

## **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 your ability to discriminate between different coastal habitats.

### **Objectives**

1. To investigate how different major features appear at a range of 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 is 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 that can be resolved in SPOT XS images 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 is poor at detecting habitats whose average patch-size is less than 20 m x 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 you can identify habitats 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 (e.g., inter-pixel variance) 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 (above), and airborne digital and aerial photographic imagery (below) used in lessons.

Specification	Landsat MSS	Landsat TM	SPOT XS	SPOT Pan	IKONOS multispectral	IKONOS panchromatic
Spatial resolution	80 m	30 m	20 m	10 m	4 m	1 m
No. of spectral bands for habitat mapping	4	6	3	1	4	1
Area covered (km)	185 x 185	185 x 170	60 x 60	60 x 60	variable	variable

Specification	CASI (airborne)	Aerial Photography
Spatial resolution	0.5 m to 10 m	variable (>0.2 m)
No. of spectral bands for habitat mapping	8-21 <i>user defined</i>	1-3 † <i>analogue</i>
Area covered (km)	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 can 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 for this lesson).

### The *Bilko 3* image processing software

Familiarity with *Bilko 3* 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. You will need experience of using the image cursor to examine and interpret images and of making colour composite images. These features are covered in Tutorials 2 and 3 of the *Introduction to using the Bilko 3 image processing software*.

### Image data

All images used in this module were acquired 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 and IKONOS panchromatic. *Note:* When geometric correction and other processing are 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 sub-scenes of multispectral satellite images at four different spatial resolutions (Landsat MSS [80 m]: Appendix 2.1; Landsat TM [30 m]: Appendix 1.1; SPOT XS [20 m]: Appendix 1.2; IKONOS [4 m]: Appendix 1.3). These can be viewed individually or connected to make false colour composites. You are also supplied with sub-scenes of SPOT (Appendix 1.2) and IKONOS (Appendix 1.3) panchromatic (single-band recorded across the visible spectrum) images at 10 m and 1 m resolution respectively and some sub-scenes from monochrome aerial photographs scanned so that each pixel is 2 x 2 m on the ground. You are also provided with sets of 3 bands of two airborne multispectral CASI images (Appendix 1.3) taken at 1 m spatial resolution.

**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)	<b>CASI_mangrove#03.dat</b> <b>CASI_mangrove#05.dat</b> <b>CASI_mangrove#07.dat</b>  <b>CASI_Cockburn_Harbour#01.dat</b> <b>CASI_Cockburn_Harbour#03.dat</b> <b>CASI_Cockburn_Harbour#05.dat</b>
IKONOS panchromatic	satellite	March 2001	1	<b>ikonos_Caicos_pan.dat</b>
Monochrome aerial photography	aircraft	1981	2	<b>AP_east_SCaicos.gif</b> <b>AP_south_SCaicos.gif</b> <b>AP_mangrove_SCaicos.gif</b>
IKONOS multispectral	satellite	March 2001	4	<b>ikonos_Caicos#01.dat</b> <b>ikonos_Caicos#02.dat</b> <b>ikonos_Caicos#03.dat</b> <b>ikonos_Caicos#04.dat</b>
SPOT panchromatic	satellite	27/03/95	10 (12)	<b>SPOTXP_SCaicos.gif</b>
SPOT XS	satellite	27/03/95	20 (23)	<b>SPOTXS_SCaicos#01.gif,</b> <b>SPOTXS_SCaicos#02.gif,</b> <b>SPOTXS_SCaicos#03.gif</b>
Landsat TM	satellite	22/11/90	30 (33)	<b>LandsatTM_SCaicos#01.gif,</b> <b>LandsatTM_SCaicos#02.gif</b> <b>LandsatTM_SCaicos#03.gif</b>
Landsat MSS	satellite	28/06/92	80 (66)	<b>LandsatMSS_Caicos#01.gif</b> <b>LandsatMSS_Caicos#02.gif</b> <b>LandsatMSS_Caicos#03.gif</b>

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 m<sup>2</sup> 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 two CASI images have been made into false colour composites and then saved as the *Bilko* sets **CASI\_Cockburn\_Harbour#05+#03+#01.set** and **CASI\_mangrove#07+#05+#03.set** to save you time.

**Table 2.3.** Band settings used on the CASI.

<b>Band</b>	<b>Part of electromagnetic spectrum</b>	<b>Wavelength (nm)</b>
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 resolutions.
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 landing strip at South Caicos international airport using each image type and in so doing, gain a practical feel for various spatial resolutions. Measurements will be made by recording several measurements of the number of pixels or metres (for images with UTM coordinates) across the landing strip and then taking their mean to calculate the width of the landing strip. Since the landing strip is more or less east-west, it is not thought worthwhile using Pythagoras to refine the measurements.

