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Aboriginal stone-walled intertidal fishtrap morphology, function and chronology investigated with high-resolution close-range Unmanned Aerial Vehicle photogrammetry

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ABSTRACT

Stone-walled intertidal fishtraps surround the Australian coastline and are among the largest structures built by Indigenous Australians. Globally, fishtraps are considered important elements in food production, domestication, territoriality and ceremonial landscapes, yet the level of detail in documentation is highly varied and scholarly fishtrap knowledge sparse. Comparative analysis is currently restricted by a lack of detail and reproducibility in recording, hindering analysis of morphology, function and chronology. In this study we employ high-resolution close-range Unmanned Aerial Vehicle (UAV) photogrammetry and a suite of spatial information analytical techniques to investigate the Kaiadilt Aboriginal stone-walled intertidal fishtraps of Sweers Island, southern Gulf of Carpentaria, Australia. Tidal inundation modelling is undertaken to assess (1) fishtrap working range, (2) individual and simultaneous trap function, (3) seasonal functionality and (4) chronology based on function relative to sea-level history. Thirteen fishtraps were identified in the study area, ranging from 38 m to 287 m in length. Flow accumulation indicates that shape and placement of fishtraps reflects underlying topography. Inundation modelling shows that all fishtraps operate most efficiently at present mean-sea level (PMSL), indicating construction in the last 3500 years. Quantitative recording techniques, analytical procedures and terminology developed in this study provide an opportunity to improve approaches to recording large-scale stone features and standardise documentation of stone-walled intertidal fishtrap sites.

1. Introduction

Stone-walled intertidal fishtraps are some of the largest structures documented in the Australian archaeological record. Constructed with rock and/or organic matter, fishtraps are argued to be primarily designed to trap or control the movements of marine resources across tidal cycles in coastal or riverine contexts (Campbell, 1982; Dortch et al., 2006; Jeffery, 2013; Rowland and Ulm, 2011). For the purposes of this study, stone-walled intertidal fishtraps are defined as structures capable of controlling the movements of marine animals.

Fishtraps, as structures testifying to local subsistence, labour organisation, occupation, and social strategies, have been cited as features of early domestication (Codding and Bird, 2015; Smith, 2014; Zeder, 2015), anthropogenic niche construction (Lepofsky and Caldwell, 2013; Lourandos, 1980; Smith, 2014; Zeder, 2015), and Australian mid-to-late Holocene economic and social intensification (Lourandos, 1980, 1983; McNiven et al., 2012, 2015). Despite interest across the fields of archaeology, evolutionary biology, and human behavioural ecology, physical and conceptual challenges of characterising fishtraps have led to a variety of approaches to site recording. As a result, researchers often adopt vague fishtrap definitions and terminologies (Bannerman and Jones, 1999; Jeffery, 2013; Ross, 2009; Rowland and Ulm, 2011), and fundamental questions concerning fishtrap construction and function are yet to be addressed (Caldwell et al., 2012; Elder et al., 2014; Moss et al., 1998).

Due to the location of fishtrap structures in intertidal and riverine settings, access is often restricted and dependent on tidal movement, and in certain parts of the world the presence of marine predators can be hazardous to field researchers. Recording time and visibility is also controlled by tides, and can further be restricted by wind, causing swell and sediment to obscure structures. Such environmental factors, along with the impacts of recreational marine vessels, cause intertidal stone

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features to erode partially or completely, which underlines the urgency in recording remaining fishtrap structures (Elder et al., 2014; Memmott et al., 2008; Roberts et al., 2016; Rowland and Ulm, 2011; Rowland et al., 2014). Despite the urgency of documentation, and a global interest in fishtrap construction (e.g. Greene et al., 2015; Jeffery, 2013), most recordings consist of basic sketch maps of limited detail, with few quantitative data or photographic records (for exceptions see Coutts et al., 1978; Greene et al., 2015; Koivisto et al., 2018; Langouët and Daire, 2009; McNiven et al., 2012; O'Sullivan, 2004). Varied approaches to site recording has led to a proliferation of terms describing fishtrap attributes, which pose challenges for site management, comparison of sites, and the ability of fishtraps to be considered meaningfully in broader debates. This study focuses on intertidal stone-walled fishtraps and proposes a standardised high-resolution recording scheme for large-scale intertidal stone features, to improve knowledge of fishtrap construction, function, and age.

2. Background

In 2011, Rowland and Ulm published a comprehensive review of coastal and inland fishtraps and weirs in the state of Queensland, Australia. The review found that stone-walled fishtraps are generally situated on coastal points or estuaries sheltered from strong winds, and while limited, evidence indicated that organic traps and weirs were generally located inland. Multiple pens (or holding areas) are observed in the Torres Strait and Gulf of Carpentaria, while isolated single pen structures are found further south. Most coastal fishtrap structures across the state displayed an arc shape, and it was recognised that traps were constructed and utilised by both Indigenous and non-indigenous Australians (Rowland and Ulm, 2011). The authors concluded that the level of detail available in Queensland fishtrap recording was largely substandard and proposed standardised recording schemes with increased detail in documentation (Rowland and Ulm, 2011).

