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Assessing the Reliability of a Small-Scale Legacy Radiocarbon Dataset Using Chronometric Transparency Approaches: Torres Strait Radiocarbon Database

DATA PAPER

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ABSTRACT

A new quality assurance framework was developed to assess the reliability of ^{14}C ages from a small-scale legacy dataset from archaeological sites across the Torres Strait (northeastern Australia). Chronometric transparency principles were applied across three stages of data analysis, comprising of a basic, immediate, and advanced assessment of the ^{14}C ages and associated metadata. Reliability ratings (1*, 2*, 3*, and 4*) were assigned to represent data confidence in individual radiocarbon ages. Results demonstrate the utility of radiocarbon ages of high, medium, and low reliability in creating chronological reconstructions. We determine that of the 343 ^{14}C ages, 73% were awarded a reliability rating of 3* or above.

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KEYWORDS:

Chronometric transparency; quality assurance; Torres Strait; radiocarbon ages; Holocene; island and coastal archaeology

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(1) OVERVIEW

CONTEXT

Data transparency in archaeological chronologies often centres on a detailed assessment of dating procedures and/or the practices used to generate site chronologies [2, 5]. Consequently, a quality assurance framework for ^{14}C ages is critical to ensuring that only reliable data are used in chronological interpretations. Transparency approaches are becoming a prominent method in data science [5, 10]. Generic quality assurance checks have been adopted for large datasets (e.g., the FosSahul 2.0 database [10]) and are utilised as a 'best method, or one-method fits all' approach. However, when applied to smaller datasets, chronometric hygiene approaches (the process of removing data that do not meet quality assurance criteria) [12] require further consideration or risk leaving too few data to support archaeological inferences. Instead, 'chronometric transparency', as advocated here, focuses on a formal approach to dealing with challenging environmental conditions (i.e., marine shell diet and local marine reservoir conditions) associated with island and coastal archaeological chronologies through quality assurance checks and reliability ratings designed for individual case studies. The Torres Strait region (Australia) presents several issues that can impact the chronology of events for understanding small island archaeology; these issues are not always able to be addressed (e.g., post-depositional movement associated with working in sandy coarse sediments (biogenic) [3]).

In this paper, we design a structure to assess reliable ages based on sample metadata presented in the Torres Strait Radiocarbon Database: version 2.0 [7] as a case study for small island legacy datasets.

SPATIAL COVERAGE

WGS1984

Description: Australia, QLD, Torres Strait

Northern boundary: –8.754

Southern boundary: –11.482

Eastern boundary: +145.226

Western boundary: +141.339

TEMPORAL COVERAGE

The dataset covers the main period of 8053 ± 42 to 0 year BP (i.e., 0 = AD 1950), representing uncalibrated radiocarbon ages from archaeological sites with evidence of human occupation and island settlement throughout Torres Strait (Australia). The Torres Strait covers the land bridge that connected Australia to Papua New Guinea until ~9000 - 8000 years ago when it was flooded by the Late Pleistocene marine transgression [8].

(2) METHODS

STEPS

The Torres Strait Radiocarbon Database: version 2.0 [7] consists of 343 (published) ^{14}C ages from a region encompassing 48,000 km^2 of land and seascape (Figure 1).

