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THE ASSESSMENT OF COASTAL HABITAT RESOURCES FROM AERIAL PHOTOGRAPHY

1. A quick and easy method for assessment of the major habitat resources

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ABSTRACT

A method is outlined for map-production and resource assessment using aerial photographic mosaics. Each stage of the method is described in sufficient detail for it to be applied by persons untrained in cartographic techniques. The method has been organized to be applicable to maps of varying size and complexity and cost is related to the information obtained. Future work will make progressively detailed use of the photography whilst still relating the information obtained to the time and cost involved.

LIST OF CONTENTS

INTRODUCTION

Aerial photography is becoming an increasingly important tool for the ecologist. It is of particular use in coastal ecology since site access is frequently limited by the nature of the terrain. The uses put to such photography vary considerably. It may be used solely as a display; or for photogrammetric survey complete with computer analysis of the land types. However, more frequently it is required by the ecologist as a guide in his field studies, and he is keen to glean as much information as is possible, within a short time, but with limited equipment and finance. This report is intended to help achieve this.

Holkham National Nature Reserve consists of salt marsh, sand dune and mud flats with an area of reclaimed marsh. It comprises nearly 20 kilometres of coastline and is up to 4 kilometres in width. The variation in habitat types makes it ideal for aerial photographic study.

In November 1969 the area was flown by Hunting Surveys Ltd. Photographs were taken at 5000' giving a contact scale of 1:10000. The individual photographs were constructed into a contact size photomosaic. This is uncontrolled; that is distortion due to tilt of plane, height changes in flight, and relief variation is uncorrected; joining of the photographs is undertaken to give the best visual fit. However, if relief variation is small, then the distortion should not be so great as to preclude the use of the photo-mosaic as a base for map production.

The area was flown about ½ hour after a medium low water spring tide. This means that the tidal level had risen to about mean low water which corresponds fairly well with the reserve boundary. However, a few centimetres vertical change in the tide can mean a change of metres horizontally and a loss or gain of many hectares overall. For this reason our mean low water line can only be taken as approximate.

The photography offered a large amount of useful information, more than could be extracted with the resources available at present. The aim has been to extract different levels of information and attempt to relate their value to the time involved in collection. At the same time an attempt has been made to use techniques applicable to each stage of complexity.

The report is divided into three parts. In Part I the methods are described in full. Reference to the Holkham Survey is only made where the example helps to explain a point. In Part II the Holkham Survey is given as a worked example in a summary of the techniques used. The results are then discussed in Part III. Readers interested only in the general method may wish to go straight to the worked example in Part II.

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PART I -- METHODS

The Holkham area can be summarized in four habitat descriptions :-

(a) Sand dune

(b) Salt marsh

(c) Sand/Mud flat

(d) Reclaimed marsh

There are of course habitats intermediate to these. However, our intention at this stage has been to maintain simplicity of classification. It is all too easy to continually add intermediate categories until the complexity of the map reaches far beyond original intentions. Intermediate habitats, where they occur, are therefore classified in the most appropriate grouping.

For this map it was considered satisfactory to trace direct from the photomosaic. The original 9" x 9" photographs were useful in interpretation since they offered the stereo-image which is of great assistance during interpretation.

As the reserve is split into two by the Wells Channel it has been convenient to treat each half separately. This makes little difference to the methods used except during the area measurement stages, as will be described later.

The method is given below :

1. Tracing

It is best to use plastic tracing sheet (Kodatrace for example). It is reasonably clear and very strong. Hard pencils are required on this surface as it is very abrasive; 4 - 6H is about right. Soft rubber is best for correction and a typist's "pencil-rubber" is useful for fine correction. The surface of the tracing sheet should be dusted with French-chalk to prevent leaving finger prints. Both the mosaic and the tracing sheet must be stuck to a smooth surface using masking tape.

2. Interpretation

Accuracy of interpretation is essential to the accuracy of the end product. To aid interpretation the 9" x 9" photographs should be studied thoroughly under a stereo viewer. Stereo-imagery helps a great deal in identification. Land-relief is depicted and textures improved to make interpretation decisions much more accurate. Field visits will also be essential unless the site is known well. On field visits the photographs should always be at hand. Features on the ground should be located on the photographs and vice versa until one is confident that photographic tones can be identified correctly.