*Activity:* Launch *Bilko* and use **File, Open** to view the monochrome photograph, **AP\_mangrove\_SCaicos.gif**.

*Question:* 2.1. What is the width of the area covered by the aerial photograph on the ground in km (to the nearest 0.1 km)?

*Activity:* Using **Edit, Go To**, place the cursor at coordinate (519, 64), which marks the northern side of the landing strip. Place the mouse cursor at the cross-hairs and double-click to zoom in<sup>1</sup> to 300–400% (see Status bar for zoom). [Alternatively, hold down <Ctrl> and rotate your mouse-wheel forwards to zoom in and backwards to zoom out.] The landing strip should be clearly visible and comprises three zones – two white areas of pavement surrounding a dark area of tarmac runway. For this exercise, the “landing strip” is defined as both the runway and areas of pavement surrounding it.

Click on the transect tool . Place the mouse pointer at the northern side of the landing strip (519, 64) and, keeping the left mouse-button depressed, drag it down to the far side of the landing strip and release. Cursor coordinates should now read approximately (514, 102). (*Note:* Since the landing strip does not run exactly from west to east so your cross-runway transect will be at a slight angle to the vertical.) Click on **Edit, Go To** in order to display the **Go To** dialog box. This should have **Line selection** highlighted under **Selection Type**:. Under **Selection Size**, the value **DX**: should be a small negative number as the runway does not due east-west. The value **DY**: represents the number of pixels across the landing strip. Enter this value into Table 2.4. Take two or more transects to the east of the first and note the widths in pixels in Table 2.4. Once you have three or more measurements, calculate their mean and use this to calculate the width of the landing strip. Enter your width calculated from Aerial photography in Table 2.4 .

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<sup>1</sup> *Note:* Using <Ctrl>+double-click zooms out.

**Table 2.4.** Width of landing strip at South Caicos airport

Image type	Measurements across landing strip (pixels or metres)	Pixel size (m)	Width of landing strip (m)
Aerial photography		2	
SPOT Pan (XP)		12	
Landsat MSS		66	

*Activity:* Close the **AP\_mangrove\_SCaicos.gif** file and open the SPOT Pan image, **SPOTXP\_SCaicos.gif**.

*Question:* 2.2. What is the width of the area covered by the SPOT Pan subscene on the ground in km (to the nearest 0.01 km)?

*Activity:* When you have answered the question, use **Edit, Go To** to place the cursor at UTM coordinate (237238E, 2381303N) and zoom in to about 500%. The landing strip should be clearly visible although the boundaries are not as clear as those in the aerial photograph. Using the methods set out above (except that you will be able to read off distance in metres), measure the width of the landing strip at coordinate 237238E, 2381303N and at various other points along the landing strip where the boundary is reasonably clear. Enter your measurements in Table 2.4. [*Note:* If you drag the transect from north to south the **DY:** gives you the distance in metres S of starting coordinate.] If you have a range of values for landing strip width, take the average as your best estimate of the landing strip width.

*Question:* 2.3. Is there any difference between the average width estimated using aerial photography and SPOT Pan? If there is a difference, how does it relate to the spatial resolution of SPOT Pan (i.e. 10 m)?

*Activity:* Close **SPOTXP\_SCaicos.gif** and open **LandsatMSS\_Caicos#02.gif**, which is band #2 (green) of the Landsat MSS image. Use <Ctrl>+A 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 (to the nearest 0.1 km)?

Use **Edit, Go To** to move the cursor to coordinate (237303E, 2381329N). Examine the image at its current magnification.

*Question:* 2.5. Is the landing strip visible?

Position the mouse pointer at the cursor and zoom in. The landing strip 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 landing strip at low magnifications but less so at higher magnifications where less of the feature is visible. At a starting point of (237303E, 2381329N), enter the number of pixels that seem to comprise the width of the landing strip (Table 2.4). [*Note:* The image cursor sits on the mid-point of the selected pixel.]

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

Close the **LandsatMSS\_Caicos#02.gif** image.

