

# RAD sequencing enables unprecedented phylogenetic resolution and objective species delimitation in recalcitrant divergent taxa

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## ABSTRACT

Species delimitation is problematic in many taxa due to the difficulty of evaluating predictions from species delimitation hypotheses, which chiefly rely on subjective interpretations of morphological observations and/or DNA sequence data. This problem is exacerbated in recalcitrant taxa for which genetic resources are scarce and inadequate to resolve questions regarding evolutionary relationships and uniqueness. In this case study we demonstrate the empirical utility of restriction site associated DNA sequencing (RAD-seq) by unambiguously resolving phylogenetic relationships among recalcitrant octocoral taxa with divergences greater than 80 million years. We objectively infer robust species boundaries in the genus *Paragorgia*, which contains some of the most important ecosystem engineers in the deep-sea, by testing alternative taxonomy-guided or unguided species delimitation hypotheses using the Bayes factors delimitation method (BFD\*) with genome-wide single nucleotide polymorphism data. We present conclusive evidence rejecting the current morphological species delimitation model for the genus *Paragorgia* and indicating the presence of cryptic species boundaries associated with environmental variables. We argue that the suitability limits of RAD-seq for phylogenetic inferences in divergent taxa cannot be assessed in terms of absolute time, but depend on taxon-specific factors such as mutation rate, generation time and effective population size. We show that classic morphological taxonomy can greatly benefit from integrative approaches that provide objective tests to species delimitation hypothesis. Our results pave the way for addressing further questions in biogeography, species ranges, community ecology, population dynamics, conservation, and evolution in octocorals and other marine taxa.

## INTRODUCTION

Species delimitation is problematic in many taxa due to the difficulty of evaluating predictions from species delimitation hypotheses derived using different species concepts. Species concepts set particular expectations of the properties used to support species delimitations (De Queiroz 2007). For example, the classic biological species concept requires intrinsic reproductive isolation between heterospecific organisms and interbreeding among homospecific organisms resulting in viable and fertile descendants (Mayr 1942; Dobzhansky 1970). In many cases, if not the majority, it is difficult to evaluate behavioral, reproductive, and ecological properties due to technical limitations of field or laboratory work, which largely determine the kind of observations and data that can be obtained. In these cases researchers conventionally rely on morphological observations and/or DNA sequence data to generate species delimitation hypotheses.

Although there have been significant attempts at developing statistical methods to objectively identify species-diagnostic morphological discontinuities (e.g., Zapata & Jimenez 2012), most species delimitations continue to be performed subjectively based on assessments made by specialized taxonomists. Molecular phylogenetic analyses of DNA sequences provide an independent way to test

these species delimitation hypotheses utilizing a variety of methods, ranging from variability thresholds of barcode sequences (Hebert *et al.* 2003), to probabilistic coalescent-based model methods (Pons *et al.* 2006; Yang & Rannala 2010; Fujisawa & Barraclough 2013; Grummer *et al.* 2014). These molecular methods rely on informative DNA sequence markers, and in many cases on resolved phylogenies.

The sub-class Octocorallia (Phylum Cnidaria), which includes animals known as gorgonians, sea pens, and soft corals, is an example of a recalcitrant group where species delimitations are problematic. Octocorals are predominantly a deep-sea group (Cairns 2007; Roberts & Cairns 2014) and therefore are extremely difficult to observe and collect. Classic morphology-based species delimitation and identification in this group is arduous for non-specialists, and challenging to replicate among taxonomists (Daly *et al.* 2007; McFadden *et al.* 2010b). Variations in octocoral colony architecture and micro-skeletal structures – sclerites – are used as species diagnostic characters (Bayer 1956). However, studies over the last 15 years have shown that in many cases species delimitations and systematics based on these morphological traits keep little to no correspondence with the patterns of genetic diversity and relatedness inferred using mitochondrial and ribosomal DNA sequence markers (McFadden *et al.* 2006; Clark *et al.* 2007; France 2007; Dueñas & Sánchez 2009). A confounding factor when analyzing mitochondrial DNA markers is the fact that anthozoans, including octocorals, have slow rates of sequence evolution relative to other metazoans (Shearer *et al.* 2002; Hellberg 2006). Furthermore, octocoral mitochondrion is unique among eukaryotes by having a functional DNA mismatch repair gene — *mtMutS* — which presumably is responsible for the extremely low sequence variability observed in this group (Bilewitch & Degnan 2011). Traditional molecular markers have thus been remarkably insufficient to resolve relationships at all taxonomic levels within the octocorals (Berntson *et al.* 2001; France *et al.* 2002; Mcfadden *et al.* 2004; Smith *et al.* 2004; Thoma *et al.* 2009; Dueñas *et al.* 2014). Alternative nuclear markers, such as the ITS2 and *SRP54* have been used to examine interspecific and intraspecific relationships (Aguilar & Sánchez 2007; Concepcion *et al.* 2007; Grajales *et al.* 2007; Herrera *et al.* 2010); however, their application and impact has been limited due to issues regarding intragenomic variability (Sanchez & Dorado 2008) and low sequencing reliability (Mcfadden *et al.* 2010a). These long-standing technical problems have caused fundamental questions in octocorals regarding species differentiation, systematics, diversity, biogeography, and species ranges to remain unanswered.

Technological developments in next-generation sequencing platforms and library preparation methodologies have made genomic resources increasingly accessible and available for the study of non-model organisms, thus offering a great opportunity to overcome the difficulties inherent to the use of traditional sequencing approaches. One of these methodologies is restriction-site-associated DNA sequencing (RAD-seq), which combines enzymatic fragmentation of genomic DNA with high-throughput sequencing for the generation of large numbers of markers (Baird *et al.* 2008). RAD-seq has shown great promise to resolve difficult phylogenetic, phylogeographic, and species delimitation questions in diverse groups of eukaryotes (Emerson *et al.* 2010; Nadeau *et al.* 2012; Wagner *et al.* 2012; Eaton & Ree 2013; Jones *et al.* 2013; Cruaud *et al.* 2014; Escudero *et al.* 2014; Hipp *et al.* 2014; Leache *et al.* 2014; Herrera *et al.* 2015), including cnidarians (Reitzel *et al.* 2013) and most recently deep-sea octocorals (Pante *et al.* 2014). The number of orthologous restriction sites that can be retained across taxa, which decreases as divergence increases, limits the usefulness of RAD-seq for these kinds of studies. *In silico* studies in model organisms indicate that RAD-seq can be used to infer phylogenetic relationships in young groups of species (up to 60 million years old), such as *Drosophila* (Rubin *et al.* 2012; Cariou *et al.* 2013; Seetharam & Stuart 2013); however, the real limits of this technique have not been significantly explored.

In this study we aim to empirically explore the limits of RAD-seq to solve questions in phylogenetics and species delimitation. We focus on the recalcitrant *Anthomastus-Corallium* clade of octocorals (sensu McFadden *et al.* 2006) to test the utility of RAD-seq to resolve phylogenetic relationships among divergent taxa, and to infer objective species boundaries. Corals in the *Anthomastus-Corallium* clade (hereafter referred as the AC clade) are among the most conspicuous, widely distributed,

and ecologically important benthic invertebrates in deep-water ecosystems (Roberts *et al.* 2009; Wating *et al.* 2011). This clade is constituted by more than 100 species defined morphologically, divided in 10 genera, and three families (World Register of Marine Species at <http://www.marinespecies.org> accessed on 2014-10-10), spanning a divergence time of over 100 million years (Ardila *et al.* 2012; Herrera *et al.* 2012). However, species delimitations and phylogenetic relationships in this clade, as in other octocorals, are controversial and conflictive (Herrera *et al.* 2010; Ardila *et al.* 2012; Herrera *et al.* 2012). Many of the species in this group are considered species indicators of Vulnerable Marine Ecosystems (e.g. ICES 2013), with some of them considered endangered (CITES 2014). Accurate species identifications, as well as complete inventories and knowledge of species ranges, are therefore critical to ensure the effectiveness and appropriateness of conservation and management policies.

## RESULTS

### *Morphological species identifications*

Using current species descriptions, colony observations, and scanning electron microscopy of sclerites, we identified a total of 12 putative morphological species among the 44 examined specimens from the AC clade (Table S1, Supplementary Material images). These species correspond to the genera *Paragorgia* (*P. arborea*, *P. stephencairnsi*, *P. johnsoni*, *P. maunga*, *P. alisonae*, *P. kaupeka*, and *P. coralloides*) and *Sibogorgia* (*S. cauliflora*) of the family Paragorgiidae; *Hemicorallium* (*H. laauense-imperiale*) and *Corallium* of the family Coralliidae; and *Anthomastus* and *Heteropolypus* of the family Alcyoniidae.

### *Octocorals are amenable to RAD sequencing*

We generated a dense genome-wide set of genetic markers from the 44 AC clade specimens via RAD sequencing, using the 6-cutter restriction enzyme PstI, and used them to perform phylogenetic inferences and species delimitation analyses. We obtained roughly  $3.9 \pm 1.4$  million reads (average  $\pm$  standard deviation) per individual, of which  $74.3 \pm 8.1\%$  were retained after stringent quality filtering steps (Table S2).

### *Optimization of RAD-loci clustering parameters*

To examine the sensitivity of the phylogenetic inference to the clustering parameters used to identify loci and create nucleotide matrices in the program pyRAD (Eaton 2014), we investigated different combinations of clustering thresholds (*c* 0.80, 0.85 and 0.90) and minimum number of taxa per locus (*m* 4, 6, and 9) in a reduced ‘**backbone**’ matrix (hereafter matrix names will be highlighted in bold) containing one individual from each of the 12 morphological species. The 9 resulting **backbone** matrices ranged in the total number of loci per matrix from approximately 9 to 60 thousand loci, increasing dramatically as the minimum number of taxa per locus was reduced (Table S3). In contrast, the different clustering thresholds did not have a significant effect on the total number of loci, but rather on the number of variable sites and, most importantly, on the number of phylogenetically informative sites (Table S3). Each resulting **backbone** matrix analyzed in RAxML (Stamatakis 2006) produced identical strongly-supported tree topologies (Fig S1). We selected *c* 0.80 (80% similarity among sequences) and *m* 9 (minimum coverage of taxa per locus of 75%) as the optimal combination of loci-clustering parameters because they minimized the proportion of missing data (0.20) in the matrix while maximizing the fraction of variable sites that were phylogenetically informative (0.24) (Table S3). The proportion of shared loci among individuals of Paragorgiidae and Coralliidae, lineages whose split has been estimated to be between 80-150 million years ago (Ardila *et al.* 2012; Herrera *et al.* 2012), was remarkably high (70-80%) (Fig 1).

We used the selected optimal loci-clustering parameters to generate the ‘**PHYLO**’ matrix, containing the sequence data of all the 44 octocoral specimens. The use of the parameter value *c* 0.80 yielded approximately  $71 \pm 15$  thousand loci – with a minimum depth of coverage of 5x and after filtering

for paralogs— per specimen (mean depth of clusters used in loci construction was  $23 \pm 8x$ ) (Table S4). The **PHYLO** matrix contained a total of 5,997 loci that contained data for at least 75% of the specimens (after a second paralog removal). There were 85,293 variable sites in this matrix, of which 53,150 were phylogenetically informative.

### ***RAD-seq data support a fully resolved phylogeny***

The phylogenetic analysis of the **PHYLO** concatenated RAD-seq matrix produced a completely resolved evolutionary tree of the AC specimens (Fig 2). In general, all branches were supported by high (greater than 95) bootstrap values, except for the one supporting the clade of *P. johnsoni*, *P. alisonae*, and *P. maunga*. Each one of the morphologically identified families, genera, and species in this dataset were monophyletic. The branching pattern of the tree is consistent with an expected transition between coalescent processes among species and genera (long deep branches), and population processes within species (short shallow branches).

The topology of the tree obtained with a traditional ‘**mitochondrial**’ matrix (711 base pairs of the *mtMutS* gene containing 130 variable sites, of which 101 were phylogenetically informative) was incongruent with the **PHYLO** tree (Fig 2). The **mitochondrial** tree indicated a well-supported alternative divergence order for *P. coralloides* and *P. kaupeka* in the *Paragorgia* clade. In addition, the families Paragorgiidae (bubblegum corals) and Coralliidae (precious corals) were not monophyletic. The bubblegum coral genus *Sibogorgia* appeared more closely related to the precious corals than to the other bubblegum coral genus *Paragorgia*, and the genera *Corallium* and *Hemicorallium* did not form a clade. However, these alternative relationships were not significantly supported by the bootstrap analysis. Indeed, a substantial proportion of branches on the **mitochondrial** tree were poorly supported (bootstrap values smaller than 80%).

### ***RAD-seq data reveal cryptic genetic diversity***

Branch-length differences among individuals, as well as well-supported sub-clades, revealed intraspecific genetic diversity that was undetected by the **mitochondrial** matrix. Two sub-clades were revealed by the phylogenetic analysis of the **PHYLO** matrix in the *P. arborea* and *P. stephencairnsi* clades. The sub-clades in *P. arborea* correspond to a pattern of segregation by geographic location with specimens from the north Pacific in one sub-clade, and specimens from the south Pacific and north Atlantic in the other. Contrastingly, the sub-clades in *P. stephencairnsi* correspond to a pattern of segregation by depth with specimens collected shallower than 350m in one sub-clade, and specimens collected deeper than 1000m in the other.

### ***Current morphological species delimitation is rejected***

To evaluate the utility of RAD-seq to perform objective species delimitations in octocorals we focused on specimens the genus *Paragorgia* as it was the best-sampled taxon in our dataset, both in terms of geographic representation and number of morphological species. We used the Bayes Factor Delimitation method with genomic data (BFD\*) (Leache *et al.* 2014), which allows for the comparison of conflictive species delimitation models in an explicit multispecies coalescent framework using genome-wide single nucleotide polymorphism (SNP) data. We calculated marginal likelihoods of taxonomy-guided and taxonomy-unguided species delimitation models from a matrix of unlinked SNPs including only specimens of *Paragorgia* (‘**PARAGORGIA**’ matrix containing 1,203 SNPs present in all individuals). We compared the marginal likelihood estimates of alternative species delimitation models to the null model ‘**morphid**’, which is based on current morphological species descriptions, using Bayesian factors.

The null model, **morphid**, was rejected in favor of alternative species delimitation models for *Paragorgia* (Fig 3) (**morphid** was ranked 7<sup>th</sup> among 10 evaluated models in terms of the marginal likelihood estimate). The ‘**PABSTE**’ model, which proposes 9 species based on the 7 morphological species in the dataset plus splits corresponding to the sub-clades in *P. arborea* and in *P. stephencairnsi*,

received decisive support from Bayes factors as the best species delimitation model. The taxonomy-unguided model ‘**geo**’ – which splits the specimens based on the geographic location where they were collected – and the models proposed by the Poisson tree processes (PTP) method based on the **mitochondrial** data matrix, were the lowest ranked and most strongly rejected models overall.

### ***Concatenated and coalescent species tree analyses are congruent***

The topology of the species tree inferred using the SNP **PARAGORGIA** matrix was entirely congruent with the topology generated by the maximum likelihood phylogenetic analysis of the concatenated sequence matrices (Fig 4). The species tree analysis also greatly improved support for the clade of *P. johnsoni*, *P. alisonae*, and *P. maunga*. The posterior distribution of species trees indicated a small fraction of conflictive topologies concentrating in this region of the tree.

## **DISCUSSION**

### ***RAD sequencing enables unprecedented phylogenetic resolution***

Our analyses of RAD-seq data provide a robust phylogenetic hypothesis for the recalcitrant octocorals in the *Anthomastus-Corallium* clade, a result never achieved before. Moreover, this study, together with the work by Pante *et al.* (2014) in the octocoral genus *Chrysogorgia*, constitute the first applications of RAD-sequencing for phylogenetics and species delimitation in cnidarians. Only a handful of previous studies, using traditional mitochondrial data and the ITS2 and 28S nuclear markers, have attempted to evaluate phylogenetic relationships in the octocoral AC clade (Herrera *et al.* 2010; Ardila *et al.* 2012; Brockman & McFadden 2012; Herrera *et al.* 2012; McFadden & van Ofwegen 2013; Uda *et al.* 2013; Figueroa & Baco 2014). These studies find support for the monophyly of the genus *Paragorgia*, the family Coralliidae, and the sister relationship between the Paragorgiidae and Coralliidae. However, those data do not provide enough phylogenetic resolution to infer the evolutionary relationships among many of the putative morphological species. Furthermore, significant incongruences between mitochondrial and nuclear ITS2 gene trees from AC taxa have been documented (Herrera *et al.* 2010). Here we reproduce similar incongruences when comparing the trees inferred from mitochondrial and RAD-seq datasets (Fig 2). Likewise, Pante *et al.* (2014) documented marked incongruence between trees inferred from mitochondrial and RAD-seq data in *Chrysogorgia*. These observations suggest that processes that can cause gene tree heterogeneity, such as incomplete lineage sorting and horizontal gene transfer (Maddison 1997; Edwards 2009), may be more prevalent in octocorals than previously recognized.

All of our analyses based on RAD-seq matrices – varying in taxon coverage, degree of divergence among taxa, proportion of missing data, number of loci, and analysis type (concatenated or species tree) – produced completely congruent trees, which together provide extremely high confidence on the phylogenetic hypothesis inferred for the octocoral AC clade (Figs 1, 2 and 3). Consequently, we suggest that single marker gene trees in octocorals, particularly from the mitochondria, should not be considered as robust hypotheses of true species phylogenies on their own, without further validation by multiple informative and independent nuclear loci. We urge systematists to be conservative when making taxonomic rearrangements based on inferences from single-marker data alone.

### ***RAD-seq data is suitable for phylogenetic inference in divergent taxa***

Contrary to the currently accepted idea that RAD-seq data are only suitable for taxa with divergence times younger than 60 million years (MY) (Rubin *et al.* 2012), we demonstrate their suitability well beyond this age threshold. Remarkably, we were able to confidently resolve phylogenetic relationships among genera from different families diverging by at least 80 MY in the AC clade. The split between the families Paragorgiidae and Coralliidae has been dated, using coralliid fossils, to be between 80-150 MY old (Ardila *et al.* 2012; Herrera *et al.* 2012). Park *et al.* (2012) estimated the age of the most recent common ancestor of the Coralliidae at approximately 50 MY (25-100 MY 95% confidence region), using independent cnidarian fossils for molecular clock calibration. The split with the genera *Anthomastus*

and *Heteropolypus* is likely older than 100 MY. It is without question that, due to evolution at restriction sites, the number of RAD loci among taxa for which orthology can be established decreases rapidly as divergence increases. However, we suggest that the suitability limits of RAD-seq for phylogenetics in divergent taxa cannot be assessed in terms absolute time, but depend on taxon-specific factors such as mutation rate, generation time and effective population size.

Bioinformatic studies addressing the issue of extent of the suitability of RAD-seq for phylogenetic inference have focused mainly on *Drosophila* as study model (Rubin *et al.* 2012; Cariou *et al.* 2013). Longer generation times and lower metabolic rates in taxa like deep-sea corals, relative to those in organisms like *Drosophila*, could cause a reduction in mutation rates (see review by Baer *et al.* (2007)), which may in turn decrease the evolutionary rates at restriction sites and allow for phylogenetic inferences using RAD-seq in situations of deeper divergence. Consistent with this hypothesis, we observe a nucleotide diversity ( $\pi$ ) calculated across all octocoral specimens from the **PHYLO** matrix of  $0.012 \pm 0.002$  (considered a minimum since RAD-seq can underestimate diversity (Arnold *et al.* 2013); see **Table S5 and Table S6 for individual values**), which is significantly lower than the nucleotide diversity in many of the *Drosophila* species included in the bioinformatic studies by Cariou *et al.* (2013) and Rubin *et al.* (2012). Nonetheless, there are other important factors known to influence genetic diversity across species – and likely the evolutionary rate as well. These factors include the effective population size, selection, habitat kind, geographic range, and mating system (Leffler *et al.* 2012). To sum up, we argue that RAD-seq can be successfully used to infer phylogenetic relationships in certain taxa with deeper divergences than previously suggested. This is particularly true when the number of RAD loci is maximized through the choice of restriction enzymes with higher cutting frequencies in the target taxon (Herrera *et al.* 2014).

