

1 RECIFS: a centralized geo-environmental 2 database for coral reef research and 3 conservation

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5 Running title: *Reef environment centralized database*

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20

21 Abstract

22 Host to intricated networks of marine species, coral reefs are among the most biologically
23 diverse ecosystems on Earth. Over the past decades, major degradations of coral reefs have
24 been observed worldwide, which is largely attributed to the effects of climate change and
25 local stressors related to human activities. Now more than ever, characterizing how the
26 environment shapes the dynamics of the reef ecosystem is key to (1) uncovering the
27 environmental drivers of reef degradation, and (2) enforcing efficient conservation strategies
28 in response. To achieve these objectives, it is pivotal that environmental data characterizing
29 such ecosystem dynamics, which occur across specific spatial and temporal scales, are easily
30 accessible to coral reef researchers and conservation stakeholders alike.

31 Here we present the Reef Environment Centralized Information System (RECIFS), an online
32 repository of datasets describing reef environments worldwide over the past few decades.

33 The data served through RECIFS originate from remote sensed datasets available in the public
34 domain, and characterize various facets of the reef environment, including water chemistry
35 and physics (e.g. temperature, pH, chlorophyll concentration), as well as anthropogenic local
36 pressures (e.g. boat detection, distance from agricultural or urban areas). The datasets from
37 RECIFS can be accessed at different spatial and temporal resolutions and are delivered
38 through an intuitive web-application featuring an interactive map requiring no prior
39 knowledge working with remote sensing or geographic information systems. The RECIFS web-
40 application is available in complete open access at <https://recifs.epfl.ch>.
41 We describe two case studies showing possible implementations of RECIFS to 1) characterize
42 coral diversity in the Caribbean and 2) investigate local adaptation of a reef fish population in
43 Northwest Australia.
44

45 Introduction

46 Host of up to a quarter of marine species, coral reefs are among the most productive and
47 biologically diverse ecosystems on Earth (Bouchet, 2006; Knowlton et al., 2010; Reaka-Kudla,
48 1997). These biodiversity hotspots are currently facing critical threats imposed by both
49 climate change and human-induced local disturbances (Hughes et al., 2017). Indeed, a 14%
50 loss of hard coral cover worldwide was recently estimated for the 2009-2018 decade, where
51 the decline was mainly attributed to anomalous heat waves causing coral bleaching (Souter
52 et al., 2021). Additionally, the resilience of corals to thermal stress can be hampered by local
53 water conditions, such as turbidity levels or nutrient loads (MacNeil et al., 2019). As hard
54 corals shape the physical reef habitat, their loss can lead declines in reef fish abundance (G.
55 P. Jones et al., 2004), and such declines can be exacerbated by local stressors such as
56 overfishing (Hughes et al., 2017) and pollution (e.g. agricultural or industrial runoff; Wenger
57 et al., 2015). Overall, the deterioration of coral reefs impairs the associated ecosystem
58 services, which are key for the well-being of human communities in the tropics (Eddy et al.,
59 2021).

60 To identify the drivers and quantify rates coral reef deterioration, researchers can investigate
61 the association between remote sensed environmental data, and *in-situ* measurements
62 replicated at multiple locations across reef systems. These *in-situ* measurements can include
63 various ecological surveys, including surveys of coral abundance (e.g., Sully et al., 2022), coral

64 diversity (e.g., Kusumoto et al., 2020), coral bleaching severity (e.g., McClanahan et al., 2020),
65 fish biomass (e.g., Cinner et al., 2016), or the presence/absence of a given reef species (e.g.,
66 Förderer et al., 2018; Ottimofiore et al., 2017; Principe et al., 2021). *In-situ* measurements
67 also include molecular data from populations that represent genetic diversity, which can be
68 used in genotype-environment association (GEA) studies to uncover genetic variants
69 potentially underpinning local adaptation processes (Fuller et al., 2020; Lundgren et al., 2013;
70 Selmoni, Lecellier, Magalon, et al., 2020; Selmoni, Rochat, et al., 2020; Sherman et al., 2020;
71 Thomas et al., 2017).

72 These association studies can expose the environmental drivers of species abundance,
73 diversity and adaptive potential, which are all pivotal elements to organize effective reef
74 conservation strategies (Foo & Asner, 2019, 2021; Hedley et al., 2016; Lecours et al., 2021;
75 Murray et al., 2018). For example, high taxonomic diversity is among the main criteria used
76 to prioritize reefs when establishing marine protected areas (MPAs; Mascia et al., 2017).
77 Additionally, MPAs could be enforced at reefs with a thermal history associated with
78 heat-adaptation in corals (Wilson et al., 2020). The optimal location of these MPAs can then
79 be decided based on regional surface water circulation, such that larval dispersal of thermally
80 adapted corals reaches the largest number of reefs downstream of protected populations
81 (Matz et al., 2020; Selmoni, Lecellier, Vigliola, et al., 2020; Selmoni, Rochat, et al., 2020; van
82 Woesik et al., 2022).