## Part 2. Spatial scales and mangrove mapping.

You are provided with a false colour composite of part of a CASI image of Cockburn Harbour and the mangroves on the west coast of South Caicos (**CASI\_mangrove#07+#05+#03.set**). Although a variety of habitats exist here (see Lesson 1), we will focus on mangrove at 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 composite, which has been saved as the *Bilko* set **CASI\_mangrove #07+#05+#03.set**. In the **Redisplay Image** dialog box, set null value to zero, select an automatic linear stretch and click on the **All** button to apply these settings to all three images making up the composite. The mangrove appears as red because the near infra-red band #7, which vegetation reflects strongly, is displayed through the red gun. At the bottom of the image (scroll down as necessary) you can see part of the Cockburn Harbour settlement and several piers.

Use **Edit, Go To** to place the cursor on the circular patch of *Rhizophora* lying just offshore at coordinate (237040E, 2379098N). Zoom in to about 400%. Calculate the diameter of the patch in the horizontal plane starting at coordinates (237022E, 2379099.7N) using the transect tool . [Hint: once you have dragged the transect over the patch, use **Edit, Go To** to find the number of metres (**DX:**) across.] Enter the distance in Table 2.5. Move the cursor to coordinate (237039E, 2379082.1N) at the north end of the patch and measure the vertical diameter of the patch (this time enter the distance in **DY:** into Table 2.5). 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  $\pi = 3.142$ .

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

**Question:** 2.7. Using your measurement of patch diameter, what is the area of the circular red mangrove patch (to nearest whole m<sup>2</sup>)?

**Activity:** Zoom out a bit. Using the coordinates in Table 2.5, measure the width of the fringing “mangrove” (estimate the distance from the waters edge to the inland (non-red) edge of the mangrove) perpendicular to the coastline. For example, if you place the cursor at (236817E, 2379531N) and lay a transect across the mangrove you should get a **DX:** of about 38 m and **DY:** of about 45.1 m. Note the **DX:** and **DY:** for each transect in Table 2.5 and then use Pythagoras to calculate distance along the hypotenuse. This is done for you for the first transect to save you time.

$$\text{Length of transect} = \sqrt{\text{DX}^2 + \text{DY}^2}$$

**Question:** 2.8. What is the average width of fringing mangrove based on the three transects in Table 2.5.?

**Table 2.5.** Measuring the dimensions of two mangrove habitats.

Habitat	<i>Rhizophora mangle</i> patch		Fringing mangrove		
Starting position of transect (X:, Y:)	237022E, 2379099.7N (DX:)	237039E, 2379082.1N (DY:)	236817E, 2379531N (DX:, DY:)	236897E, 2379460N (DX:, DY:)	236992E, 2379379N (DX:, DY:)
Habitat diameter/DX:, DY: (m)			38.0, 45.1		
Mean diameter/width of fringe (m)			59.0		

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 along the middle of the mangrove fringe. Such a transect might begin in the extreme NW of the image at around (236726E, 2379655N) and end around (237085E, 2379315N).

*Activity:* Use the mouse pointer and transect tool to lay a transect along the length of the middle of the northern mangrove fringe parallel to the coast. Select **Edit, Go To** and read off the **DX:** (metres W–E) and **DY:** (metres N–S) of the transect and use Pythagoras's theorem to work out its length as follows:

$$\text{Length of transect} = \sqrt{\text{DX}^2 + \text{DY}^2}$$

*Question:* 2.9. a) What is the length of the transect in metres (to nearest m)? b) Using the average width of the mangrove fringe calculated earlier, what is the **approximate** area in hectares (to nearest 0.1 ha) of the fringing mangrove in the northern part of the image? [*Hint:* Treat the area as a rectangle.]

Keeping **CASI\_mangrove#07+#05+#03.set** composite available for future comparisons, you will now create a false colour composite from the three SPOT XS imagery bands (**SPOTXS\_SCaicos#01.gif – SPOTXS\_SCaicos#03.gif**).

*Activity:* Close the three constituent images of the CASI false colour composite and minimize the **CASI\_mangrove#07+#05+#03.set** image. Open the SPOT XS image files **SPOTXS\_SCaicos#01.gif, SPOTXS\_SCaicos#02.gif** and **SPOTXS\_SCaicos#03.gif**. Connect the three images using the **Image, Connect** command (highlight each with the cursor whilst depressing the <Ctrl/> key). Set the **Selector** toolbar so that the XS band #3 image is 1, the XS band #2 image is 2, and the XS band #1 image is 3 (thus displaying them on the red, green and blue guns respectively in a colour composite).

Select the **Image, Composite** command to make a colour composite. Then use the **Edit, Select All** command (or <Ctrl/>+<A/>) to select all pixels in the image, and to improve the contrast within the image, apply an automatic linear stretch (click on the **Stretch** menu and apply the stretch, **Auto Linear**). [*Checkpoint:* The land should be bright red and the sea turquoise and blue if the images have been combined properly.] Select **Save As** to save the colour composite as a *Bilko* set, **SPOTXS\_SCaicos#03+#02+#01.set**, as you will need it in Part 4 of this lesson. Then close the connected tiled image and constituent SPOT images individually, leaving only the composites open. Do not save any changes to these other image files.