#### ***RAD-seq allows the formulation of robust species delineations***

Our study, the first statistical rigorous test of species hypothesis in octocorals, provides conclusive evidence rejecting the current morphological species delimitation model for the genus *Paragorgia*. We find decisive support for a nested model that combines species boundaries from morphological taxonomy with cryptic diversity linked to environmental variables of geographic location and depth (**Figs 3 and 4**). This nested model, proposes 9 species among the examined specimens. Five of these species correspond to the morphological species *P. coralloides*, *P. kaupeka*, *P. alisonae*, *P. johnsoni*, and *P. maunga*. Two splits, corresponding to sub-clades in the morphological species *P. arborea* and in *P. stephencairnsi*, indicate cases of cryptic species.

Herrera *et al.* (2012) found significant genetic differentiation of the north Pacific populations of *P. arborea* relative to the south Pacific, Atlantic and Indian ocean populations, and suggested that these populations may represent sub-species. The north Pacific populations of *P. arborea* were previously defined as a separate species, *P. pacifica*, by Verrill (1922) based on gross colony morphology, but later combined into a single species by Grasshoff (1979). Sánchez (2005) suggested potential small differences in medullar sclerite sizes and ornamentation between north Pacific specimens and specimens from elsewhere. However, we were unable to recognize these morphological differences in the few examined specimens in this study. Nonetheless, based on the decisive support for the split of *P. arborea* from analysis of genome-wide SNP makers indicates, we resurrect the species *Paragorgia pacifica* for the north Pacific populations of formerly *P. arborea*. We find no evidence of cryptic speciation between the north Atlantic and south Pacific *P. arborea* and therefore conclude it should be considered a single species as previously suggested by Herrera *et al.* (2012).

Depth is an important factor contributing to genetic differentiation and formation of species in the ocean, both shallow (Carlson & Budd 2002; Prada & Hellberg 2013) and deep (Miller *et al.* 2011; Jennings *et al.* 2013; Quattrini *et al.* 2013; Glazier & Etter 2014). The observed cryptic differentiation between specimens of *P. stephencairnsi* collected shallower than 350m and deeper than 1000m indicates that depth is also a diversifying force in octocorals from the AC clade, which had gone undetected due to

the low variability of traditional sequence data (Herrera *et al.* 2012). The holotype of *P. stephencairnsi* was collected from approximately 350m in the Georgia Strait of British Columbia, overlapping in depth range and geographic region with that of most of the specimens from the shallow sub-clade examined in this study. Therefore, we propose to conserve that name *P. stephencairnsi* for that shallow sub-clade, and consider the deep sub-clade as a new species.

Other recent species delimitation studies in anthozoan corals have also revealed significant incongruences when comparing morphological and single-locus species delimitation hypotheses (particularly from mitochondrial data) with phylogenetic evidence from multi-locus datasets (Pante *et al.* 2014; Prada *et al.* 2014). In line with the findings of Pante *et al.* (2014), we find that specimens of *Paragorgia* sharing identical *mtMutS* haplotypes can belong to more than one species. Contrastingly, Herrera *et al.* (2012) present strong evidence showing significant mitochondrial haplotype diversity in the south Pacific and north Atlantic populations of *Paragorgia arborea*. Our observations, together with those from the aforementioned studies, constitute compelling evidence indicating that there is no solid basis for the widespread assumption that *mtMutS* haplotypes may be equivalent to individual octocoral species, as proposed by Thoma *et al.* (2009). The analysis with RAD-seq, or alternative genomic multi-locus methods, of a larger number of specimens from diverse geographic locations and depth horizons will likely reveal further cryptic diversity not characterized by mitochondrial haplotypes (see Fig S2, Fig S3, and Table S8), and thus further illuminates taxonomy and systematics in this and other groups.

## CONCLUSIONS

In this case study we demonstrate the empirical utility of RAD-seq to resolve phylogenetic relationships among divergent and recalcitrant taxa and to objectively infer species boundaries by testing alternative delimitation hypotheses. We were able to make use of RAD-seq to overcome long-standing technical difficulties in octocoral genetics, and to resolve fundamental questions in species definitions and systematics. We show that classic morphological taxonomy can greatly benefit from integrative approaches that provide objective tests to species delimitation hypothesis. Our results pave the way for addressing further questions in biogeography, species ranges, community ecology, population dynamics and evolution of octocorals and other marine taxa. The results from this study also represent a valuable reference resource for the development of tools, such as SNP arrays, that can be used to perform accurate species identifications, and generate species inventories that will aid the design and implementation of conservation and management policies.

## METHODS

To perform identifications using current morphological species descriptions we performed colony observations and scanning electron microscopy of sclerites on 44 octocoral specimens from the AC clade (Table S1).

To obtain a genome-wide set of markers that could be useful for phylogenetic inferences of deep-divergent taxa and species delimitation in the AC clade (greater than 100 million years) we performed RAD sequencing with a the 6-cutter restriction enzyme PstI, which is predicted to cut between 32,000 and 110,000 times in the genome of an octocoral (Table S7). This predicted range was obtained using the observed frequency of the PstI recognition sequence, and its probability calculated using a trinucleotide composition model, in the genomes of the cnidarians *Nematostella vectensis*, *Acropora digitifera*, *Hydra vulgaris*, and *Alatina moseri* (Herrera *et al.* 2014). Genome size range of 0.3-0.5 pg was used based on observations obtained through flow cytometry in gorgoniid octocorals by Luisa Dueñas at the Universidad de los Andes, Bogotá, Colombia (personal communication). Total genomic DNA was purified from specimens following protocols described in Herrera *et al.* (2015). Concentration-normalized genomic DNA was submitted to Floragenex Inc (Eugene, OR). for library preparation and RAD

sequencing. Libraries were sequenced by 48-multiplex, using 10-base pair barcodes, on a single lane of an Illumina Hi-Seq 2000 sequencer.

To compare the inferences obtained from RAD-seq data with the inferences drawn from traditional genetic barcoding data, we performed targeted sequencing of the mitochondrial *mtMutS* gene — a genetic marker widely used for phylogenetics and species delimitation studies in octocorals. Polymerase chain reactions were carried out following the protocols by Herrera *et al.* (2015). Primer pairs used for amplifications were AnthoCorMSH (Herrera *et al.* 2010) and Mut-3458R (Sánchez *et al.* 2003). Negative controls were included in every experiment to test for contamination. Purified PCR products were submitted to Eurofins Genomics (Eurofins MWG Operon, Inc.) for sequencing.

### ***RAD-seq data filtering***

Sequence reads were de-multiplexed and quality filtered with the `process_radtags` program from the package Stacks v1.20 (Catchen *et al.* 2013). Barcodes and Illumina adapters were excluded from each read and length was truncated to 91bp (-t 91). Reads with ambiguous bases were discarded (-c). Reads with an average quality score below 10 (-s 10) within a sliding window of 15% of the read length (-w 0.15) were discarded (-r). The rescue barcodes and RAD-tags algorithm was enabled (-r). Additional filtering, and the clustering within and between individuals to identify loci was performed using the program pyRAD v2.01 (Eaton 2014). Reads with more than 33 bases with a quality score below 20 were discarded.

### ***RAD-seq loci clustering and phylogenetic inference***

We investigated different combinations of clustering thresholds (c 0.80, 0.85 and 0.90) and minimum number of taxa per locus (m 4, 6, and 9) in a reduced dataset that included one individual from each of the 12 putative morphological species. The minimum depth of coverage required to build a cluster and the maximum number of shared polymorphic sites in a locus were kept constant at 4 (d) and 3 (p) respectively. Loci sequences were concatenated into combined matrices. We refer to these 9 resulting matrices as the ‘**backbone**’ matrices. Each of the resulting backbone matrices was analyzed in RAxML-HPC2 v8.0 (Stamatakis 2006) for maximum likelihood (ML) phylogenetic tree inference. For this, and all the other phylogenetic analyses in RAxML, we assumed a generalized time-reversible DNA substitution model with a gamma-distributed rate variation across sites (GTR GAMMA). Branch support was assessed by 500 bootstrap replicates.

We selected an optimal combination of loci clustering parameters as the set of parameters that minimized the number of missing data and maximized the number of phylogenetically informative sites while producing a highly supported phylogenetic tree. The optimal set of parameters chosen was a clustering threshold of 80% similarity among sequences (c 0.80) and a minimum coverage of taxa per locus of 75% (m 9). A concatenated matrix containing the sequence data of all the 44 octocoral specimens, denominated ‘**PHYLO**’, was built using this parameter combination (c 0.80, m 33) in pyRAD and subsequently analyzed in RAxML.

### ***Phylogenetic inference with traditional genetic barcoding data***

To compare the tree topology obtained from the phylogenetic inferences of the **PHYLO** RAD-seq dataset with traditional genetic barcoding data we analyzed the ‘**mitochondrial**’ dataset (containing the *mtMutS* sequences) using RAxML. These two datasets – **PHYLO** and **mitochondrial** – contain data from the same individuals. To place the specimens from this study in a broader phylogenetic context we also analyzed the **mitochondrial** dataset in RAxML with the addition of *mtMutS* data from 233 additional specimens belonging to the AC clade, as well as outgroups (see Table S8, Fig S2, and Fig S3).

### ***Testing species delimitation models for *Paragorgia****



We constructed 5 taxonomy-guided species delimitation models for *Paragorgia*: **i)** ‘**morphid**’ model: 7 species based on current morphological species descriptions (Sánchez 2005); **ii)** ‘**PAB**’ model: 8 species based on the 7 morphological species plus a split of *P. arborea* based on previous evidence of genetic differentiation of north Pacific populations (Herrera *et al.* 2012); **iii)** ‘**STE**’ model: 8 species based on the 7 morphological species plus a split of *P. stephencairnsi* based on depth differences (specimens collected <350m vs. >1000m), as depth is known to be an important structuring variable in marine taxa (Jennings *et al.* 2013; Prada & Hellberg 2013; Quattrini *et al.* 2013); **iv)** ‘**PABSTE**’ model: 9 species based on the 7 morphological species plus the splits of the **PAB** and **STE** models; **v)** ‘**splitPAB**’ model: 10 species based on the 7 morphological species plus the split of the **STE** model and an additional split in the **PAB** model where *P. arborea* is split in 3 species corresponding to the ocean basin where the specimens were collected (north Pacific, south Pacific and north Atlantic).

We also generated taxonomy-unguided species delimitation models for *Paragorgia* through Bayesian and ML implementations of the Poisson tree processes model (PTP) (available at <http://species.h-its.org/ptp/>). PTP estimates the number of speciation events in a rooted phylogenetic tree in terms of nucleotide substitutions (Zhang *et al.* 2013). We used PTP to analyze the trees obtained from phylogenetic inferences in RAxML of reduced *mtMutS* and RAD-seq datasets that include only members of the family Paragorgiidae (genera *Paragorgia* and *Sibogorgia*). The ‘**PARAGORGIIDAE**’ RAD-seq concatenated matrix was generated in pyRAD using a clustering threshold of 80% similarity among sequences (c 0.80) and a minimum coverage of taxa per locus of 100% (m 33). The resulting phylogenetic trees of *Paragorgia* were rooted with the specimens of *Sibogorgia* and analyzed by the PTP method using a Markov Chain Monte Carlo (MCMC) chain length of 500,000 generations (100 thinning, 25% burnin). We assessed convergence by examining the likelihood trace. The combinations of the ML or Bayesian PTP implementations (mlPTP and bPTP, respectively) with the *mtMutS* or RAD-seq trees of *Paragorgia* resulted in four species delimitation models: **i)** ‘**mlPTPmt**’ model; **ii)** ‘**bPTPmt**’ model; **iii)** ‘**mlPTPrad**’ model; and **iv)** ‘**bPTPrad**’ model. Lastly, because deep-sea corals are known to show genetic differentiation at ocean basin/regional scales (Miller *et al.* 2011; Morrison *et al.* 2011; Herrera *et al.* 2012), we constructed an additional taxonomy-unguided species delimitation model – the ‘**geo**’ model – based on the geographic location where the specimens were collected (north Pacific, south Pacific or north Atlantic ocean basins).

To estimate the marginal likelihood of each species delimitation model we generated a matrix including only specimens of *Paragorgia*, denominated ‘**PARAGORGIA**’ using a clustering threshold of 80% similarity among sequences (c 0.80) and a minimum coverage of taxa per locus of 100% (m 31) in pyRAD. In contrast to the **backbone**, **PHYLO**, and **PARAGORGIIDAE** RAD-seq matrices, this matrix contained the data of one SNP per locus and not the entire locus sequence. We analyzed these data using the implementation of BFD\* in the SNAPP (Bryant *et al.* 2012) plug-in for the program BEAST v2.1.3 (Bouckaert *et al.* 2014). We performed a path-sampling of 48 steps, with a MCMC chain length of 100,000 (10,000 pre-burnin), following the guidelines from Leache *et al.* (2014). Bayesian factors were calculated from the marginal likelihood estimates for each model and compared using the framework proposed by Kass and Raftery (1995)

### **Species tree inference**

To test the tree topology in the genus *Paragorgia* obtained by the phylogenetic analysis of the **PHYLO** and **PARAGORGIIDAE** concatenated matrices we performed a species tree inference from the SNP data in the **PARAGORGIA** matrix using the program SNAPP. This program allows the inference of species trees from unlinked SNP data (only one SNP per locus retained) bypassing the inference of individual gene trees (Bryant *et al.* 2012). We performed 3 independent runs using a MCMC chain length of 10,000,000 (sampling every 1,000 generations; pre-burnin of 1,000) with default prior distributions for coalescence rate, mutation rate and ancestral population size parameters. We assessed convergence to stationary distributions and effective sample sizes >200 after 10% burnin in the program TRACER

(Rambaut & Drummond 2007). Species trees in the posterior distribution were summarized with the program DENSITREE v2.01 (Bouckaert 2010).

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## REFERENCES

- Aguilar C, Sánchez JA (2007) Phylogenetic hypotheses of gorgoniid octocorals according to ITS2 and their predicted RNA secondary structures. *Molecular Phylogenetics and Evolution* **43**, 774-786.
- Ardila NE, Giribet G, Sanchez JA (2012) A time-calibrated molecular phylogeny of the precious corals: reconciling discrepancies in the taxonomic classification and insights into their evolutionary history. *BMC Evolutionary Biology* **12**.
- Arnold B, Corbett-Detig RB, Hartl D, Bomblies K (2013) RADseq underestimates diversity and introduces genealogical biases due to nonrandom haplotype sampling. *Molecular Ecology* **22**, 3179-3190.
- Baer CF, Miyamoto MM, Denver DR (2007) Mutation rate variation in multicellular eukaryotes: causes and consequences. *Nature Reviews Genetics* **8**, 619-631.
- Baird NA, Etter PD, Atwood TS, et al. (2008) Rapid SNP discovery and genetic mapping using sequenced RAD markers. *PLoS One* **3**, 3376.
- Bayer FM (1956) Octocorallia. In: *Treatise on Invertebrate Paleontology Part F. Coelenterata* (ed. Moore RC), pp. 163-231. Geological Society of America and University of Kansas Press, Lawrence, Kansas.

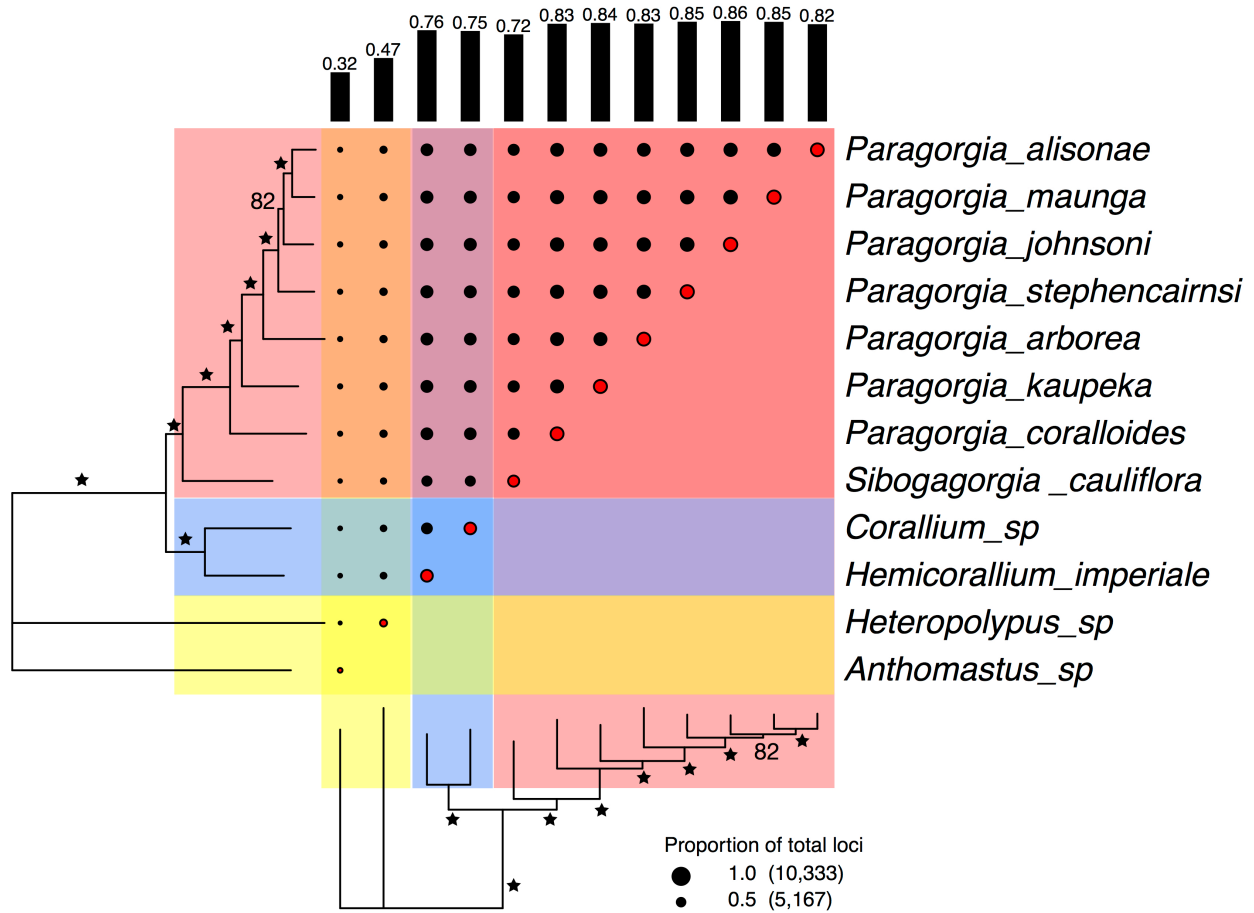
- Berntson EA, Bayer FM, McArthur AG, France SC (2001) Phylogenetic relationships within the Octocorallia (Cnidaria: Anthozoa) based on nuclear 18S rRNA sequences. *Marine Biology* **138**, 235-246.
- Bilewitch JP, Degnan SM (2011) A unique horizontal gene transfer event has provided the octocoral mitochondrial genome with an active mismatch repair gene that has potential for an unusual self-contained function. *BMC Evolutionary Biology* **11**, 228.
- Bouckaert R, Heled J, Kuhnert D, *et al.* (2014) BEAST 2: a software platform for Bayesian evolutionary analysis. *PLoS Comput Biol* **10**, e1003537.
- Bouckaert RR (2010) DensiTree: making sense of sets of phylogenetic trees. *Bioinformatics* **26**, 1372-1373.
- Brockman SA, McFadden CS (2012) The mitochondrial genome of *Paraminabea aldersladei* (Cnidaria: Anthozoa: Octocorallia) supports intramolecular recombination as the primary mechanism of gene rearrangement in octocoral mitochondrial genomes. *Genome Biology and Evolution* **4**, 994-1006.
- Bryant D, Bouckaert R, Felsenstein J, Rosenberg NA, RoyChoudhury A (2012) Inferring species trees directly from biallelic genetic markers: Bypassing gene trees in a full coalescent analysis. *Molecular Biology and Evolution* **29**, 1917-1932.
- Cairns S (2007) Deep-water corals: An overview with special reference to diversity and distribution of deep-water scleractinian corals. *Bulletin of Marine Science* **81**, 311-322.
- Cariou M, Duret L, Charlat S (2013) Is RAD-seq suitable for phylogenetic inference? An in silico assessment and optimization. *Ecology and Evolution* **3**, 846-852.
- Carlson DB, Budd AF (2002) Incipient speciation across a depth gradient in a scleractinian coral? *Evolution* **56**, 2227-2242.
- Catchen J, Hohenlohe PA, Bassham S, Amores A, Cresko WA (2013) Stacks: an analysis tool set for population genomics. *Molecular Ecology* **22**, 3124-3140.
- CITES (2014) Appendices I, II and III. Convention on International Trade in Endangered Species of wild fauna and flora, , <http://www.cites.org/sites/default/files/eng/app/2014/E-Appendices-2014-09-14.pdf>.
- Clark AG, Eisen MB, Smith DR, *et al.* (2007) Evolution of genes and genomes on the *Drosophila* phylogeny. *Nature* **450**, 203-218.
- Concepcion GT, Crepeau MW, Wagner D, Kahng SE, Toonen RJ (2007) An alternative to ITS, a hypervariable, single-copy nuclear intron in corals, and its use in detecting cryptic species within the octocoral genus *Carijoa*. *Coral reefs* **27**, 323-336.
- Cruaud A, Gautier M, Galan M, *et al.* (2014) Empirical assessment of RAD sequencing for interspecific phylogeny. *Molecular Biology and Evolution* **31**, 1272-1274.
- Daly M, Brugler MR, Cartwright P, *et al.* (2007) The phylum Cnidaria: A review of phylogenetic patterns and diversity 300 years after Linnaeus. *Zootaxa* **1668**, 127-182.
- De Queiroz K (2007) Species concepts and species delimitation. *Systematic Biology* **56**, 879-886.
- Dobzhansky T (1970) *Genetics of the Evolutionary Process* Columbia University Press, New York,.
- Dueñas LF, Alderslade P, Sánchez JA (2014) Molecular systematics of the deep-sea bamboo corals (Octocorallia: Isididae: Keratoisidinae) from New Zealand with descriptions of two new species of *Keratoisis*. *Molecular Phylogenetics and Evolution* **74**, 15-28.
- Dueñas LF, Sánchez JA (2009) Character lability in deep-sea bamboo corals (Octocorallia, Isididae, Keratoisidinae). *Marine Ecology Progress Series* **397**, 11-23.
- Eaton DA (2014) PyRAD: Assembly of de novo RADseq loci for phylogenetic analyses. *Bioinformatics* **30**, 1844-1849.
- Eaton DAR, Ree RH (2013) Inferring phylogeny and introgression using RADseq data: An example from flowering plants (Pedicularis: Orobanchaceae). *Systematic Biology* **62**, 689-706.
- Edwards SV (2009) Is a new and general theory of molecular systematics emerging? *Evolution* **63**, 1-19.

