

2: THE IMPORTANCE OF ACQUIRING IMAGES OF THE APPROPRIATE SCALE AND SPATIAL RESOLUTION FOR YOUR OBJECTIVES

Aim of Lesson

To demonstrate the effects of image spatial resolution (ranging from 1 m to 80 m) on the ability of images to discriminate between different coastal habitats.

Objectives

1. To investigate how a range of major features appear at different spatial resolutions.
2. To investigate the effect of image pixel size on habitat identification.
3. To use transects across images to determine the spatial frequency of key habitats.

Overview of Lesson

A wide variety of remotely-sensed imagery are available for coastal habitat mapping and therefore one of the most important questions to consider when planning a remote sensing project is, “Which imagery will allow me to map the habitats of interest?”. The answer to the question depends largely on the size of the habitat of interest. Remote sensing instruments divide the Earth’s surface into a grid of sampling units called “pixels” whose spatial dimensions depend on the altitude and design of the sensor. The pixel size roughly equates to the spatial resolution of the sensor. For example, each pixel in a SPOT multispectral image (XS) measures 20 m by 20 m and thus the smallest linear dimension on the Earth’s surface which can be resolved is roughly 20 m. In order to map the boundaries of a given habitat, the spatial resolution of the imagery should be smaller than the minimum size of the habitat. This means that SPOT XS imagery is incapable of detecting habitats whose dimensions are less than 20 m by 20 m.

The spatial resolutions of a range of widely-used remote sensing sensors are listed in Table 2.1. Although spatial resolution is a key consideration when selecting a remote sensing method (and we dwell upon it in this lesson), other considerations must also be taken into account. In terms of sensor specifications, the most important of these are the number of useful spectral bands and the area covered by the image. In short, the greater the number of spectral bands, the greater the likelihood that habitats will be identified correctly during image processing. For example, two different habitats might have the same overall colour when viewed in a single band of blue light, but their appearances might differ markedly if viewed in blue, green and red bands simultaneously.

An important aspect of spatial scale is texture. In a remote sensing context, texture describes the structure or pattern of a feature in the imagery. Texture can be fairly simple and uniform or complex and patchy. Many habitats have a characteristic texture (patchiness) which, if considered, can greatly improve the chances of correctly identifying habitats in image data. To measure the texture of habitats using remote sensing, the spatial resolution of the imagery must be similar in size to the smallest patch that makes up a particular pattern or texture. For example, imagine a sparse seagrass bed comprising small patches with an average width of 5 m. Although the entire bed of sparse seagrass may have a width of, say, 100 m, the imagery would need a spatial resolution of 5 m, or less, to detect its texture. Statistical measures of texture are available which measure the local variability in pixel reflectance, but you will make a qualitative assessment of texture in this lesson.

Table 2.1. Principal specifications of satellite, airborne and photographic media

Specification	Landsat MSS	Landsat TM	SPOT XS	SPOT Pan	CASI (airborne)	Aerial Photography
Spatial resolution (m)	80	30	20	10	10 - 0.5	variable (>0.2)
No. of spectral bands for habitat mapping	4	6	3	1	8-21 <i>user defined</i>	1-3 † <i>analogue</i>
Area covered (km)	185 x 172	185 x 185	60 x 60	60 x 60	variable	variable

† One band for monochrome aerial photography, three bands if colour aerial photography is scanned in the red, green and blue.

This lesson will focus on the importance of matching the spatial scale of coastal habitats to the spatial scale of imagery. To begin with, you will measure the spatial frequency (average patch size) of some key habitats. These measurements will be based on airborne imagery which usually has the highest spatial resolution. With these measures of spatial frequency in mind, you will then predict whether various types of remotely-sensed data are capable of detecting these habitats. You will then see for yourself by comparing images whose spatial resolution varies between 2 m and 30 m.

It is worth noting in passing that the term “descriptive resolution” has been coined to describe the detail to which a sensor will map a given area. For mapping benthic habitats, a coarse descriptive resolution would only separate habitats into broad classes, e.g. coral, algae, sand, and seagrass. A finer descriptive resolution would also distinguish reef zones, variations in seagrass standing crop and so on.

Background Information

The capability of different sensors for mapping coral reef, seagrass and mangrove habitats are discussed in detail in Chapters 11-13 of the *Remote Sensing Handbook for Tropical Coastal Management* and papers by Mumby *et al.* and Green *et al.* (see References section).

