The Oligocene Corals Had Circumtropical Distribution

Patrali Sinha and Kalyan Halder

Abstract An analysis of the palaeobiogeographic distribution of the Oligocene corals of the world reveals strong specific endemism whereas large generic pandemism. Four palaeobiogeographic provinces are identified here based on this distribution: the Western Indian Province (WIP) represented by Kutch, the Mediterranean-Iranian Province (MIP) consisting of Greece, Italy and Iran, the Caribbean-Northern South American Province (CNSAP) composed of Antigua, Puerto Rico and Venezuela, and the Northwestern American Province (NAP) represented by the state of Washington, USA. Different basins within a province show some specific similarity whereas specific provincialism is nearly absolute. Genera show wide distribution—the WIP shows 82% similarity with the MIP and 36% with the CNSAP; the CNSAP has 69% similarity with the MIP. However, the NAP shows significant generic endemism. The tropical affinity, and wide and rapid dispersability of the Oligocene corals are evident from this distribution pattern. Dispersal beyond tropics was apparently limited. This explains the relatively higher endemism of the NAP. Generic exchange between the WIP and the MIP, both belonging to the Tethys Realm, has been known for gastropods. Affinity of these provinces with the CNSAP is worth noticing. This similarity reflects the presence of a trans-Atlantic current during the Oligocene. The circumtropical distribution of the coral genera also evinces protracted planktotrophic larval ontogeny. However, endemism in the species level indicates rapid evolution. This distribution pattern having tropical yet wide longitudinal extent of genera and provincialism of species resembles the present day distribution of corals. It reflects that the scleractinian coral biology had already attained modern aspects in the Oligocene.

Keywords Coral · Oligocene · Kutch · Palaeobiogeography · Tethys · Tropic

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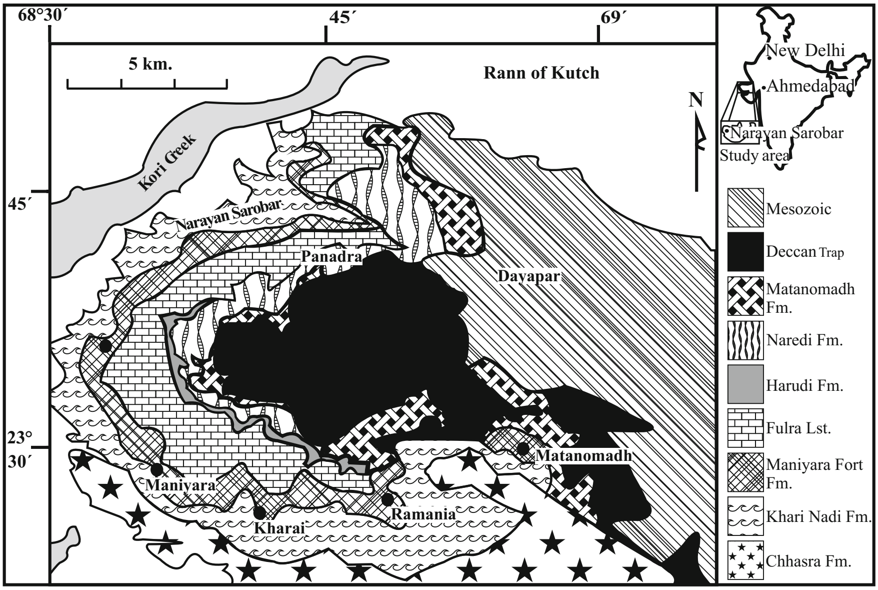

Fig. 1 Geological map of the Cenozoic of Kutch with coral collection sites marked by solid black circles

Introduction

The Oligocene marine sedimentary deposits of Kutch, Gujarat are known to house a diverse coral fauna (Biswas 1992). However, the composition of this fauna largely remains unknown to the palaeontological fraternity till date. We intend to make a rigorous systematic study of this coral fauna. Towards this goal we have collected corals from five localities that are dispersed along the entire transect of a narrow arcuate exposure of the Oligocene rocks at Kutch (Fig. 1).