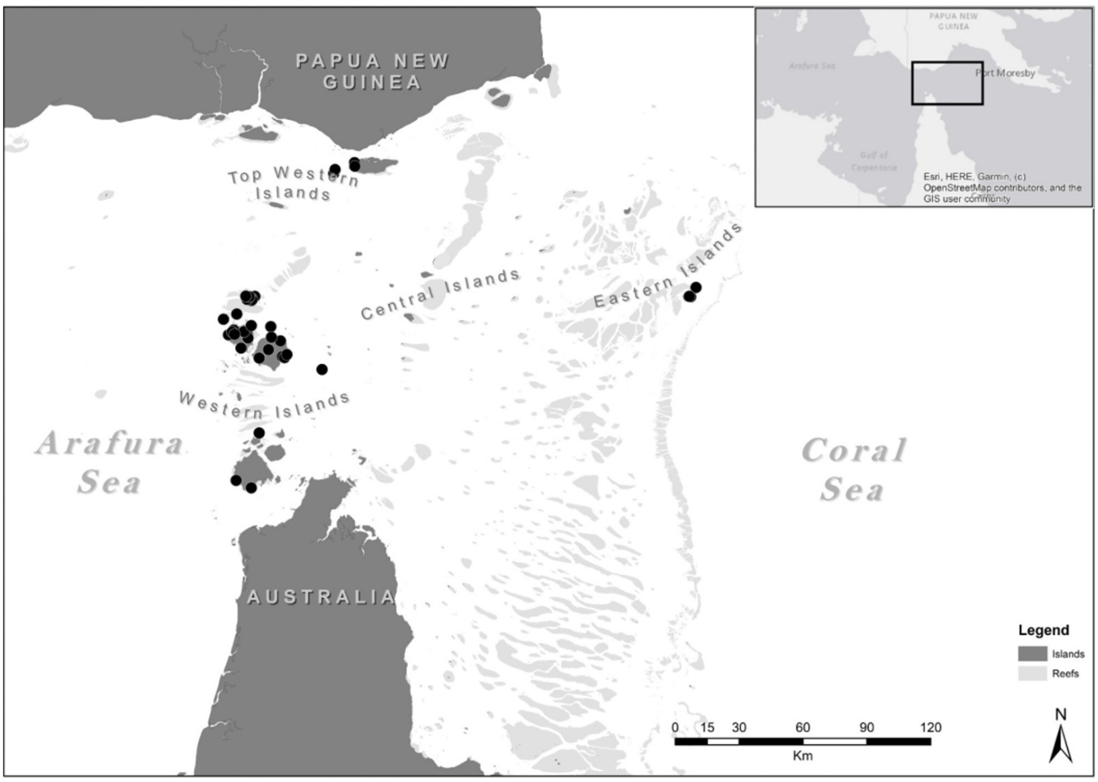

Figure 1 Map of the Torres Strait showing the location of radiocarbon-dated archaeological sites. Note that each point may contain multiple data points (n = 343).

Previous compilations of ^{14}C ages from the Torres Strait were reviewed [15, 17], and primary sources were consulted wherever possible to compile data. Keyword searches (for 'Torres Strait' and 'archaeolo*') were undertaken repeatedly between 1 June 2018 and 1 December 2021 in search engines: Google Scholar, Web of Science, Scopus, and Trove, to ensure all published data were captured in the dataset. The data collected (Table 1) focus on the following three parameters: (i) site information and stratigraphic integrity, (ii) cultural association of dated samples, and (iii) laboratory pretreatment procedures. Not all information was available due to: (1) the ^{14}C age being considered 'legacy' (older ages that may not have undergone current pretreatment techniques), (2) some information could not be confirmed by the laboratory, or (3) permission was not given by the original author to release data. As such, some entries contain minimal information.

Ninety published sites (Figure 1) were reviewed and classified into 25 different site types/features (Figure 2). Only a single ^{14}C age represents the following site types: cache, clay pipe circle, earth mound midden, pearl shell arrangement, signal place, stone-coral arrangement, and turtle shell mask (Figure 2). Possible reasons for a single-dated site may be associated with the researcher's original intent, available sample material, or limited funding. The most well-dated sites in the database are associated with middens (n = 77), village/midden sites (n = 61), rockshelters (n = 52), *bu* (*Syrinx aruanus*) shell arrangements (n = 52), village sites (n = 31), dugong bone mounds (n = 23), and *Kod* (ceremonial site) (n = 11) (Figure 2).

SAMPLING STRATEGY

Radiocarbon ages in the dataset were sourced from published literature, inclusive of journal articles, book chapters, published reports, and theses.