The *Bilko for Windows* image processing software

Familiarity with *Bilko for Windows* 2.0 and Lesson 1 of this module are required to carry out this lesson. Readers who are not familiar with the Turks and Caicos or the appearance of coral reef, seagrass and mangrove habitats should undertake Lesson 1 before continuing further.

Image data

All images used in this module were acquired for around the island of South Caicos, Turks and Caicos Islands (see Figure 1.1, Lesson 1 for a map). Images are supplied at a range of spatial resolutions (Table 2.2), the most detailed of which is CASI. *Note:* When geometric correction and other processing is carried out the pixel size may be changed from the original size (a process called resampling). Spatial resolution and **actual pixel sizes** are shown in Table 2.2.

You are supplied with three spectral bands of subscenes of multispectral satellite images at three different spatial resolutions (Landsat MSS: Appendix 2.1; Landsat TM: Appendix 1.1; SPOT XS: Appendix 1.2). These can be viewed individually or connected to make false colour composites. You are also supplied with a subscene of a SPOT panchromatic (single-band recorded across the visible spectrum) image (Appendix 1.2) at 10 m resolution and some subscenes from monochrome aerial photographs scanned so that each pixel is 2 x 2 m on the ground. To save time, the airborne multispectral CASI data (Appendix 1.3) have been stored as contrast-stretched composite images (i.e. the individual bands are not provided).

Table 2.2. Images used in this lesson and their principal specifications. Monochrome aerial photographs © Ordnance Survey. † **The actual pixel size in the images is included in brackets.**

Image type	Platform	Acquisition date	Spatial resolution (m)†	File Names
CASI	aircraft	16/07/95	1 (1 x 1.1)	CASIMANG.GIF, CASIHARB.GIF
Monochrome aerial photography	aircraft	1981	2	AP_EAST1.GIF, AP_SCAIC.GIF, AP_MANG.GIF
SPOT Panchromatic (Pan)	satellite	27/03/95	10 (12)	XPSUBSET.GIF
SPOT XS	satellite	27/03/95	20 (23)	XS1SUB.GIF, XS2SUB.GIF, XS3SUB.GIF
Landsat TM	satellite	22/11/90	30 (33)	TM1_SC.GIF, TM2_SC.GIF, TM3_SC.GIF
Landsat MSS	satellite	28/06/92	80 (66)	MSS1.GIF, MSS2.GIF, MSS3.GIF

The CASI was mounted on a locally-owned Cessna 172N aircraft using a specially designed door with mounting brackets and streamlined cowling. An incident light sensor (ILS) was fixed to the fuselage so that simultaneous measurements of irradiance could be made. A Differential Global Positioning System (DGPS) was mounted to provide a record of the aircraft's flight path. Data were collected at a spatial resolution of 1 m² in 8 wavebands (Table 2.3) during flights over the Cockburn Harbour area of South Caicos. Further details are given in Clark *et al.* (1997). The files CASIHARB.GIF and CASIMANG.GIF are false colour composites of bands 1, 3, and 5.

Table 2.3. Band settings used on the CASI.

Band	Part of electromagnetic spectrum	Wavelength (nm)
1	Blue	402.5 - 421.8
2	Blue	453.4 - 469.2
3	Green	531.1 - 543.5
4	Green	571.9 - 584.3
5	Red	630.7 - 643.2
6	Red	666.5 - 673.7
7	Near Infrared	736.6 - 752.8
8	Near Infrared	776.3 - 785.4

Lesson Outline

The activities in this lesson are divided into four parts:

1. Taking spatial measurements from various images with a view to becoming familiar with spatial resolution.
2. Measurement of the spatial frequency of mangrove habitats followed by an examination of imagery to see whether the habitats are visible.
3. Measurement of the spatial frequency of some seagrass and coral features. You will then use this knowledge to predict the spatial scales at which these features can be detected using remote sensing. Your predictions will be tested by viewing imagery of various spatial resolution.
4. The use of texture when interpreting remotely-sensed imagery. You will be provided with imagery at two spatial scales and asked to compare your ability to identify habitats in each.

Part 1. Taking measurements and comparing spatial resolutions of imagery

For this part of the lesson you will use imagery at three spatial resolutions: aerial photography (2 m), SPOT Pan (10 m), and Landsat MSS (80 m). The aim is to estimate the width of the runway at South Caicos airport using each image type and in so doing, gain a practical feel for various spatial resolutions. Measurements will be made by recording the number of pixels that cross the runway and then multiplying this number by the width (in metres) of each pixel.

Activity: Launch *Bilko for Windows* and use **File, Open** to view the monochrome photograph, AP_MANG.GIF.

