# Phantom counts ghosts: Mapping ghost crab burrows using a Phantom 2 Vision+

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**Abstract:**
Recent advances in geospatial techniques such as Structure from Motion (SfM) with Multi-View Stereo have revolutionised the collection of ultra-high resolution (cm) imagery and terrain data. Initially adopted amongst archaeologists and geomorphologists, the flexibility of the SfM approach allows for a myriad of applications across different spatial scales ranging from ground-based surveys at the plot-scale ($10^0$ - $10^1$ m$^2$) to airborne solutions covering entire landscapes ($10^2$ - $10^4$ m$^2$) based on manned or, most commonly nowadays, unmanned aerial vehicles (UAVs). The cost-effectiveness and minimal level of technical expertise required by the SfM approach also allows for an increase in data collection frequency. These characteristics are ideal for ecological studies of cryptic species that require sampling techniques that are reliable, efficient, and environmentally benign for the species and habitats. Counting and measuring the entrances of burrows made by crustaceans that tunnel deeply into beaches (Figure 1) is the most commonly employed technique to index population and body sizes of individuals, a fundamental metric in the fields of ecology and conservation biology. However, using burrow counts to predict organism density often have large uncertainties, in addition to being labour intensive and time-consuming. Despite of these limitations, this indirect census technique is widely used in the context of measuring the impacts of human activities or ecological changes attributed to climate change. Here, we aim to develop a semi-automatic approach to mapping and classifying burrows from brachyuran crabs (e.g. "ghost crabs") on sandy beaches at the landscape scale ($10^2$ m$^2$). For this, we collected imagery from a consumer grade UAV (DJI Phantom 2 Vision+) carrying a 14-megapixel 1/2.3-inch CMOS sensor. Given the sensor's wide field of view (140° - 35 mm format equivalent) and the dimension of burrows (< 10 cm diameter), surveys were undertaken at close-range (< 10 m) to minimize errors and ensure high-resolution. Well-distributed calibration points were measured using a real-time kinematic GPS with 1 cm and 1.5 cm horizontal and vertical reported accuracy, respectively. Burrows were manually counted and measured along sub-sections of the beach for validation of the final classification. The SfM software package Agisoft Photoscan was used to elaborate image orthomosaics from masked (e.g. shadows, people) images. Models were optimised and non-linear errors removed based on calibration points surveyed with the GPS. Semi-automatic classification of the image orthomosaics was done using object-based image analysis (OBIA). This allowed a robust classification of burrows using a combination of spectral, textural, contextual and geometric information. Burrows were identified as dark, circular objects commonly not exceeding 5 cm. Active burrows were additionally identified as being adjacent to highly-textured piles of "sand balls". The low altitude at which the surveys were

undertaken resulted in highly accurate models but at the expense of flying time. Further, the low accuracy of the UAV's on-board GPS and slow rate of image capture (3 s interval) precluded the pre-programming of flight lines, hence, surveys had to be done manually. Regardless of these challenges, the approach was more reliable and cost-effective than conventional field techniques.

*Figure 1. Ghost crab (Ocypode cordimanus) near burrow (approximately 3 cm in diameter) surrounded by piled "sand balls".*