QUALITY CONTROL

A metadata analysis was completed to determine specific parameters for the chronometric transparency quality assurance framework. The framework developed

CLASSIFICATION	DESCRIPTION
Site Name	The name of the archaeological site, as reported in the original publication
Alternative Site Name/s	Alternative site name/s reported in publications
Material Parameters	
Sample Type	Sample type reported (e.g., charcoal, bone, marine shell, seed)
Species Reported	Species reported in the original publication (e.g., *Dugong dugon)*
Species Confirmed	Most up-to-date name from WoRMS (World Register of Marine Species) [18]
Species Habitat	Habitat of species (e.g., intertidal)
Species Size	Size of taxa reported in the original publication (cm) (e.g., juvenile)
Carnivorous	Carnivorous shell taxa as identified in WoRMS [18]
Radiocarbon Parameters	
Laboratory Code	Unique prefix and laboratory number assigned by the radiocarbon laboratory
CRA and Error (±)	CRA (conventional radiocarbon age) and error (±) as reported in the original publication
Method (AMS or CONV)	The technique reported either Accelerator Mass Spectrometry (AMS) or Conventional Liquid Scintillation Counters (CONV) ^{14}C dating
Pretreatment Technique	Charcoal and seed Pretreatment — ABA (Acid-Base-Acid) or ABoX–SC (Acid-Base-Oxidation-Stepped Combustion) Shell Pretreatment — AW (Acid Wash) Bone Pretreatment — UF (Ultrafiltration) and G (Gelatinisation)
C: N Value	Bone only — Carbon: Nitrogen atomic ratio [4, 16]
Gelatin Yield %	Bone only — Calculated gelatin yield %
TC (%C) and TN (%N)	Bone only — Total Carbon percentage and Total Nitrogen percentage [16]
Feigl or XRD	Marine shell only — Feigl staining or XRD (x-ray powder diffraction) to determine the crystalline structure of the shell
$\delta^{13}C$ (‰) and Error (±)	$\delta^{13}C$‰ value and error (±) reported in the original publication
$F^{14}C$% and Error (±)	$F^{14}C$% and error (±) reported in the original publication
Weight (g)	The weight (g) of the sample reported in the original publication with the CRA. *Note: sample weights are inconsistent between publications due to the unknown timing of when the measurement was collected during the radiocarbon process.*

(Contd.)

CLASSIFICATION	DESCRIPTION
Archaeological Parameters	
Site Type	Site type as reported in the original publication (e.g., midden, shell arrangement, and village site). Some overlap exists between site types.
Open/Closed Site	The site is determined as either open or closed based on site type — e.g., rockshelter (closed) and village site (open)
Square	The designation given to excavation square reported in the original publication (e.g., Square A)
XU	The excavation unit (XU) reported in the original publication
Depth (cm)	Depth of the sample as reported in the original publication
Contamination Evident	Evidence of abnormalities or context displacement as reported in the original publication
Depositional Context	Depositional information as reported in the original publication
Archaeological Association	Archaeological associations either directly or indirectly mentioned in the original publication
Cultural Context	Archaeological information reported in the original publication
Location	Location of the archaeological site (e.g., region descriptor)
IBRA Region	Interim Biogeographic Regionalisation for Australia [1] *Note: This section uses geographical bioregions for Australia classified by the Australian Government based on typical climate, landform, native vegetation, and species information.*
Island Group	Top Western Island Group (TW), Western Island Group (W), Central Island Group (C), and Eastern Island Group (E)
Island	Name of the island reported in the original publication
Island Size	Area of the island (square km)
Location	Latitude and longitude WGS84 (decimal degrees)
Date Reference/s	Original reference/s included

Table 1 Metadata used in the Torres Strait Radiocarbon Database: version 2.0 [7].