- Emerson KJ, Merz CR, Catchen JM, *et al.* (2010) Resolving postglacial phylogeography using high-throughput sequencing. *Proceedings of the National Academy of Sciences of the United States of America* **107**, 16196-16200.
- Escudero M, Eaton DAR, Hahn M, Hipp AL (2014) Genotyping-by-sequencing as a tool to infer phylogeny and ancestral hybridization: A case study in *Carex* (Cyperaceae). *Molecular Phylogenetics and Evolution* **79**, 359-367.
- Figueroa DF, Baco AR (2014) Complete mitochondrial genomes elucidate phylogenetic relationships of the deep-sea octocoral families Coralliidae and Paragorgiidae. *Deep-Sea Research Part II-Topical Studies in Oceanography* **99**, 83-91.
- France SC (2007) Genetic analysis of bamboo corals (Cnidaria : Octocorallia : Isididae): Does lack of colony branching distinguish *Lepidisis* from *Keratoisis*? In: *Bulletin of Marine Science*, pp. 323-333.
- France SC, Hoover LL, Hoover LL (2002) DNA sequences of the mitochondrial COI gene have low levels of divergence among deep-sea octocorals (Cnidaria: Anthozoa). *Hydrobiologia* **471**, 149-155.
- Fujisawa T, Barraclough TG (2013) Delimiting species using single-locus data and the generalized mixed Yule coalescent approach: A revised method and evaluation on simulated data sets. *Systematic Biology* **62**, 707-724.
- Glazier AE, Etter RJ (2014) Cryptic speciation along a bathymetric gradient. *Biological Journal of the Linnean Society* **113**, 897-913.
- Grajales A, Aguilar C, Sánchez JA (2007) Phylogenetic reconstruction using secondary structures of Internal Transcribed Spacer 2 (ITS2, rDNA): finding the molecular and morphological gap in Caribbean gorgonian corals. *BMC Evolutionary Biology* **7**, 90.
- Grasshoff M (1979) Zur bipolaren verbreitung der oktodoralle *Paragorgia arborea* (Cnidaria: Anthozoa: Scleraxonia). *Senckenbergiana Maritima* **11**, 115-137.
- Grummer JA, Bryson RW, Reeder TW (2014) Species delimitation using Bayes factors: Simulations and application to the *Sceloporus scalaris* species group (Squamata: Phrynosomatidae). *Systematic Biology* **63**, 119-133.
- Hebert PDN, Cywinska A, Ball SL, DeWaard JR (2003) Biological identifications through DNA barcodes. *Proceedings of the Royal Society B-Biological Sciences* **270**, 313-321.
- Hellberg ME (2006) No variation and low synonymous substitution rates in coral mtDNA despite high nuclear variation. *BMC Evolutionary Biology* **6**.
- Herrera S, Baco A, Sánchez JA (2010) Molecular systematics of the bubblegum coral genera (Paragorgiidae, Octocorallia) and description of a new deep-sea species. *Molecular Phylogenetics and Evolution* **55**, 123-135.
- Herrera S, Reyes-Herrera PH, Shank TM (2014) Genome-wide predictability of restriction sites across the eukaryotic tree of life. *bioRxiv* preprint doi: <http://dx.doi.org/10.1101/007781>
- Herrera S, Shank TM, Sánchez JA (2012) Spatial and temporal patterns of genetic variation in the widespread antitropical deep-sea coral *Paragorgia arborea*. *Molecular Ecology* **21**, 6053-6067.
- Herrera S, Watanabe H, Shank T (2015) Evolutionary and biogeographical patterns of barnacles from deep-sea hydrothermal vents. *Molecular Ecology*, **24**: 673-689.
- Hipp AL, Eaton DAR, Cavender-Bares J, *et al.* (2014) A framework phylogeny of the american oak clade based on sequenced RAD data. *PLoS One* **9**, e93975.
- ICES (2013) Assessment of the list of VME indicator species and elements. International Council for the Exploration of the Sea, [http://www.ices.dk/sites/pub/Publication Reports/Advice/2013/Special requests/NEAFC\\_VME\\_indicator\\_species\\_and\\_elements.pdf](http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2013/Special%20requests/NEAFC_VME_indicator_species_and_elements.pdf).
- Jennings RM, Etter RJ, Ficarra L (2013) Population differentiation and species formation in the deep sea: the potential role of environmental gradients and depth. *PLoS One* **8**, e77594.
- Jones JC, Fan S, Franchini P, Schartl M, Meyer A (2013) The evolutionary history of *Xiphophorus* fish and their sexually selected sword: a genome-wide approach using restriction site-associated DNA sequencing. *Molecular Ecology* **22**, 2986-3001.

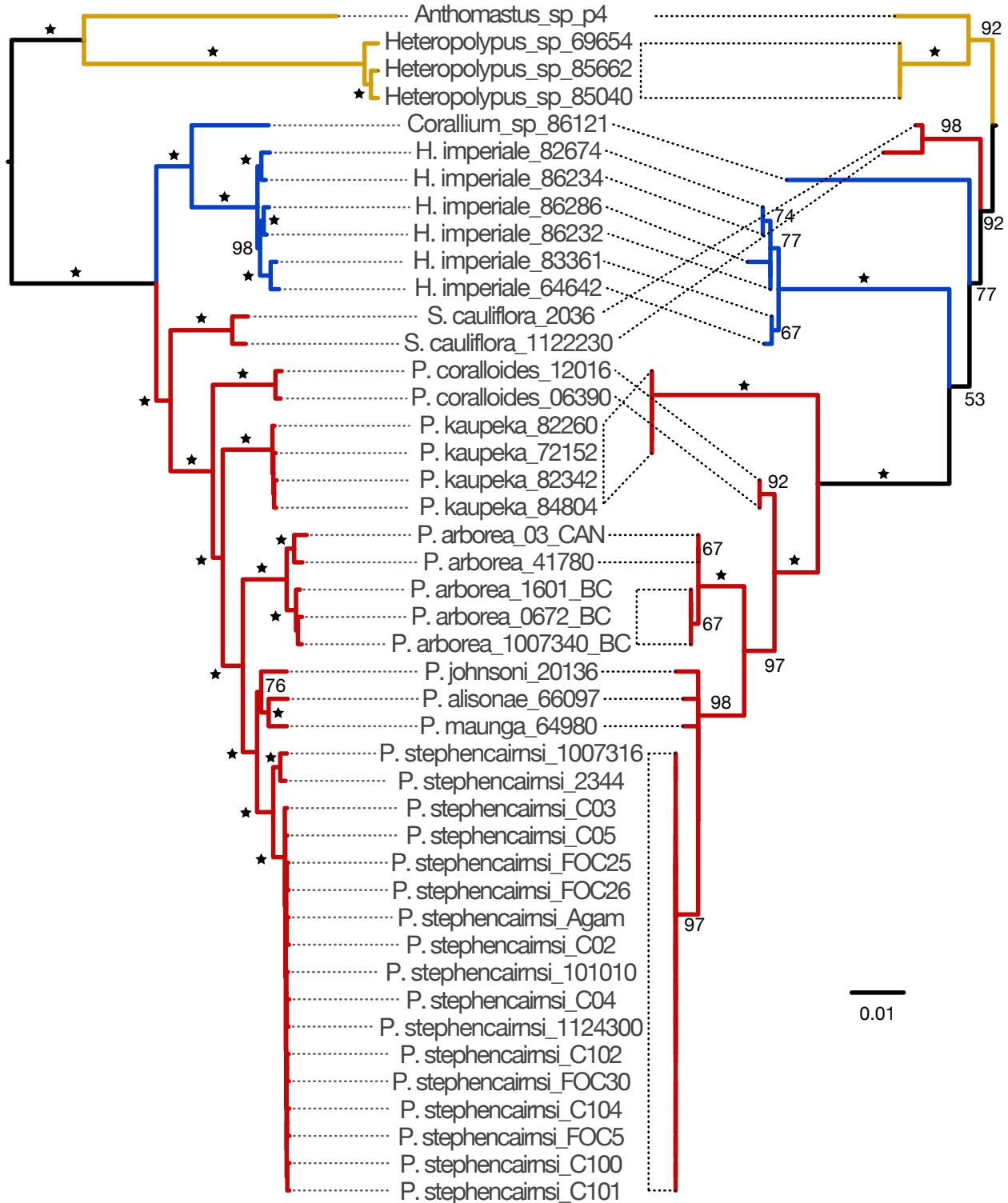
- Kass RE, Raftery AE (1995) Bayes Factors. *Journal of the American Statistical Association* **90**, 773-795.
- Leache AD, Fujita MK, Minin VN, Bouckaert RR (2014) Species Delimitation using Genome-Wide SNP Data. *Systematic Biology* **63**, 534-542.
- Leffler EM, Bullaughey K, Matute DR, *et al.* (2012) Revisiting an old riddle: What determines genetic diversity levels within species? *PLoS Biology* **10**, e1001388.
- Maddison WP (1997) Gene trees in species trees. *Systematic Biology* **46**, 523-536.
- Mayr E (1942) *Systematics and the Origin of Species from the Viewpoint of a Zoologist* Columbia University Press, New York,.
- McFadden CS, Benayahu Y, Pante E, *et al.* (2010a) Limitations of mitochondrial gene barcoding in Octocorallia. *Molecular Ecology Resources* **11**, 19-31.
- McFadden CS, France SC, Sánchez JA, Alderslade P (2006) A molecular phylogenetic analysis of the Octocorallia (Cnidaria: Anthozoa) based on mitochondrial protein-coding sequences. *Molecular Phylogenetics and Evolution* **41**, 513-527.
- McFadden CS, Sanchez JA, France SC (2010b) Molecular Phylogenetic Insights into the Evolution of Octocorallia: A Review. *Integrative and Comparative Biology* **50**, 389-410.
- McFadden CS, Tullis ID, Breton Hutchinson M, Winner K, Sohm JA (2004) Variation in Coding (NADH Dehydrogenase Subunits 2, 3, and 6) and Noncoding Intergenic Spacer Regions of the Mitochondrial Genome in Octocorallia (Cnidaria: Anthozoa). *Marine Biotechnology* **6**, 516-526.
- McFadden CS, van Ofwegen LP (2013) Molecular phylogenetic evidence supports a new family of octocorals and a new genus of Alcyoniidae (Octocorallia, Alcyonacea). *Zookeys* **346**, 59-83.
- Miller KJ, Rowden AA, Williams A, Haussermann V (2011) Out of their depth? Isolated deep populations of the cosmopolitan coral *Desmophyllum dianthus* may be highly vulnerable to environmental change. *PLoS One* **6**, e19004.
- Morrison CL, Ross SW, Nizinski MS, *et al.* (2011) Genetic discontinuity among regional populations of *Lophelia pertusa* in the North Atlantic Ocean. *Conservation Genetics* **12**, 713-729.
- Nadeau NJ, Martin SH, Kozak KM, *et al.* (2012) Genome-wide patterns of divergence and gene flow across a butterfly radiation. *Molecular Ecology* **22**, 814-826.
- Pante E, Abdelkrim J, Viricel A, Gey D, France S (2014) Use of RAD sequencing for delimiting species. *Heredity*.
- Park E, Hwang DS, Lee JS, *et al.* (2012) Estimation of divergence times in cnidarian evolution based on mitochondrial protein-coding genes and the fossil record. *Molecular Phylogenetics and Evolution* **62**, 329-345.
- Pons J, Barraclough TG, Gomez-Zurita J, *et al.* (2006) Sequence-based species delimitation for the DNA taxonomy of undescribed insects. *Systematic Biology* **55**, 595-609.
- Prada C, DeBiasse MB, Neigel JE, *et al.* (2014) Genetic species delineation among branching Caribbean *Porites* corals. *Coral Reefs* **33**, 1019-1030.
- Prada C, Hellberg ME (2013) Long prereproductive selection and divergence by depth in a Caribbean candelabrum coral. *Proceedings of the National Academy of Sciences of the United States of America* **110**, 3961-3966.
- Quattrini AM, Georgian SE, Byrnes L, *et al.* (2013) Niche divergence by deep-sea octocorals in the genus *Callogorgia* across the continental slope of the Gulf of Mexico. *Molecular Ecology* **22**, 4123-4140.
- Rambaut A, Drummond AJ (2007) Tracer v1.4, Available from <http://beast.bio.ed.ac.uk/Tracer>.
- Reitzel AM, Herrera S, Layden MJ, Martindale MQ, Shank TM (2013) Going where traditional markers have not gone before: utility of and promise for RAD sequencing in marine invertebrate phylogeography and population genomics. *Molecular Ecology* **22**, 2953-2970.
- Roberts JM, Cairns SD (2014) Cold-water corals in a changing ocean. *Current Opinion in Environmental Sustainability* **7**, 118-126.
- Roberts JM, Wheeler A, Freiwald AR, Cairns SD (2009) *Cold-Water Corals : The Biology and Geology of Deep-Sea Coral Habitats* Cambridge University Press, Cambridge, UK ; New York.

- Rubin BE, Ree RH, Moreau CS (2012) Inferring phylogenies from RAD sequence data. *PLoS One* **7**, e33394.
- Sánchez JA (2005) Systematics of the bubblegum corals (Cnidaria: Octocorallia: Paragorgiidae) with description of new species from New Zealand and the Eastern Pacific. *Zootaxa* **1014**, 1-72.
- Sanchez JA, Dorado D (2008) Intragenomic ITS2 variation in Caribbean seafans. In: *Proceedings of the 11th International Coral Reef Symposium*, pp. 1383-1387, Ft. Lauderdale.
- Sánchez JA, Lasker HR, Taylor DJ (2003) Phylogenetic analyses among octocorals (Cnidaria): mitochondrial and nuclear DNA sequences (lsu-rRNA, 16S and ssu-rRNA, 18S) support two convergent clades of branching gorgonians. *Molecular Phylogenetics and Evolution* **29**, 31-42.
- Seetharam AS, Stuart GW (2013) Whole genome phylogeny for 21 *Drosophila* species using predicted 2b-RAD fragments. *PeerJ* **1**, e226.
- Shearer TL, Van Oppen MJH, Romano SL, Worheide G (2002) Slow mitochondrial DNA sequence evolution in the Anthozoa (Cnidaria). *Molecular Ecology* **11**, 2475-2487.
- Smith P, McVeagh S, Mingoia J, France S (2004) Mitochondrial DNA sequence variation in deep-sea bamboo coral (Keratoisidinae) species in the southwest and northwest Pacific Ocean. *Marine Biology* **144**, 253-261.
- Stamatakis A (2006) RAxML-VI-HPC: Maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics* **22**, 2688-2690.
- Thoma J, Pante E, Brugler M, France S (2009) Deep-sea octocorals and antipatharians show no evidence of seamount-scale endemism in the NW Atlantic. *Marine Ecology Progress Series* **397**, 25-35.
- Uda K, Komeda Y, Fujita T, *et al.* (2013) Complete mitochondrial genomes of the Japanese pink coral (*Corallium elatius*) and the Mediterranean red coral (*Corallium rubrum*): a reevaluation of the phylogeny of the family Coralliidae based on molecular data. *Comparative Biochemistry and Physiology D-Genomics & Proteomics* **8**, 209-219.
- Verrill AE (1922) Part G: Alcyonaria and Actiniaria. *Report of the Canadian Arctic Expedition 1913-18* **8**, 1-164.
- Wagner CE, Keller I, Wittwer S, *et al.* (2012) Genome-wide RAD sequence data provide unprecedented resolution of species boundaries and relationships in the Lake Victoria cichlid adaptive radiation. *Molecular Ecology* **22**, 787-798.
- Wating L, France SC, Pante E, Simpson A (2011) Biology of deep-water octocorals. *Advances in Marine Biology, Vol 60* **60**, 41-122.
- Yang ZH, Rannala B (2010) Bayesian species delimitation using multilocus sequence data. *Proceedings of the National Academy of Sciences of the United States of America* **107**, 9264-9269.
- Zapata F, Jimenez I (2012) Species delimitation: Inferring gaps in morphology across geography. *Systematic Biology* **61**, 179-194.
- Zhang J, Kapli P, Pavlidis P, Stamatakis A (2013) A general species delimitation method with applications to phylogenetic placements. *Bioinformatics* **29**, 2869-2876.

