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July 26, 2013
Project 12018

Great Bay Municipal Coalition
288 Central Ave
Dover NH 03820

Attention: Dean Peschel

Subject: Peer Review of Eelgrass Mapping
UNH Eelgrass Monitoring Program for 2010-2014
Great Bay, NH

Dear Mr. Peschel:

New England EnviroStrategies, Inc. (NE2S) has completed a peer review of the methods and procedures used to map eelgrass cover for the 2010-2014 UNH Eelgrass Monitoring Program. Resultant GIS data from this program have been incorporated into the New Hampshire Department of Environmental Services (NHDES) assessment methodology for water quality impairment determinations and regulatory rule-making for the Great Bay Estuary and surrounding communities under Section 303 of the Clean Water Act. The accuracy of these data is an important consideration for determining data limitations and appropriate level of reliance on the data.

SUMMARY

Methodology described in the UNH Eelgrass Monitoring Program (2010-2014) Quality Assurance Project Plan (QAPP) do not meet industry accepted practices for mapping of natural resources based on aerial imagery as described by Paine and Kiser (2003). The methodology used was also not consistent with national standards for mapping submersed rooted vascular plants (SRV) from aerial photography (NOAA, 1995). The NOAA (1995) C-CAP Guidance outlines nationally recognized standards for mapping SRV (such as eelgrass) from aerial photography for the purposes of supporting policy, regulatory, or research activities. Due to unknown spatial accuracy, these data should be considered as field reconnaissance level data only.

INTRODUCTION

In 2008 the NHDES developed an assessment methodology for determining compliance with water quality standards for biological integrity (Env-Ws 1703.19) using eelgrass cover in the Great Bay Estuary as an indicator. NHDES has determined that eelgrass cover is an appropriate indicator for water quality impairment determinations because supporting data are "collected using accepted and standardized protocols and is ground-truthed annually" (NHDES 2008).

Based on our review of the UNH (2010) methods used to map eelgrass cover in Great Bay, we find that:

- Methods and equipment used to obtain aerial imagery do not meet the national standards of the NOAA C-CAP guidance or other industry accepted practices for mapping based on aerial photo interpretation;

- Methods of transferring interpreted eelgrass boundaries from aerial imagery to a planimetric base map do not meet the national standards of the NOAA C-CAP guidance or other industry accepted practices for mapping of natural resources;

- Ground-truthing methods do not meet the national standards of the NOAA C-CAP guidance and are insufficient to determine the spatial accuracy of resultant eelgrass data; and,

- Data limitations due to unknown spatial accuracy of resultant map data preclude the use of these data in quantitative change analysis of eelgrass extent in Great Bay.

Therefore eelgrass mapping data generated by the UNH (2010) study are inappropriate for use as indicators of water quality impairment in Great Bay due to non-standardized equipment and methods used to generate the data.

METHODS ASSESSMENT

The methods used for eelgrass mapping in Great Bay are described in the UNH Eelgrass Monitoring Program QAPP (UNH, 2010). The study authors reference the standardized NOAA C-CAP Guidance methods for mapping SRV from aerial photography, but the authors note that the use of near-vertical photographs deviates from these methods. The methodology was described as follows:

- Aerial photographs were acquired from a "near-vertical" perspective using a handheld small-format digital camera from a light aircraft.

- Aerial photographs were interpreted using methods from Short and Burdick (1996) and NOAA (1995) to delineate boundaries of eelgrass beds.

- These boundaries were then "digitized" using GIS software.

- Resultant maps were "adjusted and verified" based on "ground-truthing" observations from a small boat with a handheld GPS receiver.

- The stated data quality objectives for the mapping study specify a precision and accuracy of +/- 5m for eelgrass bed boundaries.

The following components of the UNH (2010) mapping program are deficient in comparison with the NOAA (1995) C-CAP guidance:

- Methods and equipment used for aerial imagery acquisition; and,

- Transfer of interpreted eelgrass boundaries from oblique (non-vertical) aerial photos to a planimetrically accurate basemap.