83 For conservation strategies to make the most of these environmental drivers, the underlying
84 environmental data must be easily accessible for both the researchers running the association
85 analyses and the decision makers enforcing reef conservation strategies (Hedley et al., 2016;
86 Lecours et al., 2021). There are already online repositories that provide synthesized variables
87 of marine environments worldwide, such as Bio-ORACLE (Assis et al., 2018; Tyberghein et al.,
88 2012) and MARSPEC (Sbrocco & Barber, 2013). The synthesized variables are derived from
89 remotely sensed data obtained from public initiatives, such as the World Ocean Atlas (Boyer
90 et al., 2018) and the Copernicus Marine Service (EU Copernicus Marine Service, 2022), and
91 describe long-lasting trends in global oceanic conditions. These synthesized datasets are
92 predominantly produced (and widely used) for spatial distribution modelling of marine
93 organisms (Sbrocco & Barber, 2013; Tyberghein et al., 2012).

94 However, these repositories are not coral reef-centered, and therefore do not give access to
95 environmental variables that are key to understand the dynamics of the coral reef ecosystem,

96 such as coral heat stress indices (e.g., those from the Coral Reef Watch; Liu et al., 2014) or
97 indices of local fishing activities or of human land use along the coastline. In addition, these
98 repositories offer limited possibilities for customizing the spatial and temporal extents of
99 environmental data, where such customization is key when analyzing the relationship with *in-*
100 *situ* measurements (Leempoel et al., 2015; Murray et al., 2018). For example, a certain *in-situ*
101 measurement (e.g., the abundance of a given species; the presence of an adaptive genetic
102 trait) could be driven by an environmental variation during a specific season (e.g., thermal
103 stress during the hot season), or by pollution-related human activities within a certain
104 distance from the coastline (e.g., agricultural areas in a 50 km radius). As the sub-setting and
105 processing of environmental data is generally performed using dedicated software (e.g., R-
106 packages, Python), this data processing generally requires competences with geographic
107 information systems (GIS) and scientific programming. The lack of an interactive and easy-to-
108 use user interface hampers the integration of these data by non-GIS experts, as may be the
109 case for coral reef conservation practitioners (Guisan et al., 2013; Selmoni, Lecellier, Ainley,
110 et al., 2020).

111 Here, we present the Reef Environment Centralized Information System (RECIFS), an online
112 repository of datasets describing the reef environment worldwide over the past decades. The
113 datasets provided through RECIFS originate from the public domain, and characterize various
114 facets of the reef environment including water chemistry (e.g., chlorophyll concentration,
115 salinity, etc.) and physics (e.g., temperature, heat, velocity, etc.), as well as anthropogenic
116 impacts (e.g., population density, land use of agricultural and urban areas) along the
117 neighboring coastlines. The datasets from RECIFS can be accessed at different spatial
118 resolutions and are sub-settable along the temporal dimension (*i.e.*, select specific seasons
119 and/or specific years). The data are delivered through an intuitive a free-to-use web-GIS
120 application, available at <https://recifs.epfl.ch>. We hereunder present the functionalities of
121 this tool, and describe two cases studies showing possible implementations: 1) the
122 characterization of coral diversity in the Caribbean, and 2) the study of local adaption of a reef
123 fish population along the northwestern coast of Australia.

124

125 Methods

126 Data structure: reef environment

127 The RECIFS repository is based on three types of datasets describing the reef environment
128 retrospectively at different temporal resolutions: monthly, annual and non-temporal (i.e.,
129 variables without a temporal resolution; Table 1). These datasets were accessed at a global
130 level as raw data, and were then processed and synthesized as outlined here below (and as
131 summarized in Figure 1).

132 Raw datasets with a monthly temporal resolution were stacks of raster images, where every
133 image described a monthly statistic (usually the average) of a given oceanic environmental
134 variable globally. RECIFS includes the raw monthly datasets for the following environmental
135 variables: chlorophyll concentration, degree heating week, iron concentration, oxygen
136 concentration, pH, nitrate concentration, phosphate concentration, sea current velocity,
137 suspended matter concentration, salinity, and temperature. These variables represent data
138 at near-surface depth, with spatial resolutions ranging between 5-25 km, and across temporal
139 windows generally covering the past 2-3 decades (see Table 1 for details). These raw monthly
140 datasets are sourced from the repositories from the Coral Reef Watch of the National Oceanic
141 and Atmospheric Administration (NOAA Coral Reef Watch, 2022) and the Copernicus Marine
142 Service (EU Copernicus Marine Service, 2022).

