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An Indo-Pacifc coral spawning database

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DATA DESCRIPTOR

An Indo-Pacific coral spawning database

Andrew H. Baird *et al.*#

The discovery of multi-species synchronous spawning of scleractinian corals on the Great Barrier Reef in the 1980s stimulated an extraordinary effort to document spawning times in other parts of the globe. Unfortunately, most of these data remain unpublished which limits our understanding of regional and global reproductive patterns. The Coral Spawning Database (CSD) collates much of these disparate data into a single place. The CSD includes 6178 observations (3085 of which were unpublished) of the time or day of spawning for over 300 scleractinian species in 61 genera from 101 sites in the Indo-Pacific. The goal of the CSD is to provide open access to coral spawning data to accelerate our understanding of coral reproductive biology and to provide a baseline against which to evaluate any future changes in reproductive phenology.

Background & Summary

Scleractinian corals are the ecosystem engineers of coral reefs, the most species-rich marine ecosystems. Scleractinian corals have a bipartite life history, with a sessile adult stage and a planktonic larval stage that allows dispersal among reefs. Corals produce larvae in one of two ways: gametes are broadcast-spawned for external fertilization or the eggs are retained for internal fertilization, followed by the release of planula larvae from the polyp. The discovery of multi-species synchronous spawning on the Great Barrier Reef[1] stimulated a large effort to document coral spawning times in other regions of the world. Similar multi-species spawning events *sensu*[2] have now been documented in over 25 locations throughout the Indo-Pacific[3–5]. However, much additional data on coral sexual reproductive patterns remain unpublished. Even when spawning data are published, there is often insufficient detail, such as the precise time and duration of spawning, to address many important questions. Consequently, predicting the month of spawning has been the focus of many studies to date[6].

Coral spawning times can be used to address many significant and fundamental questions in coral reef ecology. Most coral species are notoriously difficult to identify and spawning times have been used to infer pre-zygotic barriers to fertilization and thus assist decisions about species boundaries[7,8]. While proximate cues associated with the month of spawning are reasonably well understood in some taxa[6,9], the relationship between cues for the date and time of spawning are poorly understood. Similarly, potential phylogenetic patterns and geographical variation in spawning times are only beginning to be explored[10]. Knowing when corals spawn is also important for managing coastal development. For example, in Western Australia, legislation requires dredging operations to cease during mass spawning events[11,12]. Coral spawning is also an economic boon for tourist operators in many parts of the world, such as the Great Barrier Reef. Furthermore, population level records of spawning times provide a baseline against which to evaluate potential changes in spawning synchrony or seasonality associated with anthropogenic disruptions to environmental cues, in particular, sea surface temperature[13]. Knowledge of the timing of spawning is also essential for accurately estimating levels of connectivity among populations, given season differences in current flow[14]. The value of long-term species level data on coral spawning has recently been demonstrated in a test of the influence of temperature and wind on the night of coral spawning[15].

In this data descriptor, we present the Coral Spawning Database (CSD). The CSD includes spawning observations for reef building coral species from the Indo-Pacific. The CSD includes 6178 observations (3085 of which were unpublished) of the time or day of spawning for 300+ scleractinian species in 61 genera (Online-only Table 1) from 101 sites (Fig. 1) in the Indo-Pacific. The goals of the CSD are: (i) to assemble the scattered and mostly unpublished observations of scleractinian coral spawning times and (ii) to make these data readily available to the research community. Our vision is to help advance many aspects of coral reef science and conservation at a time of unprecedented environmental and societal change.

#A list of authors and their affiliations appears at the end of the paper.

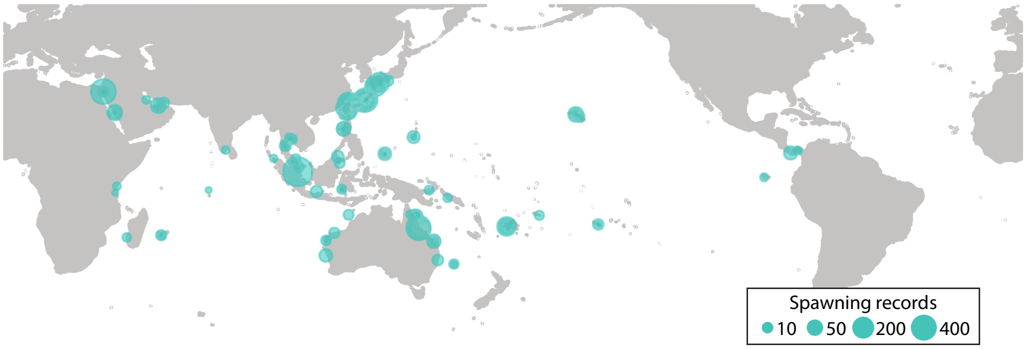

Fig. 1 The number of spawning records by site.

