MESH MAPPING EUROPEAN SEABED HABITATS

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Title:	**Recommended operating guidelines (ROG) for aerial photography**
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Reviewed by:	J. White 18th Jan 2007
Workgroup:	
MESH action:	Action 2
Version:	2
Date published:	31/01/2007
File name:	ROG_aerial_photography.doc
Language:	English
Number of pages:	8
Summary:	This document gives some hints about the use of aerial photography for coastal seabed mapping and directs the reader to some literature references.
Reference/citation:	
Keywords:	Survey, aerial photography, mapping, low tide
Bookmarks:	
Related information:	

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Change history		
Version:	**Date:**	**Change:**
3	07/09/07	Final review for MESH Guidance publication
2	15/01/07	Version 2
1	11/9/06	Initial version of document

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Recommended operating guidelines for aerial photography

1. General principles of operation

Aerial photography has been used for well over 100 years to help support a wide range of mapping applications. Though its use for land-based surveying and mapping applications is widespread, it is only in the last few decades that aerial photography has become a useful tool for certain broad-scale benthic habitat mapping applications. More recently, aerial photography has benefited from the huge progress made in computer technology, making it possible to digitise photographic prints down to their ground resolution (roughly 10 microns, typically 25 cm on the ground for 1:25000 prints) and for them to be easily handled on PCs. This has also made georeferencing of aerial photos a more common and easier task. There is abundant literature (Bunker *et al.* 2001; Wyn *et al.* 2000) about surveying the coastal zone with anologue cameras. A key reference (Finkbeiner *et al.* 2001) used by the US National Oceanic and Atmospheric Administration (NOAA) is outlined in Figure 1.

This paper deals more particularly with the field of aerial photos. The methods described are designed to meet the following general objectives:

- Produce digital baseline data on the spatial extent and characteristics of benthic habitats
- Produce synoptic data over estuary-sized study areas
- Provide data that optimise the efficiency of further *in-situ* sampling
- Provide data at a resolution that can contribute to environmental-permitting processes
- Produce data that support change detection over extensive areas.

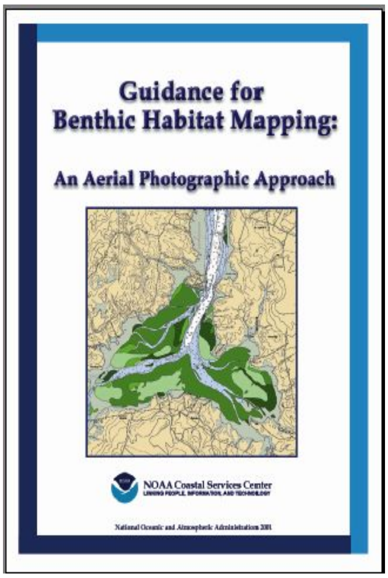

Figure 1. Technical guidance for data developers working to produce digital spatial data on benthic habitats (Finkbeiner *et al.* 2001).

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The advantages of aerial photography are as follows:

- Photographs provide a visual assessment of relatively remote areas;
- Orthophotographs provide a very highly accurate background layer;
- Photographs can often be found from the present day back to the 1940s, providing insights into habitat change.

The disadvantages of aerial photography include:

- Maximum water depths for bottom visibility are often <10 m (furthermore, few photos are taken under low-tide conditions);
- Sun glint and waves can render an image virtually useless and are a considerable nuisance for seamless mosaicking and interpretation.

When photos are extracted from archives, additional drawbacks arise:

- The photography's coverage can be patchy – over both time and space;
- The photography was almost certainly acquired to map the land – not the water – and many areas of shallow water are missed;
- Photos must be used with caution as their date of acquisition is often not consistent with important habitat fluctuations.

2. Variety of systems available

Rather than a variety of systems, a variety of configurations is addressed here. Typically, aerial photography for broad-scale coverage is acquired on a scale of around 1:25000, although more local studies may survey at more detailed scales.

Aerial photographs can be acquired either in natural colour or infrared colour composite. The latter are much more difficult to find today, although they provide an invaluable advantage in terms of interpreting vegetal cover, namely seaweed, seagrass and saltmarshes in the coastal zone.

Aerial surveys are neither time- nor cost-effective, as they require highly technical facilities in terms of the carrier and platform set-up. When more

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flexible and/or cheaper surveys are required (e.g. for mapping seagrass beds in summer at low tide), then using lighter carriers, such as ULMs or even UAVs, may be envisaged. These carriers can be hired and lightweight professional cameras mounted on them at short notice when suitable conditions occur. Such photographs, however, have several drawbacks: a) being shot from low altitude, they are small in size, though with very high definition; b) their verticality is only approximate; and c) their location on the ground is unknown, which is critical in tidal zones where very few conspicuous marks are available. These issues may be dealt with as described below.

