In memory of Dawn A.T. Phillip 1965-2017
BIODIVERSITY OF FRESHWATER FISHES OF

TRINIDAD AND TOBAGO, WEST INDIES

Dawn Arlene Teresa Phillip

Thesis submitted for the degree of Doctor of Philosophy

University of St Andrews

October 1998
An Illustrated Guide to the Freshwater Fishes of Trinidad and Tobago

Dawn A. T. Phillip

Indar W. Ramnarine

April 2001
Annotated list and key to the stream fishes of Trinidad & Tobago

DAWN A.T. PHILLIP¹, DONALD C. TAPHORN², ERLING HOLM³, JAMES F. GILLIAM⁴,
BRADLEY A. LAMPHERE⁴ & HERNÁN LÓPEZ-FERNÁNDEZ⁵,⁶

¹Department of Life Sciences, The University of the West Indies, St Augustine, Trinidad & Tobago, W.I.
²1822 North Charles Street, Belleville, IL 62221, USA
³Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6, Canada
⁴Department of Biological Sciences, North Carolina State University, Raleigh, NC 27695-7617, USA
⁵Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2, Canada
Abundance and dominance become less predictable as species richness decreases

Maria Dornelas¹*, Dawn A. T. Phillip² and Anne E. Magurran³
In 1855 Darwin recorded all 142 plant species in the meadow, Great Pucklands, next to his family home at Downe in England.

This appears to be the first systematic survey of species richness.
The number of species of butterflies and beetles increases with the number of grid squares in the study area.

For butterflies, the relationship appears to be saturating, reaching a steady state.

For beetles, the relationship shows a clear positive trend, with species richness increasing as the number of grid squares increases.

The map highlights the region of Scotland under study.
Trinidad & Tobago 513,000 ha.
How many species of freshwater fish?
1. Dawn’s PhD data

Figure 2.3. Sample sites in Trinidad and Tobago. Sites that were sampled once are indicated by ● and those sampled twice by ◊. Maps not to scale.
2. Museum records at University of the West Indies
Trinidad & Tobago
Annotated list and key to the stream fishes of Trinidad & Tobago

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How many freshwater fish species in Trinidad & Tobago?

Dawn’s PhD data

UWI museum collections

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Jones et al. in prep
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Jones et al., in prep
85% overlap between PhD data and Museum data

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native fauna, natural colonist, introduced exotic, possibly extinct
‘...we forget that each species, even where it most abounds, is constantly suffering enormous destruction at some period of its life, from enemies or from competitors for the same place and food; and if these enemies or competitors be in the least degree favoured by any slight change of climate, they will increase in numbers; and as each area is already fully stocked with inhabitants, the other species must decrease.’

Charles Darwin, Origin of Species
Time 1

Time 2

**Scenario 1**
- Species richness: change
- Abundance: no change
- Composition: change

**Scenario 2**
- Species richness: no change
- Abundance: change
- Composition: no change

**Scenario 3**
- Species richness: no change
- Abundance: no change
- Composition: change
Biodiversity Change

Temporal $\alpha$ diversity

Temporal $\beta$ diversity
100 time series
35,613 species
6.1 million species occurrence records

Dornelas, Gotelli, McGill, Shimadzu, Moyes, Sievers, Magurran. 2014 Science
Temporal $\alpha$ diversity
Temporal $\alpha$ diversity

- Common trend
- Global
- Polar
- Polar/temperate
- Temperate
- Temperate/Tropical
- Tropical

Temporal $\beta$ diversity

- Common trend
- Global
- Polar
- Polar/temperate
- Temperate
- Temperate/Tropical
- Tropical
1. \( \alpha \) diversity: there was neither a systematic loss nor a systematic gain in the number of species recorded through time. 59 communities showed an increase in species richness through time and 41 communities showed a decrease
1. **α** diversity: there was neither a systematic loss nor a systematic gain in the number of species recorded through time. 59 communities showed an increase in species richness through time and 41 communities showed a decrease.

2. **β** diversity: 79 of the 100 communities showed substantial changes in species composition, measured relative to the baseline of the first available survey of the community, and greater than predicted by two null models of turnover.
Climate change

Invasive species

Habitat transformation
Are ecological assemblages regulated?
Community-level regulation means that biodiversity has a tendency to return to a central level following a perturbation.

In 90% of the (59) communities analyzed, the pattern was in the direction of a regulated trajectory, as revealed by an Augmented Dickey-Fuller test.

