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ADRIAIndicators.jl: a Julia package for summarizing reef ecological model outputs

Daniel Tan [1], **Takuya Iwanaga** [1], **Rose Crocker** [1], **Pedro Ribeiro de Almeida** [1], **Ken Anthony**[2], **Arne A. S. Adam** [3], **Ryan F. Heneghan** [4], **Michael McWilliam** [5], **Morgan Pratchett** [5], **Vanessa Haller-Bull** [1], **Yves-Marie Bozec** [3], **Anna K. Cresswell** [1], **and Juan Carlos Ortiz**[1]

1 Australian Institute of Marine Science, Townsville, Queensland, Australia **2** Nature Assets Consulting **3** School of the Environment, University of Queensland, St Lucia, Queensland, Australia **4** School of Environment and Science, Griffith University, Nathan 4111, QLD Australia **5** College of Science and Engineering, James Cook University, Townsville, QLD 4811, Australia

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Software

- Review
- Repository
- Archive

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Summary

ADRIAIndicators.jl is a Julia package for analyzing outputs from coral reef ecological models. Its primary purpose is to provide a standardized and dependency-free toolkit for transforming high-dimensional model outputs such as coral abundance by reef, time, species, and size class into lower-dimensional, interpretable metrics. The package offers a wide range of functions, from simple aggregations and unit conversions to more complex indices and estimators derived from regression models. These tools help with the estimation of functional diversity, juvenile abundance, shelter volume, fish biomass, and overall reef condition, enabling consistent and comparable analysis across different coral ecology models such as CoralBlox (Ribeiro de Almeida et al., 2024), C~Scape (Cresswell et al., 2024), ReefMod (Bozec et al., 2022), and CoCoNet (Condie, 2022).

Statement of Need

Models of coral reef ecosystems often produce large volumes of high-dimensional data. There is a need for standardized tools to summarize and analyze these model outputs to facilitate inter-model comparison of environmental projections and communicate results to managers and stakeholders. ADRIAIndicators.jl provides a set of standard indicator metrics that can be used to summarize reef state in ecological model outputs. These were originally implemented within the ADRIA.jl Decision Support package (Iwanaga et al., 2025) but were being reproduced in many workflows that did not use ADRIA.jl. Separating these indicators from ADRIA.jl is part of efforts to better compartmentalize code in a more reusable and interoperable manner.

ADRIAIndicators.jl is written in Julia (Bezanson et al., 2017), a high-level, high-performance programming language for technical computing. This package is designed to be easy to use, and provides an in-place option for all metrics for any eventual wrappers that may be implemented in other languages such as Python and R. Such wrappers could be developed leveraging Julia's support for language interoperability and compilation capabilities (such as those provided by JuliaC.jl).

Available Indicators

The indicators implemented in ADRIAIndicators.jl are classified into three categories: Aggregations, Conversions, and Metrics. Aggregations are convenience methods for reducing the dimensionality of data by summarizing arrays. Conversions handle transformations between different units or representations of coral cover. Metrics derive higher-level, interpretable indicators from the raw model data, such as coral diversity, shelter volume, and composite indices for reef health.

Metric Name	Type	Reference
Relative Cover	Aggregation	
Relative Location Taxonomy Cover	Aggregation	
Relative Taxonomy Cover	Aggregation	
LTMP Cover	Aggregation	
LTMP Location Taxonomy Cover	Aggregation	
LTMP Taxonomy Cover	Aggregation	
Relative Juveniles	Aggregation	
Relative Location Taxonomy Juveniles	Aggregation	
Relative Taxonomy Juveniles	Aggregation	
Relative Habitable Cover to Reef Cover	Conversion	
Reef Cover to Relative Habitable Cover	Conversion	
Absolute Shelter Volume	Metric	(Aston et al., 2022; Urbina-Barreto et al., 2021)
Relative Shelter Volume	Metric	-
Coral Diversity	Metric	(Hill, 1973)
Coral Evenness	Metric	-
Reef Condition Index	Metric	(Heneghan et al., 2025)
Reef Fish Index	Metric	(Graham & Nash, 2013)

A dash (-) in the 'Reference' column indicates the reference is the same as the entry directly above it.

Indicator Summaries

Each indicator is briefly summarized below. Full implementation details are found in the documentation, including descriptions of their mathematical formulations where appropriate.

Coral Cover

Estimates of coral cover are provided in both **Relative** and **Absolute** forms and estimated for each location by summing over functional groups and their size classes. As the indicators are agnostic to the spatial scale being assessed, the term "location" is used to convey an arbitrary unit of analysis. For example, a location could be a representative reef, site within a reef, a transect, or patch/plot of reef.

