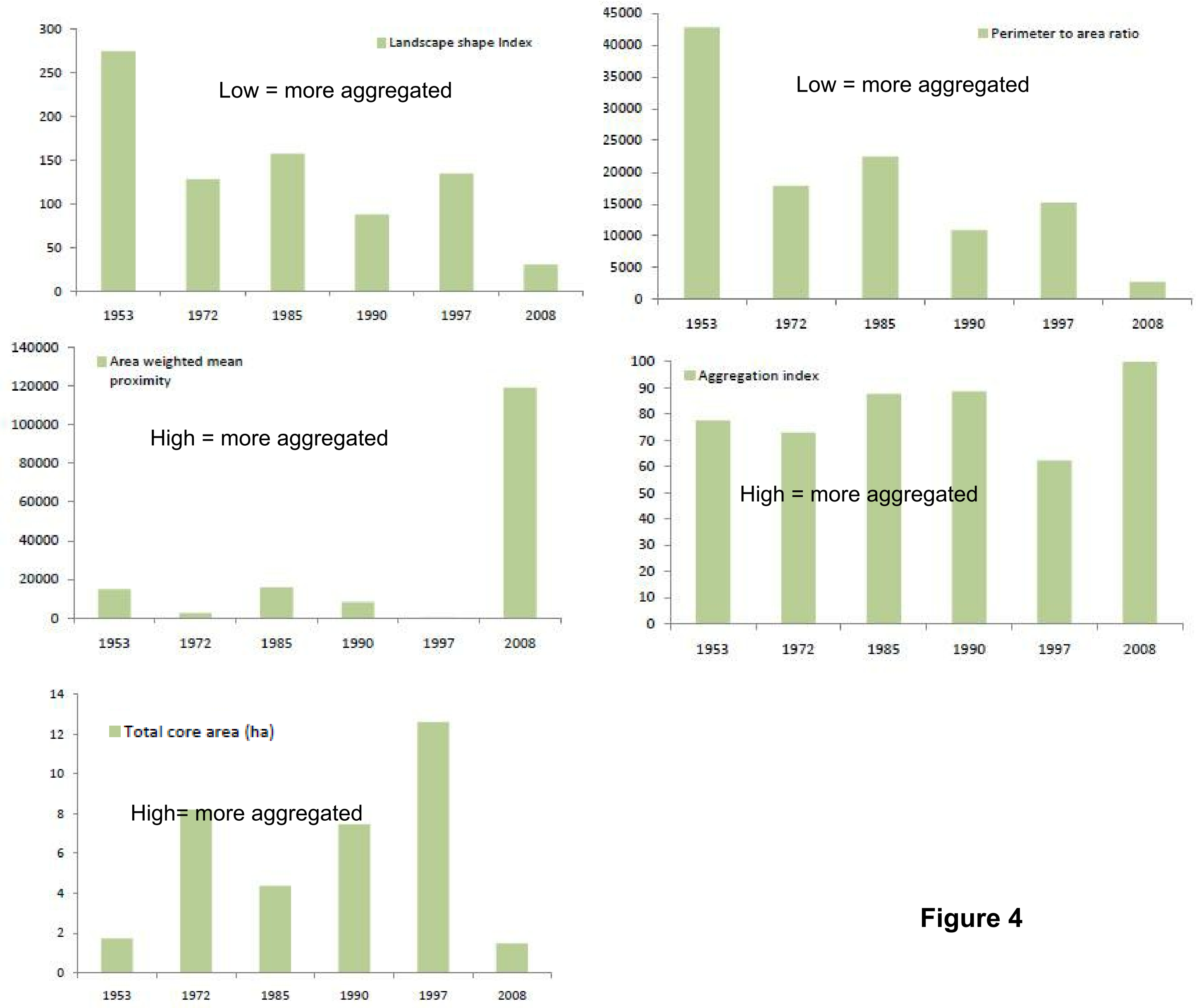


Figure 4

Total Core Area is defined as the total area of dense seagrass occurring more than 0.5 m from a patch edge. The total area of dense seagrass was shown in Figure 1 to be 18 ha, but the total core area in Figure 4 is 1.6 ha. Therefore, according to these findings, 16.4 ha, some 90% of the dense seagrass in the 2008 aerial image must be within 0.5 m of a patch edge. That is nine parts out of ten of the seagrass being within 0.5 m of an edge, a topography which is hard to visualise.