143 Raw datasets at yearly temporal resolution were also raster stacks, but here each image was
144 a yearly measure of a given variable worldwide. The datasets of this type included in RECIFS
145 were: land cover of built-up and cropland areas (covering the 2015-2019 period, at 100m
146 resolution; Copernicus Global Land Service, 2022), boat detection (2017-2020, at 500m
147 resolution; Elvidge et al., 2015, 2018; Hsu et al., 2019), and human population density
148 (available for the years 2000, 2005, 2010, 2015, 2020, at 5 km resolution, Center for
149 International Earth Science Information Network, 2022).

150 Two raw datasets without a temporal resolution were included in RECIFS, both derived from
151 the Global Multi-Resolution Topography Data Synthesis, which is a single raster image
152 describing topography (on land) and bathymetry (on sea) worldwide at ~1 km of spatial
153 resolution (Ryan et al., 2009). The first derived dataset is a depth map where the pixels
154 represent the topography of below sea surface level, and the second is a binary map where
155 pixels were either assigned to land (topography > 0) or to sea (topography < 0).

156 To process these raw environmental datasets, we extracted values from the raster stacks
157 using custom R scripts (v. 4.1; R Core Team, 2021), featuring the raster (v. 3.5; Hijmans, 2021)
158 and the rgdal (v. 1.5; Bivand et al., 2021) libraries. First, polygons representing coral reefs
159 worldwide were retrieved from the Global Distribution of Coral Reefs dataset (v. 4.1; UNEP-
160 WCMC et al., 2021), and were reported to 5-by-5 km cells. The resulting grid was composed
161 of 61,038 reef cells. For each reef cell, we extracted the environmental values from each raw
162 dataset using a buffer to average over different radii (2.5 km, referred to as “on reef”
163 extraction, and 10 km, 25 km and 50 km). The result was a set of tables (called “Extended
164 tables”), with one table per environmental variable at a given buffer size. For each table, the
165 rows represented the worldwide reef cells (such that there were 61,038 rows in each table)
166 and columns represented the temporal dimension (monthly, yearly or a single column for
167 variables without temporal resolution).
168 Finally, the “Extended tables” were synthesized together into a single table (called the
169 “Summary table”). For the variables at a monthly resolution, each reef cell had overall
170 temporal average and standard deviation “on reef” (i.e., using the 2.5 km buffer) for each
171 environmental variable. For the annual and non-temporal variables, each reef cell had overall
172 averages measured using two of the buffer sizes: 10 and 50 km.
173

Table 1. Datasets included in RECIFS. For each dataset, the table shows the name and description of the variable of interest, the temporal window covered by the dataset (with the temporal resolution in parenthesis), the spatial resolution of the dataset, the source repository of the dataset (with the abbreviations explicited in the bottom) and the identifier of the original product from the source repository.