Rowland and Ulm's (2011) findings apply to Australia more broadly, where site comparison is challenged by uncertainty in identification, a variety of recording techniques, and a wide range of associated terminology. Australian intertidal stone-walled fishtrap documentation is dominated by sketch maps to varied detail of fishtrap location, shape, and dimensions. More sophisticated documentation techniques and global navigation satellite systems (GNSS) have only been adopted in recent ground and aerial documentation strategies. While the recommendation by Rowland et al. (2014) to utilise Light Detection and Ranging (LiDAR) to capture large-scale coastal sites in detail has not yet been adopted in the Australian fishtrap context, various aerial recording techniques have been trialled. Low-level aerial photography was utilised in fishtrap site identification and analysis by Campbell (1982) at Hinchinbrook Island, Queensland, Dortch (1997) at Wilson inlet, Western Australia, and by Connah and Jones (1983) and Memmott et al. (2008) in the Gulf of Carpentaria. Photogrammetry, today a well-established technique in three-dimensional (3D) modelling (Sapirstein, 2016), has been sparsely applied in Australian fishtrap literature. The technique, allowing the generation of geometrically accurate photo-mosaics from which precise measurements can be retrieved, was used by Smith (1987) in a close range (< c.300 m) ground photo mosaic of a Bardi fishtrap, Dampier Peninsula, Western Australia, which provided a detailed map of the trap to scale. The anthropogenic inland stone-walled structures of Gunditjmara country, Lake Condah, southwest Victoria, have received the most detailed documentation to date. Van Waarden and Wilson (1994) used aerial photogrammetry (> c.300 m) to map the region, creating 1 m contoured topographic maps (1:5000), followed by Richards' (2013) detailed surface mapping using Real-Time Kinematic (RTK) Differential GNSS (DGNSS), and Builth's (2014) use of the same technology to create a 2 m × 2 m digital elevation model (DEM) for sites within the lava flow.

The various recording techniques applied in fishtrap studies have led to a wide range of terminology across the literature. While some studies describe stone-walled structures by physical composition (e.g. *alignment* by Dortch et al. (2006), *continuous walls* by Stockton (1975) or observed or perceived function e.g. *barrier* by Roberts et al. (2016)), the majority of studies focus on the morphology of structures. Aligning with Rowland and Ulm's (2011) findings, the *arc* (also described as *U-shape* or *semi-circular*), and *circular* terms are the most common shape characteristics applied across Australian fishtrap publications. Such morphological descriptors are problematic owing to their arbitrary and subjective nature, and risk neglecting or recording multiple traps as single features, and vice versa (e.g. one w-shaped trap or two v-shaped, or semicircular traps). Dimensions generally consist of a measure of the tallest and widest points of the trap, and an east-west and north-south measure of the enclosed area, but complete metrics are rarely presented for individual sites. Focusing on shape and size, fishtrap assessments generally neglect 3D aspects of structures, with the exception of Campbell (1982) who estimated holding capacity of the Scraggy Point fishtrap complex on Hinchinbrook Island. Although Campbell's (1982) early volume calculations assume homogenous wall height and a uniform substrate, it provides the only quantitative estimate of a fishtrap complex's holding capacity in the Australian literature.

The most significant challenges facing Australian fishtraps concern documentation, monitoring and management. The risk of structural degradation of fishtraps is an urgent practical implication of increasing coastal developmental pressures and climatic impacts (Memmott et al., 2008; Roberts et al., 2016; Rowland and Ulm, 2011). These threats cannot be appropriately managed without knowledge of current status of the intertidal stone-walled structures. To improve understandings of fishtraps, this study applies high-resolution Unmanned Aerial Vehicle (UAV) photogrammetry to document the stone-walled intertidal fishtraps of Sweers Island, southern Gulf of Carpentaria, Australia.

3. Methods

3.1. Case study area

The stone-walled intertidal fishtraps of Sweers Island are situated on the traditional lands of Kaiadilt people in the South Wellesley Islands, comprising an archipelago of 10 islands with Sweers Island the easternmost (c.13 km^2) (Fig. 1). A local sea-level curve for the southern Gulf of Carpentaria demonstrates that rising post-glacial sea-levels separated the islands from the mainland c.8000 cal BP (Sloss et al., 2018). At 7700 cal BP sea-levels reached present mean sea level (PMSL), continuing to increase to +1.5 m-2 m above PMSL, with relatively stable sea-levels remaining until 4000 cal BP. Sea-levels rapidly regressed to 0.5 m ± PMSL between 4000 and 3500 cal BP (Sloss et al., 2018). The earliest documented occupation of the South Wellesley Islands occurs at 3483 cal BP on Bentinck Island and 3421 cal BP on Sweers Island, with a continuous occupation signal from around 2000 cal BP and strong evidence for permanent occupation in the last 1000 years (Memmott et al., 2016; Peck, 2016; Ulm et al., 2010). Archaeological and ethnographic evidence indicate that Bentinck Island was the focus of residence, with smaller surrounding islands, such as Sweers, visited for resource extraction and temporary occupation (Evans, 1995; Memmott et al., 2016; Tindale, 1962a; Ulm et al., 2010). The Kaiadilt population, believed to have reached a maximum of 123 individuals (Tindale, 1962b), were forcibly removed to a European mission on Mornington Island in 1948. Kaiadilt were the last coastal Aboriginal group to be institutionalised in Australia (Memmott, 1982).

The South Wellesley Islands generally experience a diurnal tidal range (one high and low tide each day) of approximately 3 m in amplitude, with an exception every fortnight where 'double' tides occur for 1–3 days, resulting in little water movement (Forbes and Church, 1983). Tidal fluctuations are most prominent during the wet season due to the strong northeast winds (Memmott, 1982). However, the southern part of the Gulf can experience varied tidal patterns when the combined effects of the shallow basin, strong winds, atmospheric pressure, and