Question: 2.1. What is the width of the area covered by the aerial photograph on the ground in km?


Using **Edit, GoTo**, place the cursor at coordinates (519, 64) which mark the northern side of the runway. Place the mouse cursor at the cross-hairs and double-click 4 times to zoom in (if you zoom in too far, you can zoom out using <CTRL>+double-click). The runway should be clearly visible and comprises three zones - two white areas of pavement surrounding a dark area of tarmac. For this exercise, the runway *includes* both areas of pavement. Click on the transect tool . Place the mouse at the northern side of the runway (519, 64) and, keeping the button depressed, drag it down vertically to the far side of the runway and release. Cursor coordinates should now read approximately (519, 105). (*Note:* the runway does not run exactly from west to east and therefore to ease the calculation of distance, we are making an approximation of width using the vertical distance from one side of the runway to the other). Click on **Edit, GoTo** to display the **Go To** dialog box. This should have **Line selection** highlighted under **Selection Type**:. Under **Selection Size**, the value **DX**: should be close to zero because you have selected a vertical line. The value **DY**: represents the number of pixels across the runway. Enter this value (or if unsure precisely where the runway begins and ends, a range of values) into Table 2.4 and calculate the width of the runway.

Table 2.4. Width of runway at South Caicos

Image type	Number of pixels across runway	Pixel size (m)	Width of runway (m)
Aerial photography		2	
SPOT Pan		12	
Landsat MSS		66	

Close the AP_MANG.GIF file and open the SPOT Pan image, XPSUBSET.GIF.

Question: 2.2. What is the width of the area covered by the SPOT Pan subscene on the ground in km?

Use **Edit, GoTo** to place the cursor at column and row coordinates (234, 544) and zoom in 8 times. The runway should be clearly visible although the boundaries are not quite as clear as those in the aerial photograph. Using the methods set out above, measure the vertical width of the runway at coordinates (234, 544) and at one pixel to the east and west. Enter your value (or range of values) in Table 2.4. [*Note:* If you select **View, Coords** then **DY**: gives you the distance in metres along the transect (as a negative value, because UTM coordinates increase from south to north and your transect is running north to south). If you have a range of values for runway width take the average width as your best estimate.

Question: 2.3. Is there any difference between the average width estimated using aerial photography and SPOT Pan? Does this difference approximate the spatial resolution of SPOT Pan (i.e. 10 m)?

Close XPSUBSET.GIF and open MSS2.GIF which is band 2 (green) of the Landsat MSS image. Use <CTRL>+A or <SHIFT>+<SPACEBAR> to select all pixels in the image and apply a contrast stretch using **Stretch, Auto Linear**.

Question: 2.4. What is the width of the area covered by the MSS subscene on the ground in km?

Use **Edit, GoTo** to move the cursor to coordinates (389, 82). Examine the image at its current magnification.

Question: 2.5. Is the runway visible?


Position the mouse pointer at the cursor and double-click to zoom in 7 times. The runway will probably become progressively more difficult to identify as you zoom in. Our eyesight is good at picking out the general linear shape of the runway at low magnifications but less so at higher magnifications where less of the feature is visible. At a starting point of (389, 82), enter the number of pixels which seem to comprise the width of the runway (Table 2.4).

Question: 2.6. Would you have much confidence in your estimate of runway width from the MSS image? Which of the three remote sensing methods tested, would you recommend for mapping roads of South Caicos (you may list more than one)?

Close the MSS2.GIF image.

Part 2. Spatial scales and mangrove mapping.

You are provided with a false colour CASI image of Cockburn Harbour and the mangroves on the west coast of South Caicos (CASIMANG.GIF). Although a variety of habitats exist here (see Lesson 1), we will focus on two levels of descriptive resolution. The first is the entire fringe of mangrove forest, which encompasses a variety of sub-habitats, and is simply termed “mangrove”. The second is a sub-class of mangrove dominated by the red mangrove, *Rhizophora mangle*. An isolated circular patch of mangrove trees just off the coast of South Caicos is a good example of this habitat.