This Core Area metric, which is simply a number coming from a complex set of computer operations, is in direct conflict with the other four metrics, it shows a remarkable reversal in historic trend as shown by the bottom left diagram in Figure 4, and is physically implausible anyway. Further there have been no reports from observers in Studland Bay of any such dramatic change in the topography of the eelgrass - the area is regularly explored by divers. NECR111 fails to discuss or provide any supporting evidence for this surprising finding, and fails to show any direct imagery in support of it. In view of all these negative considerations, it is reasonable to question the fundamental validity of the 2008 Core Area metric.

Examination of the 2008 Imagery

An image file from which the spatial configuration metrics in NECR111 were derived was available to the author. It shows high resolution aerial imagery of the area shown in the 2008 image in Figure 2, with an additional area extending 350 m to the east. (The Figure 2 image was obtained from this larger file). It is an an ECW file (enhanced compression wavelet, a very efficient form of data compression) and was opened with the ERDAS ER Viewer and converted to other file formats as appropriate.

To study the extent of the alleged “fragmentation”, the file was converted to tif (tagged image file) format, imported into an editing program and a grid pattern of 50 m scaled squares imposed on it, then exported as a single large tif file of 49.5 MB. The grid squares were thus each 0.25 ha in scaled area, and the line width corresponded to 0.4 - 0.5 m width, thus defining an approximate 0.5 m measure within the image. There were 144 grid squares within the area of interest. This image is available for examination at full resolution in jpeg format at http://boatownersresponse.org.uk/aerial2008grid.jpg **(4)** .

Each square was examined in turn, and each one which appeared to contain eelgrass was viewed at high magnification so that any 0.5 m features would be visible, by reference to the width of the grid lines. The proportion of the grid square which contained eelgrass was estimated by eye and recorded. The estimates were within 10% bands. Shown below are screen captures of grid squares estimated to contain approximately 30, 50, 80 and 100% dense seagrass (Figure 5). The estimates were done conservatively, so as not to over-estimate the area of eelgrass. Note the towed dinghy in the 100% shot gives another reference of scale: the side tubes of an inflatable dinghy are typically 35 to 50 cm in diameter. The 30% and 50% images are from the southern and south western edges of the eelgrass beds respectively, the others from a more central and deeper area. The water column effect is visible, the deeper areas having a bluer and less yellow appearance. There is no sign of the 90% “fragmentation” in areas of dense seagrass which is implied by the Core Area metric in The Report, the seagrass is present either as clumps or tufts, or as solid seagrass, in some cases with clearly defined bare patches.