Each habitat should be traced on the mosaic overlay sheet, care being taken that no relevant detail is lost. Rear illumination may be useful for this, though not essential.

Verification

Verification of interpretation can only be carried out in the field. This may be considered unnecessary if one is confident of the interpretation, especially if the site is well known anyway. However, it is advisable to visit any sites on the mosaic where there is some doubt as to the nature of the habitat. Whilst checking this it would be wise to check some areas supposedly interpreted correctly!

3. Inking-In

Inking-in is done straight onto the tracing in order that it may be used for dyeline copying. Consideration must be given to the possibility of reduction or enlargement at a later date. Any enlargement is unlikely to produce a good map, hand-drawn lines tending to appear very untidy.

In the case of reduction a final line thickness of 0.1 mm is the minimum to be aimed at for most purposes.

The more detail to be shown the finer the lines should be. Shading and symbols used to denote areas can be drawn with a finer nib than used for the outline but these will suffer the same fate as outlines on reduction. The uses to which the map will be put determine the definition required and the nib sizes used.

Once the map has been inked the pencil may be erased with a soft rubber. This should also remove any finger marks that have got onto the tracing. Very grubby marks may be removed with solvents but care must be taken that these do not dissolve the ink. This should be tested on a scrap of tracing sheet beforehand. Carbon tetrachloride proved suitable with "Rotring" ink. Alcohol did not!

4. Dyeline copying *

This is a cheap method of reproduction if the map is in the form of a transparency. If however the copies are required at scales other than that of the tracing, the price is increased since a new transparency must be made at contact size. As this is a photographic process, producing the transparency on film, this can be relatively expensive. However, once this transparency is made copies are produced as cheaply as with the tracing. Copies are best produced on extra stout paper if the map is to be shaded using water-colour or to be used frequently. Otherwise, for rough field copies, light weight paper may be more convenient, if rather short-lived.

5. Shading

Whether the tracing or its copies are shaded depends on one's demands from the map. The advantages of shading

* See appendix - "Methods of Improvement"

on the tracing is that the finished article can be mass produced from the tracing.

There are several disadvantages :-

(1) The shading must be black and white (half tones must take the form of dots or stripes etc.)

(2) The type of shading cannot be varied for different purposes (colours for visual aid in lectures, large symbols for reduction and publishing etc.)

(3) A shaded map may not be suitable for addition of further detail (field observations, transect positions etc.)

The only advantage of shading the tracing is that mass production is then cheap. If however, only few copies are wanted it may be better to shade these individually. Ideally a copy could be made of the tracing (photographically or by hand). Then one can be shaded for any mass production required whilst the other is always available should base-line maps be wanted.

The form of shading depends on :

(1) Whether tracing or copy to be shaded.

(2) Time worth spending on shading.

(3) Whether further detail needs to be added to the shaded map.

(4) Whether to be used as working document, publication, visual aid etc.

To go into great detail regarding the different shades, tints and colours available would take much time.

Listed below are some of the options, their advantages and disadvantages :

Shade/Tint	Pros.	Cons.
Pen and Ink	Cheap easy : Can be quick depending on complexity of symbols: Can be dyeline copied published etc.	Not always very tidy Slow for fine detail. Obscures detail to be added later
Letraset Letratone Instantex	Very good finish, suitable for publication, very large range of half-tones etc.	Slow and tedious in use Best method of lettering
Felt tip pens	Very quick, easy.	Untidy, colours very bright, can't be copied cheaply
Water colour	Colour range very large, can add detail with pen and ink later	Brush marks, wrinkle all but Extra Stout paper, can't be copied cheaply
Town and Country Planning colours	Used by TCP, colours good; aimed at vegetation maps.	Can't be copied cheaply; but if using colour reproduction then seem to be ideal.

For the Holkham map we opted for the simplicity of pen and ink, using symbols based on those of the Ordnance Survey. Letraset was used for all lettering.

Whatever method is chosen it is important to check on scraps of the paper to be used that the shade takes well, does not soak into the paper as in blotting paper, takes no longer than anticipated etc.