Name	Description	Time window (resolution)	Spatial res.	Source	Original product id
Chlorophyll concentration [mg m-3]	Monthly averages of mass concentration of chlorophyll-a in seawater.	1997-2021 (monthly)	4 km	CMEMS	OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_082
Degree heating week [°C-week]	Monthly maxima of degree heating week (DHW). DHW is calculated as the accumulation of thermal stress (i.e. temperature >1°C above the monthly maximal mean temperature) over the previous 12 weeks.	1985-2021 (monthly)	5 km	NOAA CRW	ct5km_dhw-max_v3.1
Iron concentration [mmol m-3]	Monthly averages of mole concentration of dissolved iron in sea water.	1993-2019 (monthly)	0.25 deg	CMEMS	GLOBAL_MULTIYEAR_BGC_001_029
O2 concentration [mmol m-3]	Monthly averages of mole concentration of dissolved molecular oxygen in sea water.	1993-2019 (monthly)	0.25 deg	CMEMS	GLOBAL_MULTIYEAR_BGC_001_029
Sea water pH	Monthly averages of sea water pH reported on total scale.	1993-2019 (monthly)	0.25 deg	CMEMS	GLOBAL_MULTIYEAR_BGC_001_029
Nitrate concentration [mmol m-3]	Monthly averages of mole concentration of nitrate in sea water.	1993-2019 (monthly)	0.25 deg	CMEMS	GLOBAL_MULTIYEAR_BGC_001_029
Phosphate concentration [mmol m-3]	Monthly averages of mole concentration of phosphate in sea water.	1993-2019 (monthly)	0.25 deg	CMEMS	GLOBAL_MULTIYEAR_BGC_001_029
Sea water velocity [m s-1]	Monthly averages of sea water surface velocity, computed as the Euclidean norm of eastward and northward velocity.	1993-2019 (monthly)	0.083 deg	CMEMS	GLOBAL_REANALYSIS_PHY_001_030
Suspended matter concentration [g m-3]	Monthly averages of mass concentration of suspended matter in sea water.	1997-2021 (monthly)	4 km	CMEMS	OCEANCOLOUR_GLO_OPTICS_L4_REP_OBSERVATIONS_009_081
Sea surface salinity [1e-3]	Monthly averages of sea surface salinity.	1993-2019 (monthly)	0.083 deg	CMEMS	GLOBAL_REANALYSIS_PHY_001_030
Sea surface temperature [°C]	Monthly average of sea surface temperature.	1985-2021 (monthly)	5 km	NOAA CRW	ct5km_sst-mean_v3.1
Density of built-up [%]	Percentage of ground cover of built-up areas per pixel	2015-2019 (yearly)	100 m	CGLS	LandCover100m:collection_3:epoch2019
Density of cropland [%]	Percentage of ground cover of cropland per pixel	2015-2019 (yearly)	100 m	CGLS	LandCover100m:collection_3:epoch2019
Boat detection [%]	Percentage of boat detections per satellite overpass coverage	2017-2020 (yearly)	0.04 deg	EOG	VBD_npp_global-saa_pc_v23
Human population density [hab km2-1]	Human population density	2000-2020 (yearly - by 5 years)	0.04 deg	SEDAC	gpw-v4- rev11
Depth [m]	Depth	-	0.017 deg	GMRT	GMRTv3_9
Surface land	Binary map, indicating whether pixel is on land or sea.	-	0.017 deg	GMRT	GMRTv3_9
Data sources					
<i>Source id</i>	<i>Source name</i>			<i>Reference</i>	
CMEMS	Copernicus Marine Service			(EU Copernicus Marine Service, 2022)	
NOAA CRW	National Oceanic and Atmospheric Administration, Coral Reef Watch			(NOAA Coral Reef Watch, 2022)	
CGLS	Copernicus Global Land Service			(Copernicus Global Land Service, 2022)	
EOG	Earth Observation Group - Payne Institute for Public Policy			(Elvidge et al., 2015, 2018; Hsu et al., 2019)	
SEDAC	Socioeconomic Data and Applications Center, Columbia University			(Center for International Earth Science Information Network, 2022)	
GMRT	Global Multi-Resolution Topography Data Synthesis			(Ryan et al., 2009)	

174

175 **Data structure: surface currents**

176 The raw environmental dataset used to characterize sea currents was sourced from the

177 Copernicus Marine Service (dataset id: GLOBAL_REANALYSIS_PHY_001_030; EU Copernicus

178 Marine Service, 2022). This dataset is obtained from a stack of raster images displaying global
179 monthly averages of eastward and northward sea surface velocity, from 1993 to 2019. Using
180 custom R-scripts featuring the raster and the circular (v. 0.4; Agostinelli & Lund, 2017)
181 libraries, we combined eastward and northward velocities of each pixel into a vector of sea
182 currents, and then computed (1) sea current direction (the angle of the vector) and (2) sea
183 current velocity (the norm of the vector) for each monthly measure. Finally, we summarized
184 trends of surface circulation by computing raster images representing the overall yearly
185 average and twelve by-month averages for both sea current direction and velocities.

186

187 Web-app and queries

188 The web-based application of RECIFS is built on a NodeJS server (v. 10.13; OpenJS
189 Foundation). On the front-end, the server features an Openlayers (v 5.3; Open Source
190 Geospatial Foundation) map interface displaying the reef cells grid, while the back-end of the
191 server stores environmental data in a tabular format and the raster images summarizing sea
192 surface currents.

193 When the front-end user defines an “Area of Interest” through the interactive map, the server
194 queries the RECIFS database through R-scripts (featuring the raster and the sp libraries; v. 1.4;
195 Bivand et al., 2013) processing, sub-setting and finally returning the data stored on the back-
196 end. Three types of query are possible:

197 (1) standard environmental query: the user selects an “Area of Interest”, and the server
198 returns precomputed environmental values from the “Summary table” for the reef cells from
199 this area.

200 (2) advanced environmental query: the user selects an “Area of Interest”, an environmental
201 variable of interest, a spatial buffer size, a temporal window (years and/or months), and a
202 statistic to summarize environmental variation over time (mean, standard deviation, median,
203 minimum or maximum), and the server returns the corresponding values from the “Extended
204 tables” for the reef cells in the area.