## FIGURES & TABLES

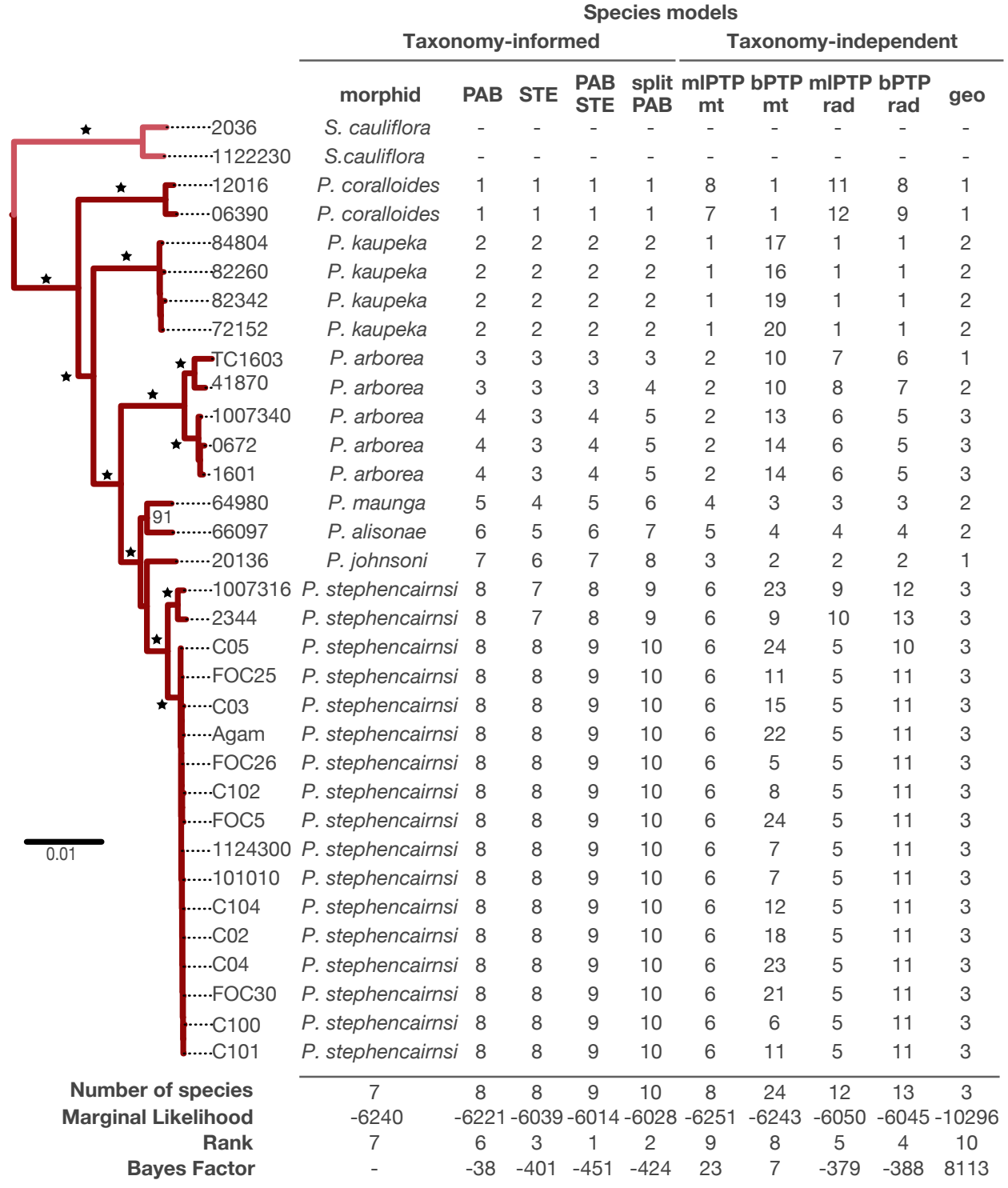


**Figure 1.** Proportion of loci shared among individuals of the AC clade in the optimal backbone matrix (c 0.80, m 9). Each family is indicated with a different color: red for Paragorgiidae; blue for Coralliidae; and yellow for Alcyoniidae. Black-filled circles represent the proportion of the total number of loci shared among individuals. Red-filled circles represent the proportion of the total number of loci present in each individual. Circle scale shows the number of loci represented by 1.0 and 0.5 circle sizes. Black vertical bars represent the average proportion of loci shared by each individual. Phylogenetic tree was inferred with RAxML. Stars on the tree represent branch bootstrap support of 100. Smaller bootstrap support values are indicated with numbers. This figure was generated with the package RADami (Hipp *et al.* 2014).



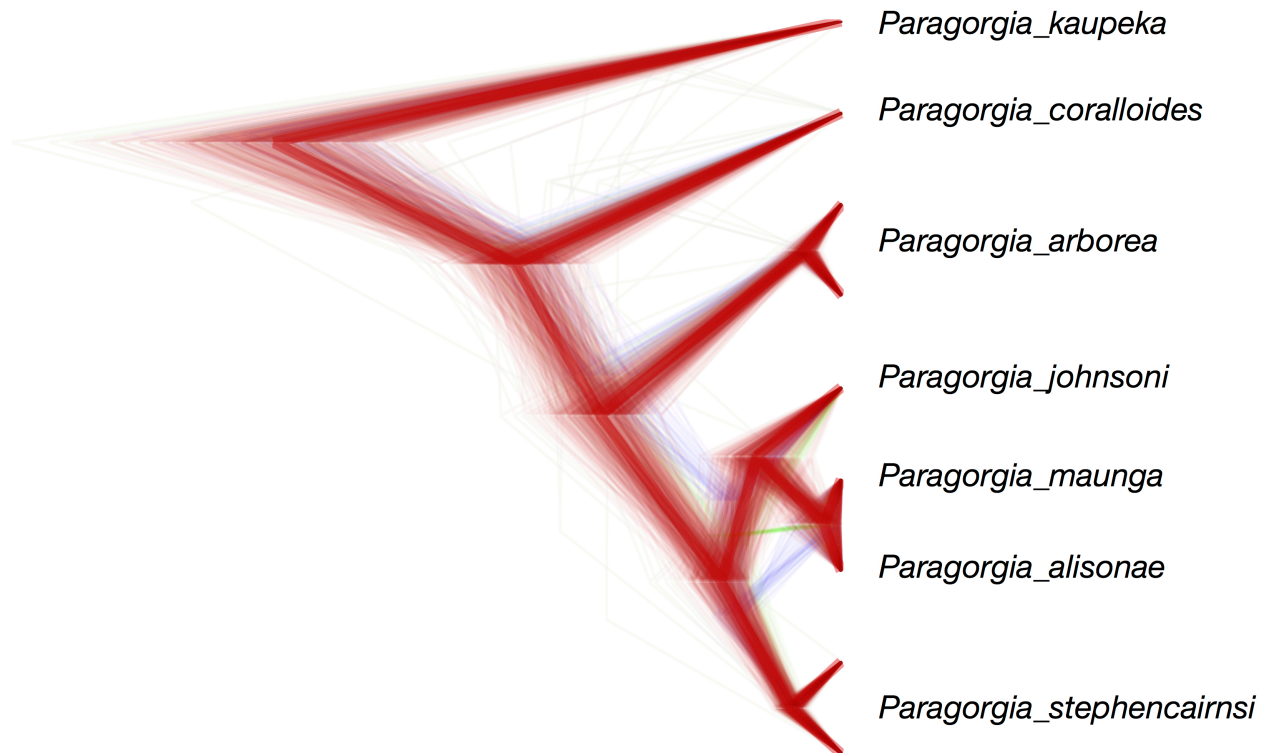
**Figure 2.** Phylogenetic trees of the AC clade based on RAD-seq and mitochondrial data. Left tree based on the RAD-seq concatenated PHYLO matrix. Right tree based on the mtMutS mitochondrial matrix. Each family is indicated with a different branch color: blue red for Paragorgiidae; blue for Coralliidae; and yellow for Alcyoniidae. Phylogenetic trees were inferred with RAxML. Stars on the trees represent bootstrap support of 100. Smaller bootstrap values are indicated in numbers. Scale bar indicates substitutions per site.





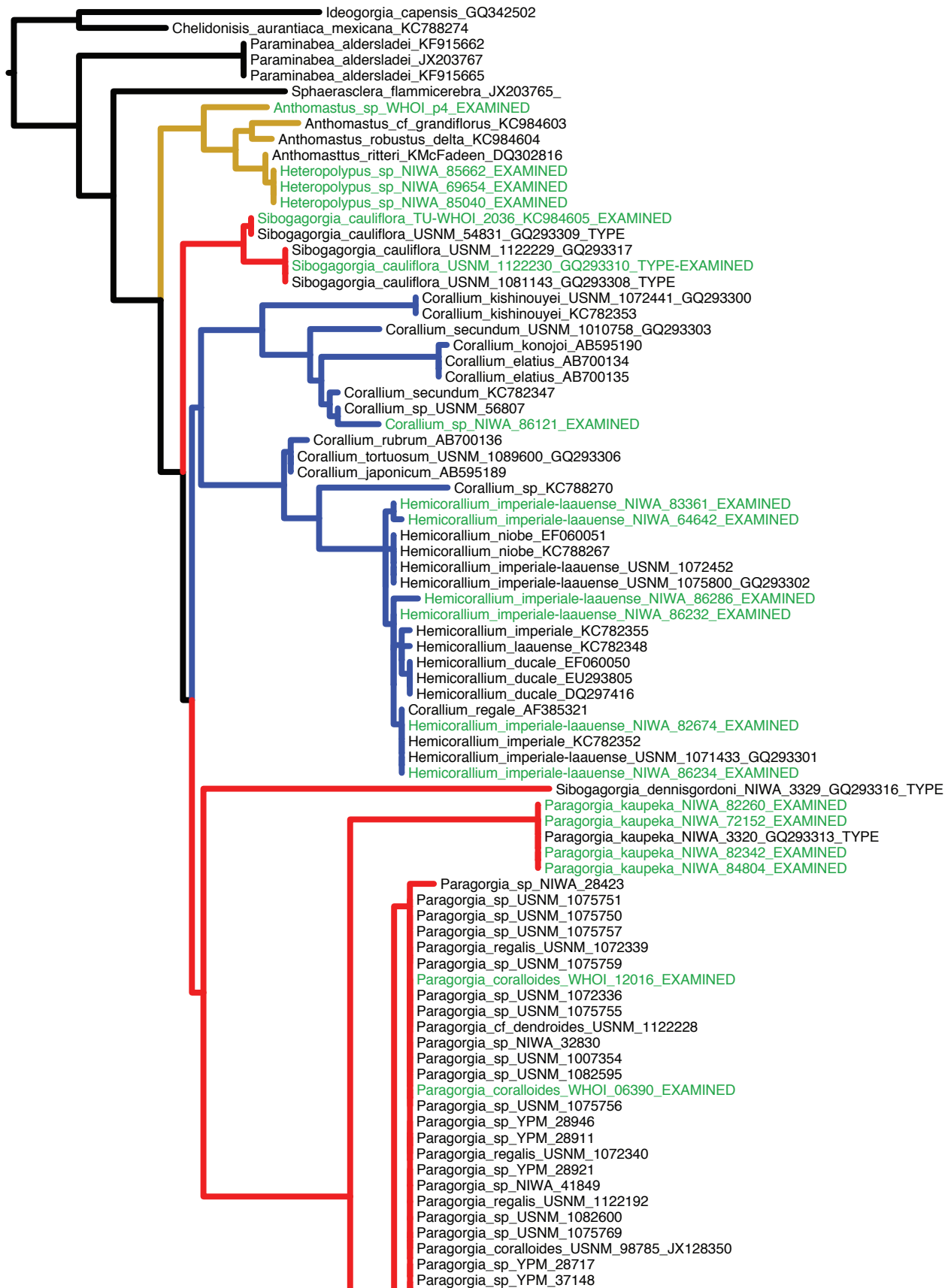
**Figure 3.** Species delineation hypotheses for *Paragorgia*. Table shows the different species delimitation models for *Paragorgia* evaluated with the BFD\* method and their results. *Sibogorgia* was included as outgroup to root the inferences for *Paragorgia*. Each row indicates a different specimen. Each column indicates a different species delimitation model. The first column, model morphid, indicates the species identifications based on morphology.

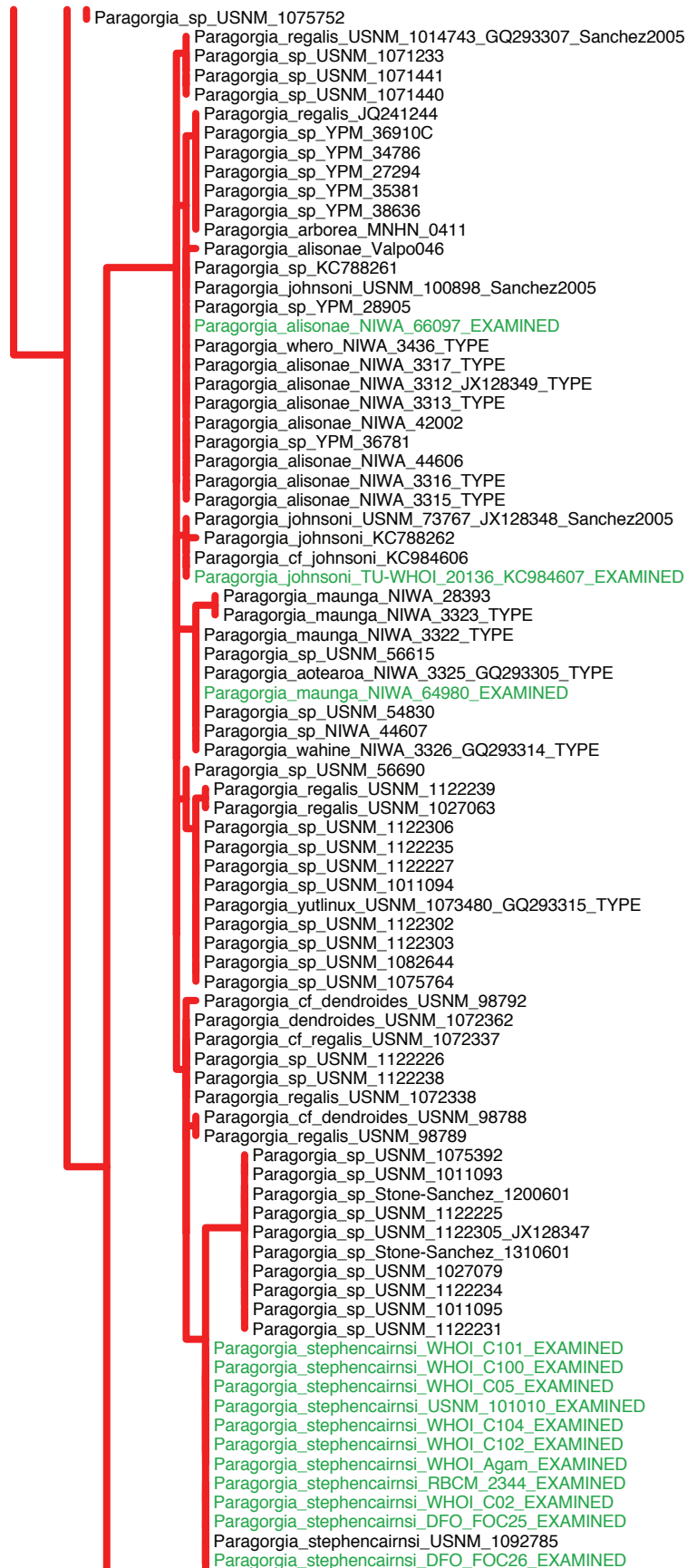
For all other models, numbers indicate the species assignments. Bottom rows show the total number of species proposed, the marginal likelihood estimate, and rank for each model. The Bayes factor comparisons were calculated with respect to the null morphid model. Phylogenetic tree on the left, shown only for visual reference, was inferred with the RAD-seq concatenated PARAGORGIID matrix in RAxML. Each genus is indicated with a different branch color: pink for *Sibogorgia*; and dark red for *Paragorgia*. Stars on the trees represent bootstrap support of 100. Smaller bootstrap values are indicated in numbers. Scale bar indicates substitutions per site.



**Figure 4.** Species tree of *Paragorgia*. This cladogram illustrates the posterior distribution of species trees inferred with SNAPP based on the best species delimitation model PABSTE. High color density is indicative of areas in the species trees with high topology agreement. Different colors represent different topologies. The maximum clade credibility species tree is shown with thicker branches. Trees with the same topology as the maximum clade credibility species tree are colored in red. Trees with different topologies are colored green or blue. With the exception of the branch leading to the clade of *P. johnsoni*, *P. maunga*, and *P. alisonae*, which has a posterior probability of 0.87, all interior branches have posterior probabilities of 1.0.