6. Calibration of the Photograph

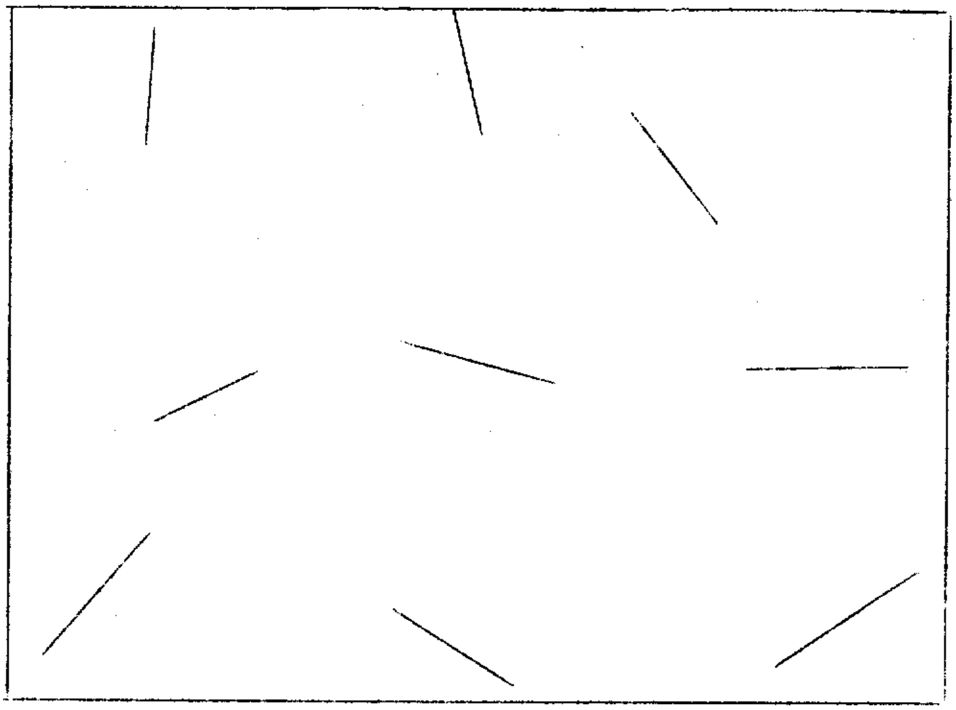
The photo-mosaic was not corrected for the distortions caused mainly by plane tilt, height changes and land relief (although the latter is unimportant on this site). For this reason any scale given can only be an average for the area it describes.

Comparison of the photograph with a standard is necessary. Ordnance Survey maps are the obvious standards. Distortion may not be linear along the runs or across them and for great accuracy the scale must be estimated over the total area. However, for accuracies of measurement of $\pm$ 10% it may be taken to average out over fairly flat areas.

On our map the distortion produced a larger scale to the east than the west, and again slightly larger to the south than north. As the photo-mosaic is in two halves, east and west, it was considered more accurate to scale each independently rather than average for the total area.

Stages of Calibration :

(a) It is worthwhile trying to assess the distortion in the mosaic. This can be fairly great and must be known to give area measurements within known limits. Distances between points on the photograph should be compared with those between the same points on the Ordnance Survey map. Ideally the lengths should be measured on a "Union Jack" pattern to span as much of the photograph as possible, but the lines should not be too long (best about the length of "a-one-photograph-section" of the mosaic). The pattern of lines may look like this :-



Using a mean scale value for the whole map area, we would have had an error of ± 2-3% at the limits of distortion. Although this is not very great it is easily lessened by dividing the area into half, and scaling each half separately. This seemed worthwhile for Holkham since our mosaic was already divided into two on account of its size.

The plane seemed to have dropped in height as it flew west to east along the main run of the mosaic, making the scale at the eastern end larger than that in the west. Hence, our distortion was mainly east to west and the division separated these. Obviously with north to south distortion division should be north from south.

The larger the number of divisions, the more accurate the scaling of each section. Hence this should be borne in mind when scaling the photo-mosaic.

(b) To achieve an accurate area measure, recognisable areas are delineated on the map and each mosaic section to be measured. A triangle delineates a suitable area as it is easy to measure. (A rectangle on the map may prove to be an irregular polygon on the mosaic due to distortion). The delineated area should span as much of the mosaic section to be scaled as possible.