Operational constraints for conducting aerial photography surveys are rather well known. Many useful tips for can be found in the technical guidance given by Finkbeiner *et al.* (2001) for data developers working to produce digital spatial data on benthic habitats.

3. Review of existing standards and protocols

3.1 Planimetric interpretation

Diverse benthic habitats have been successfully mapped using aerial photography. These include seagrass meadows (patchy or continuous), coral reefs, unconsolidated sediments, shellfish beds (oysters and mussels), hard-bottom areas, soft corals, macroalgal beds and drifting algal accumulations. Aerial photographs can reveal the spatial extent and distribution of a habitat, habitat fragmentation (expressed as a percent bottom-cover value) and, in the case of submerged aquatic vegetation, qualitative measurements of biomass. Habitats or characteristics that are more difficult to map with aerial photography include low-biomass submerged aquatic vegetation, clam beds, bacterial mats, tube-worms, habitat health, species composition, and sediment texture. Though the depth of the photic zone varies with water clarity, the typical penetration of light in clear temperate waters that gives a signature on aerial photography is roughly 10 m.

Within the framework of the French benthic network (Rebent), mapping of seagrass undertaken along the Brittany coast showed that some habitats can be easily delineated using littoral orthophotography. Moreover, the seagrass beds inventory carried out by Levêque (2004) introduced criteria of density (fragmentation rate) and quality (reliability rate) for each of the polygons digitised from aerial photography (Figure 2).

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RR: 1 ; FR: 1 RR: 1 ; FR: 2

RR: reliability rate; FR: fragmentation rate (on a scale of 1 to 5).

Figure 2. Seagrass habitat mapping (*Zostera marina*), Aber Wrac'h (left), Saint Jacut de la Mer (right), France (from Levêque 2004).

3.2 Change detection

When considering multi-date surveys with very high definition photography, attention must be given to potential georeferencing hazards. It is advisable to rely wherever possible on a high-quality archive orthophotographic mosaic upon which specific subsequent imagery will be overlaid and rectified. Image registration can then be performed by image warping, using ground control points identified on both sources. This operation has been well described in the remote sensing literature and is even currently available in image processing freeware.

3.3 Stereoscopic interpretation

Primarily designed for elevation mapping and Digital Terrain Model (DTM) production by stereo-restitution, photogrammetry is also used to detect objects. This only concerns the tidal zone, as underwater stereoscopy is affected by water refraction. The advantage for the interpreter, with respect to classic planimetric studies, is the enhanced vision of the terrain provided by the third dimension and hence greater ability to delineate units which appear identical on the photo.

This entails time-consuming and costly processes (aero-triangulation, stereo preparation, etc). After digitising the printouts, the two files are input to an analytical device that performs automatic correlation and provides 3D vision. The quality of the stereo-restitution depends largely on the quality of the local correlation of the two photographs. Typically, for photos at 1:25000, vertical accuracy of 40-60 cm can be expected on targets with enough texture to ensure proper aero-triangulation and correlation (basically rocky units), while only 1-1.2 m is achieved on smooth terrain (e.g. tidal flats). Typical horizontal accuracies were 2 m.

Besides automatically computing a DTM, the 3D vision can be used to delineate homogeneous units and label them according to the interpreter's knowledge of the terrain. Subtle breakpoints and slope changes can help the operator make up his mind in some tricky cases. This technique is, however, only available in the very few laboratories equipped with analytical stereo-plotters, which are primarily used for DTM production rather than photo-interpretation. It is therefore of quite limited use to the benthic habitat mapping community.

4. Provenance and current usage

Aerial photography is still widely used for habitat mapping in tidal and shallow-water zones. Full intertidal mapping coverage of the Welsh coast was carried out in accordance with the CCW handbook for marine intertidal phase 1 (Wyn 2000). Thanks to high-resolution aerial photography, restitution was done at the very high scale of 1:5000, which shows very small units on the ground.

In France, full coverage of the coast in spring low-tide conditions was conducted between 2000 and 2002, with production of a 1:25000 orthomosaic, which currently provides planimetric interpretation capability to a scale of 1:5000. In Brittany, the Rebent programme made use of this comprehensive photographic coverage. The orthophoto layer was used as: a) a geometric reference, its absolute positioning accuracy being 1-2 m; and b) as an interpretation reference, since quite a number of targets could be identified in them. It was felt, however, that the production of the orthorectified mosaic suffered from many flaws, and in many instances it was deemed preferable to use the original films, despite the amount of additional work necessary (scanning and georegistration, absence of orthorectification). The quality of the initial films could not be matched by the mosaic, the films giving much deeper insight into subtle nuances. Much care had to be taken, however, to limit errors due to the lower geometric quality inherent in these images.

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