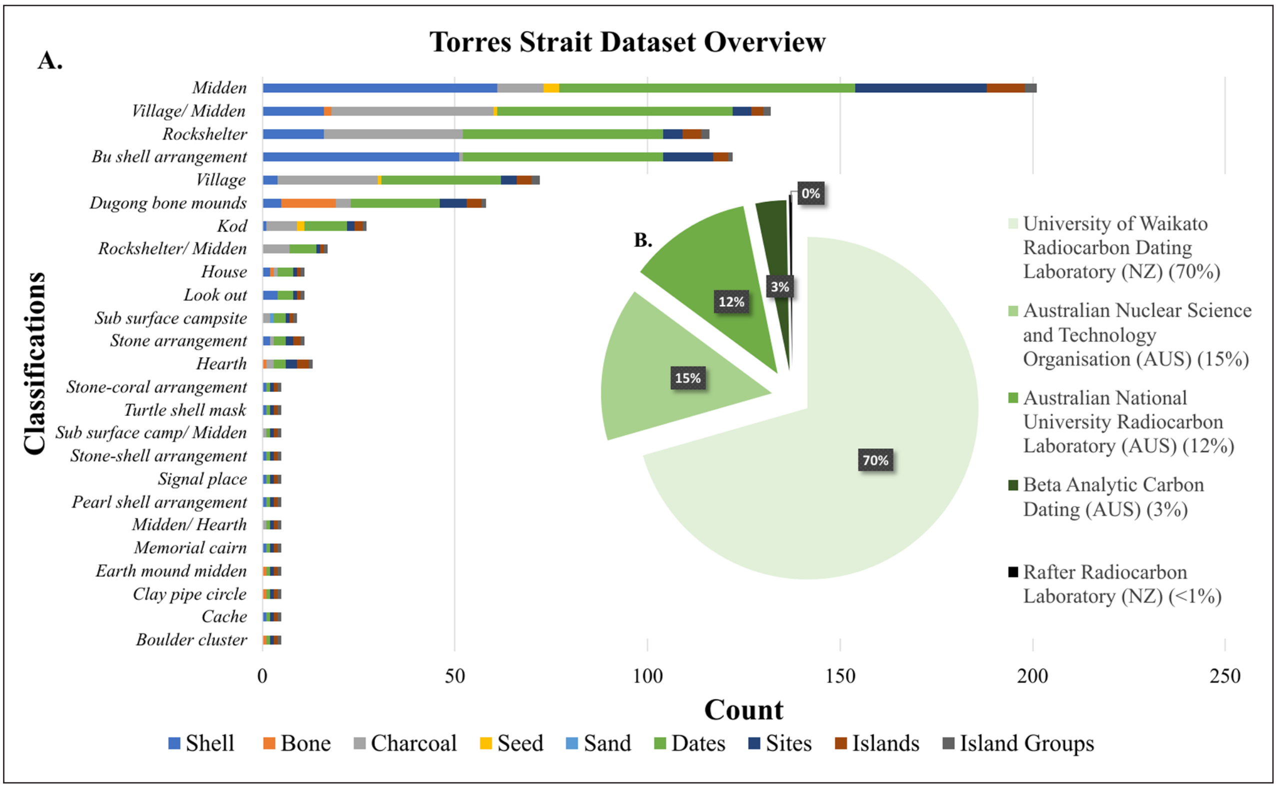

Figure 2 (A) Breakdown by sample and site classification of ^{14}C ages in the Torres Strait Radiocarbon Database: version 2.0 [7], including **(B)** the percentage of ages dated from different radiocarbon dating laboratories.

here has been designed to incorporate and enable interpretation of: (i) a large number of legacy ages (as defined above), (ii) single-dated sites (range finder ages), and (iii) small-scale excavations and dating programs (fewer than 10 dated samples per site). Based on these three points, the following quality criteria stages (1, 2, and 3) and reliability ratings (1*, 2*, 3* and 4*) were implemented. All stages are illustrated as a decision tree in Figure 3, with the criteria highlighted below.

CONSTRAINTS

The reliability rating system has four categories: 1*, 2*, 3*, and 4* (Figure 3). The sample is determined to have a 1* rating if either a direct or indirect archaeological association is found and there is no evidence that sample or site integrity has been compromised. If the sample does not meet either of these criteria, then the sample is excluded from further analysis and is not recommended for use in any future chronological modelling. Samples awarded a reliability rating of 1* are further assessed based on the availability of other metadata (i.e., archaeological, depositional, and laboratory). If <80% of these criteria are available in Stage 2 (i.e., ^{14}C age, location, sample type, and reference only), then the sample is given a reliability of 2*. When >80% of the information is available, the date is given a 3* rating. The 80% cut-off is an arbitrary point assigned based on the inclusion of the minimum required information initially recommended by Stuiver and Polach (1977) [13]. These recommendations have since been added to as demonstrated by the Torres Strait Radiocarbon Database: version 2.0 [7] — which is based on previous classifications reported across Torres Strait literature and other radiocarbon databases, e.g., SahulArch database [11] and FosSahul 2.0 database [10]. Samples that received a 3* rating undergo Stage 3 assessment focusing on pretreatment and stable isotope data. These additional assurance measures were included to enable a focus on a region-specific assessment of stable isotope information based on the three common material types in Torres Strait archaeology (i.e., charcoal, marine shell, and bone). Samples that are found to have a majority of criteria (defined in Figure 3) are rated 4* (highest reliability category).