(c) We can now compare the ratio of the photographic scale to the map scale:

		Map	Photo	Ratio (Photo / map)
West	Base	23.6 cm	56.9 cm	2.411 : 1
	Height	10.7 cm	26.0 cm	2.430 : 1
	Area	126.3 cm^2	739.7 cm^2	5.857 : 1
East	Base	32.7 cm	80.5 cm	2.462 : 1
	Height	13.4 cm	33.4 cm	2.493 : 1
	Area	219.1 cm^2	1344.4 cm^2	6.136 : 1

It is the simple matter of conversion to a ground area.

The OS $2\frac{1}{2}$" map gives :

$$1 \text{ cm}^2 \equiv 6.4232 \text{ ha.}$$

$$\therefore \ 1 \text{ cm}^2 \text{ Photo (West)} \equiv \frac{6.4232}{5.857} \text{ ha} \equiv \underline{\underline{1.097 \text{ ha}}}$$

$$\text{and : } 1 \text{ cm}^2 \text{ Photo (East)} \equiv \frac{6.4232}{6.136} \text{ ha} \equiv \underline{\underline{1.047 \text{ ha}}}$$

Area Assessment

There are many suitable methods of area assessment. Each offers different advantages dependent on the nature of the areas to be measured. A small number of large, smooth outlined areas is easy to measure. A few smaller areas may be equally easy, but to achieve reasonable accuracy, require more care. However, more than likely, the area under study will consist of a mixture of types, some areas large with smooth outlines, others small but few in number; also a range of sizes shapes and distributions that make area measurement more difficult.

Our area provided something of this range. We had large expanses, easily measured with accuracy. But on Holkham West we had a small patch of marsh, on Holkham East a small area of dune. We wanted to pick these up with fair accuracy and without intricate methods of measurement. The creeks dissecting the marsh also defy measurement by such techniques as planimetry and square grids. We also wanted a method which would be suitable for much more complex areas. A dot grid seemed the obvious answer, suiting our area yet versatile enough for a great range of map types.

However, different sized areas require different sized dot grids. It is impossible to measure accurately a small area with a single count of an open grid. But on the other hand it is pointless having thousands of dots to count, when large areas are being assessed.

This problem can be overcome by using an open grid, doing several counts, and moving the grid randomly after each count. Ten counts of a 100 dot grid are as good as one count of 1000 dot grid. Indeed for several reasons we found this better.

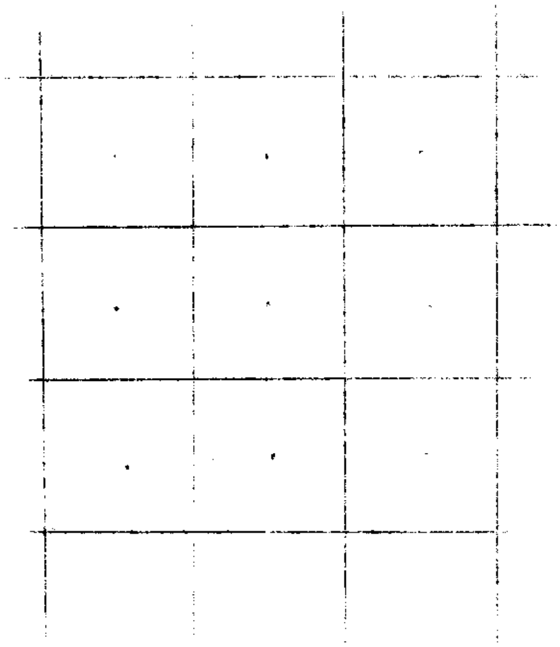
The method, as used, was crude. In an effort to save time some shortcuts were made. However, methods of improvement are discussed later and may be of value where complete reliability is essential. For our purposes the emphasis was placed on speed of operation and some sacrifices of exactness were made.

<u>Grid Size</u>

The size of the grid is proportional to the areas to be measured. Small areas require more counts of the grid but since the dot number will be small these need not take too long. Very large areas may need fewer counts but if the dot number is too high this can be laborious. So it is necessary to base the grid size on the relative areas of the smallest and largest habitats.