Imagery Acquisition Method Deficiencies

The NOAA C-CAP Guidance specifically states that the collection of "metric-quality aerial photographs (< 3° of tilt off-nadir and including camera calibration data) are essential" for mapping of SRV from aerial photography (NOAA 1995). A metric camera is one with a calibrated focal length (distance between the lens and imaging film/sensor) and low-distortion (or known-distortion) lens. A metric-quality aerial photograph is therefore one with low image distortion and a known scale when obtained from a vertical position (defined as < 3° of tilt off-nadir) (Paine and Kiser, 2003). Non-metric cameras, such as the small format digital camera used in the UNH (2010) study, do not have a known or calibrated focal length and therefore cannot be used for the purposes of analytical measurement or mapping. A non-metric camera is also prone to unknown degrees of lens distortion which can significantly influence the size and shape of objects identified in the image. Object displacement and image distortion are further exaggerated in oblique images, making image interpretation problematic (Paine and Kiser, 2003). Camera equipment and imagery acquisition methods described in UNH (2010) are therefore not suitable for use according to NOAA (1995) C-CAP.

The UNH (2010) authors note the accepted use of "near-vertical" imagery using non-metric equipment for aerial photo interpretation of eelgrass boundaries in Short and Burdick (1996), a publication co-authored by Fred Short, Program Manager of the UNH Eelgrass Monitoring Program. The Short and Burdick (1996) study suggests that "near-vertical" aerial photography provides reliable aerial assessment data for the identification of the deep edge of eelgrass beds in Waquoit Bay, Massachusetts. Interpretation of eelgrass boundaries from non-metric oblique imagery is not in question. However, the use of such imagery does not provide the necessary data for producing accurate maps of SRV, as defined by the standardized methods of the NOAA (1995) C-CAP guidance.

Mapping Method Deficiencies

The methods described by UNH (2010) for the mapping of eelgrass beds based on aerial imagery interpretation is ambiguous and not consistent with the standardized methods of the NOAA C-CAP guidance or industry accepted practices for mapping of natural resources. The NOAA C-CAP guidance clearly defines accepted methods of photointerpretation and mapping of SRV from aerial photography (NOAA 1995). According to NOAA (1995), photointerpretation of SRV such as eelgrass, is performed using stereo-paired metric-quality aerial photographs and high quality stereoscopic instruments. Polygons of habitat interpreted from aerial photographs are then transferred onto planimetrically accurate basemaps using one of the following three approaches:

1.) Stereoscopically interpret photographs and optically scale the mapped polygons and photographic image to fit basemap control points,

2.) Georeference aerial photographs to a series of identifiable control points on a planimetrically accurate basemap, and interpret and directly trace habitat polygons onto the planimetric basemap, or

3.) Delineate and simultaneously rectify and digitize habitat polygons by using an analytical stereo plotter.

Methods described in UNH (2010) ambiguously state that interpreted boundaries are "digitized" using GIS software. The process of digitizing boundaries is a straightforward procedure that is easily accomplished with the appropriate software and the necessary supporting data. However, the methods described by UNH (2010) fail to address how the oblique imagery is adequately registered to horizontal control points on a planimetric basemap prior to digitizing interpreted eelgrass boundaries, or alternatively, how digitized boundaries are registered to a planimetric basemap. The inherent limitations of the aerial imagery obtained by the UNH (2010) study preclude the accurate registration of these images to horizontal control points on a planimetric basemap. As stated in UNH (2010) section B4 – *Analytical Methods*, "maps are then adjusted and verified using ground-truthing data." From this statement it is not clear whether ground observations with GPS coordinates are incorporated as part of boundary determination or as part of accuracy assessment. If ground-truthing GPS data are incorporated as part of eelgrass boundary determination, then it is not appropriate for use as an independent means of determining map accuracy (NOAA 1995, Paine and Kiser 2003).