Relative cover is calculated to be *relative* to the location's coral habitable area. The meaning of "habitable" area is subject to much debate, however it can be construed as being representative of the area of hard substrate or a location's carrying capacity. The term *LTMP cover* is used to convey that cover estimates are made relative to estimates of the total reef area, inclusive of reef areas where corals are unable to settle. As such, LTMP cover estimates may never reach 100%. This approach is more in line with the values reported by the Long-Term Monitoring Program (LTMP). The *Absolute* form provides estimates of the area of coral cover expressed in SI units (typically m^2).

Relevant indicators:

- **Relative Cover**: Calculates the total relative cover per location by summing over functional groups and size classes.
- **Relative Location Taxonomy Cover**: Calculates the relative cover for each location and functional group by aggregating size classes.
- **Relative Taxonomy Cover**: Provides an indication of the coral cover decomposed by functional group by aggregating their size classes for all locations.
- **LTMP Cover**: Calculates the coral cover for each location relative to estimated total reef area. More comparable to the values reported by the Long Term Monitoring Program (LTMP).
- **LTMP Location Taxonomy Cover**: As above, but decomposes the coral cover estimates to each functional group by location.
- **LTMP Taxonomy Cover**: As above, but providing total values per functional group.
- **Relative Juveniles**: Calculates the relative coral cover provided by juvenile corals. User indicates which size classes are construed to be "juvenile".
- **Relative Location Taxonomy Juveniles**: As above, but for each location and functional group.
- **Relative Taxonomy Juveniles**: As above, but summed across all locations.

Shelter Volume

Calculates the volume of shelter provided by the given coral cover. In typical use, values are indicative of the modelled *live* coral population, however it is noted that non-living substrate may also provide some form of shelter.

Relevant indicators:

- **Absolute Shelter Volume**: Calculates the absolute shelter volume (in m^3) provided by corals.
- **Relative Shelter Volume**: Calculates the relative shelter volume, expressed as a proportion of the theoretical maximum shelter volume for a given area.

Diversity and Evenness

These indicators provide estimates of the diversity and evenness of coral functional groups.

Relevant indicators:

- **Coral Diversity**: Calculates coral diversity at each location using the Simpson's Diversity Index, which accounts for the number and relative abundance of coral functional groups.
- **Coral Evenness**: Calculates the evenness of coral functional groups at each location using the Inverse Simpson's Index, indicating how similar in abundance the different functional groups are.

Condition Indices

Composite indices (or meta-metrics; metrics of metrics) that provide a single value indication of reef condition(s).

- **Reef Condition Index**: A categorical index (from 'Very Poor' to 'Very Good') that assesses overall reef health based on coral cover, shelter volume, juvenile abundance, and rubble cover.
- **Reef Fish Index**: An index that estimates fish biomass based on a relationship between coral cover and structural complexity.

Conversions

These are convenience/helper methods to aid in data transformations to various forms.

Relevant methods:

- **Relative Habitable Cover to Reef Cover**: Converts relative coral cover (proportion of habitable area) to LTMP cover (proportion of total reef area).
- **Reef Cover to Relative Habitable Cover**: Converts LTMP cover to relative coral cover.

Usage

The order of dimensions is always the same in ADRIAIndicators.jl,

1. Time
2. Groups
3. Sizes
4. Locations
5. Scenarios

If a dimension is missing then the order remains the same however the missing dimensions are excluded. Furthermore, all metrics have an option to provide a buffer as input in the cases where one wants to write the metric into an existing array or sub-array. This implementation is relied upon by functions that allocate the returned array as-well and was chosen to account for any any decisions in the future where another language may wrap this library and need to pass memory that is not managed by Julia.

```julia
using ADRIAIndicators

# Create some dummy model output data
n_timesteps = 75
n_groups = 5
n_sizes = 7
n_locations = 3806

# Raw model coral cover outputs with dimensions [timesteps · groups · sizes · locations]
raw_model_cover = rand(Float64, n_timesteps, n_groups, n_sizes, n_locations);

# Juveniles mask with dimensions [sizes]
is_juvenile = [true, true, false, false, false, false, false];

# Calculate and allocate new array for metric
rel_juveniles = relative_juveniles(raw_model_cover, is_juvenile);

# Users can provide output buffers if it is more convenient for them
rel_juveniles_out = zeros(Float64, n_timesteps, n_locations);
relative_juveniles!(raw_model_cover, is_juvenile, rel_juveniles_out);
```


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