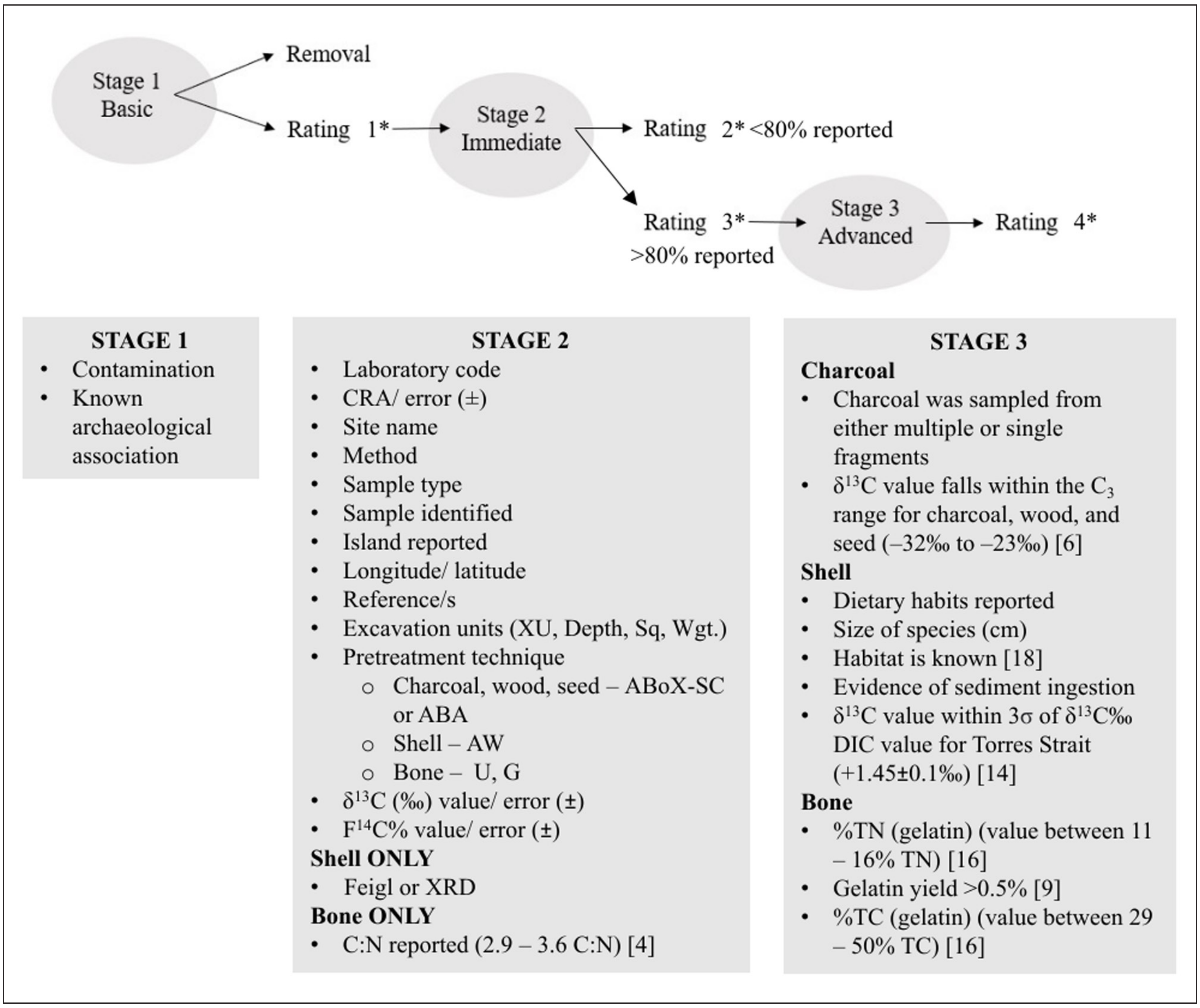

Figure 3 Decision tree for the three quality assurance stages and four reliability ratings.