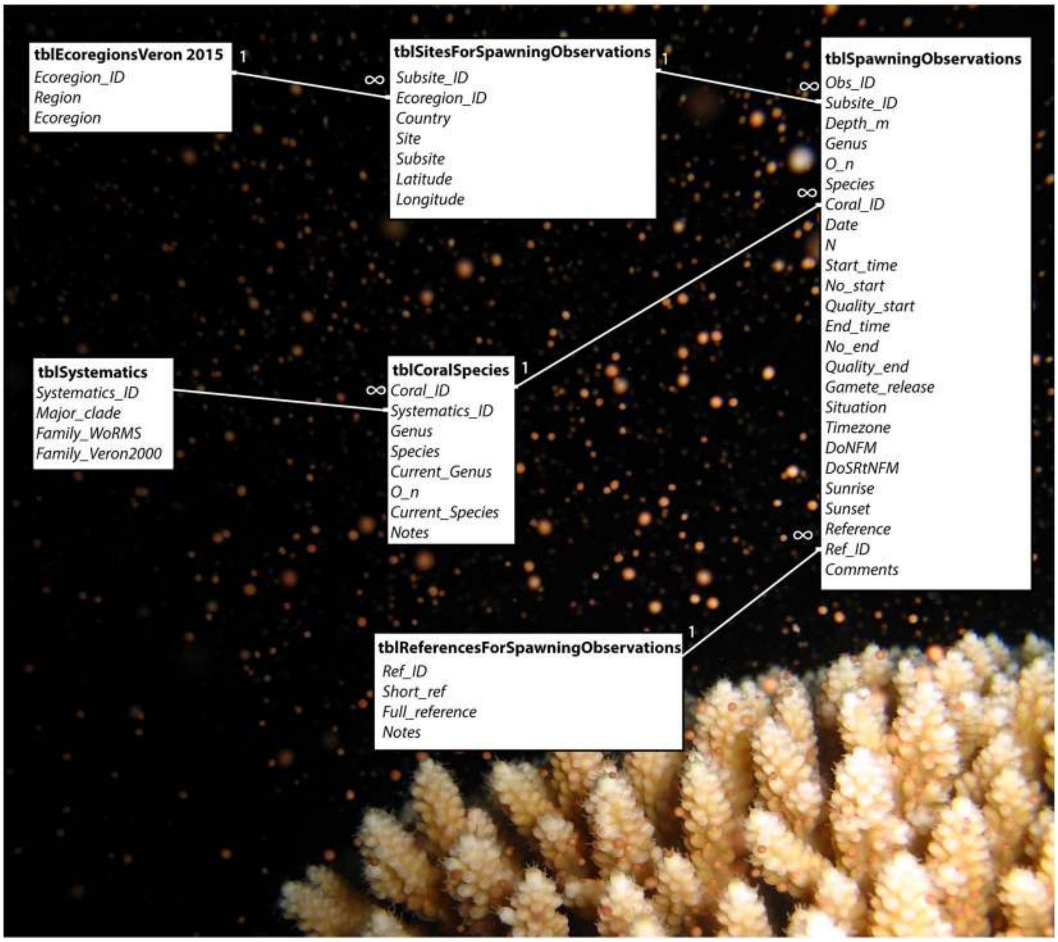

Fig. 2 Arrangement of data tables in the Access relational database.

Methods

The CSD includes spawning times for broadcast spawning scleractinian coral species in the Indo-Pacific. There are two sources for these data: the literature and unpublished observations. Published literature was selected based on the authors' knowledge of the subject area and a literature search using the terms "coral AND spawn*". Over 50 researchers known by the authors to have extensive data on coral spawning times were approached to contribute unpublished data. This initial invitation led to a subsequent round of invitations to additional contributors. Of course, we encourage any researchers with data we have missed to contribute their observations in the annual update of the database. The database focusses on spawning times. Many other biological variables related to coral reproduction, such as fecundity, are available in the Coral Traits Database[16].

The database is available as a Microsoft Access relational database or an Excel spreadsheet. To minimise repetition in data entry, spawning observation information is entered in three primary tables (Fig. 2). The first ("tblSitesForSpawningObservations") is used to enter geographic information on each study site; the second ("tblSpawningObervations") contains details of the spawning activity recorded at each site; the third ("tblReferencesForSpawningObervations") contains either full bibliographic details for published studies or details of the source of unpublished data. To assist with data analysis, three accessory tables are also linked. The first ("tblEcoregionsVeron2015") allows sites to be grouped into the biogeographical Ecoregions proposed by[17] or by broader region (e.g. Indian Ocean, Western and Central Pacific, Eastern Pacific). The remaining two tables allow the coral species to be grouped systematically for analysis. The first ("tblCoralSpecies") has a list of over 1600 coral species with genus and species names (primarily from[18] or subsequent descriptions of new species) mapped to currently accepted names (primarily from[19]) where the taxonomy has changed. The second ("tblSystematics") allows species to be grouped into major clades or currently accepted families[19] as revealed by molecular studies[20–22].