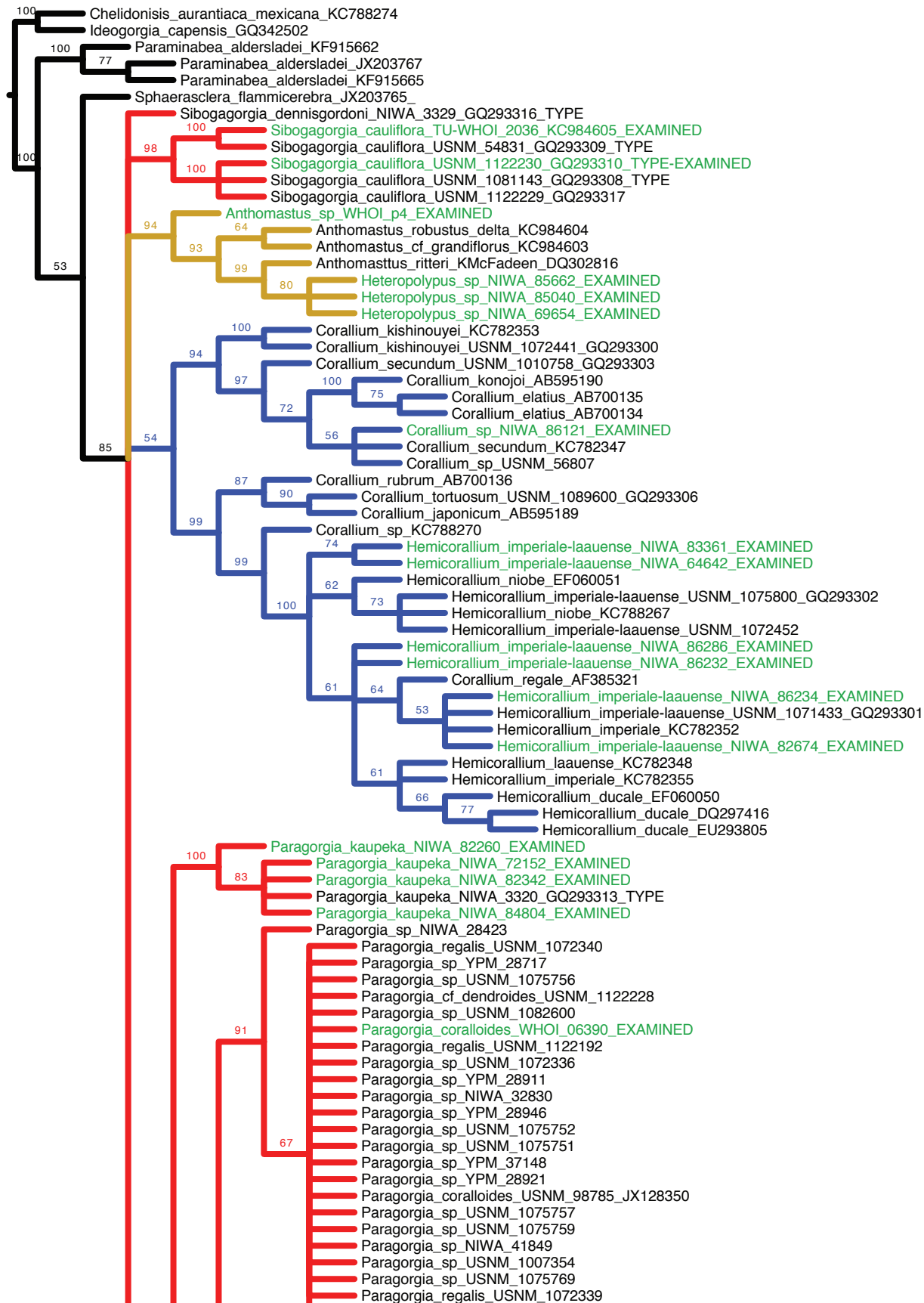


Paragorgia\_stephencairnsi\_DFO\_FOC30\_EXAMINED  
Paragorgia\_stephencairnsi\_USNM\_1123931  
Paragorgia\_stephencairnsi\_USNM\_1075741  
Paragorgia\_stephencairnsi\_DFO\_FOC5\_EXAMINED  
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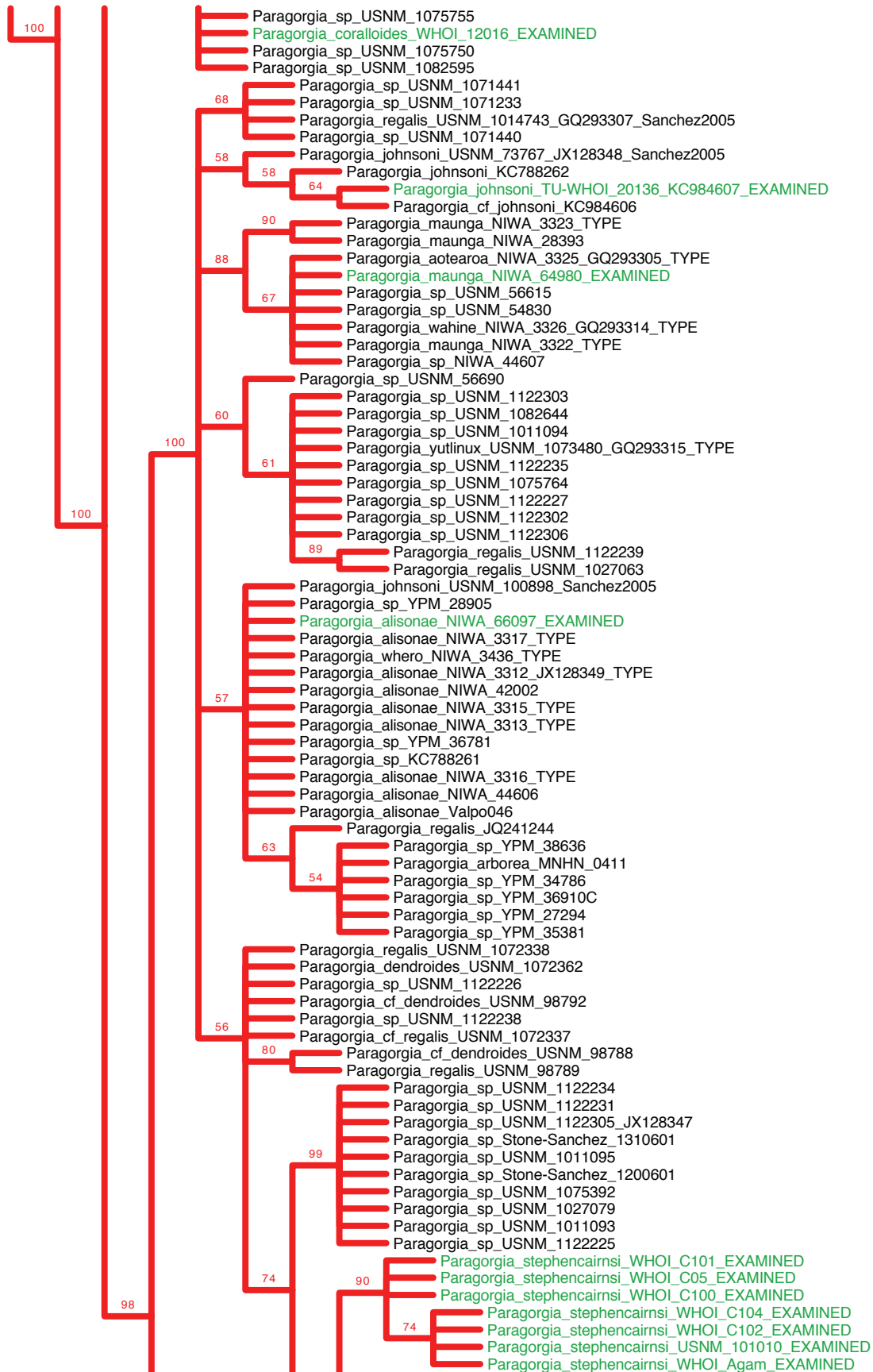
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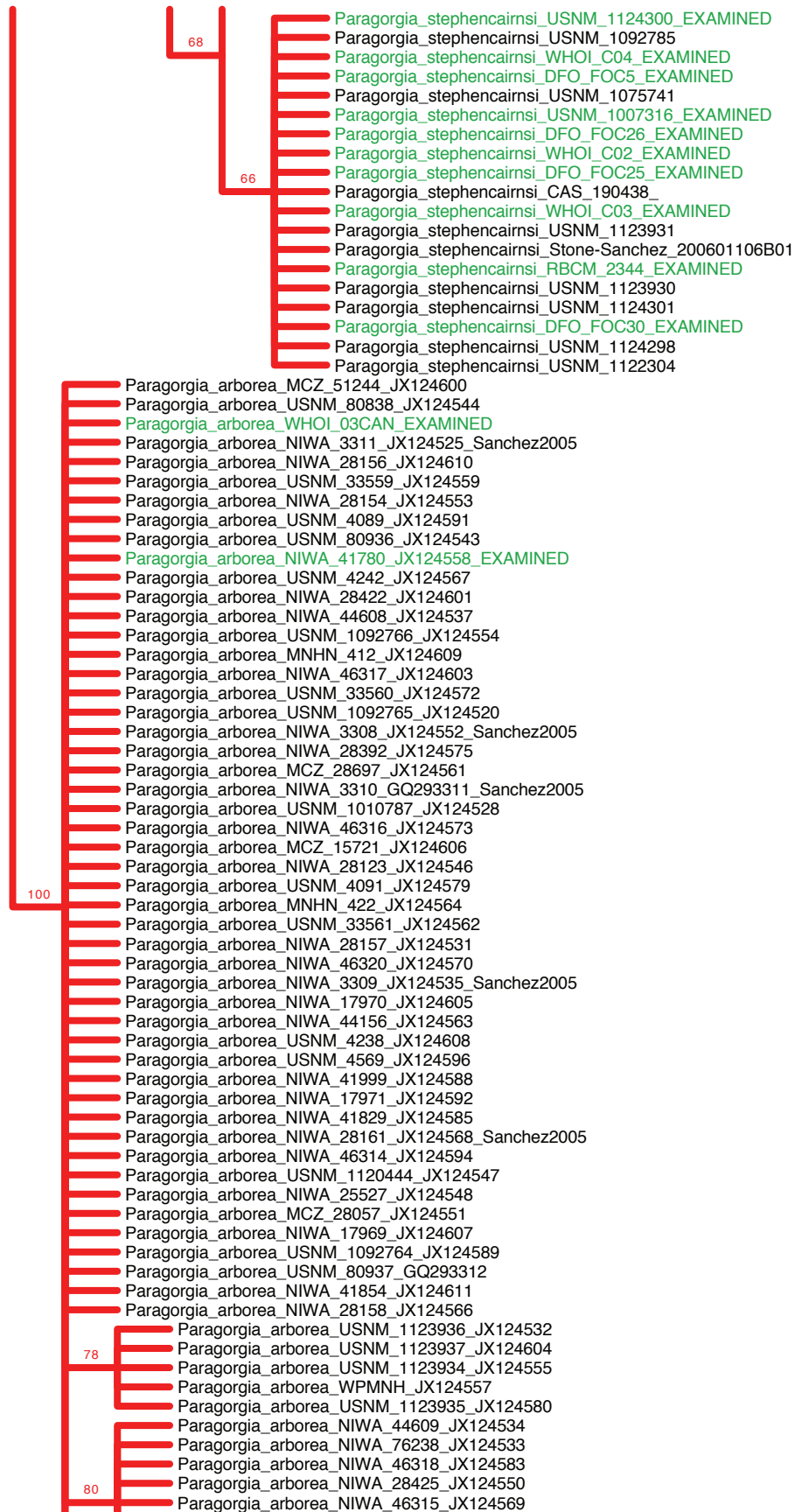
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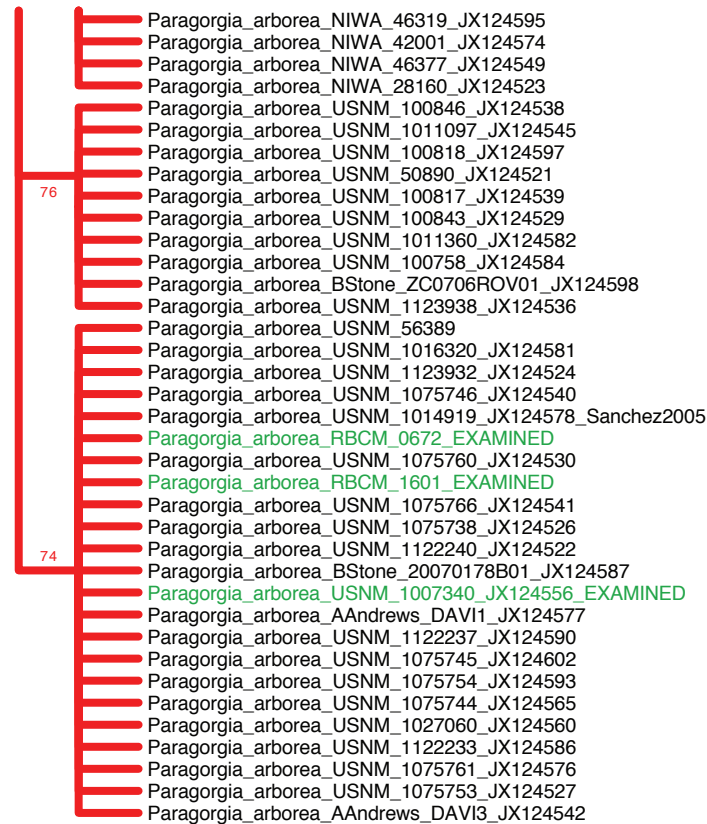
**Figure S2.** Mitochondrial *mtMutS* gene tree of all available sequences for the clade AC. Tree inferred from *mtMutS* sequence data from specimens examined in this study, GenBank, and additional specimens. Each family is indicated with a different branch color: red for Paragorgiidae; blue for Coralliidae; and yellow for Alcyoniidae. Outgroups are indicated with black branches. Specimens examined in detail in this study are indicated with green labels. Type specimens are labeled TYPE. Specimens examined in Sanchez (2005) are labeled “Sanchez2005”. Tree was inferred with RAxML. Scale bars indicate substitutions per site.











**Figure S3.** Mitochondrial *mtMutS* bootstrap support consensus tree of all available sequences for the clade AC. Tree inferred from *mtMutS* sequence data from specimens examined in this study, GenBank, and additional specimens. Each family is indicated with a different branch color: red for Paragorgiidae; blue for Coralliidae; and yellow for Alcyoniidae. Outgroups are indicated with black branches. Specimens examined in detail in this study are indicated with green labels. Type specimens are labeled “TYPE”. Specimens examined in Sanchez (2005) are labeled “Sanchez2005”. Tree was created with RAxML using a 50% majority consensus from 500 bootstrap replicates.

**Table S1.** Collection and sequence information for the specimens used in this study.

ID	Morphological Species	Delimitation model PABSTE	Collection	Date Collected	Locality	Depth (m)	Lat.	Lon.
p4	<i>Anthomastus sp</i>		WHOI	2011	Patagonian shelf	380	-30.19	179.72
86121	<i>Corallium sp</i>		NIWA	2012	Kermadec Ridge; Colville ridge volcano; TAN1213/18	1050	-35.42	178.65
64642	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2010	Kermadec Ridge; Rumble II East seamount cone; TAN1007/97	948	-37.19	176.98
83361	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2012	Bay of Plenty; Site SM1b, Matatara Knoll; TAN1206/168	878	-36.81	177.47
82674	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2012	Kermadec Ridge; Site SM2aa, summit of Whakatane Seamount; TAN1206/77	483	-30.08	179.82
86234	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2012	Kermadec Ridge; Northeast pimple volcano; TAN1213/22	860	-31.13	-179.05
86286	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2012	Kermadec Ridge; Havre volcano; TAN1213/30	483	-30.08	179.82
86232	<i>Hemicorallium imperiale-laauiense</i>		NIWA	2012	Kermadec Ridge; Northeast pimple volcano; TAN1213/22	495	-44.33	-177.22
69654	<i>Heteropolypus sp</i>		NIWA	2011	Chatam Rise; TRIP3306/78	2098	-42.59	179.42
85040	<i>Heteropolypus sp</i>		NIWA	2012	Chatam Rise; TAN1208/22	1931	-42.59	179.59
85662	<i>Heteropolypus sp</i>		NIWA	2012	Chatam Rise; TAN1208/61	875	-50.02	175.00
66097	<i>Paragorgia alisonae</i>	<i>P. alisonae</i>	NIWA	2008	Cambell Plateau; TRIP2718/50	600	-44.52	175.78
41780	<i>Paragorgia arborea</i>	<i>P. arborea</i>	NIWA	2008	Chatam Rise; TRIP2617/120	540	40.54	-67.01
TC16_03	<i>Paragorgia arborea</i>	<i>P. arborea</i>	WHOI	2013	NE US Canyons; Munson Canyon; TowCam 16			
0672	<i>Paragorgia arborea</i>	<i>P. pacifica</i>	RBCM	2004	British Columbia; VE14280	1168	48.44	-126.38
1007340	<i>Paragorgia arborea</i>	<i>P. pacifica</i>	USNM	2001	British Columbia; Vancouver Island	695	53.31	-135.58
1601	<i>Paragorgia arborea</i>	<i>P. pacifica</i>	RBCM	2009	British Columbia; VE14444	1821	37.46	-59.95
063902	<i>Paragorgia coralloides</i>	<i>P. coralloides</i>	WHOI	2005	New England Seamounts; Rehobot Seamount; H13	2000	38.23	-60.46
12016	<i>Paragorgia coralloides</i>	<i>P. coralloides</i>	WHOI	2003	New England Seamounts; Manning Seamount, station 4; AD3890	438	28.19	-89.80
20136	<i>Paragorgia johnsoni</i>	<i>P. johnsoni</i>	TU/WHOI	2009	Gulf of Mexico; MC751; J2-464	877	-36.45	177.84
72152	<i>Paragorgia kaupeka</i>	<i>P. kaupeka</i>	NIWA	2011	Kermadec Ridge; Clark Seamount, chimney field, north cone; TAN1104/13	850	-36.45	177.84
82260	<i>Paragorgia kaupeka</i>	<i>P. kaupeka</i>	NIWA	2012	Kermadec Ridge; Site SM3a, summit of Clark Seamount; TAN1206/34	1100	-36.45	177.84
82342	<i>Paragorgia kaupeka</i>	<i>P. kaupeka</i>	NIWA	2012	Kermadec Ridge; Site SM3a, Clark Seamount; TAN1206/40	870	-36.45	177.84
84804	<i>Paragorgia kaupeka</i>	<i>P. kaupeka</i>	NIWA	2005	Kermadec Ridge; Clark Seamount; KOK0506/12	772	-35.17	178.89
64980	<i>Paragorgia maunga</i>	<i>P. maunga</i>	NIWA	2010	Kermadec Ridge; Silent II seamount; TAN1007/120	1168	48.44	-126.38
1007316	<i>Paragorgia stephencairnsi</i>	<i>P. sp. nov</i>	USNM	2001	British Columbia; Vancouver Island	1194	53.37	-133.31
2344	<i>Paragorgia stephencairnsi</i>	<i>P. sp. nov</i>	RBCM	2004	British Columbia; VE13978			

101010	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	USNM	2008	California; Piggy Bank, southern California; DW-026-02	283	33.92	-119.47
1124300	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	USNM	2006	British Columbia; Vancouver Island, Ohiat Island; OC 06/952	188	48.83	-125.13
Agam	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2012	British Columbia; Agamemnon Channel	32	49.72	-124.05
C02	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
C03	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
C04	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
C05	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
C100	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
C101	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
C102	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
C104	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	WHOI	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
FOC25	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	DFO	2012	British Columbia; W of Graham Island; 2012-65	204	53.31	-133.03
FOC26	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	DFO	2012	British Columbia; W of Graham Island; 2012-65	221	53.30	-133.04
FOC30	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	DFO	2012	British Columbia; W of Graham Island; 2012-65	318	53.48	-133.07
FOC5	<i>Paragorgia stephencairnsi</i>	<i>P. stephencairnsi</i>	DFO	2009	British Columbia; E of Graham Island; 2009-47	201	52.13	-128.90
1122230	<i>Sibogorgia cauliflora</i>		USNM	2006	California; Davidson seamount; dive 945	2502	35.83	-122.61
2036	<i>Sibogorgia cauliflora</i>		TU/WHOI	2009	Gulf of Mexico; DC583; J2-454	2440	28.39	-87.39

**Table S2.** RAD sequencing results and filtering statistics.

Morphological Species	Delimitation model	RAD-seq data file ID	Total sequenced reads	STACKS filtering		pyRAD filtering			
				Reads discarded due to low quality	Retained reads	Reads that passed quality filtering	Trimmed reads due to detection of adapters	Total number of retained reads	% of retained reads after filtering steps
<i>Anthomastus sp</i>		PoC_p4_ARG	2,207,834	151,391	1,312,903	1,076,607	38,570	1,115,177	50.51
<i>Corallium sp</i>		COR_86121_NZ	3,826,317	305,019	3,013,324	2,555,644	22,650	2,578,294	67.38
<i>H. imperiale-laaouense</i>		COR_64642_NZ	4,344,702	239,625	4,105,077	3,697,256	21,823	3,719,079	85.60
<i>H. imperiale-laaouense</i>		COR_83361_NZ	3,351,944	291,963	2,588,492	2,103,039	37,016	2,140,055	63.85
<i>H. imperiale-laaouense</i>		HEM_82674_NZ	4,455,288	364,162	3,777,461	3,216,577	40,911	3,257,488	73.12
<i>H. imperiale-laaouense</i>		HEM_86234_NZ	2,408,325	186,372	2,142,057	1,876,187	16,195	1,892,382	78.58
<i>H. imperiale-laaouense</i>		HEM_86286_NZ	5,324,532	446,268	4,266,674	3,577,980	42,661	3,620,641	68.00
<i>H. imperiale-laaouense</i>		PAR_86232_NZ	6,092,276	503,438	5,206,376	4,454,042	35,518	4,489,560	73.69
<i>Heteropolypus sp</i>		ANT_69654_NZ	4,300,289	349,226	3,645,814	3,139,309	32,395	3,171,704	73.76
<i>Heteropolypus sp</i>		ANT_85040_NZ	4,498,336	393,748	3,882,304	3,333,172	26,687	3,359,859	74.69
<i>Heteropolypus sp</i>		ANT_85662_NZ	3,487,138	283,856	2,812,750	2,382,184	40,135	2,422,319	69.46
<i>P. alisonae</i>	<i>P. alisonae</i>	PAR_66097_NZ	3,007,362	220,209	2,511,717	2,219,265	21,207	2,240,472	74.50
<i>P. arborea</i>	<i>P. arborea</i>	PAR_41780_NZ	6,668,080	367,144	6,300,936	5,655,328	33,758	5,689,086	85.32
<i>P. arborea</i>	<i>P. arborea</i>	PAR_TC16_03_CAN	2,259,880	167,106	1,799,244	1,556,363	17,448	1,573,811	69.64
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_0672_BC	4,348,226	293,526	4,054,700	3,543,642	29,284	3,572,926	82.17
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1007340_BCD	2,808,882	251,102	2,431,829	2,063,940	25,831	2,089,771	74.40
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1601_BC	4,202,185	221,386	3,980,799	3,606,334	25,434	3,631,768	86.43
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_063902_NES	3,244,860	185,122	3,059,738	2,746,228	20,408	2,766,636	85.26
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_12016_NES	3,838,375	226,253	3,612,122	3,255,440	15,945	3,271,385	85.23
<i>P. johnsoni</i>	<i>P. johnsoni</i>	PAR_20136_GOM	7,751,624	422,203	7,329,421	6,623,446	38,692	6,662,138	85.95
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_72152_NZ	3,909,139	268,871	2,926,960	2,531,796	26,984	2,558,780	65.46
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82260_NZ	5,511,873	475,292	4,558,291	3,824,683	42,782	3,867,465	70.17
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82342_NZ	4,056,319	307,425	3,339,653	2,866,786	33,020	2,899,806	71.49
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_84804_NZ	2,828,879	230,493	2,313,997	1,968,495	19,602	1,988,097	70.28
<i>P. maunga</i>	<i>P. maunga</i>	PAR_11369_NZ	2,536,311	252,554	2,008,028	1,619,915	34,477	1,654,392	65.23
<i>P. stephencairnsi</i>	<i>P. sp. nov</i>	PAR_1007316_BCD	2,257,183	151,729	1,606,180	1,371,398	36,692	1,408,090	62.38
<i>P. stephencairnsi</i>	<i>P. sp. nov</i>	PAR_2344_BC	2,858,311	159,073	2,699,238	2,414,787	26,272	2,441,059	85.40
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_101010_CA	6,642,673	398,317	6,244,356	5,595,342	39,240	5,634,582	84.82
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_1124300_WA	3,843,250	215,859	3,627,391	3,260,864	27,921	3,288,785	85.57
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_Agam_BC	4,322,564	260,095	4,062,469	3,619,988	26,669	3,646,657	84.36