30%

50%

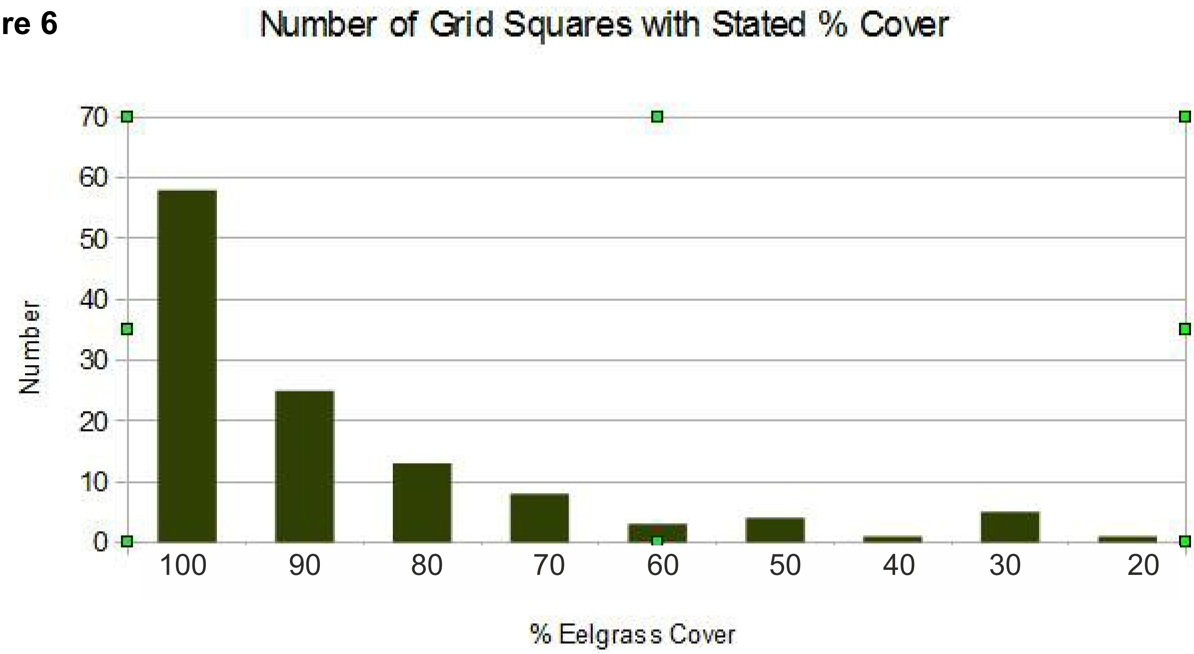
80%

100%

Figure 5

The total area of dense eelgrass was calculated by adding together each 0.25 ha square multiplied by the proportion of dense eelgrass present, which gave a total value of 26 ha of dense eelgrass. This is in excess of the 18 ha shown in figure 1, but it may include a larger area of the Bay than the “mooring area” to which Figure 1 refers. The distribution of % cover amongst the grid squares is shown in Figure 6.

Figure 6



81% of the grid squares containing eelgrass had 80% or more dense eelgrass cover, suggesting a low degree of fragmentation.

Close examination of the aerial image used in report NECR111 therefore shows no evidence of the extremely low Core Area which came out of the FRAGSTATS analysis. So, how did that low value arise?

For 90%, or nearly all, of the area of the seagrass to be within 0.5 m of an “edge “ would require a very large number of edges spaced at up to 1 m apart. There is some evidence for such an effect in the image.

Figure 7 below shows a series of screen captures of the original ecw file image at increasing levels of zoom. The irregular patch of bare sand is a feature known as the Gulley, and it is surrounded by dense eelgrass. The white dot just north of the boat is a mooring buoy, and its its apparent size is approximately 0.5 m, which gives a convenient scale reference.