Activity: Open the pre-stretched composite CASIMANG.GIF. The mangrove appears as red and at the bottom of the image (scroll down as necessary) you can see the settlement and several piers. Use **Edit, GoTo** to place the cursor on the circular patch of *Rhizophora* lying just offshore at coordinates (241, 425). Position the mouse pointer on the cursor and double-click 4 times to zoom in. Calculate the diameter of the patch in the horizontal plane starting at coordinates (241, 425) using the transect tool . (*Hint:* once you have dragged the transect over the patch, use **Edit, GoTo** to see the number of pixels, DX:). Enter the count in Table 2.5. Move the cursor to coordinates (256, 412) and measure the vertical diameter of the patch (this time enter the value of DY: into Table 2.5). Convert the numbers of pixels into diameters in metres and calculate the average diameter of the patch, entering your results in Table 2.5. The area of a circle is calculated using the formula below where the radius is half the diameter and $\pi = 3.142$.

$$\text{area of circle} = p \times (\text{radius})^2$$

Question: 2.7. Using your measurement of patch diameter, what is the area of the circular red mangrove patch (m²)?

Using the coordinates in Table 2.5, repeat the measurement process for the larger habitat of fringing “mangrove”(estimate the horizontal distance from the waters edge to the left-hand (non-red) edge of the mangrove). For example, if you place the cursor at (173, 47) and measure the **horizontal** extent of mangrove, you should have a value of approximately 71 pixels (= 71 m).

Question: 2.8. What is the average width of fringing mangrove for the three transects listed in Table 2.5.?

Table 2.5. Average size of two mangrove habitats. Each pixel is 1 m wide x 1.1. m long.

Habitat	<i>Rhizophora mangle</i>		Fringing mangrove		
Coordinates (X, Y)	241, 425 (DX:)	256, 412 (DY:)	173, 47 (DX:)	225, 129 (DX:)	278, 186 (DX:)
Habitat width/diameter (pixels)			71		
Habitat diameter/width (m)					
Average habitat diameter/width (m)					

To make a rough estimate of the area of this mangrove fringe on the northern part of the image (north of the gap in the mangrove fringe) one can measure its length by using the mouse pointer to lay a transect parallel to the coast in the middle of the mangrove. Such a transect might begin around (166, 4) and end around (362, 268).

Activity: Use the mouse pointer and transect tool to lay a transect along the length of the northern mangrove fringe parallel to the coast. Select **File, New** and then choose TRANSECT Document. To see how long the transect is in pixels click on the right hand end of it and read off the number of pixels long on the status bar. However, the transect runs diagonally across pixels and so you cannot readily convert this value to distance. To do this click on **Edit, GoTo** and read off the **DX:** (number of columns) and **DY:** (number of rows) the transect runs and use Pythagoras’s theorem to work out its length as follows:

$$\text{Length of transect} = \sqrt{(\text{DX} \times \text{pixel width})^2 + (\text{DY} \times \text{pixel length})^2}$$

Question: 2.9. a) What is the length of the transect in pixels crossed, b) what is its length in metres, and c) what is the **approximate** area in hectares of the fringing mangrove in the northern part of the image? [*Hint:* Treat the area as a rectangle].

Keeping CASIMANG.GIF available for future comparisons, you will now create a false colour composite from SPOT XS imagery (XS1SUB.GIF, XS2SUB.GIF, XS3SUB.GIF).

Activity: Minimize the CASIMANG.GIF image. Open the SPOT XS image files XS1SUB.GIF, XS2SUB.GIF and XS3SUB.GIF. Connect the three images using the **Image, Connect** function (highlight each with the cursor whilst depressing the <CTRL> key). Set the connect toolbar so that the XS3 image is 1, the XS2 image is 2, and the XS1 image is 3 (thus displaying them on the red, green and blue guns respectively in a colour composite).

Use the **Image, Composite** function to make a colour composite. Make sure the **Apply stretches to charts, clipboard etc.** checkbox is checked in the **Stretch, Options** dialog box, then use the **Edit, Select All** command (or <SHIFT>+<SPACEBAR>) to select all pixels in the image, and improve the contrast within the image, by applying an automatic linear stretch (click on the **Stretch** menu and apply the stretch, **Auto Linear**). [The land should be bright red and the sea turquoise and blue if the images have been combined properly]. Use the **File, New** command to make a copy of the **stretched** composite and save this as XSFCC.BMP as you will need it in Part 4 of this lesson. Then

close all the other SPOT images individually (using **File, Close**). Do not save any changes to these other image files.

Use the **Edit, GoTo** command to move to coordinates (211, 513) on the colour composite then zoom in several times by double-clicking. The mangrove area is visible as a red fringe but with much less detail than in the CASI image viewed earlier. The patch of *Rhizophora* is just visible at (211, 513) but its circular shape is not preserved because it is now represented by one SPOT pixel. (*Remember*: the same patch was represented by approximately 700 pixels in CASI imagery!).