<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C02_BCS	2,149,938	153,978	1,594,818	1,377,002	16,157	1,393,159	64.80
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C03_BCS	2,815,327	245,051	2,264,951	1,916,452	19,800	1,936,252	68.78
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C04_BCS	3,240,713	267,042	2,754,373	2,379,284	22,261	2,401,545	74.11
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C05_BCS	3,465,396	294,547	2,972,548	2,538,577	25,005	2,563,582	73.98
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C100_BCS	5,998,914	480,465	4,984,766	4,330,930	38,445	4,369,375	72.84
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C101_BCS	5,332,619	446,452	4,652,535	4,030,919	30,684	4,061,603	76.17
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C102_BCS	4,347,757	348,662	3,710,381	3,221,934	26,559	3,248,493	74.72
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C104_BCS	2,720,994	210,479	2,203,568	1,893,649	19,213	1,912,862	70.30
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC25_BCD	5,479,109	453,625	4,693,804	4,073,503	34,583	4,108,086	74.98
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC26_BCD	5,242,949	477,361	4,528,629	3,778,655	37,137	3,815,792	72.78
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC30_BCD	4,417,520	337,501	3,781,973	3,312,791	32,621	3,345,412	75.73
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC5_BCD	2,834,377	239,051	2,455,041	2,109,251	23,444	2,132,695	75.24
<i>S. cauliflora</i>		SIB_1122230_DAV	1,701,751	123,755	1,220,077	1,016,203	26,104	1,042,307	61.25
<i>S. cauliflora</i>		SIB_2036_GOM	2,638,533	191,392	2,373,232	2,077,092	20,727	2,097,819	79.51
<b>AVERAGE</b>			3,944,974	292,232	3,395,704	2,950,279	28,840	2,979,119	74.27
<b>STD DEV.</b>			1,392,573	105,332	1,352,276	1,219,146	7,968	1,222,799	8.09

**Table S3. RAD-seq backbone clustering and matrix statistics.**

Matrix	Min. # of taxa per locus (m)	Cluster threshold (c)	Total # loci in matrix	Number of loci recovered in final data set for each taxon												Total # of phylogenetically informative sites (pis)	Total # of variable sites (var)	Total # of missing data	
				ANT_85040_NZ	COR_86121_NZ	HEM_82674_NZ	PAR_0672_BC	PAR_11369_NZ	PAR_12016_NES	PAR_20136_GOM	PAR_66097_NZ	PAR_82260_NZ	PAR_PR27_BCD	POC_p4_ARG	SIB_2036_GOM				
e80d5m4p3	4	80	62,726	10,588	24,303	25,369	41,190	44,891	38,333	46,858	42,472	41,810	45,377	7,154	26,243	601,763	109,290	0.18	49.6
e80d5m6p3	6	80	35,340	8,518	18,512	19,033	28,087	29,555	27,273	30,193	28,098	28,763	29,647	5,665	19,485	388,349	81,574	0.21	38.3
e80d5m9p3	9	80	10,333	5,176	8,607	8,701	9,558	9,778	9,528	9,879	9,477	9,635	9,794	3,458	8,183	132,803	32,017	0.24	20.7
e85d5m4p3	4	85	62,318	8,692	22,647	23,757	40,930	45,124	37,243	46,984	42,725	41,154	45,540	5,918	24,943	519,766	89,806	0.17	50.1
e85d5m6p3	6	85	33,785	7,020	17,146	17,608	27,047	28,504	26,012	29,192	27,197	27,640	28,608	4,715	18,225	328,464	66,419	0.20	38.3
e85d5m9p3	9	85	9,411	4,374	7,947	8,024	8,752	8,922	8,729	9,041	8,666	8,852	8,953	2,960	7,447	109,189	26,048	0.24	20.1
e90d5m4p3	4	90	58,765	5,796	18,775	19,255	37,994	43,101	33,306	44,722	40,899	37,911	43,075	4,073	21,371	402,245	63,938	0.16	51.4
e90d5m6p3	6	90	28,923	4,674	13,826	13,932	23,212	24,715	22,141	25,263	23,694	23,804	24,705	3,226	14,961	236,051	45,285	0.19	38.5
e90d5m9p3	9	90	7,312	2,943	6,277	6,318	6,855	6,955	6,836	7,048	6,779	6,905	6,984	2,029	5,815	72,149	16,695	0.23	19.4



**Table S4. RAD-seq PHYLO clustering and matrix statistics.**

Morphological Species	Delimitation model PABSTE	RAD-seq data file ID	Total number of clusters	Mean cluster depth	Std. dev. of cluster depth	Number of clusters with depth greater than 5	Mean depth of clusters with depth greater than 5	Std. dev. of cluster depth for clusters with depth greater than 5	Number of loci with >5 depth coverage	Number of loci with >5 depth and passed paralog filter	Number of sites across loci	Number of polymorphic sites	Frequency of polymorphic sites
<i>Anthomastus sp</i>		PoC_p4_ARG	142,551	5.7	11.5	54,060	11.9	16.9	142,551	54,050	3,917,645	12,866	0.0032841
<i>Corallium sp</i>		COR_86121_NZ	176,085	9.6	34.3	85,869	17.8	47.8	176,085	85,816	6,332,203	29,627	0.0046788
<i>H. imperiale-lauense</i>		COR_64642_NZ	177,897	4.3	26.1	29,162	16.7	62.8	177,897	29,125	1,205,608	6,515	0.0054039
<i>H. imperiale-lauense</i>		COR_83361_NZ	190,447	7.2	63.8	74,091	15.7	101.7	190,447	74,069	5,426,154	20,057	0.0036964
<i>H. imperiale-lauense</i>		HEM_82674_NZ	219,724	8.9	53.4	92,866	18.8	81.1	219,724	92,810	6,834,388	29,969	0.0043850
<i>H. imperiale-lauense</i>		HEM_86234_NZ	155,795	7.8	35.4	70,304	14.7	51.8	155,795	70,274	4,900,969	25,071	0.0051155
<i>H. imperiale-lauense</i>		HEM_86286_NZ	252,395	9.0	76.6	96,846	20.8	122.8	252,395	96,772	6,912,750	30,928	0.0044741
<i>H. imperiale-lauense</i>		PAR_86232_NZ	219,190	12.6	95.8	106,265	24.0	136.7	219,190	106,145	7,282,625	32,347	0.0044417
<i>Heteropolypus sp</i>		ANT_69654_NZ	151,154	15.1	52.2	88,266	24.7	66.7	151,154	88,178	6,864,699	18,791	0.0027373
<i>Heteropolypus sp</i>		ANT_85040_NZ	159,357	15.1	42.4	92,201	24.8	53.7	159,357	92,099	7,115,901	27,473	0.0038608
<i>Heteropolypus sp</i>		ANT_85662_NZ	165,100	10.5	120.2	82,840	19.2	169.2	165,100	82,793	6,309,974	23,863	0.0037818
<i>P. alisonae</i>	<i>P. alisonae</i>	PAR_66097_NZ	134,879	11.1	54.8	79,570	17.5	70.7	134,879	79,531	5,954,159	23,831	0.0040024
<i>P. arborea</i>	<i>P. arborea</i>	PAR_41780_NZ	107,360	17.7	78.9	76,515	24.0	92.7	107,360	76,367	68,928	20,899	0.0035690
<i>P. arborea</i>	<i>P. arborea</i>	PAR_TC16_03_CAN	138,933	7.7	46.4	62,427	14.9	68.6	138,933	62,399	54,495	13,801	0.0029837
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_0672_BC	116,545	21.4	71.8	85,334	28.5	82.8	116,545	85,165	77,189	25,068	0.0038214
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1007340_BCD	149,606	9.9	30.4	76,311	17.6	41.0	149,606	76,259	5,736,203	22,134	0.0038587
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1601_BC	118,243	21.7	65.9	85,263	29.3	76.2	118,243	85,074	77,035	24,879	0.0037997
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_063902_NES	132,778	20.1	61.7	87,919	29.4	74.1	132,778	87,756	79,692	26,579	0.0039236
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_12016_NES	129,675	36.8	207.3	90,736	51.8	246.3	129,675	90,474	82,903	21,990	0.0031193
<i>P. johnsoni</i>	<i>P. johnsoni</i>	PAR_20136_GOM	122,432	29.8	487.2	89,665	40.0	568.9	122,432	89,630	81,301	23,857	0.0034518
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_72152_NZ	132,520	12.7	197.2	77,976	20.2	256.8	132,520	77,929	69,780	16,005	0.0027004
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82260_NZ	186,768	13.1	77.9	89,892	25.4	110.9	186,768	89,766	80,556	17,710	0.0025870
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82342_NZ	148,202	12.6	43.0	83,517	21.0	55.8	148,202	83,429	74,747	16,935	0.0026670
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_84804_NZ	124,756	10.5	119.9	69,174	17.3	160.6	124,756	69,119	61,022	15,300	0.0029525
<i>P. maunga</i>	<i>P. maunga</i>	PAR_11369_NZ	113,838	19.3	161.8	84,649	25.2	187.3	113,838	84,510	76,038	26,079	0.0040358
<i>P. stephencairnsi</i>	<i>P. sp nov</i>	PAR_1007316_BCD	166,722	5.9	17.7	60,649	12.9	27.9	166,722	60,636	4,357,427	19,584	0.0044944

<i>P. stephencairnsi</i>	<i>P. sp nov</i>	PAR_2344_BC	125,366	13.4	51.7	80,271	19.9	63.7	125,366	80,218	72,194	6,132,435	25,912	0.0042254
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_101010_CA	115,888	33.2	134.3	92,526	41.1	149.3	115,888	92,225	84,367	7,173,308	24,279	0.0033846
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_1124300_WA	109,466	20.9	103.4	83,749	26.8	117.6	109,466	83,645	76,157	6,471,962	21,532	0.0033270
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_Agam_BC	131,554	19.3	95.4	87,778	28.1	115.8	131,554	87,648	79,612	6,766,163	23,143	0.0034204
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C02_BCS	111,985	9.0	22.7	63,618	14.2	29.0	111,985	63,597	56,380	4,786,614	16,361	0.0034181
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C03_BCS	116,493	11.7	41.1	75,396	17.0	50.3	116,493	75,356	67,485	5,732,283	20,104	0.0035072
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C04_BCS	128,452	13.0	47.9	81,845	19.4	59.1	128,452	81,792	73,789	6,269,830	21,010	0.0033510
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C05_BCS	128,134	13.9	64.4	83,590	20.3	79.0	128,134	83,533	75,306	6,399,562	21,288	0.0033265
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C100_BCS	152,749	19.9	55.9	92,858	31.6	69.2	152,749	92,693	84,309	7,168,326	22,907	0.0031956
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C101_BCS	152,447	18.4	82.8	92,630	29.2	104.8	152,447	92,487	83,853	7,129,265	23,371	0.0032782
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C102_BCS	131,680	17.3	46.6	88,133	24.9	55.3	131,680	88,038	79,983	6,798,340	21,816	0.0032090
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C104_BCS	119,764	11.4	29.6	74,773	17.0	36.3	119,764	74,738	67,146	5,703,606	18,976	0.0033270
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC25_BCD	154,768	18.3	56.3	93,419	29.2	70.4	154,768	93,284	84,570	7,190,050	24,801	0.0034494
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC26_BCD	440,488	6.3	26.0	107,701	20.5	49.9	440,488	107,621	94,298	8,008,313	28,868	0.0036048
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC30_BCD	314,181	7.6	44.3	95,360	21.1	78.8	314,181	95,276	84,774	7,202,768	24,900	0.0034570
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC5_BCD	197,822	7.5	60.1	75,192	16.9	96.8	197,822	75,145	66,755	5,669,791	19,056	0.0033610
<i>S. cauliflora</i>	<i>S. cauliflora</i>	SIB_1122230_DAV	123,947	5.5	29.3	40,167	12.8	50.7	123,947	40,157	33,058	2,804,036	11,864	0.0042310
<i>S. cauliflora</i>	<i>S. cauliflora</i>	SIB_2036_GOM	127,391	11.3	36.4	71,374	18.6	47.3	127,391	71,315	63,094	5,358,510	17,312	0.0032307
		<b>AVERAGE</b>	157,171	13.9	76.4	80,744	22.6	99.0	157,171	80,658	71,425	6,068,313	21,810	0.0036393
		<b>STANDARD DEVIATION</b>	59,920	7.2	77.0	15,153	8.0	89.6	59,920	15,119	14,833	1,262,657	5,318	0.0006234

**Table S5.** Nucleotide diversity and error rate estimates per specimen based on the **PHYLO** matrix

<b>Morphological Species</b>	<b>PABSTE</b>	<b>RAD-seq data file ID</b>	<b>Nucleotide diversity (Pi)</b>	<b>Error Rate</b>
<i>Anthomastus sp</i>		PoC_p4_ARG	0.01295412	0.0029032
<i>Corallium sp</i>		COR_86121_NZ	0.01467291	0.00258843
<i>H. imperiale-laauiense*</i>		COR_64642_NZ	0.04406216	0.01630744
<i>H. imperiale-laauiense</i>		COR_83361_NZ	0.01399387	0.00269528
<i>H. imperiale-laauiense</i>		HEM_82674_NZ	0.01440962	0.00268885
<i>H. imperiale-laauiense</i>		HEM_86234_NZ	0.01676557	0.00254558
<i>H. imperiale-laauiense</i>		HEM_86286_NZ	0.01526906	0.00234296
<i>H. imperiale-laauiense</i>		PAR_86232_NZ	0.01633107	0.00217237
<i>Heteropolypus sp</i>		ANT_69654_NZ	0.00936378	0.00151989
<i>Heteropolypus sp</i>		ANT_85040_NZ	0.01122064	0.00146665
<i>Heteropolypus sp</i>		ANT_85662_NZ	0.01161827	0.00189506
<i>P. alisonae</i>	<i>P. alisonae</i>	PAR_66097_NZ	0.0127996	0.00205016
<i>P. arborea</i>	<i>P. arborea</i>	PAR_41780_NZ	0.01209999	0.00186767
<i>P. arborea</i>	<i>P. arborea</i>	PAR_TC16_03_CAN	0.01293451	0.00241858
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_0672_BC	0.01189447	0.00170062
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1007340_BCD	0.01285038	0.00223148
<i>P. arborea</i>	<i>P. pacifica</i>	PAR_1601_BC	0.01205019	0.00164477
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_063902_NES	0.01182997	0.00146894
<i>P. coralloides</i>	<i>P. coralloides</i>	PAR_12016_NES	0.01035726	0.00116583
<i>P. johnsoni</i>	<i>P. johnsoni</i>	PAR_20136_GOM	0.01159218	0.00137491
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_72152_NZ	0.01085919	0.00209157
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82260_NZ	0.01077562	0.00211998
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_82342_NZ	0.01082052	0.00225821
<i>P. kaupeka</i>	<i>P. kaupeka</i>	PAR_84804_NZ	0.01169178	0.00221668
<i>P. maunga</i>	<i>P. maunga</i>	PAR_11369_NZ	0.01225252	0.00176518
<i>P. stephencairnsi</i>	<i>P. sp. nov</i>	PAR_1007316_BCD	0.01488811	0.00295065
<i>P. stephencairnsi</i>	<i>P. sp. nov</i>	PAR_2344_BC	0.01260347	0.00188425
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_101010_CA	0.01063818	0.00134692
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_1124300_WA	0.01092481	0.00163497
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_Agam_BC	0.01117934	0.00151902
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C02_BCS	0.01180863	0.00194975
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C03_BCS	0.01129071	0.00175198
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C04_BCS	0.01098867	0.00171446
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C05_BCS	0.01117442	0.00167389
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C100_BCS	0.01063313	0.00155401
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C101_BCS	0.0109634	0.00160305
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C102_BCS	0.01060609	0.00159815
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_C104_BCS	0.01124495	0.00175065
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC25_BCD	0.01104859	0.00154584
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC26_BCD	0.01263196	0.00180015
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC30_BCD	0.01196811	0.00182162
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	PAR_FOC5_BCD	0.0119129	0.00186229
<i>S. cauliflora</i>		SIB_1122230_DAV	0.01525699	0.00328691
<i>S. cauliflora</i>		SIB_2036_GOM	0.01214983	0.00221517
		<b>AVERAGE</b>	0.01291599	0.00228532
		<b>SD</b>	0.00513429	0.00223806

\*Excluded from calculations due to low number of loci

**Table S6.** Nucleotide diversity and error rate estimates per species based on the **PHYLO** matrix

Morphological Species	Delimitation model PABSTE	Nucleotide diversity (Pi)			Per-site sequence error rate (Epsilon)		
		mean	SD	SE	mean	SD	SE
<i>Anthomastus sp</i>		0.01295412			0.00290320		
<i>Corallium sp</i>		0.01467291			0.00258843		
<i>H. imperiale-laauense</i>		0.01935775	0.01094005	0.00489254	0.00447727	0.00522005	0.00233448
<i>Heteropolypus sp</i>		0.01073423	0.00120338	0.00069477	0.00162720	0.00023350	0.00013481
<i>P. alisonae</i>	<i>P. alisonae</i>	0.01279960			0.00205016		
<i>P. arborea</i>	<i>P. arborea</i>	0.01245029	0.00056582	0.00040010	0.00193813	0.00041487	0.00029336
<i>P. arborea</i>	<i>P. pacifica</i>	0.01073423	0.00120338	0.00069477	0.00162720	0.00023350	0.00013481
<i>P. coralloides</i>	<i>P. coralloides</i>	0.01245029	0.00056582	0.00040010	0.00193813	0.00041487	0.00029336
<i>P. johnsoni</i>	<i>P. johnsoni</i>	0.01159218			0.00137491		
<i>P. kaupeka</i>	<i>P. kaupeka</i>	0.01241323	0.00175196	0.00087598	0.00229768	0.00048923	0.00024462
<i>P. maunga</i>	<i>P. maunga</i>	0.01225252			0.00176518		
<i>P. stephencairnsi</i>	<i>P. sp. nov</i>	0.01290646	0.00280248	0.00198165	0.00229281	0.00093033	0.00065784
<i>P. stephencairnsi</i>	<i>P. stephencairnsi</i>	0.01137950	0.00066172	0.00016543	0.00169174	0.00016364	0.00004091
<i>S. cauliflora</i>		0.01370341	0.00219709	0.00155358	0.00275104	0.00075783	0.00053587

**Table S7.** Predictions of # of RAD-tags in octocorals using PstI. Data for *Nematostella vectensis* obtained from the U.S. Joint Genome Institute (JGI-DOE) database. Data for *Acropora digitifera*, *Hydra vulgaris*, and *Alatina moseri* obtained from the U.S. National Center for Biotechnology Information (NCBI) WGS database. Observed frequency of recognition sequences and calculated probability based on a trinucleotide genome composition model were generated following the methodology described by Herrera et al. (2014). Octocoral genome size ranges were obtained by Luisa Dueñas from gorgoniid octocorals through flow cytometry at the Universidad de los Andes, Bogota, Colombia. Abbreviation: restriction sites (RS).