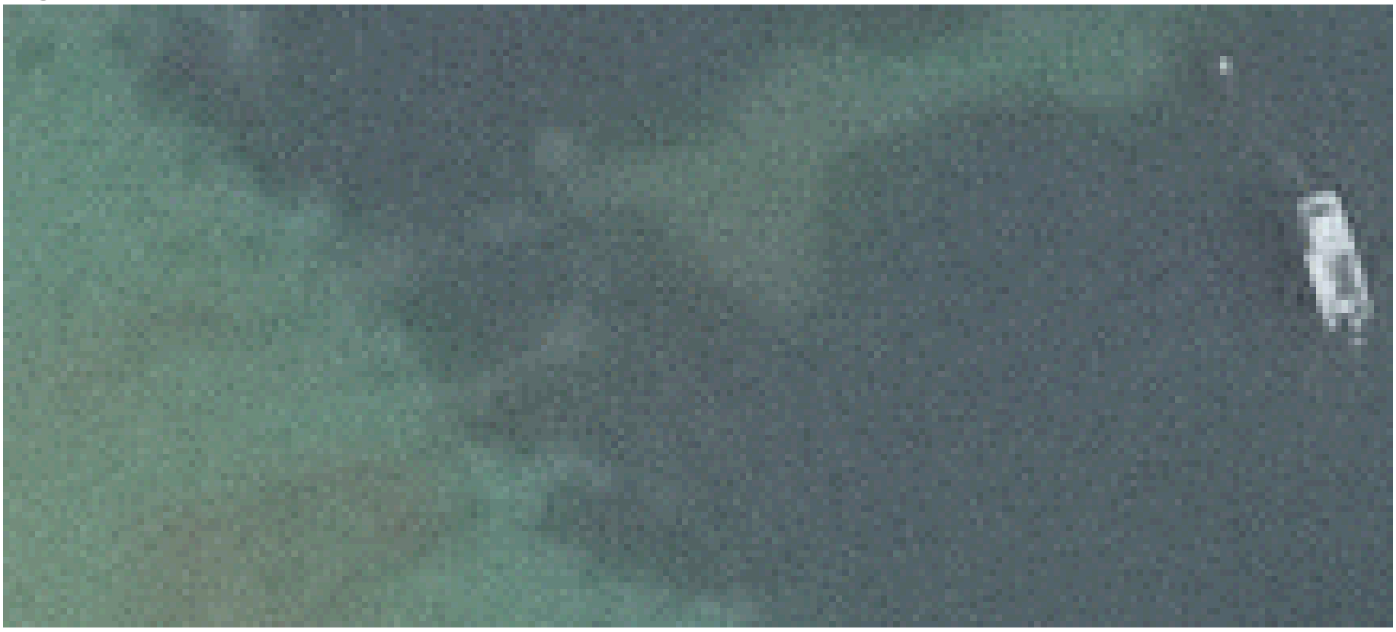
Figure 7

As the level of zoom or magnification of the image increase, a speckled pattern becomes apparent. This speckle is nothing to do with seagrass, it is photographic image noise, an artefact of the imaging system which produced the images. At the highest level of zoom it can be seen that individual pixels of similar colour apparently group together to form interlocking clusters of two, three or four pixels in length, corresponding to scene dimensions of 0.4, 0.6 and 0.8 m, a perfect size to create the illusion to a computer program (which knows no better) of edges within a 0.5 m radius. The eelgrass is not fragmented, just suffering from image noise.

The apparent clusters do not reflect any actual pattern, they are simply he result of random chance juxtaposition of pixels of similar properties.

Figure 8 below is shown to counter any argument that the pixel dispositions reflect some underlying structure within the seagrass bed. It will be seen that the random noise pattern is similar in areas of dense eelgrass and in areas of bare sand: the light area in the Gulley is known to be bare sand, and the light area to the left of the scene is the bare sandy seabed which lies shoreward of the eelgrass. The random noise pattern occurs over the whole scene, eelgrass or no eelgrass.

Figure 8



The low Core Area metric for 2008 is thus shown to be an artefact of the imaging system.

Consideration of the FRAGSTATS Protocols Used

While the FRAGSTATS procedures appear to have been busily measuring image noise in the 2008 image, questions also arise about the overall validity of the measurement of the Core Area metric in the series as a whole.

The FRAGSTATS Help Documentation **(5)** clearly states on p.11

"From a statistical perspective, we cannot extrapolate beyond the population sampled, nor can we infer differences among objects smaller than the experimental units. Likewise, in the assessment of landscape pattern, ***we cannot detect pattern*** *beyond the extent of the landscape* ***or below the resolution of the grain."*** **-** and - *"Grain is the size of the individual units of observation".*

It also warns on p.12

"*Key Point One of the most important considerations in any landscape ecological investigation or landscape structural analysis is* ***(1) to explicitly define the scale of the investigation or analysis,*** *(2) to describe any observed patterns or relationships relative to the scale of the investigation, and* ***(3) to be especially cautious when attempting to compare landscapes measured at different scales.****"*

In other words you can't measure things smaller than the imaging system can see, and you can't properly compare things at different scales (think of a tree: from a distance, a mass of green above a trunk, close up a complex network of leaves, twigs and branches).

So we need to consider scale and image resolution in the images used in the FRAGSTATS analysis in NECR111.