This review outlines the limitations associated with the potential dating of each specific material class (e.g., charcoal (seed included), marine shell, and bone) and enables additional nuance to the interpretation of radiocarbon ages by assessing data quality. The results indicate that from a total of 343 ^{14}C ages, 26 were rejected in Stage 1 due to a lack of cultural association or potential contamination. Figure 4(A) presents a total of 21 bone samples, six were given a reliability rating of 2*, with 15 rated either a 3* (*n* = 3) or 4* (*n* = 12). From 132 charcoal samples, 115 were assigned 3* (*n* = 57) or 4* (*n* = 58) reliability. The majority of shell samples (*n* = 164) were awarded a 3* (*n* = 42) or 4* (*n* = 85) rating. From these results, we conclude that out of the 317 ^{14}C ages, 251 were awarded a reliability rating of 3* or greater.

Analysis of the dataset presented here allows further interrogation of what can be considered a reliable age. From these results, we can create a range of chronological modelling approaches based on the most to least reliable ^{14}C ages, depending on the focus. For example, ages assigned a 3* or higher can be used to establish high-confidence models that can be compared with models incorporating a (low) 2* rating. Figure 4(B) shows a time series (year BP) comparison of categories 2*, 3*, and 4*. These data can be used to refine the likely duration of archaeological events and produce the most reliable Torres Strait chronological reconstructions.

(3) DATASET DESCRIPTION

OBJECT NAME

Torres Strait Radiocarbon Database: version 2.0 [7]

DATA TYPE

Primary data

FORMAT NAMES AND VERSIONS

Excel (.xlsx)
Open Document (.ods)

CREATION DATES

Database sourcing 05/02/2018 to 05/02/2022.

DATASET CREATORS

Lauren Linnenlucke, Michael Bird, Ian McNiven, Fiona Petchey and Sean Ulm.