Our smallest habitat type, treating Holkham East and West separately was the sand-dune area to the East. This covered about 30 cm^2 of the map, about 2% of the Holkham East. The dot grid we chose to use scored about 7 dots to this area. This small score meant many counts of the grid but, since the score was low, counts were very quick. However, it would not seem advisable to score lower than this by using a more open grid; nor it is not desirable, to have too many dots to count in the total area. A balance must be drawn between the minimum and maximum number of dots which will be counted over the individual areas. As a guide it might be best to count no less than 5 dots in the smallest area, no more than 1000 in the total. It may however, be necessary to go beyond these limits if the total area is large, but sub-units are small.

Our dot grid used to achieve this range was one dot per 4 cm^2. To ease systematic counting they were positioned within a square grid as below :



The Number of Counts of the grid

The number of counts of the grid required is dependant on several factors :

(a) The size of the area to be measured.

(b) The accuracy required.

(c) The degree of confidence that the area is within the pre-specified accuracy.

The more counts made the greater the reliability of the results. Hence, it is a question of the time worth spending on area measurement and the importance of accuracy. We pre-specified an area measurement to within ± 5% error

The area is given by

$$A = \bar{x} \pm \frac{s}{\sqrt{N}} . t$$

(i.e. Area = Mean ± $\frac{\text{Standard deviation}}{\text{Number of counts}}$ x t.)

where :-

Area = Area in terms of dots

t = Students-t value for confidence required at N-1 degrees freedom

The more counts performed, the larger N, hence the smaller is the error:

$$\pm \frac{s}{\sqrt{N}} .t$$

Counts are made until this is acceptably small.

Confidence Limits

We chose to measure the area to ± 5% with 90% Confidence. Again this can be altered and the value should be set to satisfy one's particular needs. Under most circumstances however, it would be pointless to set a high confidence level with a low accuracy.

Dot areas to Hectares

The actual ground area of each habitat is easily converted to ground measure units as follows :-

Map area (cms^2) = Dot count x cms^2 per dot

We have already scaled the mosaic to the Ordnance Survey map and it is now only necessary to convert cms^2 of mosaic to units of ground measurement.

Area measurement - Overall error

The major sources of error have been mentioned and are :

(a) Tracing error

(b) Interpretation error

(c) Photo-scaling error

(d) Area measurement error

Tracing error and interpretation error are not easy to assess. Ideally they should be checked by field verification. A method of quantitative field verification is under development for use on vegetation maps and it is hoped that this might be applicable to the general habitat-type survey. However, in this case, the errors are taken to be very small. The mapping from the photograph was well within its resolution. Interpretation decisions were generally obvious and boundaries were clearly defined for tracing.

The photo-scaling method has been discussed. On relatively flat areas a mosaic can be scaled quite accurately and by subdivision the portions can be scaled even more so. In the case of the Holkham Survey each half of the mosaic incorporated a scale error of ± 1% at the limits of accuracy.

The error incorporated into the dot-count area measurement can be set to whatever value is required. The more counts made the less is the error. We worked to a ± 5% error limit on the dot counts with a 90% confidence level set on the value of t (from Students-t).

We can now sum the total possible error. In fact summation may over-estimate error in that there is a possibility of errors cancelling out.

Max. Error = ± (dot count error + tracing/interpretation error + Scaling error)

i.e. :-

Max. Error = ± (5% + 0% + 1%)

∴ Max. error = ± 6%

It may be considered optimistic under some circumstances to assume tracing/interpretation error to be negligible. For the Holkham Survey it is safe to assume it to be minimal compared with other error sources and the time necessary to assess interpretation error would be poorly rewarded.

Correction Factors

It may be considered necessary to correct area measures for distortion of the photo mosaic. We know, for example, that the extreme western end of the mosaic is at a 1% smaller scale than the scale conversion factor used for the Holkham West map. Similarly the eastern portion of Holkham West is at a 1% larger scale. Areas which span equally the eastern and western ends will average out correctly. However, the only salt marsh on Holkham West is in the extreme west, is drawn at a smaller scale and so is under-estimated by approximately 1%. Correction could be made for this. It does not seem worthwhile as, in this example, it is so small.

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PART II - EXAMPLE - HOLKHAM NATIONAL NATURE RESERVE

To map and measure

(1) Dunes

(2) Sand/mud flats

(3) Salt marsh

(4) Reclaimed marsh

Methods

1. Trace — Trace from photo-mosaic keeping two halves separate. Use ground verification and stereo vision of 9" x 9" prints wherever possible to assist interpretation.