Of the aerial images used in the study, the most recent, 2008, was captured by a digital camera, the rest were on film. The film images were subsequently scanned. It is important to understand that, provided the scanning was fine enough, the resolution of the film images is limited by the resolution on the film, not by the pixel size of the scanner. It is impossible to add detail by scanning at high resolution, although of course detail can be lost by scanning at too low a resolution. The resolution of the aerial images prior to 2008 is not determined by the pixel size, it must be assessed by estimating the finest detail visible in the picture.

Fortunately there are objects visible in the pictures whose sizes are approximately known. The side buoyancy tubes of inflatable dinghies are usually between 35 and 50 cm in diameter. The commonest dinghy lengths are 2.3 and 2.8 m. A typical sailing yacht is about 10 m long and 3 m in the beam. The Studland beach huts are 10 ft (3 m) long and 8 ft wide. Thus the resolution in the image can be approximately estimated.

This applies to objects above water. Objects below the surface are viewed or photographed through the undulating surface of the water, the light waves are refracted to varying extents by the ripples or waves, and resolution is lost. The sea bed normally cannot be seen clearly through a moving surface, detail is lost unless the surface is made smooth by a device such as a glass-bottomed bucket. Therefore the resolution of objects on the seabed must be estimated by finding the smallest underwater object which can be resolved, and scaling it against the pixel dimensions or against an object on the surface. This resolution will of course vary with the sea state, and also with depth. Turbidity will also have an effect, but the method described also takes account of the prevailing turbidity conditions.

Figure 9 shows estimated resolution together with pixel size data from NECR111:

Year	Capture medium	Colour/b&w	Pixel size, m	Resolution above surf.	Res. under water
2008	digital	colour	0.25	0.2 m	0.5 m
1997	film	colour	0.9	1	1
1990	film	colour	0.4	1	
1985	film	b&w	0.2	0.3	
1972	film	b&w	0.2	1	

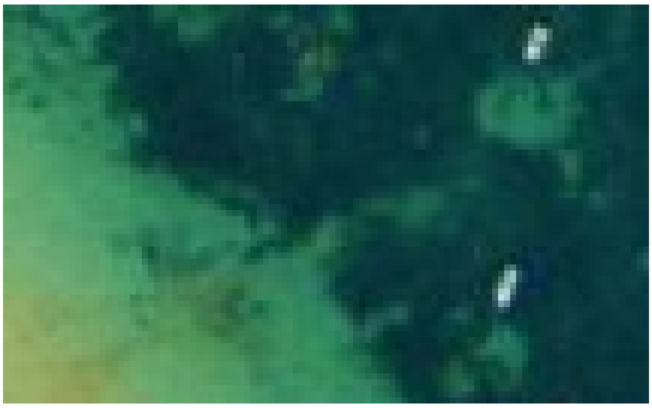
NECR111 does state (p. 4) that for the analysis “All images were standardised to the same resolution”, but the report neglects to reveal what that resolution was. As explained above, the images can only be standardised in terms of resolution by bringing them to the lowest resolution in the set, i.e. one metre, or, close enough, the 0.9 m pixel size of the 1997 image.

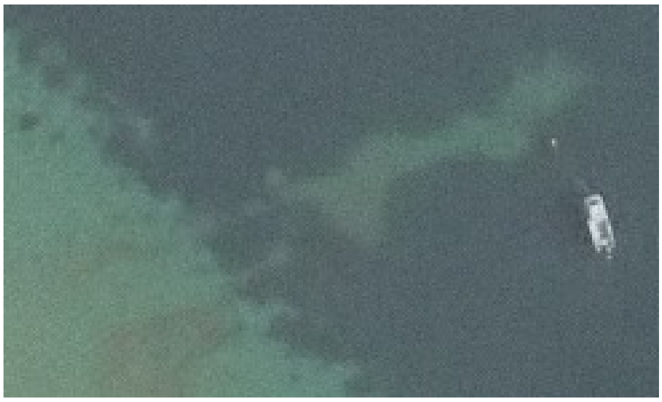
The problem is that at a resolution of 1 m, the 0.5 m edge depth used to define the Core Area becomes meaningless, it is half the image resolution, it is “below the resolution of the grain” and the analysis cannot be valid. On the other hand, if a resolution of say 0.5 m were chosen, which might perhaps allow the specified edge depth, the images would then be at different scales, because the 1997, 1990 and 1972 images would still be at a 1 m resolution as explained. Then comparison between the different images would not be valid.