Use the **Edit, Go To** command to move to coordinates (237045E, 2379095N) on the SPOT composite then zoom in to around 450%. 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* red mangrove is just visible at (237043E, 2379094N) but its circular shape is not preserved because it is now represented by one SPOT pixel (though it influences neighbouring pixels to give 'mixels'). (*Remember:* the same patch was represented by about 900 pixels in CASI imagery!).

*Question:* 2.10. Why isn't the offshore mangrove patch visible as distinct from the coastal mangrove? [Explain why quantitatively.]

*Activity:* 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 3–4 SPOT pixels (i.e. 60–80 m). Note that it is much harder to determine exactly where the mangrove begins and ends, with many 'mixels' where the mangrove meets the sea.

Minimize the SPOT false colour composite. 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 **LandsatMSS\_Caicos#01.gif, LandsatMSS\_Caicos#02.gif** and **LandsatMSS\_Caicos#03.gif**.] As before, display the

infra-red band through the red-gun so that vegetation (which has a high reflectance in the near-IR) appears bright red. Use **Edit, Go To** to place the cursor at coordinates (237040E, 2379150N) 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 1 or 2 pixels wide.

When you have finished, close the CASI and Landsat MSS 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 Red mangrove, *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 pixels wide which in this case equals 66 m or 132 m with no possible intermediate values).

### Part 3. Spatial frequency of seagrass and coral features

In this part you will work with a colour composite CASI image (1 m spatial resolution) of Cockburn Harbour (**CASI\_Cockburn\_Harbour#05+#03+#01.set**) showing seagrass and reef habitats. These habitats were described in some detail in Lesson 1 and photographs may be opened in the *Bilko* viewer for further familiarisation (files **Seagrass\_blowout.bmp**, **Seagrass\_dense.bmp**, **Montastraea\_colonies.bmp**). The first exercise is to measure the width of two important features that have different spatial frequencies: seagrass blowouts (**Seagrass\_blowout.bmp**) and colonies of the hard coral, *Montastraea annularis* (**Montastraea\_colonies.bmp**).

*Activity:* Open the *Bilko* set **CASI\_Cockburn\_Harbour#05+#03+#01.set**. In the **Redisplay Image** dialog box, set null value to zero, select an automatic linear stretch and click on the **All** button to apply these settings to all three images making up the composite. Select **View, Coords** to switch from UTM coordinates to column and row coordinates (these are shorter and less hassle to enter!). Then use the **Edit, Go To** command to place the cursor on the seagrass blowout (coordinate 428, 230). Zoom in so that you can accurately measure width. Using the transect tool  and **Edit, Go To** to measure the horizontal widths of the remaining unmeasured blowouts listed in Table 2.6. The coordinates are in the middle of the blowouts. [*Hint:* Since the pixel width = 1 m then you can directly read off distance.] Enter your results in Table 2.6.

The next task is to measure horizontal distances across clumps of *Montastraea* colonies on sand. For this exercise 5 clumps have been selected (three of which have been measured for you). The coordinates in Table 2.6 are just to the west of each clump. In each case you should assume that values in band #3 (displayed through green gun) <2200 are coral and those >2200 are sand. You need to position the image cursor at each Table 2.6 coordinate and then use <Ctrl>+<Right arrow> keys to move the cursor one pixel at a time to the right, counting the number of pixels <2200 (in band #3) for each coral patch.

*Activity:* Use the **Edit, Go To** command and the coordinates listed in Table 2.6 to place the cursor to the left of each patch of *Montastraea*, which contrast with the pale background. Measure the horizontal width of the two remaining darker coral patches (pixels <2200 in green = band#3) as indicated above 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				<i>Montastraea</i> colonies				
	Coordinates	468, 179	428, 230	320, 87	469, 154	612, 383	574, 393	588, 340	580, 384
Width (m)	23			5	10	3			8
Average width (m)									

*Question:* 2.11. What are the average widths of seagrass blowouts 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	Top left of study area (c, r)	DX:, DY: (c, r)	Spatial res. (m)	blowout		coral colonies	
				pred.	test	pred.	test
Aerial photography	210, 305	230, 205	2				
SPOT Pan	255, 800	45, 35	10				
Landsat TM	135, 252	20, 15	30				

To check your predictions entered in Table 2.7, you are provided with monochrome aerial photography (**AP\_south\_SCaicos.gif**), SPOT Pan imagery (**SPOTXP\_SCaicos.gif**), and Landsat TM imagery (**LandsatTM\_SCaicos#01.gif – LandsatTM\_SCaicos#03.gif**).