Data entry. *Coral Spawning Database fields.*

1) **Site information (in tblSitesForSpawningObservations):**

Ecoregion_ID link to Ecoregions (150) as defined by[17]
Country the country, territory (e.g. Guam) or island group (e.g. Hawaiian Islands) where spawning observation was made
Site accepted name for broad geographical location (e.g. archipelago, island, offshore reef, bay, etc.) of the observation
Subsite more precise site name within location (where applicable; na entered where no subsite)
Latitude in decimal degrees (-ve values for sites South of the Equator).
Longitude in decimal degrees (-ve values for sites West of the Greenwich Meridian).

2) **Spawning observations (in tblSpawningObservations):**

Depth_m the approximate depth at which the colony was collected (for *ex situ* observations) or observed (for *in situ* observations). If not recorded then −99 entered.
Genus currently accepted genus name[19]
O_n open nomenclature qualifier: see explanation below under "Species identifications".
Species the species name used by the observer
Date date of spawning observation in the format day/month/year (e.g. 24/11/1983)
N number of colonies or individuals observed spawning. Used −99 if not known. If exact number of colonies not counted but more than a specific number were observed to spawn (e.g. > 25), then minimum number counted was entered (e.g. 25).
Start_time time of first observation of spawning for colony(ies) of species: time (hh:mm) on a 24 hour clock e.g. 18:30. See "recording the time of spawning" below for ways to use the time fields to capture the various ways spawning is usually observed. No threshold applied to the intensity of spawning.
No_start no information on time that spawning started: True or False.
Quality_start if No_start is False, Exact or Approx.
End_time time of last observation of spawning for colony(ies) of species (if later than start time, normally): time (hh:mm) on a 24 h clock e.g. 18:30
No_end no information on time that spawning ended: True or False
Quality_end if No_end is False, Exact or Approx
Gamete_release (five character states as follows)

- Bundles – eggs and sperm released together packaged in bundles
- Eggs – only eggs released
- Sperm – only sperm released
- Both separately – eggs and sperm released separately from the same colony. Examples include *Lobophyllia hemprichii* and *Goniastrea favulus*
- Not recorded – release of gametes not observed or not reported

Situation *In situ* = spawning observed underwater or *Ex situ* = spawning observed in tanks of colony(ies) recently removed from the reef.
Timezone local time zone on the date of the spawning observation. This allows local time of spawning to be related to local time of sunset (or occasionally sunrise, for daytime spawners). This field is not an integer to accommodate 30 minute time differences (e.g. India and Sri Lanka are on UTC + 5.5). Enter -ve values for sites west of the Greenwich Meridian: e.g. −11 for Hawaii. (Note: Daylight Saving Times mean that time zones at some sites vary with date, e.g. Fiji goes from UTC + 12 to UTC + 13 from early November to early January).

The next four fields contain benchmarks for comparing spawning among sites for different species or groups of species[23]. The first is the date of the nearest full moon (DoNFM) to the date of spawning (with 75% of spawning recorded in the week after the full moon). This allows all spawning dates to be calculated in terms of days before or after the full moon (DoSRtNFM). Sunset provides a benchmark for comparing the times of spawning for most spawners (over 90% of spawning started within 4 hours of sunset) and sunrise for a few daytime spawners such as *Pocillopora verrucosa*. Dates of full moon and times of sunrise and sunset are available for given locations from the web (e.g. www.timeanddate.com) and can be entered manually. However, they can also be calculated automatically in the database based on the date, time zone and, for sunrise and sunset, the latitude and longitude. Excel spreadsheets are also available on request from the corresponding authors to calculate dates of full moon and times of sunrise and sunset in addition to a data entry template.

DoNFM	Date of Nearest Full Moon. Calculated automatically and corrected for longitude based on the local time zone.
DoSRtNFM	Date of Spawning Relative to Nearest Full Moon. Calculated automatically using time zone and date of observation in days before (-ve) or after (+ve) the nearest full moon (ranges from −15 days to + 14 days).
Sunset	local time of sunset using a 24 h clock e.g. 18:30. Sunset and sunrise times were calculated for each observation based on latitude, longitude and time zone of the site and the date, using the method in the NOAA solar calculations day spreadsheet at https://www.esrl.noaa.gov/gmd/grad/solcalc/calcdetails.html. An Excel spreadsheet (Sunrise_Sunset_DoNFM_Calculations.xlsx) is provided for anyone wishing to use the Excel version of the dataset.
Sunrise	local time of sunrise using a 24 h clock e.g. 05:30. See above.
Ref_ID	a link to reference information for the data if available. If not the names of the observers are listed (e.g. Baird, Connolly, Dornelas and Madin unpublished)
Comments	any additional details provided