2. Map — Produce dyeline, and shade accordingly on copy. (We required many blank copies for field, but few complete copies).

3. Map calibration — Calibrate air-map to O.S. Map by measuring an area of ground on each. Check that scale ratio of one to other constant or within acceptable limits over whole area. If not sub-divide area until each sub-division can be calibrated within acceptable error limits. Our overall scale was acceptable but since the mosaic was divided into two it seemed sensible to treat each half separately.

4. Grid Size — Select suitable dot grid - 1 dot per 4 cm^2 good enough for total map area up to about 0.5 m^2. Larger than that more open grid advisable. If interested in habitat area of less than 2 - 3 % of total may need finer grid. If the small areas are not broken into too many fragments it may be

possible to count this separately with its own section of finer grid.

5. Accuracy

Count 3 grids first for each habitat. If dot count high (200+) and difference between 3 counts of a habitat low then there may be no need for further counts. In most cases they will be necessary. Count grids, moving grid randomly between counts until -

$$\frac{s.t}{\sqrt{N}} \times 100$$

is less than allowable % error. t is given from Students - t tables for pre-specified confidence limits, where the number of degrees of freedom is the number of counts made minus one. Error estimates are not made after each count, but when it is expected that enough have been made. If this is not so then some idea will be given by the size of the error how much larger N must be to reduce this to acceptable limits.

5. Confidence

7. Map area

Convert dot count to a true area measurement (i.e. cm^2 or in^2 on the aerial photograph).

Results

Our total map area was about 0.5 m^2. Our smallest units comprised about 3% of this. Therefore, a 1 dot/4cm^2 grid was suitable.

The individual dot counts are given in the following table for each half of the area.

	HOLKHAM WEST					HOLKHAM EAST			
	Saltmarsh	Reclaimed marsh	Sand-dune	Mud-flat	Total	Saltmarsh	Sand-dune	Mud-flat	Total
counts	7 8	174	52	120	353	161	6 6 7 6	336	503
	9 6	179	47	116	351	152	9 6 6 5	319	480
	7 7	172	52	108	339	158	6 7 6 11	328	492
	6 9	*(176)	51	123	*(356)	*(158)	6 7 8 9	*(335)	*(499)
	7 7	*(173)	47	116	*(343)	*(163)	8 7 8 9	*(323)	*(494)
	6 7						6 9 8 5		
	10 6						9 5 5 7		
	8 7						6 6 4 9		
	7 8						9 7 9 8		
	8 8						8 8 8 10		
	6 9						8 6 11 7		
	8 7						10 9 8 9		
	10 8						7 9 7 8		
	7 7						6 9 10 8		
	7 8						7 6 6 7		
mean	7.5	175.0	49.8	116.6	347.7	157.0	7.45	327.7	491.7
S.D.	1.11	3.6	2.59	5.64	7.57	4.58	1.58	8.5	11.5
S.E.	0.20	2.08	1.16	2.52	4.37	2.64	0.20	4.91	6.64
t	1.70	2.92	2.13	2.13	2.92	2.92	1.67	2.92	2.92
error	0.34	6.08	2.47	5.37	12.8	7.7	0.34	14.3	19.4
% error	4.5%	3.5%	5.0%	4.6%	3.7	4.9%	4.6%	4.4%	3.9%

* The figures in brackets represent counts made to test the normality of the distribution. These were not used in the errors estimated but are discussed later.

So on Holkham East 1 $cm^2 \equiv \frac{6.4232}{6.139} \equiv 1.0463$ ha

" " " West " $\equiv \frac{6.4232}{5.857} \equiv 1.0967$ ha

1 dot $\equiv$ 4 $cm^2 \equiv$ 4.185 ha (Holkham East)

$\equiv$ 4.387 ha (Holkham West)

We can now convert the dot areas to hectares.

Habitat Areas (Hectares)

	Saltmarsh	Sand dune	Reclaimed marsh	Sand/Mud flat	Total
East Holkham	689	33	0	1438	2157
West Holkham	33	218	768	512	1525
Total Reserve	722	251	768	1950	3682
Crown Estate Figures		1700		2225	3925

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PART III - DISCUSSION

The estimates of area obtained for the habitats on Holkham Nature Reserve differ slightly from those issued by the Crown Estate Commissioners. This is due largely to four factors:

1) The Crown Estate figures do not claim great accuracy and are intended only as a guide.
2) Our area measurement allows ± 6% error.
3) Spread of pioneer marsh and possible erosion of flats has altered the distribution of the habitats since Crown Estate measurements.
4) Slight changes in tidal level can greatly alter the area of flats uncovered.