Question: 2.10. Why isn't the offshore mangrove patch visible as distinct from the coastal mangrove?

Inspect the mangrove fringe and note that detail of the larger, fringing mangrove habitat (bright red pixels) is also much reduced as it is now has an average width of 3-6 SPOT pixels (i.e. 60-120 m). Note that it is much harder to determine exactly where the mangrove begins and ends.


Close the SPOT false colour composite image (XSFCC.BMP) which you saved earlier. Then create a new false colour composite from bands 1, 2 and 3 of Landsat MSS. [*Hint*: Follow exactly the same procedure as set out for SPOT XS above but use files MSS1.GIF, MSS2.GIF, and MSS3.GIF]. The infra-red band is again displayed through the red-gun so that vegetation (which has a high reflectance in the near-IR) appears bright red. Use **Edit, GoTo** to place the cursor at coordinates (385, 115) and then zoom in as required. Note that at this spatial scale (66 m pixels, 80 m spatial resolution), the patch of *Rhizophora* cannot be distinguished but the fringing mangrove habitat is just visible as a strip of 1 or 2 pixel-widths.

When you have finished, close all images.

To conclude, the spatial resolution of imagery has a significant influence on the detail to which mangrove habitats can be identified. CASI imagery allows us to make fairly precise estimates of the shape and area of even small habitats such as patches of *Rhizophora mangle*. SPOT XS allows us to make moderately crude estimates of these parameters but detail is drastically reduced. At the broadest scale, however, Landsat MSS does not identify small (< 80 m) patches as distinct entities and even where fringing mangrove is visible, measurements of habitat width are not precise (i.e. the width is estimated as 1 - 2 pixel widths which equals 80 m or 160 m with no possible intermediate values).

Part 3. Spatial frequency of seagrass and coral features

In this part you will work with a pre-stretched colour composite CASI image (1 m spatial resolution) of Cockburn Harbour (CASIHARB.GIF) showing seagrass and reef habitats. These habitats were described in some detail in Lesson 1 and photographs may be opened in the *Bilko for Windows* viewer for further familiarisation (files BLOWOUT.GIF, SEAG_DEN.GIF, MONT_COL.GIF). The first exercise is to measure the width of three important features which have their own spatial frequencies; seagrass blowouts (BLOWOUT.GIF), dense seagrass beds (SEAG_DEN.GIF) and colonies of the hard coral, *Montastraea annularis* (MONT_COL.GIF).

Activity: Open CASIHARB.GIF and use the **Edit, GoTo** command to place the cursor on a seagrass blowout (coordinates 272, 119). Double-click twice to zoom in. Using the transect tool  and **Edit, GoTo** commands described above, measure the horizontal widths of the three seagrass blowouts listed in Table 2.6. The coordinates are the left hand edges of the blowouts. [*Hint*: Treat each pixel as being 1 m square (ignore fact that they are 1.1 m long) so the number of pixels = distance in metres]. Enter your results in Table 2.6.

The seagrass blowouts lie within a large bed of dense seagrass. Use the procedures set out above to estimate the width of this seagrass bed at three points. The upper coordinates of the bed are given in Table 2.6 and you should measure the width in the vertical plane (i.e. drag the transect towards the bottom of the image). Enter your results in the table.

Use the **Edit, GoTo** command to place the cursor on a colony of *Montastraea* (341, 244) which contrasts strongly with the pale green of sand and seagrass. Measure the horizontal width of the dark colonies at the coordinates listed in Table 2.6 and enter your results in the table.

Table 2.6. Estimating the spatial frequency of seagrass and coral features using CASI imagery

Feature	Seagrass blowouts			Dense seagrass bed			<i>Montastraea</i> colonies		
Coordinates	272, 119	250, 147	244, 158	228, 82	269, 96	194, 50	341, 244	349, 213	366, 239
Width (pixels)									
Average width (pixels)									
Average width (m)									

Question: 2.11. What are the average widths of seagrass blowouts, the dense seagrass bed and *Montastraea* colony clusters in Cockburn Harbour?

You should now use your knowledge of spatial frequency to predict which of these features you would expect to see in various types of imagery. Table 2.7 lists these sources of imagery and their spatial resolutions.

Activity: Place a tick in the predicted presence columns (labelled “pred.”) if you expect to see a particular feature and remember to consider the maximum size of each feature as well as its average size because some larger examples of, say, blowouts may be visible. Once you have made your predictions, proceed with the exercise to check your accuracy.