Cnidarians with sequenced genomes

Species	Common name	C-value	Genome size (Mbp)	Unambiguous	Observed frequency of PstI RS per bp	Prob. of PstI recognition site per bp based on trinucleotide model	
						0.00016661	0.00019608
<a href="#">Nematostella vectensis</a>	Starlet Anemone	297.39	293.40	0.00016661	0.00016661	0.00019608	0.00019608
<a href="#">Acropora digitifera</a>	Staghorn Coral	364.97	489.00	0.00021313	0.00021313	0.00022777	0.00022777
<a href="#">Hydra vulgaris</a>	Hydra	1189.96	0.3	0.00010830	0.00010830	0.00010871	0.00010871
<a href="#">Alatina moseri</a>	Sea Wasp	1544.15	0.5	0.00020617	0.00020617	0.00021637	0.00021637

Predictions of # of PstI RS in known octocoral genome size range

Octocoral C-value	Genome size (Mbp)	Predicted # of PstI RS based on <i>N. vectensis</i>		Predicted # of PstI RS based on <i>A. digitifera</i>		Predicted # of PstI RS based on <i>H. vulgaris</i>		Predicted # of PstI RS based on <i>A. moseri</i>	
		observed frequency	composition probability	observed frequency	composition probability	observed frequency	composition probability	observed frequency	composition probability
0.3	293.40	48,882.95	57,529.94	62,533.09	66,828.40	31,774.37	31,895.01	60,489.13	63,482.46
0.5	489.00	81,471.59	95,883.23	104,221.81	111,380.67	52,957.29	53,158.36	100,815.22	105,804.09

Predictions of # of PstI RAD-tags in known octocoral genome size range

Octocoral C-value	Genome size (Mbp)	Predicted # of PstI RS based on <i>N. vectensis</i>		Predicted # of PstI RS based on <i>A. digitifera</i>		Predicted # of PstI RS based on <i>H. vulgaris</i>		Predicted # of PstI RS based on <i>A. moseri</i>	
		observed frequency	composition probability	observed frequency	composition probability	observed frequency	composition probability	observed frequency	composition probability
0.3	293.40	97,765.91	115,059.87	125,066.17	133,656.80	63,548.75	63,790.03	120,978.26	126,964.91
0.5	489.00	162,943.18	191,766.45	208,443.62	222,761.34	105,914.58	106,316.71	201,630.43	211,608.19

**Table S8.** Collection information for all specimens in the clade AC with available mtMutS sequences

Species	ID	Genbank Number	Collecti on	Date	Locality	Depth (m)	Lat.	Lon.	Taxonomic remarks
<i>Anthomastus ritteri</i>		DQ302816	K. McFadden	1998	Off Pebble Beach: California: USA	300	36.58	-122.10	
<i>Anthomastus cf grandiflorus</i>		KC984603							
<i>Anthomastus robustus delta</i>		KC984604							
<i>Anthomastus sp</i>	p4		WHOI p4	2011	Patagonian shelf				
<i>Chelidonis aurantiaca mexicana</i>		KC788274							
<i>Corallium elatius</i>		AB700134							
<i>Corallium elatius</i>		AB700135							
<i>Corallium japonicum</i>		AB595189							
<i>Corallium kishinouyei</i>		GQ293300	USNM 1072441	2003	Off Laysan Island: Hawaii: USA	1490	25.70	-171.45	
<i>Corallium kishinouyei</i>		KC782353							
<i>Corallium konojoi</i>		AB595190							
<i>Corallium regale</i>		AF385321							
<i>Corallium rubrum</i>		AB700136							
<i>Corallium secundum</i>		GQ293303	USNM 1010758	2001	Off Maui: Hawaii: USA	240	20.88	-156.73	
<i>Corallium secundum</i>		KC782347							
<i>Corallium sp</i>	86121		NIWA 86121	2012	Kermadec Ridge; Colville ridge volcano; TANI213/18	380	-30.19	179.72	
<i>Corallium sp</i>	Coralliumsp56807		USNM 56807	1978	USA, Hawaii, Oahu Island, Makapuu Point	366	21.30	-157.53	
<i>Corallium sp</i>		KC788270			New Caledonia	470-621	-23.71	168.26	
<i>Corallium tortuosum</i>		GQ293306	USNM 1089600	2003					
<i>Hemicorallium ducale</i>		DQ297416							
<i>Hemicorallium ducale</i>		EF060050							
<i>Hemicorallium ducale</i>		EU293805							
<i>Hemicorallium ducale</i>		KC782352							
<i>Hemicorallium imperiale</i>		KC782355							
<i>Hemicorallium imperiale</i>	64642		NIWA 64642	2010	Kermadec Ridge; Rumble II East seamount cone; TAN1007/97; 1050		-35.42	178.65	
<i>Hemicorallium imperiale-lauense</i>	82674		NIWA 82674	2012	Kermadec Ridge; Site SM2aa, summit of Whakatane Seamount 878		-36.81	177.47	
<i>Hemicorallium imperiale-lauense</i>	83361		NIWA 83361	2012	Bay of Plenty; Site SM1b, Matatara Knoll; TANI206/168	948	-37.19	176.98	
<i>Hemicorallium imperiale-lauense</i>	86232		NIWA 86232	2012	Kermadec Ridge; Northeast pimple volcano; TANI213/22	483	-30.08	179.82	
<i>Hemicorallium imperiale-lauense</i>	86234		NIWA 86234	2012	Kermadec Ridge; Northeast pimple volcano; TANI213/22	483	-30.08	179.82	
<i>Hemicorallium imperiale-lauense</i>	86286		NIWA 86286	2012	Kermadec Ridge; Havre volcano; TANI213/30	860	-31.13	-179.05	
<i>Hemicorallium imperiale-lauense</i>	Clauense1072452		USNM 1072452	2003	USA, Hawaii, Laysan Island	1509	25.70	-171.44	
<i>Hemicorallium imperiale-lauense</i>		GQ293301	USNM 1071433	2004	Off Keahole Point: Hawaii Island: Hawaii: USA	867	19.80	-156.13	
<i>Hemicorallium imperiale-lauense</i>		GQ293302	USNM 1075800	2004	Pratt Seamount: Alaska: USA	1627	56.32	-142.44	
<i>Hemicorallium laauense</i>		KC782348							
<i>Hemicorallium laauense</i>		EF060051							
<i>Hemicorallium niobe</i>		KC788267							
<i>Hemicorallium niobe</i>	69654		NIWA 69654	2011	Chatam Rise; TRIP3306/78	495	-44.33	-177.22	
<i>Heteropolypus sp</i>	85040		NIWA 85040	2012	Chatam Rise; TANI208/22	2098	-42.59	179.42	
<i>Heteropolypus sp</i>	85662		NIWA 85662	2012	Chatam Rise; TANI208/61	1931	-42.59	179.59	
<i>Ideogorgia capensis</i>		GQ342502							
<i>Paragorgia allisonae</i>	66097		NIWA 66097	2008	Cambell Plateau; TRIP2718/50	875	-50.02	175.00	
<i>Paragorgia allisonae</i>	Palisomae3312		IX128349	1998	New Zealand, Otago Hill, 1171/25, Z9596	980	-48.02	166.08	type

Paragorgia alisonae	Palisonae3313	NIWA	3313	1998	New Zealand, Otara Hill, 1171/25, Z9596	980	-48.02	166.08	type
Paragorgia alisonae	Palisonae3315	NIWA	3315	1998	New Zealand, Otara Hill, 1171/24, Z9595	940	-48.02	166.10	type
Paragorgia alisonae	Palisonae3316	NIWA	3316	1997	New Zealand, TAN9713/037, Z8981	1041	-44.96	174.19	type
Paragorgia alisonae	Palisonae3317	NIWA	3317	1998	New Zealand, TRIP1171/12, Z9583	935	-48.03	166.10	type
Paragorgia alisonae	Palisonae42002	NIWA	42002	2008	New Zealand, TRIP2551/258	930.0	-44.7850	-176.583333333333	
Paragorgia alisonae	Palisonae44606	NIWA	44606	2007	New Zealand, TRIP2521/9	1068	-44.7433	-177.05333333	
Paragorgia alisonae	ParagospValpo046	Valpo046			Chile, Valparaiso, deep seamount				
<i>Paragorgia aotearoa</i>		GQ293305	NIWA	3325	New Zealand, Mt. Muck (Box Hill Complex), TAN9609/40	700	-42.83	176.92	type
Paragorgia arborea	0672	RBCM	011-00067-002	2004	British Columbia, VE14280		53.33	-135.66	
Paragorgia arborea	1601	RBCM	011-00160-001	2009	British Columbia, VE14444	695	53.31	-135.58	
Paragorgia arborea	41780	JX124558	NIWA	41870	New Zealand, TRIP2617/120	600	-44.52	175.78	
Paragorgia arborea	1007340	JX124556	USNM	1007340	British Columbia, Vancouver Island	1168	48.44	-126.38	
Paragorgia arborea	Paragosp1014919	JX124578	USNM	1014919	Davidson Seamount, California, USA	1313	35.70	-122.70	Sanchez 2005
Paragorgia arborea	Paragosp1027060	JX124560	USNM	1027060	Pioneer Seamount, South of farallon Islands, California, USA	1712	37.40	-123.44	
Paragorgia arborea	Paragosp1075738	JX124526	USNM	1075738	Dickins Seamount, Gulf of Alaska, USA	760	54.55	-136.84	
Paragorgia arborea	Paragosp1075744	JX124565	USNM	1075744	Dickins Seamount, Gulf of Alaska, USA	851	54.51	-136.91	
Paragorgia arborea	Paragosp1075745	JX124602	USNM	1075745	Dickins Seamount, Gulf of Alaska, USA	849	54.51	-136.91	
Paragorgia arborea	Paragosp1075746	JX124540	USNM	1075746	Welker Seamount, Gulf of Alaska, USA	780	55.05	-140.31	
Paragorgia arborea	Paragosp1075753	JX124527	USNM	1075753	Welker Seamount, Gulf of Alaska, USA	1112	55.07	-140.41	
Paragorgia arborea	Paragosp1075754	JX124593	USNM	1075754	Welker Seamount, Gulf of Alaska, USA	1084	55.07	-140.41	
Paragorgia arborea	Paragosp1075760	JX124530	USNM	1075760	Pratt Seamount, Gulf of Alaska, USA	959	56.17	-142.70	
Paragorgia arborea	Paragosp1075761	JX124576	USNM	1075761	Pratt Seamount, Gulf of Alaska, USA	941	56.17	-142.70	
Paragorgia arborea	Paragosp1075766	JX124541	USNM	1075766	Welker Seamount, Gulf of Alaska, USA	1114	55.07	-140.41	
Paragorgia arborea	Paragosp17971	JX124592	NIWA	17971	New Zealand, 1172/06, Z9566	1235	-44.80	-177.12	
Paragorgia arborea	Paragosp200701	JX124587	B. Stone	20070178B01	Gulf of Alaska, USA	867	55.91	-154.02	
Paragorgia arborea	Paragosp44156	JX124563	NIWA	44156	New Zealand, TRIP2416/54	720-741	-47.47	177.02	
Paragorgia arborea	Paragosp46314	JX124594	NIWA	46314	New Zealand, TRIP2324/48	843-998	-50.05	174.73	
Paragorgia arborea	Paragosp46315	JX124569	NIWA	46315	New Zealand, TRIP2571/65	888-1011	-47.55	177.86	
Paragorgia arborea	Paragosp46316	JX124573	NIWA	46316	New Zealand, TRIP2617/120	600	-44.52	175.77	
Paragorgia arborea	Paragosp46317	JX124603	NIWA	46317	New Zealand, TRIP2494/13	931-1021	-47.58	177.78	
Paragorgia arborea	Paragosp46318	JX124583	NIWA	46318	New Zealand, TRIP2551/254	794-987	-44.73	-177.04	
Paragorgia arborea	Paragosp46319	JX124595	NIWA	46319	New Zealand, TRIP2614		-49.50	176.00	
Paragorgia arborea	Paragosp46377	JX124549	NIWA	46377	New Zealand, TRIP2571/53	952-1111	-50.00	176.06	
Paragorgia arborea	Paragosp56389		USNM	56389	USA, Hawaii, Bushnell Seamount	1920	18.55	-155.44	
Paragorgia arborea	ParagospDAV11	JX124577	A. Andre	DAV11	Davidson Seamount, California, USA	1313	35.75	-122.70	
Paragorgia arborea	ParagospDAV13	JX124542	A. Andre	DAV13	Davidson Seamount, California, USA	1313	35.75	-122.70	
Paragorgia arborea	Paragospnizinski	JX124547	USNM	1120444	off Maryland, USA	400	37.06	-74.62	
Paragorgia arborea	Parboreal100758	JX124584	USNM	100758	Aleutian Islands	52.00	52.00	-170.00	
Paragorgia arborea	Parboreal100817	JX124539	USNM	100817	Atka Island, Andreanof Islands, Aleutian Islands	53.00	53.00	-174.00	
Paragorgia arborea	Parboreal100818	JX124597	USNM	100818	Semisopchnoi Island, Rat Islands, Aleutian Islands	52.17	52.17	179.72	
Paragorgia arborea	Parboreal100843	JX124529	USNM	100843	Tanaga Island, Andreanof Islands, Aleutian Islands	52.00	52.00	-178.00	
Paragorgia arborea	Parboreal100846	JX124538	USNM	100846	Yunaska Island, Islands of Four Mountains, Aleutian Islands	53.00	53.00	-171.00	
Paragorgia arborea	Parboreal1010787	JX124528	USNM	1010787	Norfolk Canyon, Virginia, USA	375-489	37.07	-74.66	
Paragorgia arborea	Parboreal1011097	JX124545	USNM	1011097	Buldir Reef, Rat Islands, Aleutian Islands	160	51.96	176.83	
Paragorgia arborea	Parboreal1011360	JX124582	USNM	1011360	off Ummak Island, Fox Islands, Aleutian Islands	102	53.68	-169.11	

<i>Paragorgia arborea</i>	Parborea1092764	JX124589	USNM	1092764	2000	East of Virginia Beach, Virginia, USA	375-489	37.07	-74.66	Sanchez 2005
<i>Paragorgia arborea</i>	Parborea1092765	JX124520	USNM	1092765	2000	East of Virginia Beach, Virginia, USA	375-489	37.07	-74.66	
<i>Paragorgia arborea</i>	Parborea1092766	JX124554	USNM	1092766	2000	East of Virginia Beach, Virginia, USA	375-489	37.07	-74.66	
<i>Paragorgia arborea</i>	Parborea17969	JX124607	NIWA	17969	2002	New Zealand, 1621/18, Z11010	900	-44.74	-177.19	
<i>Paragorgia arborea</i>	Parborea17970	JX124605	NIWA	17970	2001	New Zealand, AEX0101/80, Z10956	753	-44.74	-177.19	
<i>Paragorgia arborea</i>	Parborea25527	JX124548	NIWA	25527	2004	New Zealand, TAN0408/23	826	-42.83	177.42	
<i>Paragorgia arborea</i>	Parborea28123	JX124546	NIWA	28123	2000	New Zealand, 1390/12, Z11161	872	-47.31	165.83	
<i>Paragorgia arborea</i>	Parborea28154	JX124553	NIWA	28154	1981	New Zealand, T16	427	-43.35	178.66	
<i>Paragorgia arborea</i>	Parborea28156	JX124610	NIWA	28156	2002	New Zealand, 1621/08, Z11008	920	-33.92	167.92	
<i>Paragorgia arborea</i>	Parborea28157	JX124531	NIWA	28157	1999	New Zealand, TRIP1223/29	959	-44.58	-177.88	
<i>Paragorgia arborea</i>	Parborea28158	JX124566	NIWA	28158	2001	New Zealand, AEX0101/80, Z10907	753	-44.74	-177.18	
<i>Paragorgia arborea</i>	Parborea28160	JX124523	NIWA	28160	2001	New Zealand	753	-44.74	-176.81	
<i>Paragorgia arborea</i>	Parborea28161	JX124568	NIWA	28161	2001	New Zealand, AEX0101/80, Z10920	753	-44.74	-177.19	
<i>Paragorgia arborea</i>	Parborea28392	JX124575	NIWA	28392	2001	New Zealand, AEX0101/80, Z10956	753	-44.74	-176.81	
<i>Paragorgia arborea</i>	Parborea28422	JX124601	NIWA	28422	2001	New Zealand, AEX0101/80, Z10920	753	-44.74	-176.81	
<i>Paragorgia arborea</i>	Parborea28425	JX124550	NIWA	28425	1997	New Zealand, TAN9713/52, Z8979	858	-44.45	-179.96	
<i>Paragorgia arborea</i>	Parborea3308	JX124552	NIWA	3308	2002	New Zealand, Z10987	1225	-33.93	167.92	Sanchez 2005
<i>Paragorgia arborea</i>	Parborea3309	JX124535	NIWA	3309	2002	New Zealand, Z11009	955	-33.93	167.91	Sanchez 2005
<i>Paragorgia arborea</i>	Parborea3310	GQ293311	NIWA	3310	1999	New Zealand, Z9862	687	-44.75	174.82	Sanchez 2005
<i>Paragorgia arborea</i>	Parborea3311	JX124525	NIWA	3311	1996	New Zealand, Southern Havre trough, X700	1525	-35.84	177.91	Sanchez 2005
<i>Paragorgia arborea</i>	Parborea33559	JX124559	USNM	33559	1878	Fishing Banks, North Carolina, USA	457	36.00	-74.00	
<i>Paragorgia arborea</i>	Parborea33561	JX124562	USNM	33561		Off NE North America, USA				
<i>Paragorgia arborea</i>	Parborea4089	JX124591	USNM	4089		Sable Island, 50 Mile E Of E Light, Nova Scotia, Canada	512	43.90	-58.80	
<i>Paragorgia arborea</i>	Parborea4091	JX124579	USNM	4091	1879	Banquereau Bank, Nova Scotia, Canada	366	44.58	-57.68	
<i>Paragorgia arborea</i>	Parborea4178B	JX124524	USNM	1123932	2002	South of Trinity Islands, Aleutian Islands	746	55.87	-154.06	
<i>Paragorgia arborea</i>	Parborea41829	JX124585	NIWA	41829	2006	New Zealand, TRIP2324/76	1044	-47.25	178.33	
<i>Paragorgia arborea</i>	Parborea41854	JX124611	NIWA	41854	2007	New Zealand, TRIP2494/10	867-986	-47.53	177.87	
<i>Paragorgia arborea</i>	Parborea41999	JX124588	NIWA	41999	2007	New Zealand, TRIP2551/50	1203-121	-44.50	-174.79	
<i>Paragorgia arborea</i>	Parborea42001	JX124574	NIWA	42001	2007	New Zealand, TRIP2551/55	1283-131	-44.50	-174.82	
<i>Paragorgia arborea</i>	Parborea4238	JX124608	USNM	4238	1879	Banquereau Bank, South Of, Nova Scotia, Canada	457	43.90	-58.67	
<i>Paragorgia arborea</i>	Parborea4242	JX124567	USNM	4242	1879	Grand Banks, W Part Of, Newfoundland, Canada	1106-131	-46.91	171.88	
<i>Paragorgia arborea</i>	Parborea44608	JX124537	NIWA	44608	2007	New Zealand, TRIP2506/81	870-967	-47.53	177.92	
<i>Paragorgia arborea</i>	Parborea44609	JX124534	NIWA	44609	2007	New Zealand, TRIP2506/135	457	43.42	-60.00	
<i>Paragorgia arborea</i>	Parborea4569	JX124596	USNM	4569	1879	Sable Island Bank, Nova Scotia, Canada	750-855	-46.48	170.60	
<i>Paragorgia arborea</i>	Parborea46320	JX124570	NIWA	46320	2008	New Zealand, TRIP2320/70	480	38.17	-73.84	
<i>Paragorgia arborea</i>	Parborea50890	JX124521	USNM	50890	1927	Burdwood Bank, S Of Falkland Islands, Scotia Sea	680-370	40.38	-67.66	
<i>Paragorgia arborea</i>	Parborea80838	JX124544	USNM	80838	1979	Baltimore Canyon, Off Eastern Shore, Maryland, USA	613-430	40.38	-67.66	
<i>Paragorgia arborea</i>	Parborea80936	JX124543	USNM	80936	1979	Lydonia Canyon, Massachusetts, USA	843	51.81	-173.83	
<i>Paragorgia arborea</i>	Parborea80937	GQ293312	USNM	80937	1979	Lydonia Canyon, Massachusetts, USA	843	51.81	-173.83	
<i>Paragorgia arborea</i>	Parborea2095271	JX124532	USNM	1123936	2004	Amlia Island, Andreeof Islands, Aleutian Islands	1269	51.51	-177.04	
<i>Paragorgia arborea</i>	Parborea2095272	JX124580	USNM	1123935	2004	Amlia Island, Andreeof Islands, Aleutian Islands	747	51.72	-179.58	
<i>Paragorgia arborea</i>	Parborea2099211	JX124604	USNM	1123937	2004	Adak Canyon, Andreeof Islands, Aleutian Islands	857	51.68	-179.58	
<i>Paragorgia arborea</i>	Parborea210441	JX124536	USNM	1123938	2004	Amchitka Pass, Andreeof Islands, Aleutian Islands	480	37.67	-74.65	
<i>Paragorgia arborea</i>	Parborea210462	JX124555	USNM	1123934	2004	Amchitka Pass, Andreeof Islands, Aleutian Islands				
<i>Paragorgia arborea</i>	ParboreaMCZ1572	JX124606	MCZ	15721	2002	Atlantic Ocean				