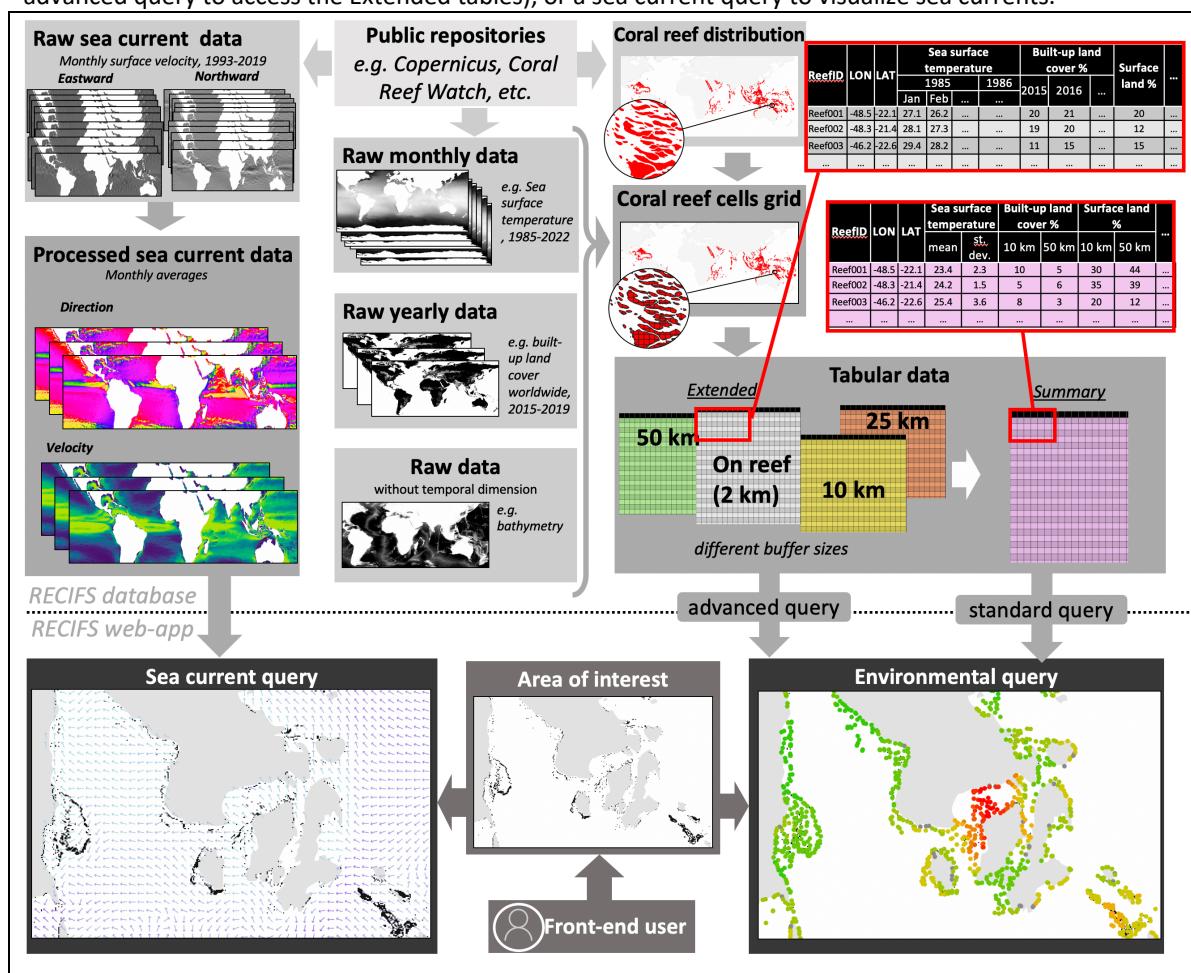
205 (3) sea current query: the user selects an “Area of Interest” and specifies a month of interest,
206 and the server returns a visual display of arrows indicating the corresponding strength and
207 direction of sea surface currents.

208 The results of the queries are displayed on the interactive map. The front-end interface
209 features different functionalities allowing the user to customize map visualization, such as
210 defining the color scale used to display environmental data, setting the transparency of layers
211 or modifying the background layer. The map rendered on the web-interface can be
212 downloaded either in a pdf or a tabular format. Furthermore, the user can define “Points of
213 interest” on the map (e.g., sampling locations, reefs of interest) and download the
214 environmental data for the closest reef cells to such points. All these functionalities are
215 available in complete open access, without any registration required.