Table 2.7. Predicting the descriptive resolution of aerial photography, SPOT Pan and Landsat TM for key marine features. res. = resolution, pred. = predicted presence, c = column, r = row.

Sensor	Coordinates of study area (c, r)	Spatial res. (m)	blowout		seagrass bed		coral colonies	
			pred.	test	pred.	test	pred.	test
Aerial photography	259, 356	2						
SPOT Pan	264, 808	10						
Landsat TM	141, 257	30						

To check your predictions entered in Table 2.7, you are provided with monochrome aerial photography (AP_SCAIC.GIF), SPOT Pan imagery (XPSUBSET.GIF), and Landsat TM imagery (TM1_SC.GIF, TM2_SC.GIF, TM3_SC.GIF).

Activity: Open the aerial photographic image AP_SCAIC.GIF and apply an automatic linear contrast stretch. Then open the SPOT Pan image XPSUBSET.GIF which does not need to be stretched. Finally open the three Landsat TM bands and create a colour composite, assigning TM bands 3, 2, and 1 to the red, green, and blue colour guns respectively.

For each image in turn, place the cursor at the position suggested in Table 2.7 and double-click until you are satisfied with the zoom. Visually interpret each image to check for the presence of blowouts, seagrass beds and *Montastraea* heads. Were your predictions correct? Fill in the test boxes in Table 2.7.

Part 4. The advantage of considering habitat texture when interpreting remotely-sensed imagery

Activity: Open the SPOT XS false colour composite image XSFCC.BMP which you created in Part 2 of this lesson. Move the cursor to position (419, 387) and zoom in several times. The cursor represents a large area of sand in shallow water just to the east of South Caicos. The sand bed is surrounded by patches of seagrass and coral reef. All of the patches are at least several pixels wide and easily detected using SPOT XS. However, SPOT pixels are 20 m wide and reveal very little of the texture of each habitat. The coordinates of 5 patches are given in Table 2.8. Using the **Edit, GoTo** function to locate the patches, can you identify which patches are coral and which are seagrass based on their colour and texture? Enter “S” in Table 2.8 for seagrass and “C” for coral reef. [*Note:* You will probably need to scroll up and down the image to find the cursor].

Minimize the false colour composite of SPOT XS and then open the image AP_EAST1.GIF which is a monochrome aerial photograph with a spatial resolution of 2 m. **Select All** pixels and apply an **Auto Linear** stretch. Place the cursor near coordinates 400, 497 and zoom in to view the sand area examined earlier in the SPOT scene. The high spatial resolution of the aerial photograph reveals considerable textural detail to help with habitat identification.

Question: 2.12. What are the principal textural differences between the seagrass beds and coral reef patches?

Examine this image in detail and visit the coordinates provided in Table 2.8 to see whether your identification of habitats differs in light of the greater textural information now available. (*Note:* each position on the image is equivalent to that provided for SPOT). You can use the **Window** menu to alternate between the SPOT XS image and aerial photograph.

Table 2.8. Identification of seagrass and coral patches based on their texture.

Use “S” for seagrass and “C” for coral.

	SPOT XS		Aerial photography	
	coordinates	S / C	coordinates	S / C
patch 1	412, 434		260, 899	
patch 2	409, 362		170, 269	
patch 3	421, 410		360, 739	
patch 4	402, 388		135, 490	
patch 5	423, 374		366, 324	

Finally, assess the average width of the 9 coral patches scattered around coordinates 420, 790 on the aerial photographic image.

Question: 2.13. What is the average width of the nine coral reef patches? Which image(s), among all those you have looked at, is/are likely to be ineffectual at resolving these patches?

Close the two images.

This part of the lesson should have illustrated the significance of texture when mapping habitats. Although the resolution of SPOT XS was fine enough to map the boundaries of these patches, it could not resolve the texture of each habitat. Aerial photography was capable of both because its spatial resolution was an order of magnitude finer than that of SPOT XS. In practice, a habitat map of coral reefs and seagrass beds would probably contain a greater number of errors (mis-identifications) if created from SPOT XS than if derived from aerial photography. However, we mentioned at the

beginning of this lesson that spatial resolution is not the only important image specification; spectral resolution is also important. Even if remotely sensed data cannot distinguish two habitats on the basis of their texture, their spectra might be distinguishable, hence, resolving the issue of habitat identification. Therefore, whilst a measure of texture is often useful, it is perhaps most needed where the spectra of two habitats are difficult to distinguish.