3) **Reference information (in tblReferencesForSpawningObservations):**

Each set of observations is referenced to its published or unpublished source in this table via a Ref_ID. The table contains two main fields: "Short_ref" (e.g. Baird *et al*. 2015) and "Full_reference" (e.g. Baird AH, Cumbo VR, Gudge S, Keith SA, Maynard JA, Tan C-H, Woolsey ES (2015) Coral reproduction on the world's southernmost reef at Lord Howe Island, Australia. Aquatic Biology 23:275–284). These can be filled in before or after entering spawning observations. An email address is provided for all unpublished contributions.

Notes to recording the time of spawning. For the quality of a start or end time to be 'Exact', a colony must be under continuous observation and the time of onset or end of spawning be observed and recorded. Most *in situ* observations would be expected to be approximate ('Approx').

The Quality_start, Quality_end, No_start and No_end fields are designed to accommodate the most common ways spawning is observed. A series of examples are given below.

1. A colony is observed spawning but it is not known exactly when it started. No end time is recorded.
   Here enter the time the colony was first observed spawning as the Start_time and the Quality_start as 'Approx'. Leave the End_time blank and set No_end to True.
2. A colony is followed closely until spawning is observed to begin but the precise time when spawning ends is not recorded. However, the colony is observed to be still dribbling spawn 30 minutes after spawning started.
   Here enter the Quality_start_ as 'Exact' with the End_time set to 30 minutes after the Start_time and the Quality_end set to 'Approx'.
3. A colony is followed closely from the beginning until the end of spawning.
   Here enter the times and note Quality_start and Quality_end as 'Exact'.
4. A colony is placed in a bucket and checked every 30 minutes. At the first observation there is no evidence of spawning, 30 min later the surface of the water is covered in bundles and the colony is no longer spawning.
   Here enter the time of the first observation as the start time and the time of the second observation as the end time and set Quality_start and Quality_end to 'Approx'.
5. Only the night of spawning is known, for example, gametes are no longer apparent in a tagged and sequentially sampled colony.
   Here don't enter either a start time or an end time and leave Quality_start and Quality_end blank. Set No_start and No_end to True.

Species identifications. Species were generally identified following[18,24] or by comparing skeletons to the type material or the original descriptions of nominal species. Specimens identified following[18,24] were updated to the currently accepted names at the World Register of Marine Species[19]. The database also allows for uncertainties in species identifications to be indicated with the use of a series of open nomenclature qualifiers[25,26] that allow the assignment of specimens to a nominal species with varying degrees of certainty. Specimens that closely resemble the type of a nominal species are given the qualifier cf. (e.g. *Acropora* cf. *nasuta*). Specimens that have morphological affinities to a nominal species but appear distinct are given the qualifier aff. (e.g. *Acropora* aff. *pulchra*): these specimens are either geographical variants of species with high morphological plasticity or potentially undescribed species. Species that could not be matched with the type material of any nominal species were labelled as sp. in addition to the location where they were collected (e.g. *Acropora* sp_1_Fiji). These specimens are most probably undescribed species. For 1% of records spawning colonies were only identified to genus (e.g. *Montipora* sp.). Contact the sources of these data for further information on the species identity.

Data Records

A snapshot of the data contained in this descriptor can be downloaded from figshare[27]. The data includes 6178 observations, 3085 of which were unpublished with the remainder gleaned from the literature[28–128]. These data have been through a rigorous quality control and editorial process. Annual updates of the dataset will be uploaded to figshare as new version and also made available at any time on request from the Editor (JRG). Contributions to the CSD are welcome at any time and should be sent to the Editor (JRG).

Technical Validation

The database is governed on a voluntary basis, by an Editor (JRG), Assistant Editors (JB & AGB), a Taxonomy Advisor (AHB) and a Database Administrator (AJE). Quality control of data and editorial procedures include:

1. **Contributor approval**. Database users must request permission to become a database contributor.
2. **Editorial approval**. Once a contributor sends data to the Editor, the data will be checked and if correctly formatted will be forward to the Database Administrator
3. **User feedback**. Data issues can be reported for any observation by email to the Editor

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A.H.B. and J.R.G. conceived the idea. A.H.B., J.R.G., A.J.E., J.B., A.G.B., S.-H.N. & H.M. compiled the data and jointly wrote the data descriptor. A.J.E. designed the database. All other authors contributed unpublished data and commented on the text.

Competing interests

The authors declare no competing financial interest.

Additional information

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