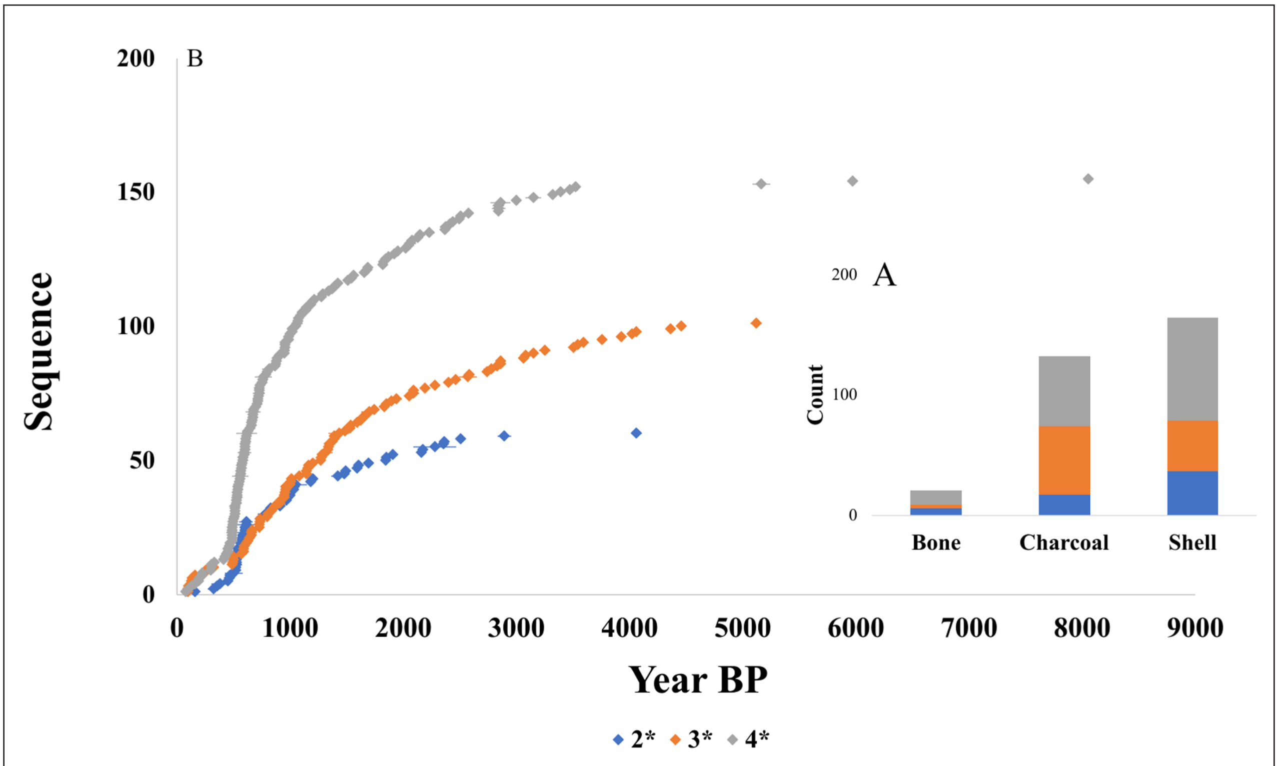

Figure 4 (A) Number of radiocarbon ages (y-axis) per reliability category (2*, 3*, and 4*) based on material classification (x-axis) grouped via pretreatment technique (e.g., seed and charcoal undergo the same technique) (Fiona Petchey, personal communication, 2019). Results indicate that most samples were assigned a 3* or greater reliability rating from the dataset (*n* = 343). **(B)** Time series of ^{14}C ages for archaeological sites in the Torres Strait that pass Stage 1 of the quality assurance criteria. The graph indicates the temporal sequence of archaeological sites from youngest to oldest ages (y-axis) against the ^{14}C ages (positive and negative error included) (x-axis). Supplementary Tables S1 – 4 are provided for reliability ratings of individual radiocarbon ages that have undertaken the quality assurance framework, including excluded ages (Table S1), bone (Table S2), charcoal (Table S3), and shell (Table S4) indicating all 2*, 3*, and 4*ratings.

LANGUAGE
English

LICENSE

REPOSITORY LOCATION
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PUBLICATION DATE
02/02/23

(4) REUSE POTENTIAL

We have presented an approach that assesses the reliability of the ^{14}C ages (and their associated metadata) to more robustly identify the timing of demographic changes across the region. This two-step process for Holocene archaeological ages undergoes analysis and categorisation into four reliability categories. Applying the chronometric transparency quality assurance framework to the case study dataset (Torres Strait) has allowed an objective assessment of the reliability of all available radiocarbon ages and their corresponding metadata via a metadata analysis overview (Figure 2). By applying multiple review stages, we can ensure that varying levels of detail can be checked and then cross-checked against species-specific information and regional determinations (stable isotope information) to ensure data reliability. This review found that few data points were removed in the first stage, after assessment of the adequacy of association with the archaeological record and evidence for contamination. Understanding the limitations of the data used in subsequent statistical analyses to address further archaeological questions about the Torres Strait is essential; otherwise, unreliable results may lead to erroneous conclusions. We recommend using the most reliable ages (3* and higher) for future analyses using this framework as an example to produce the most reliable reconstructions. Various approaches can be designed from this framework to assess different strategies to examine and yield results for archaeological research surrounding the re-examination of chronologies.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Supplementary Tables.** Tables S1 to S4 and references. DOI: https://doi.org/10.5334/joad.95.s1

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

The lead author provided the main conceptual ideas, sourced the dataset, performed analysis, and wrote the initial draft of the paper.

The second author provided dating expertise and editorial support.

The third author provided dating expertise and editorial support.

The fourth author created the spatial figure of dataset entry points and editorial support.

The fifth author provided radiocarbon data and metadata associated with radiocarbon ages, advice on conceptual ideas, assisted with sourcing the dataset, and provided editorial support.

The sixth author provided unpublished radiocarbon data.

The seventh author provided radiocarbon dating expertise, advice on conceptual ideas, assisted with sourcing the dataset, and provided editorial support.

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