Gotelli, Shimadzu, Dornelas, McGill, Moyes, Magurran 2017 Science Advances
Evidence for widespread temporal regulation of S and N..... 
..... underpinned by marked temporal turnover in composition in excess of levels predicted by ecological theory

Gotelli, Shimadzu, Dornelas, McGill, Moyes, Magurran 2017 Science Advances
387 time series (Marine & Terrestrial)
44,884 species
12,618,393 species occurrence records

biotime.st-andrews.ac.uk

Free to anyone, anywhere in the world, to use for education, research or conservation
Dornelas M, Antão LH, Moyes F, Bates AE, Magurran AE & >>200 authors 2018

Biodiversity change varies across scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Temporal $\beta$ diversity</th>
<th>$\alpha$ diversity</th>
<th>Spatial $\beta$ diversity</th>
<th>N or Biomass</th>
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<tbody>
<tr>
<td>Global</td>
<td>$T\beta-G$</td>
<td>$\alpha-G$</td>
<td>$S\beta-GB$</td>
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<td>Local</td>
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<td>$\alpha-L$</td>
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<td>N-L</td>
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</table>
Annual survey in first quarter, since 1980

Data from ICES portal

Sample-based rarefaction

Magurran, Dornelas, Moyes, Gotelli, McGill 2015 Nature Communications
Pairwise similarity across latitudinal bands
$\alpha$ diversity
β diversity
Environmental variables

Fish

16 localities

3 assemblages

Environmental variables

Sampled 4x year for

5 years

Benthic invertebrates

Diatoms
How can we tell whether any changes we detect in $\alpha$ or $\beta$ diversity are greater than what would be expected, given baseline turnover?
NULL Model of Biodiversity Change

Calculate metric for each time step

Compute Z score for observed slope relative to null distribution

Fit OLS slope to observed data

Fit OLS slope to each cyclic shifted assemblage

Cyclic shift observed data x1000

Cyclic shift preserves within species temporal autocorrelation but breaks cross correlations
### Cyclic-shift permutation

#### A observed (no trend)

<table>
<thead>
<tr>
<th></th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
<th>t4</th>
<th>t5</th>
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#### B observed (trend)

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#### cyclic-shift

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</tbody>
</table>

#### A. No trend

![Graph A. No trend](image)

#### B. With trend

![Graph B. With trend](image)
More change in $\beta$ diversity than in $\alpha$ diversity in all taxa, but,

no correlation in pattern of change across taxa, and,

$\alpha$ and $\beta$ diversity changed independently of one another.
site compositional change over time

fish  homogenization

invertebrates  homogenization

diatoms  differentiation
Recreational Sites (Liming)

Undisturbed Sites
**α diversity**

Fish PIE

Invertebrate PIE

Diatom PIE

**β diversity**

Fish JACCARD

Invertebrate JACCARD

Diatom JACCARD

---

**fish**

**invertebrates**

**diatoms**
Divergent biodiversity change within ecosystems

Anne E. Magurran\textsuperscript{a,1,2}, Amy E. Deacon\textsuperscript{a,b,1}, Faye Moyes\textsuperscript{a}, Hideyasu Shimadzu\textsuperscript{a,c}, Maria Dornelas\textsuperscript{a}, Dawn A. T. Phillip\textsuperscript{b,3}, and Indar W. Ramnarine\textsuperscript{b}

\textsuperscript{a}Centre for Biological Diversity, School of Biology, University of St Andrews, St Andrews KY16 9TH, Scotland, United Kingdom; \textsuperscript{b}Department of Life Sciences, The University of the West Indies, St. Augustine, Trinidad and Tobago; and \textsuperscript{c}Department of Mathematical Sciences, Loughborough University, Loughborough LE11 3TU, United Kingdom

Edited by Nils Chr. Stenseth, University of Oslo, Oslo, Norway, and approved December 20, 2017 (received for review July 14, 2017)

The Earth’s ecosystems are under unprecedented pressure, yet the nature of contemporary biodiversity change is not well understood. Growing evidence that community size is regulated high-

levels anticipated by two different null models, even though temporal α-diversity metrics detected no systematic change (7). The contrasting conclusions emerging from the growing
Ecosystems that have not been massively transformed tend to support similar numbers of species over time – and provide evidence for regulation of community size.
Ecosystems are not museums – species composition changes over time, at rates that are greater than ecological theory predicts.
We do not understand the consequences for ecosystem function of elevated biodiversity change in the contemporary world
Effective conservation and resource management needs high-quality data on the distributions and abundances of species.
Thanks to:
Laura Antão, Amanda Bates, Amy Deacon, Maria Dornelas, Nick Gotelli, Faith Jones, Peter Henderson, Brian McGill, Faye Moyes, Dawn Phillip, Indar Ramnarine, Hideyasu Shimadzu