216

217

Figure 1. Data workflow. Raw environmental data used in RECIFS comes from publicly available repositories, and have distinct temporal resolutions (monthly, annual or no resolution). Shapes of coral reefs worldwide were summarized into a regular grid (reef cell size: 5-by-5 km), and raw environmental values were extracted for each reef cell. These extractions were performed using four different buffer sizes (2.5 km – on reef, 10 km, 25 km or 50 km) around the centers of reef cells. The result is a set of tables (“Extended tables”) describing variation across reef cells for each environmental variable, at different buffer sizes and through different time periods (months or years). These tables are synthesized into a “Summary table”, reporting overall temporal average and standard deviation of each environmental variable, at every reef cell. RECIFS also includes data on sea surface current velocity and direction, obtained from processed raw data describing eastward and northward surface water velocity. These processed data are accessible through the RECIFS web-application: the user selects an area of interest through an interactive map and runs either an environmental query to visualize environmental variation (standard query to access the Summary table, advanced query to access the Extended tables), or a sea current query to visualize sea currents.



218

219

220 Results & Discussion

221 A repository to characterize the reef environment

222 RECIFS is the first repository that synthesizes data from various sources to describe reef
223 environments globally. In comparison to existing repositories of marine environmental data
224 (Bio-ORACLE, Assis et al., 2018; Tyberghein et al., 2012; MARSPEC, Sbrocco & Barber, 2013),
225 RECIFS has distinctive features to support (1) the study of coral reef ecosystem dynamics, and
226 (2) the organization of reef conservation strategies.

227 The data provided through RECIFS is centered on the reef environment and characterize key
228 environmental constraints of this ecosystem, including conditions that trigger coral bleaching
229 events and represent coastal pollution-related activities. RECIFS data are available under
230 specific spatial and temporal scales, providing pivotal information for researchers
231 investigating how the reef environment shapes ecosystem dynamics (Melo-Merino et al.,
232 2020; Murray et al., 2018). For instance, modelling the abundance or diversity (e.g., Box 1) of
233 reef taxa with different characteristics (e.g., sessile vs. mobile), or facing different types of
234 environmental constraints (e.g., constant vs. episodic), will require distinct spatial and
235 temporal resolutions of the environmental dataset (Fernandez et al., 2017; Mannocci et al.,
236 2017; Melo-Merino et al., 2020). The same considerations apply to molecular studies on local
237 adaptation (e.g., Box 2), as the genetic makeup of sampled individuals is shaped by ancestors
238 exposed to differing frequencies of environmental stressors (i.e., temporal resolution of
239 variables to be adjusted accordingly), which dispersed over larger or smaller spatial scales
240 (i.e., spatial resolution of variables to be adjusted accordingly; Leempoel et al., 2017; Riginos
241 et al., 2016).

242 RECIFS data are available in open access through an intuitive interface requiring no prior
243 knowledge on use of geographic information systems. These characteristics make remotely
244 sensed environmental data accessible to non-specialists of the field, such as practitioners of
245 coral reef conservation (Selmoni, Lecellier, Ainley, et al., 2020). Indeed, RECIFS can be a
246 platform to facilitate exchanges between coral reef researchers and conservation
247 practitioners, as it provides a common syntax to describe the environmental factors shaping
248 the dynamics of the reef ecosystem (Guisan et al., 2013). Overall, the goal of RECIFS is to
249 encourage the use of remote sensed data in coral reef conservation strategies worldwide, as
250 advocated by previous review in the domain (Foo & Asner, 2019, 2021; Hedley et al., 2016).