MAP ACCURACY ASSESSMENT

The UNH (2010) study fails to specify adequate means of assessing the accuracy of resultant map data in accordance with the NOAA (1995) C-CAP guidance. As part of Section B5 - *Quality Control* of the UNH (2010) study, the authors note that 10 eelgrass bed boundaries are to be located from a boat equipped with a GPS receiver (of unknown type or accuracy). The "ground-truth" GPS points along those 10 eelgrass beds are compared to the mapped eelgrass boundaries using GIS software (UNH 2010). Section A7 of UNH (2010) – *Quality Objectives and Criteria* specify acceptance criteria of +/- 5m for both accuracy and precision. Assuming that ground-truth GPS data are not incorporated as part of eelgrass boundary determination, ground truthing in the field with a GPS receiver is a generally accepted practice as part of map accuracy assessment (NOAA 1995, Paine and Kiser 2003). However, it is critical that the type of GPS receiver is documented along with other environmental factors that may affect positional accuracy and any differential correction that is applied to the data. Based on the type of GPS receiver used (e.g. recreation grade versus mapping grade), satellite distribution (or positional dilution of precision - PDOP), environmental factors, and differential correction applied to the data, GPS accuracy may range between 1-15 meters (Paine and Kiser 2003). A GPS accuracy assessment is therefore an essential component in the use of ground truth GPS data to determine map accuracy (NOAA 1995, Paine and Kiser 2003).

Ground truthing methods described in UNH (2010) also differ from the NOAA (1995) guidance, which states that verification locations are to be predetermined from the map by latitude and longitude coordinates and then visited in the field with GPS navigation for independent field observation and classification. This contrasts with the UNH (2010) procedure of mapping eelgrass boundaries with a GPS in the field and then comparing those locations to the eelgrass boundaries in GIS. Due to unknown GPS accuracy and non-standardized methods and procedures for map accuracy assessment, as described in UNH (2010), the spatial accuracy of resultant eelgrass data is currently unknown.

DATA LIMITATIONS AND USE

Eelgrass mapping data generated by the UNH Eelgrass Monitoring Program, and described in UNH (2010), are based on equipment and methodology that are not consistent with the nationally recognized NOAA (1995) C-CAP standards or industry standard practices for mapping of natural resources based on aerial imagery interpretation (Paine and Kiser 2003). These data are therefore considered to be reconnaissance level quality, generally suitable for use only as a means to identify broad areas of suspected change. The eelgrass mapping data are not suitable for areal extent calculations, as the statistical error of such calculations cannot be determined without knowing the spatial accuracy of the data. Spatial accuracy is of primary concern for reference data used in the NOAA C-CAP program, which creates a standardized database of land use change over time. When data of unknown spatial accuracy are compared over time, positional errors tend to compound the problem of recognizing real changes which tend to concentrate at polygon edges and class boundaries (NOAA 1995). For this reason, resultant data from the UNH (2010) Eelgrass Mapping Program should only be used for general qualitative assessment.

CONCLUSIONS

NHDES has determined that eelgrass cover is an appropriate indicator for water quality impairment determinations in Great Bay because supporting data are "collected using accepted and standardized protocols and is ground-truthed annually." However, eelgrass mapping data generated by the UNH Eelgrass Monitoring Program, and described in UNH (2010), are based on equipment and methodology that are not consistent with the nationally recognized NOAA C-CAP standards or industry standard practices for mapping of natural resources based on aerial imagery interpretation. Furthermore, ground-truthing methods described in UNH (2010) are not adequate to determine the spatial accuracy of eelgrass mapping data. These data are therefore considered to be reconnaissance level quality, generally suitable for use as a means to identify broad areas of suspected change.

New England EnviroStrategies appreciates the opportunity to provide this peer review of the UNH study. Please don't hesitate to contact James Gaynor if you have any questions regarding our evaluation.

Sincerely yours,
NEW ENGLAND ENVIROSTRATEGIES, Inc.

James R. Gaynor
GIS Specialist

Muriel S. Robinette, PG
President

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