The dot grid area measurement was shown to be quite valid by comparing the results with those obtained by cutting out and weighing the areas on the map. In fact it also proved as quick as the "cut and weigh" method for even the simple habitat map. For more complex maps the "cut and weigh" method would undoubtedly take longer, and it is not often that one wants to cut maps to pieces purely to estimate areas.

	Holkham W	Holkham E
Reclaimed marsh	+ 1.2%	-
Sand/mud flat	- 3.6%	- 2.4%
Sand dune	0%	+ 0.7%
Saltmarsh	0%	+ 3.6%

CONCLUSIONS

The method used to produce the Holkham map was relatively quick and needed little expertise to yield results. In an attempt to maintain simplicity the accepted methods of controlled plotting were avoided and use of the uncontrolled mosaic proved satisfactory.

The method of dot counting for area assessment was also a departure from the standard techniques such as planimetry, and may have been more elaborate than needed for this particular survey. However, the beauty of the method is that it can be applied to a wide range of maps. The vegetation map in production at present has some vegetation types dissected into so many small sub-units so as to make planimetry, square grid counting and other methods virtually impossible. The dot grid should deal with this as easily as it has the habitat map.

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PART IV - APPENDIX

Time commitment

The following is a break-down of the estimated time required for a similar survey on another site. It is difficult to assess where problems might arise and for this reason it is intended only as a guide.

Stage 1 "Photo-acquaintance" - 1 day

Less than one day studying the photo-mosaic thoroughly. Compare areas seen on mosaic with the same area viewed under a stereo viewer. Try to locate all the variation in the area and prepare field visit to see those sites which are not easy to interpret.

Stage 2 Field visit - 1 day

This will only be necessary where the area is little known. All the information required at this stage should be given by the photographs if the mapper is familiar with the terrain. If this is not the case the company of a person acquainted with the area under study is always of help when in the field.

Stage 3 Tracing and Inking-in - approx. 2-3 days

One or two days should be required for tracing according to the complexity of the area. Inking-in will take only about half the time of the tracing, probably less than one day.

Stage 4 Shading - ½-3 days

Shading can be very quick. A water colour wash, stripes, symbols can be applied quickly. Letraset can take a long time. The time taken will depend on whether the map is solely intended as a working document, a display piece or intended for publication. Labels, titles, and keys can all take time if done properly.

Stage 5 Dot grid construction/scaling photo-mosaic - approx. 1 day

The time for this stage may vary greatly. On a straight-forward area, with mainly large units to be counted the dot-grid size is not too important. Where the area is more complex more detailed organization of the area measurement method is required.

Similarly scaling the mosaic may be difficult if the distortion is great. If it is linear and small then little trouble should be experienced in applying a scale.

Stage 6 Dot grid counting - $\frac{1}{2}$-3 days

This is another stage taking a varying time. A few large areas are counted quickly. The errors need only be computed once if all goes well and the job may be finished in $\frac{1}{2}$ day. If the number of areas to be assessed are large and the areas themselves small, far more dots will need to be counted. If it is found repeatedly that the error is greater than allowable, then more counts and more statistics will be required. If a good calculator is available this can be easy. About $1\frac{1}{2}$ days were spent on this stage. If the calculations have to be done on a simple calculator, or none, then the time required could have been doubled.

Stage 7 Conversion to actual areas - $\frac{1}{2}$ day

This process is quick and easy and should easily be completed in less than $\frac{1}{2}$ a day.

This means that our total time expenditure could be as little as 10 days. This assumes that all materials are at hand as and when wanted, that no mistakes are made, that no problems arise.

The Holkham Survey took 20 man-days but half of this time was spent developing the techniques used and planning the survey. To speed up the process all the materials required are best obtained in advance. A check list is provided to assist planning.