251

252 **Perspectives**

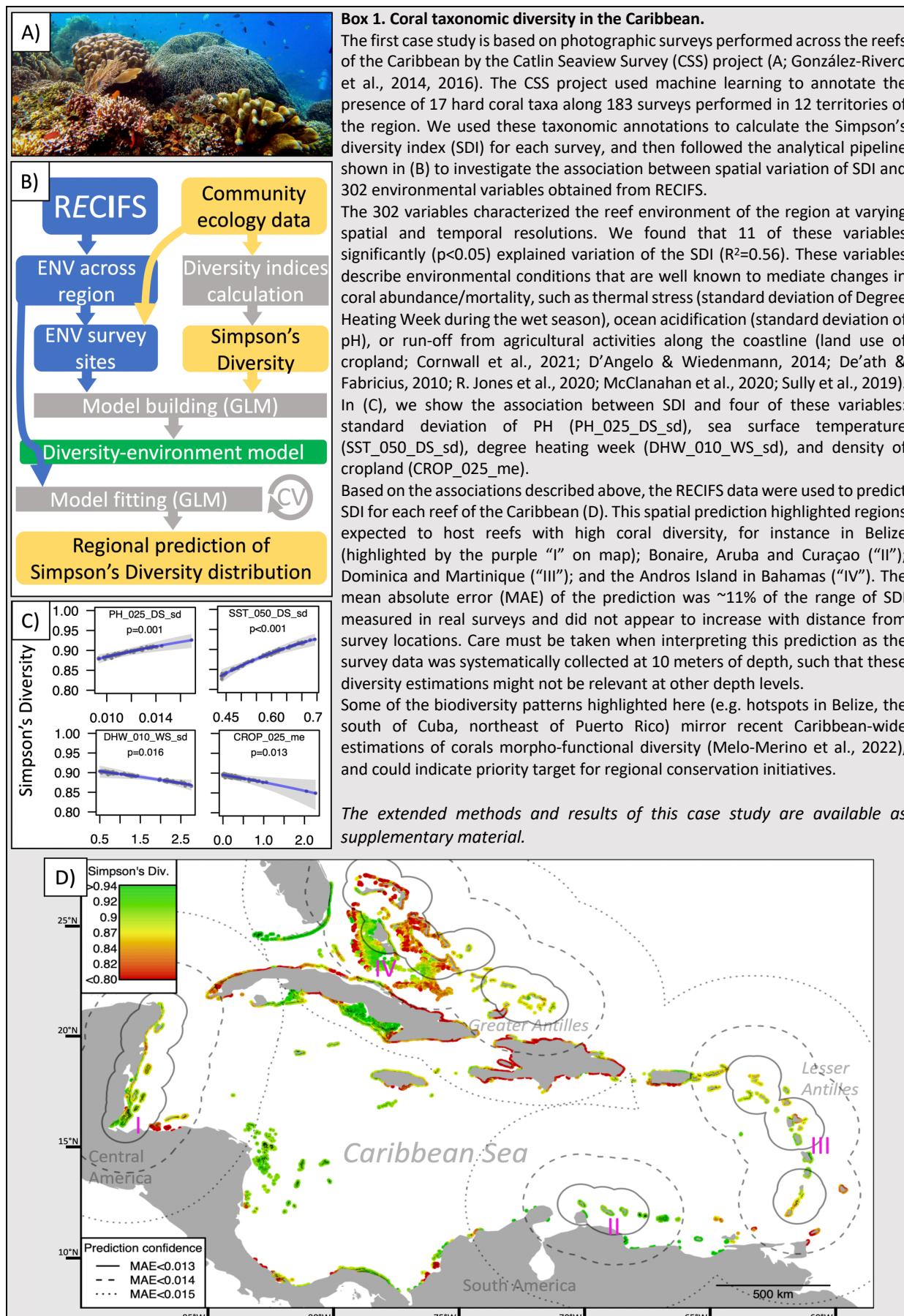
253 In the years to come, the development of RECIFS will focus on three domains: data,
254 functionalities and integration. The current data available in the repository will be updated
255 on an annual basis to provide updated records for the different environment variables.
256 Furthermore, new variables that describe environmental factors shaping the dynamics of
257 coral reef species will be added to the database as these variables become available and/or
258 are required; we encourage coral reef researchers and conservation actors to contact us (the
259 authors) to propose environmental descriptors to be added to RECIFS. With the future
260 improvements of remote sensed data and environmental modelling techniques, we also aim
261 to increase the spatial and temporal resolution of the reef cells, so that the environmental
262 characterization can be more pertinent to fine-scale dynamics of the reef ecosystem (Murray
263 et al., 2018). For example, one future goal will be to characterize reef pools located a few
264 hundreds of meters apart, or to characterize daily fluctuations in sea surface temperature
265 (Schoepf et al., 2015; Smith et al., 2007).