<i>Paragorgia arborea</i>	ParboreaMCZ2805	JX124551	MCZ	28057	2001	Nantucket Island, Massachusetts, USA	156	41.97	-65.87
<i>Paragorgia arborea</i>	ParboreaMCZ2869	JX124561	MCZ	28697	1878	off Maine, USA	245	42.60	-65.73
<i>Paragorgia arborea</i>	ParboreaMCZ5124	JX124600	MCZ	51244	1979	Georges Bank, Massachusetts, USA	700	41.00	-67.00
<i>Paragorgia arborea</i>	ParboreaMNH0411	JX124609	MNH	0411	1997	France, North Atlantic Ocean, France	700	48.83	-11.33
<i>Paragorgia arborea</i>	ParboreaMNH04	JX124564	MNH	412	2002	off Norway	66.70	66.70	11.60
<i>Paragorgia arborea</i>	ParboreaMNH04	JX124572	MNH	422	2002	Tromsø fjord, Norway	63.50	63.50	10.50
<i>Paragorgia arborea</i>	ParboreaP33560	JX124572	USNM	33560	2002	Fishing Banks, North Carolina, USA	45.00	45.00	-53.50
<i>Paragorgia arborea</i>	ParboreaT661A10	JX124590	USNM	1122237	2002	Rodriguez Seamount, California, USA	894.5	34.06	-121.08
<i>Paragorgia arborea</i>	ParboreaT662A28	JX124522	USNM	1122240	2002	San Juan Seamount, California, USA	1362.9	32.97	-121.04
<i>Paragorgia arborea</i>	ParboreaT662A29	JX124586	USNM	1122233	2002	San Juan Seamount, California, USA	1360.8	32.97	-121.04
<i>Paragorgia arborea</i>	ParboreaZ11166	JX124533	NIWA	76238	2007	New Zealand	891	-44.44	175.54
<i>Paragorgia arborea</i>	ParboreaZC0706	JX124598	B. Stone	ZC0706ROV01	2005	Zhemchug Canyon, Bering Sea	171	-47.54	177.93
<i>Paragorgia arborea</i>	PcfarboreaJapan	JX124557	WPMNH		2005	Off Yaizu-shi, Shizuoka Pref., Japan	760-800	33.00	138.40
<i>Paragorgia arborea</i>	Ppacific1016320	JX124581	USNM	1016320	2002	British Columbia, Canada	1152-1153	70	-133.42
<i>Paragorgia arborea</i>	TC16_03		WHOI	HBI1302_TC016	2013	NE US Canyons; Munson Canyon; TowCam 16	540	40.54	-67.01
<i>Paragorgia cf. dendroides</i>	Pcdendro98788		USNM	98788	1996	USA, Hawaii, Lanai Island, Keenapapa Point, SW of Point	1007	20.78	-157.15
<i>Paragorgia cf. dendroides</i>	Pcdendro98792		USNM	98792	1996	USA, Hawaii, Lanai Island, Keenapapa Point, SW of Point	1018	20.78	-157.15
<i>Paragorgia cf. dendroides</i>	PcdendroT662A30		USNM	1122228	200?	USA, California, San Juan Seamount	1237.6	32.97	-121.03
<i>Paragorgia cf. johnsoni</i>									
<i>Paragorgia cf. johnsoni</i>	Pcfregalis1072337		USNM	1072337	2003	USA, Hawaii, Pioneer Bank	1211	25.81	-173.50
<i>Paragorgia coralloides</i>	06390		WHOI	REH112-5	2005	New England Seamounts; Rehobot Seamount; H13	1821	37.46	-59.95
<i>Paragorgia coralloides</i>	12016		WHOI	leftover sieving	2003	New England Seamounts; Manning Seamount, station 4; AD38	2000	38.23	-60.46
<i>Paragorgia coralloides</i>	Pfcorallo98785	JX128350	USNM	98785	1995	East Pacific Rise, off Mexico	1950	12.73	-102.60
<i>Paragorgia dendroides</i>	Pdendroid1072362		USNM	1072362	2003	USA, Hawaii, Necker Island, Seamount East of Island	1536	23.30	-163.70
<i>Paragorgia johnsoni</i>	20136	KC984607	TU-WHC	0909-Oct1	2009	Gulf of Mexico; MC751; J2-464	438	28.19	-89.80
<i>Paragorgia johnsoni</i>	Paragosp100898		USNM	100898	2000	USA, North Atlantic Ocean, South of Georges Bank	608	39.86	-67.42
<i>Paragorgia johnsoni</i>	Pjohnsoni73767	JX128348	USNM	73767	1984	Little Bahama Bank, Bahamas	608	27.10	-79.70
<i>Paragorgia johnsoni</i>									
<i>Paragorgia kaupeka</i>	72152		NIWA	72152	2011	Kermadec Ridge; Clark Seamount, chimney field, north cone;	877	-36.45	177.84
<i>Paragorgia kaupeka</i>	82260		NIWA	82260	2012	Kermadec Ridge; Site SM3a, summit of Clark Seamount; TAN 850	850	-36.45	177.84
<i>Paragorgia kaupeka</i>	82342		NIWA	82342	2012	Kermadec Ridge; Site SM3a, Clark Seamount; TAN1206/40	1100	-36.45	177.84
<i>Paragorgia kaupeka</i>	84804		NIWA	84804	2005	Kermadec Ridge; Clark Seamount; KOK0506/12	870	-36.45	177.84
<i>Paragorgia kaupeka</i>	Pkaupeka3320	GQ293313	NIWA	3320	1989	New Zealand, X152	820	-36.16	176.81
<i>Paragorgia maunga</i>	64980		NIWA	64980	2010	Kermadec Ridge; Silent II seamount; TAN1007/120	772	-35.17	178.89
<i>Paragorgia maunga</i>	Pmaunga28393		NIWA	28393	1999	New Zealand, Z9779	1121	-34.12	174.90
<i>Paragorgia maunga</i>	Pmaunga3322		NIWA	3322	2002	New Zealand, Wanganella Bank, TRIP, Z10989	1082	-33.89	167.94
<i>Paragorgia maunga</i>	Pmaunga3323		NIWA	3323	1999	New Zealand, Z9779	1121	-34.12	174.90
<i>Paragorgia regalis</i>	ParagospT629A6		USNM	1122239	200?	USA, California, Rodriguez Seamount	1843.8	33.95	-121.14
<i>Paragorgia regalis</i>	Pcdendro98789		USNM	98789	1996	USA, Hawaii, Lanai Island, Keenapapa Point, SW of Point	1018	20.78	-157.15
<i>Paragorgia regalis</i>	PdendroidT630A5		USNM	1122192	200?	USA, California, Rodriguez Seamount	1031.8	34.00	-121.10
<i>Paragorgia regalis</i>	Pregalis1027063		USNM	1027063	2003	USA, California, Rodriguez Seamount, West of San Miguel Pa	1840	33.95	-121.14
<i>Paragorgia regalis</i>	Pregalis1072338		USNM	1072338	2003	USA, Hawaii, Lanai Island, SE of Island	1136	25.67	-171.41
<i>Paragorgia regalis</i>	Pregalis1072339		USNM	1072339	2003	USA, Hawaii, Lanai Island, SE of Island	1743.7	25.57	-173.51
<i>Paragorgia regalis</i>	Pregalis1072340		USNM	1072340	2004	USA, Hawaii, Pioneer Bank	1744.7	25.57	-173.51
<i>Paragorgia regalis</i>									
<i>Paragorgia regalis</i>		GQ293307	USNM	1014743	2003	Cross Seamount; Hawaii: USA	452	19.74	-158.30

Paragorgia regalis	JQ241244	USNM	1007354	2001	Canada, British Columbia, Vancouver Island	1168	48.44	-126.38
Paragorgia sp	Paragosp1007354	USNM	1007354	2001	Canada, British Columbia, Vancouver Island	1168	48.44	-126.38
Paragorgia sp	Paragosp1011093	USNM	1011093	2002	USA, Bering Sea, Forrester Island	601-800	55.40	-134.83
Paragorgia sp	Paragosp1011094	USNM	1011094	2002	USA, Bering Sea, East of Kodiak Island	601-836	58.22	-148.70
Paragorgia sp	Paragosp1011095	USNM	1011095	2002	USA, Bering Sea, Alaska, Alexander Archipelago, Baranof Isl	601-715	57.19	-136.24
Paragorgia sp	Paragosp1027079	USNM	1027079	2002	USA, California, Rodriguez Seamount, West of San Miguel Pa	1030	34.05	-121.10
Paragorgia sp	Paragosp1071233	USNM	1071233	2004	USA, Hawaii, Cross Seamount	410	18.73	-158.26
Paragorgia sp	Paragosp1071440	USNM	1071440	2004	USA, Hawaii, Cross Seamount	427.51	18.73	-158.26
Paragorgia sp	Paragosp1071441	USNM	1071441	2004	USA, Hawaii, Cross Seamount	427.51	18.73	-158.26
Paragorgia sp	Paragosp1072336	USNM	1072336	2003	USA, Hawaii, Raita Bank	573	25.63	-169.32
Paragorgia sp	Paragosp1075392	USNM	1075392	2004	USA, Gulf of Alaska, Alaska, Giacomini Seamount	733	56.42	-146.37
Paragorgia sp	Paragosp1075750	USNM	1075750	2004	USA, Gulf of Alaska, Alaska, Welker Seamount	718	55.05	-140.31
Paragorgia sp	Paragosp1075751	USNM	1075751	2004	USA, Gulf of Alaska, Alaska, Welker Seamount	782	55.05	-140.31
Paragorgia sp	Paragosp1075752	USNM	1075752	2004	USA, Gulf of Alaska, Alaska, Welker Seamount	1119	55.06	-140.41
Paragorgia sp	Paragosp1075755	USNM	1075755	2004	USA, Gulf of Alaska, Alaska, Welker Seamount	1050	55.06	-140.41
Paragorgia sp	Paragosp1075756	USNM	1075756	2004	USA, Gulf of Alaska, Alaska, Welker Seamount	1050	55.06	-140.41
Paragorgia sp	Paragosp1075757	USNM	1075757	2004	USA, Gulf of Alaska, Alaska, Pratt Seamount	1093	56.30	-142.47
Paragorgia sp	Paragosp1075759	USNM	1075759	2004	USA, Gulf of Alaska, Alaska, Pratt Seamount	1069	56.17	-142.70
Paragorgia sp	Paragosp1075764	USNM	1075764	2004	USA, Gulf of Alaska, Alaska, Pratt Seamount	920	56.17	-142.70
Paragorgia sp	Paragosp1075769	USNM	1075769	2004	USA, Gulf of Alaska, Alaska, Giacomini Seamount	730	56.42	-146.37
Paragorgia sp	Paragosp1082595	USNM	1082595	2002	USA, Gulf of Alaska, Alaska, Murray Seamount	855	53.89	-148.53
Paragorgia sp	Paragosp1082600	USNM	1082600	2002	USA, Gulf of Alaska, Alaska, Murray Seamount	1376	53.99	-148.50
Paragorgia sp	Paragosp1082644	USNM	1082644	2002	USA, Washington, Warwick Seamount	768	48.05	-132.74
Paragorgia sp	Paragosp1200601	Stone-Sea	1200601	2006	Gulf of Alaska	741	53.98	-162.85
Paragorgia sp	Paragosp121	USNM	1122305	2004	British Columbia, Canada	549	53.73	-163.98
<i>Paragorgia</i> sp	JX128347	USNM	1122305	2004	British Columbia, Canada	549	53.73	-163.98
Paragorgia sp	Paragosp1310601	Stone-Sea	1310601	2006	Gulf of Alaska			
Paragorgia sp	Paragosp159	USNM	1122302	2003	Canada, British Columbia			
Paragorgia sp	Paragosp165	USNM	1122303	2003	Canada, British Columbia, Brooks Peninsula			
Paragorgia sp	Paragosp27294	YPM	27294	2000	Bear Seamount		39.92	-67.44
Paragorgia sp	Paragosp28905	YPM	28905	2003	USA, Atlantic Ocean, Muir Seamount	1713	33.85	-62.66
Paragorgia sp	Paragosp28911	YPM	28911	2003	USA, Atlantic Ocean, Manning Seamount	1550	38.22	-60.46
Paragorgia sp	Paragosp28921	YPM	28921	2003	USA, Atlantic Ocean, Manning Seamount	1579	38.21	-60.53
Paragorgia sp	Paragosp28946	YPM	28946	2003	USA, Atlantic Ocean, Manning Seamount	1597	38.20	-60.53
Paragorgia sp	Paragosp291	USNM	1122306	2004	Canada, British Columbia			
Paragorgia sp	Paragosp34786	YPM	34786	2004	Atlantic Ocean, Manning Seamount, on summit	1336	38.22	-60.51
Paragorgia sp	Paragosp35381	YPM	35381	2004	USA, Manning Seamount, on summit	1337	38.22	-60.51
Paragorgia sp	Paragosp36781	YPM	36781	2004	Bear Seamount, South rim of table top peak	1428-16:	39.87	-67.36
Paragorgia sp	Paragosp36910C	YPM	36910C	2004	Bear Seamount, South rim of table top peak	1428-16:	39.87	-67.36
Paragorgia sp	Paragosp37148	YPM	37148	2003	USA, Manning Seamount	1483	38.26	-60.55
Paragorgia sp	Paragosp38636	YPM	38636	2004	Bear Seamount, South rim of table top peak	1428-16:	39.87	-67.36
Paragorgia sp	Paragosp41849	NIWA	41849	2007	New Zealand, TRIP2494/97	1155.0	-47.0100	175.580000000000
Paragorgia sp	Paragosp44607	NIWA	44607	2007	New Zealand, TRIP2506/24	858.0	-50.0516	174.7150000000
Paragorgia sp	Paragosp54830	USNM	54830	1974	USA, Florida, Straits of Florida, Off Delray Beach	743-761	26.38	-79.60
Paragorgia sp	Paragosp56615	USNM	56615	1974	USA, Florida, Straits of Florida, Off Mile Beach	770-660	25.71	-79.79
Paragorgia sp	Paragosp56690	USNM	56690		USA, Hawaii, Oahu Island, Makapuu Point	366		

Paragorgia sp	Paragospn32830	NIWA	32830	2005	New Zealand, Tangaroa Seamount, P629-4B, KOK0507/4	790	-36.3284	178.0359955
Paragorgia sp	ParagospT665A3	USNM	1122225	2007	USA, California, San Juan Seamount	706.6	33.11	-120.96
Paragorgia sp	Parborea28423	NIWA	28423	1998	New Zealand, 1152/48, Z9275	660	-34.18	162.65
Paragorgia sp	Parborea28717	YPM	28717	2003	Manning Seamount	1372	38.22	-61.51
Paragorgia sp	PefaoteaT668A3	USNM	1122226	2007	USA, California, Little Joe Seamount	2397.8	31.89	-120.05
Paragorgia sp	PefaoteaT669A15	USNM	1122227	2007	USA, California, San Marcos Seamount	2061.7	32.64	-121.51
Paragorgia sp	PcfstepheT665A4	USNM	1122235	2007	USA, California, San Juan Seamount	720.5	33.11	-120.96
Paragorgia sp	PcfwahineT627A3	USNM	1122238	2007	USA, California, Pioneer Seamount	1771.5	37.40	-123.44
Paragorgia sp	PcfwahineT630A6	USNM	1122234	2007	USA, California, Rodriguez Seamount	1031.9	34.00	-121.10
Paragorgia sp	PcfyutliT663A1614	USNM	1122231	2007	USA, California, Northeast Bank	546.6	32.32	-119.61
Paragorgia sp								
Paragorgia stephencairnsi	2344	RBCM	010-00234-004	2004	British Columbia, VE13978	1194	53.37	-133.31
Paragorgia stephencairnsi	101010	USNM	1157074	2008	California; Piggy Bank, southern California; DW-026-02	283	33.92	-119.47
Paragorgia stephencairnsi	1007316	USNM	1007316	2001	British Columbia; Vancouver Island	1168	48.44	-126.38
Paragorgia stephencairnsi	1124300	USNM	1124300	2006	British Columbia; Vancouver Island, Ohlat Island; OC 06/952	188	48.83	-125.13
Paragorgia stephencairnsi	Agam	WHOI	Agam	2012	British Columbia; Agamemnon Channel	32	49.72	-124.05
Paragorgia stephencairnsi	C02	WHOI	C02	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
Paragorgia stephencairnsi	C03	WHOI	C03	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
Paragorgia stephencairnsi	C04	WHOI	C04	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
Paragorgia stephencairnsi	C05	WHOI	C05	2013	British Columbia; Agamemnon Channel; Dive02	41	49.74	-124.03
Paragorgia stephencairnsi	C100	WHOI	C100	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
Paragorgia stephencairnsi	C101	WHOI	C101	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
Paragorgia stephencairnsi	C102	WHOI	C102	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
Paragorgia stephencairnsi	C104	WHOI	C104	2013	British Columbia; Vancouver Island, Tahsis Inlet; Dive07	40	49.86	-126.67
Paragorgia stephencairnsi	FOC25	DFO	25	2012	British Columbia; W of Graham Island; 2012-65	204	53.31	-133.03
Paragorgia stephencairnsi	FOC26	DFO	26	2012	British Columbia; W of Graham Island; 2012-65	221	53.30	-133.04
Paragorgia stephencairnsi	FOC30	DFO	30	2012	British Columbia; W of Graham Island; 2012-65	318	53.48	-133.07
Paragorgia stephencairnsi	FOC5	DFO	5	2009	British Columbia; E of Graham Island; 2009-47	201	52.13	-128.90
Paragorgia stephencairnsi	Paragosp1075741	USNM	1075741	2004	USA, Gulf of Alaska, Alaska, Dickens Seamount	751	54.55	-136.84
Paragorgia stephencairnsi	Paragosp1092785	USNM	1092785	2005	USA, North Pacific Ocean, Alexander Archipelago, Baranof I; 171	56.19	-135.10	
Paragorgia stephencairnsi	Paragosp200601	Stone-Sea	200601106B01	2006	Gulf of Alaska	479	55.40	-134.83
Paragorgia stephencairnsi	Paragosp77	USNM	1122304	2004	Canada, British Columbia, Brooks Peninsula	49.94	-128.06	
Paragorgia stephencairnsi	Parborea41106	USNM	1123931	2004	USA, Bering Sea, GOA	417	55.37	-134.78
Paragorgia stephencairnsi	Parborea411081	USNM	1123930	2004	USA, Bering Sea, GOA	427	54.47	-133.97
Paragorgia stephencairnsi	ParboreaNew100	USNM	1124301	2006	Canada, British Columbia, Vancouver Island, Barkley Sound	270.22	48.26	-125.01
Paragorgia stephencairnsi	ParboreaNew545	USNM	1124298	2006	Canada, British Columbia, Vancouver Island, Barkley Sound	309.5	48.15	-125.07
Paragorgia stephencairnsi		CAS	190438	2010	California, Farallon Escarpment	424	37.74	-123.19
<i>Paragorgia walinae</i>	Pwahine3326	NIWA	3326	2001	New Zealand, Diabolical seamount, TAN0104/113	900	-42.79	179.99 type
Paragorgia whero	Pwhero3436	NIWA	3436	1998	New Zealand, TRIP1171/12, Z9583	935	-48.03	166.10 type
<i>Paragorgia yutlinax</i>	Pyutlinux1073480	USNM	1073480	2003	Off Vancouver Isl., British Columbia, Canada	846-861	50.23	-128.58 type
Paraminabea aldersladei								
Paraminabea aldersladei								
Paraminabea aldersladei								
Sibogorgia cauliflora	2036	KC984605	TU-WHC 2036-Oct1	2009	Gulf of Mexico; DC583; J2-454	2440	28.39	-87.39
Sibogorgia cauliflora	1122230	GQ293310	USNM 1122230	2006	California; Davidson seamount; dive 945	2502	35.83	-122.61 type

<i>Sibogorgia cauliflora</i>	Sibogasp1T947A9	GQ293317	USNM	1122229	2006	Davidson Seamount, California, USA	3042.4	35.63	-122.83
<i>Sibogorgia cauliflora</i>		GQ293308	USNM	1081143	2004	Derrickson Seamount, Alaska: USA	2766	52.98	-161.25
<i>Sibogorgia cauliflora</i>		GQ293309	USNM	54831	1968	Straits of Florida: Havana: Cuba	1638-17:23.55		-82.78
<i>Sibogorgia dennisgordoni</i>		GQ293316	NIWA	3329	1998	New Zealand, 1124/70, Z9228	820	-36.69	176.46
<i>Sphaerocleria flammicerebra</i>		JX203765							

Acronyms as follows: National Museum of Natural History, Smithsonian Institution, USA (USNM); The National Institute of Water and Atmospheric Research, New Zealand (NIWA); Museum of Comparative Zoology, Harvard University, USA (MCZ); Muséum National d'Histoire Naturelle, Paris, France (MNHN); Senckenberg Research Institute And Natural History Museum Frankfurt, Germany (SMF); Uppsala University Evolutionsmuseet, Sweden (UUZM); Wakayama Prefectural Museum of Natural History, Japan (WPMNH); Yale Peabody Museum of Natural History, USA (YPM), Department of Fisheries and Oceans Canada (DFO), Woods Hole Oceanographic Institution (WHOI), Temple University (TU), Royal British Columbia Museum (RBCM), California Academy of Sciences (CAS)

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