*Activity:* Open the aerial photographic image **AP\_south\_SCaicos.gif** and apply an automatic linear contrast stretch. Then open the SPOT Pan image **SPOTXP\_SCaicos.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. Apply an automatic linear stretch.

For each image in turn, use **Edit, Go To** in order to outline the study areas 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:* Maximize (or if necessary, open) the SPOT XS false colour composite image **SPOTXS\_SCaicos#03+#02+#01.set** which you created in Part 2 of this lesson and apply an automatic linear stretch if you’ve had to open the file. Use **View, Coords** to switch from UTM coordinates to column and row coordinates. 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 column and row coordinates of 5 patches are given in Table 2.8. Using the **Edit, Go To** function to locate the patches, can you identify which patches are coral and which are seagrass based on their colour, size 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\_east\_SCaicos.gif** which is a monochrome aerial photograph with a spatial resolution of 2 m. Use **View, Coords** to switch from UTM coordinates to column and row coordinates. 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?

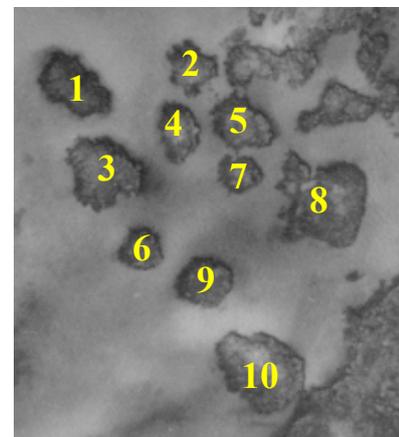
*Activity:* Examine this image in detail and visit the column and row coordinates provided in Table 2.8 to see whether your identification of habitats differs in light of the greater textural information now available. (Note: each position on the image is equivalent to that provided for SPOT.) You can 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 coordinates		Aerial photography coordinates	
		S / C		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	439, 380		553, 391	

You should have found it very easy to determine coral and seagrass patches on the aerial image but more difficult on the SPOT image. On the aerial image the texture clearly shows what is coral reef and what is seagrass. On the SPOT image one has to use habitat size and shape as a guide and then make an educated guess. A histogram equalization stretch of the SPOT image gives more detail but does not help identification.

*Activity:* Finally, assess the average width of the 10 coral patches scattered around coordinates 420, 790 on the aerial photographic image (see below for image showing location). [Hint: Use the mouse to drag a horizontal transect across the middle of each patch. When the transect is in position, select **Edit, Go To**. In the **Go To** dialog box click on the **Coords** checkbox and read off the distance (**DX:**) in metres.]



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

*Activity:* 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 sensor attribute; 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. This has been shown to be the case for IKONOS multispectral imagery (Mumby and Edwards, 2002).

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. Mumby and Edwards (2002) show that whilst the 4 m spatial resolution of IKONOS satellite imagery significantly improves classification accuracy at a fine descriptive resolution (13 habitat categories), the overall accuracy is still only 50% compared to around 80% using CASI airborne imagery. Although the high spatial resolution of the IKONOS imagery allows textural information about habitats to be used in classification, the lack of spectral resolution (which is very similar to Landsat TM and ETM+) prevents satisfactory fine-level discrimination (Mumby and Edwards, 2002). The main operational lesson is: make sure that your imagery can achieve your mapping objectives.

*Activity:* To finish, you should examine IKONOS satellite imagery at a spatial resolution of 4 m (multispectral) and 1 m (panchromatic). Open the *Bilko* set ***ikonos\_Caicos#03+#02+#01.set*** (set null value to zero and use an automatic linear stretch) and the panchromatic image ***ikonos\_Caicos\_pan.dat*** (set null value to zero and use a histogram equalization stretch). Examine these images with special regard to discrimination of roads, houses, boats, dense seagrass beds, seagrass blowouts, *Montastraea* colonies and reef and seagrass texture. Note the marked improvement on Landsat TM and SPOT XS and panchromatic imagery.

These images show the amazing detail of the latest generation of satellite images but if compared to the CASI image of the same area show the loss of radiance contrast due to the atmosphere (Mumby and Edwards, 2002).

*Activity:* When you have finished your examination, close all images.

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## 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  $\mu$ 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 resampled pixel size in this lesson of 66 m x 66 m is approximately

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.