1. Plastic tracing sheet (e.g. Kodatrace) sufficient for the tracing and the dot grid.
2. Pencils - about 5H - "Rexel clutch" pencil very good.
3. Rubbers - 1 soft, 1 typists pencil rubber.
4. Pen - dependant on personal preference - recommend a "Rotring Variant" plus assortment of nibs, plus "Rotring" ink.
5. "Chinagraph" - to mark up aerial photographs.

6. "Pounce" - French chalk to prevent grease marks.

7. Masking tape.

8. Rules - 1 metre may be necessary.

9. Shading tints - may use own pen and ink symbols, therefore no further materials required. Otherwise acrylic paints, felt tip pens, Draughtsman's paints, "Letraset" etc. may be necessary. Essential to check that the Dyeline paper takes the shading to be used; remember, extra stout dyeline advisable. Letraset lettering will be needed for titles and keys.

10. Students - t tables.

* 11. Tally Counter - useful if available.

* 12. Mirror stereoscope, very valuable if one is available.

* 13. Electronic calculator - access to a good calculator will save much time during area measurement.

With the initial preparation, collection of equipment, determining the nature of the results to evolve, such a study should take about 2-3 working weeks. If more detail is required the time will increase.

Cost

Most of the drawing equipment is fairly cheap and may be at hand already. Otherwise £5 should cover the cost of the materials required for the map production.

A mirror stereoscope is of course a far more costly item and, unless one is at hand, it may be necessary to do without. However, it is a very valuable aid, essential to more detailed mapping and worth investing in if aerial photographs are used frequently.

IMPROVEMENTS TO THE AREA MEASUREMENT

The method of area measurement was intended to be fast and easy and it was realised that it had limitations. Improvement of the method means more time spent on it, but this may be considered worthwhile, where reliability is important.

* Not absolutely essential

Dyeline copying

Dyeline copying is a wet process and can result in some shrinkage or stretching of the paper so distorting scale. The image may also fade on exposure to strong light. For this reason true to scale copying (TTS) may be worthwhile. It is a little more expensive and less readily available but well worth the extra in the long run.

The Number of Counts

Another point to change is to increase the minimum number of counts of the grid to at least 6, ideally 10. The error quantification assumes the count results to be normally distributed. But this may not be the case. The more counts taken however, the less the departure from normality. This obviously increases measurement time. It was considered unnecessary for this study since great accuracy was not essential and the variation between counts was so small in the larger areas as to be within the $\pm$ 5% limit anyway. Further counts were taken (in brackets in results table) to show that they were with the $\pm$ 5% but were omitted from the calculations since the sequential procedure predicts them to be unncessary.

The Grid

The grid used proved satisfactory for the job in hand. However, a carefully constructed grid made using a very fine nib would be easier to use and is worth constructing for more complex areas.

The Sequential procedure

The sequential procedure seemed good since it demanded no more counting than was necessary. However, the standard error may have been worked out several times per area. This is easy using a calculator with statistical programme but may be as time consuming as counting if performed by long-hand. Also the sequential procedure does not give a strictly valid estimate of the confidence limits.

We can predict the number of counts required from :-

$$\frac{S_{10}\ t_{N-1}}{\bar{x}_{10} \cdot \sqrt{N}} = .05$$

where S_{10} = Standard deviation for first 10 counts

$\bar{x}_{10}$ = mean of first 10 counts

N = number of counts to be made

t_{n-1} = Students - t value at N-1 degree of freedom and chosen percentage.

Since N is unknown, let t = 1.8 (10%, 10 d.f.) then :-

$$N = \frac{S^2_{10}}{\bar{x}^2_{10}} \cdot \frac{(1.8)^2}{(0.05)^2}$$

If the N obtained is larger than 10 take another N - 10 observations and repeat the procedure until the value for N is less than the number of observations taken.

Applied to the Holkham data the method predicted very closely the counts needed. It predicted a need for 37 counts on the Holkham West Saltmarsh as against the 30 taken. 62 counts were the prediction for the Holkham East dune. 60 were in fact taken. However, this was predicted after 40 counts. 49 was predicted after N = 10 but this had a standard error of about 24. The value of N predicted can be an extremely variable quantity. So one could predict a value of N which was much too large and commit oneself to too much sampling. It does however give a useful guideline and also reduces the possible bias involved when counts are stopped immediately the standard error falls within acceptable limits.

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