The lesson as a whole should have indicated that while satellite imagery at resolutions of 20-80 m is able to map habitats to a coarse descriptive resolution, for finer discrimination and mapping of patchy habitats airborne imagery with a spatial resolution of <5m is likely to be needed. The key thing is to make sure that your imagery can achieve your mapping objectives.

References

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Answers to Questions

Part 1.

- 2.1. The quickest way to determine the width of the AP_MANG.GIF aerial photograph is to use <SHIFT>+<SPACEBAR> (or **Edit, Select All**, or <CTRL>+A) to select the whole image and then use **Edit, GoTo** dialog box to read off the width of the image (DX:) in pixels. It is 600 pixels wide so the width of the image is $600 \times 2 \text{ m} = 1.2 \text{ km}$.
- 2.2. You can either read off the width of XPSUBSET.GIF in pixels by selecting the whole image and inspecting the **Edit, GoTo** dialog box as above, or you can select **View, Coords** before inspecting the **Edit, GoTo** dialog box in which case the width (DX:) will be expressed in metres and UTM coordinates of the top left of the image will be displayed. For the former you will find the image is 720 pixels across, so its width is $720 \times 12 \text{ m} = 8.64 \text{ km}$. For the latter you can read off the DX: of 8640 m directly.
- 2.3. Even on the aerial photography it is not absolutely clear where the edge of the runway pavement is. The runway appears to be between 38 and 40 pixels across, giving a mean width of 78 m. On the SPOT Pan image it appears to be 7-8 pixels across, giving a mean width of 90 m. The difference is about 12 m, which happens to be roughly the resolution of the SPOT sensor. "Mixels", that is pixels which are half vegetation and half runway pavement, on either side of the runway make it very difficult to be sure exactly where the runway edges are.
- 2.4. You can either read off the width of MSS2.GIF in pixels by selecting the whole image and inspecting the **Edit, GoTo** dialog box as above, or you can select **View, Coords** before inspecting the **Edit, GoTo** dialog box in which case the width (DX:) will be expressed in metres. For the former you will find the image is 501 pixels across, so its width is $501 \times 66 \text{ m} = 33.1 \text{ km}$. For the latter you can read off the DX: of 33066 m directly.
- 2.5. The runway is visible in the Landsat MSS scene. But would you have recognised it as such if you did not know it was there?
- 2.6. No, one can see that some linear structure is there but all one can say is that it is similar in width to the spatial resolution of the sensor (80 m). Both aerial photography and SPOT Pan appear to be suitable for mapping roads with the aerial images picking out narrower tracks which cannot be seen on the SPOT imagery.

Table 2.4. Width of runway at South Caicos

Image type	Number of pixels across runway	Pixel size (m)	Width of runway (m)
Aerial photography	38-40	2	76-80 (mean = 78)
SPOT Pan	7-8	12	84-96 (mean = 90)
Landsat MSS	1	66	approx. 66

Part 2.

2.7. The average diameter is about 31.4 m giving a radius of 15.7 m. This gives an area of about 774 m² for the mangrove patch.

2.8. The average width of the mangrove fringe is 82 m.

2.9. a) The mangrove transect is about 260 pixels long. b) Its length in metres is about 350 m (see equation to right). c) The average width is 82 m so the area is 350 x 82 = 28,700 m², which is equivalent to about 2.9 ha.

$$\sqrt{(196 \times 1)^2 + (264 \times 1.1)^2} = 350 \text{ m}$$

2.10. Because it is less than a half SPOT pixel width (about 8 m) offshore and the shallow water area between the mangrove islet and the coast cannot be resolved by the SPOT imagery.

Table 2.5. Average size of two mangrove habitats. Each pixel is 1 m wide x 1.1. m long.

Habitat	<i>Rhizophora mangle</i>		Fringing mangrove		
Coordinates (X:, Y:)	241, 425 (DX:)	256, 412 (DY:)	173, 47 (DX:)	225, 129 (DX:)	278, 186 (DX:)
Habitat width/diameter (pixels)	32	28	71	93	83
Habitat diameter/width (m)	32	30.8	71	93	83
Average habitat diameter/width (m)	31.4		82		

Part 3.

2.11. The average width of the blowouts is about 7 m, the average width of the dense seagrass bed is about 62 m, and the average width of the *Montastraea* colony clusters is 3 m.