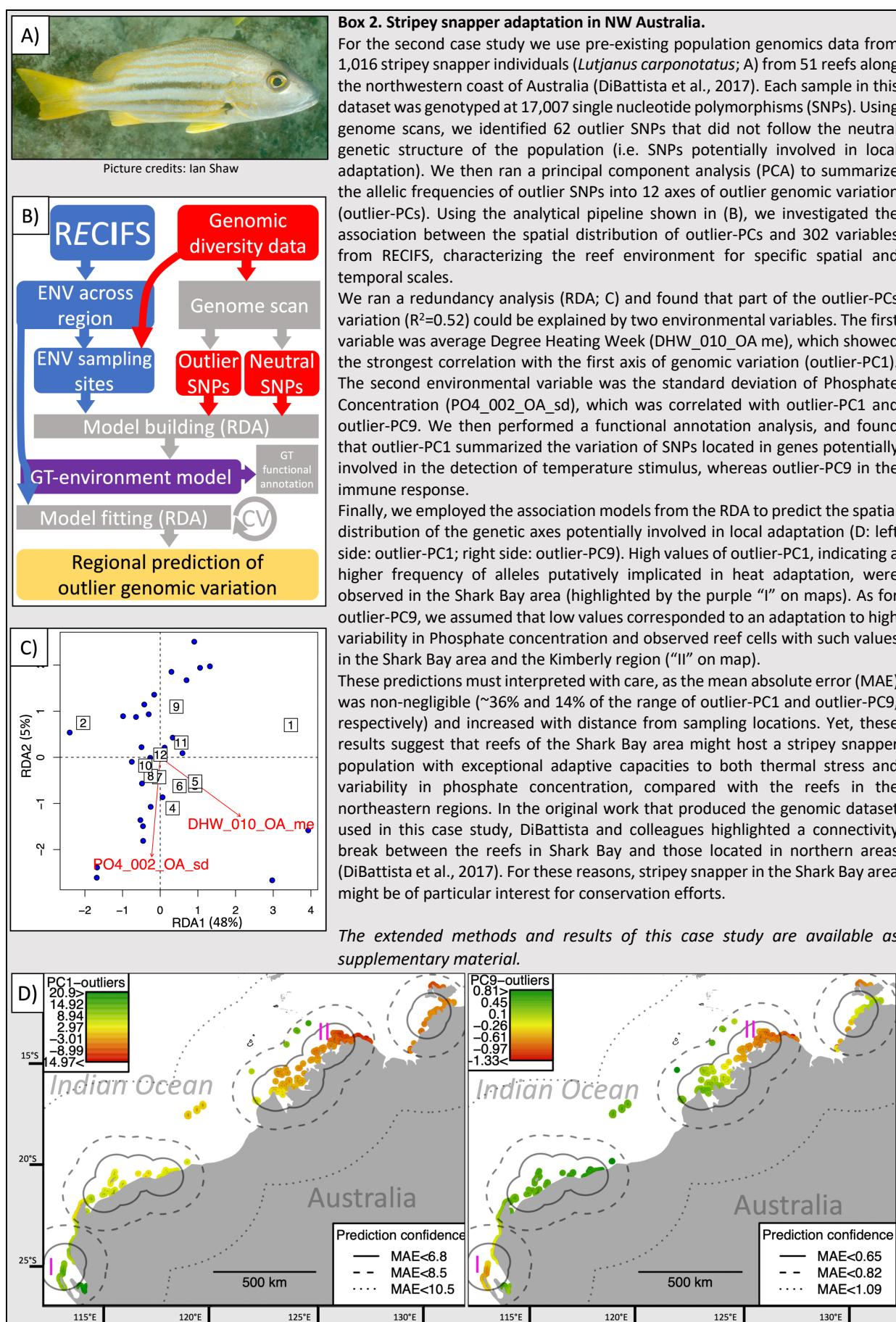
266 Concerning functionalities, the main future goal is to develop an objective quantification of
267 reef connectivity calculated from sea current data. Such quantification could be based on
268 transition matrices and graph theory (such as is implemented in the gdistance R package; van
269 Etten, 2018), and process sea surface current during a particular season to estimate the
270 probability of transition from one reef to another. The combination of such sea current
271 estimates with population genomics data could be used to assess patterns of reef connectivity
272 for a given species. Overall patterns of regional connectivity could then be synthesized in
273 connectivity indices, summarizing how each reef of a given region is interconnected to those
274 located downstream or upstream via oceanic currents (Selmoni, Rochat, et al., 2020).
275 Information on reef connectivity is necessary for undertaking effective conservation efforts,
276 as it informs MPA managers on how to establish networks that best facilitate the larval
277 dispersal to/from key conservation units (e.g. reefs hosting thermally adapted corals; Matz et
278 al., 2020; McCook et al., 2010).

279 Going forwards, it will also be important to integrate RECIFS with other projects and
280 complementary datasets that characterize alternative facets of reef environments. This could
281 be done, for instance, by linking RECIFS with Reef Cover, which is a classification system based

282 on remote sensing and *in-situ* data that categorizes reefs worldwide by habitat type (e.g. reef
283 slope, reef crest, shallow lagoon, etc.; Kennedy et al., 2021). Importantly, the cross-link
284 between repositories should also be extended to other types of data (i.e., non-environmental)
285 that describe the reef ecosystem (Hedley et al., 2016; Lecours et al., 2021). Such data could
286 be virtually any type of geo-referenced information, for example field surveys on species
287 abundance and diversity, or genomic data characterizing the genetic diversity of a given reef
288 population. The case studies presented here (Box 1 and 2) show how linking different layers
289 of information on the state of the reef can produce valuable insights to orientate conservation
290 strategies. A hub centralizing different data sources on the state of the reef will be of
291 paramount importance in the future, as it will facilitate the establishment of the links
292 between all the different information layers. In the long-term, the goal of RECIFS is to serve
293 as foundation to build such a hub.

294





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301

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