Thus, according to the published FRAGSTATS guidance, a historical comparison with a metric containing a 0.5 m edge depth based on this set of maps can not be valid.

It is instructive to illustrate these issues of resolution and scale by comparing similar scenes at the native resolution of the 1997 and 2008 images. Both show approximately the same area, “the Gulley”, identifiable by the persistent reddish streak in the sand in that area. Note the edge of the eelgrass bed had advanced 25 metres inshore between 1997 and 2008, from measurements on the classification maps which are shown at reduced scale in Figure 4. This, incidentally, is further visual evidence of the downright untruth of the assertions in NECR111 pp iv - v that the eelgrass in 2008 was both less in area and more fragmented than in 1997.

Figure 10 **1997** **2008**





Conclusions

The statement in NECR111 that the 2008 aerial images show “a low coverage of seagrass” is based on the (mis)identification of areas in the 1997 image as “sparse seagrass”, as other evidence in NECR111 shows that 2008 had much the highest cover of dense eelgrass. Confusingly, the areas in question are clearly identified on p 52 of NECR111 as sand, but on p58 as sparse seagrass. We conclude from close examination of the 1997 aerial image that the areas between the dense seagrass are sand, and see no evidence of significant sparse seagrass. An explanation for the mis-identification might be that no correction was applied in the 1997 image for “water column”, the blue-green colour cast which occurs when light travels through water, and clearly visible on the left in Figure 10 above, and the blue-green appearance of the sand was incorrectly interpreted as sparse seagrass. The highest area of total seagrass in the set of aerial images is then in 2008 and there is no plausible evidence which says otherwise.

The statement in NECR111 that the 2008 seagrass has “the lowest core area” and is suffering from “fragmentation” is not supported by close examination of the imagery, which is discussed and shown above in this report. As Figure 2 shows, on a coarse scale the eelgrass is more extensive and less fragmented in 2008 than 2007. The “core area” statement comes from use of a computer program called FRAGSTATS. Four out of five metrics from the NECR111 FRAGSTATS analysis show 2008 to have the least fragmented seagrass. The Core Area metric, which depends on the amount of seagrass within 0.5 m of an edge is out of line with the other four, would require a quite implausible seagrass topography, with nine parts in ten of the large seagrass meadow being within 0.5 m of an edge, and the metric shows an extreme deviation from the historical trend as reported. No supporting evidence for, or discussion of, this out-of-line metric is presented in NECR111.

We conclude, and present visual evidence, that the FRAGSTATS Core Area analysis in NECR111 was measuring not any property of the eelgrass, but rather the speckle pattern of image noise which is clearly present in the image at the correct spatial frequency. It is a system artefact, and nothing to do with the configuration of the seagrass beds in Studland Bay. It says nothing about eelgrass “fragmentation”.

Questions are also raised about the validity of the FRAGSTATS analysis on the basis of non-compliance with FRAGSTATS procedures in respect of scale and resolution.

References

1. JACKSON, E.L., GRIFFITHS, C.A., COLLINS,K. & DURKIN, O., 2013, *A guide to assessing and managing anthropogenic impact on marine angiosperm habitat - Part 2: Studland Bay vulnerability assessment*. Natural England Commissioned Reports, Number 111. Downloadable from http://publications.naturalengland.org.uk/publication/3665058

2. http://www.unesco.org/csi/pub/source/rs10.htm

3. JACKSON, E.L., HIGGS, S., ALLSOP, T.,CAWTHRAY, A., EVANS, J. & LANGMEAD, O. 2011. *Isles of Scilly Seagrass Mapping*. Natural England Commissioned Reports, Number 087. Downloadable at http://publications.naturalengland.org.uk/file/82006

4. jpeg full resolution image with superimposed 50 m grid can be viewed at http://boatownersresponse.org.uk/aerial2008grid.jpg

5. http://www.umass.edu/landeco/research/fragstats/documents/fragstats.help.4.pdf