Table 2.6. Estimating the spatial frequency of seagrass and coral features using CASI imagery

Feature	Seagrass blowouts			Dense seagrass bed			<i>Montastraea</i> colonies		
Coordinates	272, 119	250, 147	244, 158	228, 82	269, 96	194, 50	341, 244	349, 213	366, 239
Width (pixels)	9	8	5	54	71	60	3	3	3
Average width (pixels)	7			62			3		
Average width (m)	7			62			3		

Table 2.7. Predicting the descriptive resolution of aerial photography, SPOT Pan and Landsat TM for key marine features. A tick indicates that the features are visible.

Sensor	Coordinates of study area (c,r)	Spatial res. (m)	blowout		seagrass bed		coral colonies	
			pred.	test	pred.	test	pred.	test
Aerial photography	259,356	2	✓	✓	✓	✓	✓	✓
SPOT Pan	264, 808	10	?	✓ †	✓	✓	✗	✗
Landsat TM	141, 257	30	✗	✗	✓	✓	✗	✗

† The largest blowouts can be seen but smaller ones do not appear visible. Blowout size is right on the borderline of the spatial resolution of SPOT Pan.

Part 4.

- 2.12. Seagrass beds have a fairly uniform texture whereas coral reefs have a complex patchy texture. The seagrass beds tend to be fairly uniformly dark whilst the reef areas tend to be lighter and of varied texture internally but have dark bands around their edges.
- 2.13. The patch widths are approx. 33, 42, 25, 24, 32, 25, 23, 31, 41 pixels giving an average width of 31 pixels or 62 m (each pixel is 2 x 2 m). The MSS imagery (80 m) resolution would be ineffectual at resolving the patches but most should be visible on all the other images.

Table 2.8. Identification of seagrass and coral patches based on their texture.
 “S” = seagrass and “C” = coral.

	SPOT XS		Aerial photography	
	coordinates	S / C	coordinates	S / C
patch 1	412, 434	S	260, 899	S
patch 2	409, 362	S	170, 269	S
patch 3	421, 410	C	360, 739	C
patch 4	402, 388	S	135, 490	S
patch 5	423, 374	C	366, 324	C

APPENDIX 2.1

Landsat Multi-Spectral Scanner (MSS)

The Landsat Multispectral Scanner (MSS) was operational from 1972, following the launch of Landsat-1, until 1993. The spatial resolution for the sensor is 79 m. The radiometric resolution is 6 bits (64 grey levels). The swath width for the sensor is 185 km. Multi-Spectral Scanner data ceased to be collected in 1993.

The spectral characteristics of the Landsat MSS bands are as follows:-

MSS Band		Colour	Wavelengths (nm)
Landsat 1-3	Landsat 4-5		
4	1	Green	500-600
5	2	Red	600-700
6	3	Near Infra-red	700-800
7	4	Near Infra-red	800-1100

Images are produced by reflecting the radiance from 79 m wide scan lines on the Earth's surface to detectors on board the satellite using an oscillating mirror. Each scan line is 185 km long (thus the **swath width** or width of ground covered by the sensor in one overpass is 185 km). The Instantaneous Field of View (IFOV) of the sensor is a 79 x 79 m square on the Earth's surface. This area can be regarded as the **spatial resolution** of the sensor, that is the smallest area which can be sampled by the sensor. Each picture element or **pixel** in a MSS digital image is thus a measurement of the brightness of the radiance from a 79 x 79 m square on the Earth's surface.

Because the satellite is moving so fast over the Earth's surface, it has to scan 6 lines at a time (thus covering 474 m along track). Since the MSS sensor measures the radiance in four different wavebands at the same time, it thus has 24 detectors in total. Each detector converts the recorded irradiance into a continuous electrical signal which is then sampled at fixed time intervals (approximately every 10 μ s) and converted to a 6 bit number (64 grey levels). During this interval the ground distance covered by the oscillating mirror is only 56 m. Thus the picture elements or pixels making up an MSS image are 56 x 79 m rectangles.

The 6 bit numbers representing reflectances recorded from each point (79 x 79 m on the Earth's surface) are either recorded on magnetic tape on board the satellite (in earlier Landsats) or transmitted to an Earth receiving station where they are recorded on high-density digital tapes (HDDTs).

A full Landsat MSS scene consists of measurements of the radiance from a ground area of 185 x 185 km and thus consists of 2340 scan lines each consisting of 3240 pixels. There are thus about 7.5 million pixels per scene, each of which has radiances recorded in four wavebands, giving a total of 30 million bytes of information. It takes about 25 seconds to record one scene. The digital information for a scene is supplied on Computer Compatible Tapes (CCTs) or on Exabyte tapes to users who then need to process it on computers according to their needs.