The systematic study of our collection from one of the localities, which is exposed near village Ramania, has so far been completed. It has been observed during this study that almost all the species from Kutch are new whereas nearly all the genera to which they belong were reported from other parts of the world. The genera are known mainly from the Middle-East, southern European countries and the Caribbean archipelago. This strong specific endemism and large generic pandemism of the Kutch fauna prompted us to analyse global distribution patterns of the Oligocene reef corals. We would like to see through this analysis:

(1) whether this pattern of specific endemism and generic pandemism is true for other contemporaneous coral faunas from different areas of the world,
(2) if formal palaeobiogeographic units can be erected based on coral faunas, and
(3) if the units can be compared to the existing palaeobiogeographic units, mainly based on molluscs.

Table 1 Geographic areas from where taxonomic data have been gathered along with number of species and genus known from each

Name of the Area	No. of species	No. of genera
Kutch	24	11
Iran	61	38
Greece	38	27
Italy	20	18
Antigua	45	26
Venezuela	32	18
Puerto Rico	25	13
Washington	46	35
California	14	7

Further, we intend to investigate the factors that were responsible for the development of paleobiogeographic distribution patterns of the Oligocene corals and possible routes and mechanism of their dispersal.

Materials and Methods

The Oligocene deposits of Kutch are included in the Maniyara Fort Formation (Biswas 1992). It is composed of claystone, foraminiferal limestone and thick coral biostrome. This formation is underlain by a thick foraminiferal limestone formation (Fulra Limestone) and overlain by the Khari Nadi Formation, which is composed of shale, siltstone and sandstone. The rocks of the Maniyara Fort Formation outcrop in a nearly continuous arc, roughly paralleling the present day coastline (Fig. 1).

Our systematic study revealed that the coral fauna from Ramania (Fig. 1) is constituted of 24 species belonging to 11 genera. We have gathered systematic and geographic information of the Oligocene corals from some major publications pertaining to different areas of the world. The sources of information used in this study are: Vaughan (1900), Durham (1942), Geister and Ungaro (1977), Schuster and Wielandt (1999), Budd (2000), Schuster (2002), Kolodziej and Marcopoulou-Diacantoni (2003), Johnson (2007), Johnson et al. (2009), Champagne (2010) and López-Pérez (2012).

The areas for which taxonomic data could be gathered are Iran, Italy, Greece, USA, Puerto Rico, Antigua and Venezuela (Table 1). All the data were analysed in specific and generic levels to see the degree of compositional similarities between different geographic areas (Tables 2, 3 and 4). The data were plotted in palaeogeographic maps of Smith et al. (1994) (Figs. 2 and 3). Formal palaeobiogeographic units are erected based on the global distribution of corals.

Table 2 Similarity matrix showing specific similarities among different geographic areas

	Iran	Greece	Italy	Antigua	Venezuela	Puerto Rico	Kutch	Washington	California
Iran	61	11	4	1	0	3	2	1	0
Greece		38	7	0	0	5	1	1	0
Italy			20	0	0	3	0	0	1
Antigua				45	17	5	0	0	0
Venezuela					32	6	0	0	0
Puerto Rico						25	0	3	0
Kutch							24	0	0
Washington								46	1
California									14

Table 3 Similarity matrix showing generic similarities among different geographic areas

	Iran	Greece	Italy	Antigua	Venezuela	Puerto Rico	Kutch	Washington	California
Iran	38	19	12	19	13	12	7	10	1
Greece		27	11	14	9	9	3	5	1
Italy			18	11	9	9	8	4	1
Antigua				26	16	12	4	9	2
Venezuela					18	10	3	8	2
Puerto Rico						13	2	6	2
Kutch							11	1	1
Washington								35	6
California									7

Table 4 Similarity matrix showing specific/generic similarities among different provinces

	Western Indian Province (WIP)	Mediterranean-Iranian Province (MIP)	Caribbean Northern South American Province (CNSAP)	Northwestern American Province (NAP)	California
WIP	24/11	2/9	0/4	0/1	0/1
MIP		98/49	8/20	1/11	1/2
CNSAP			76/29	3/9	0/3
NAP				46/35	1/6
California					14/7

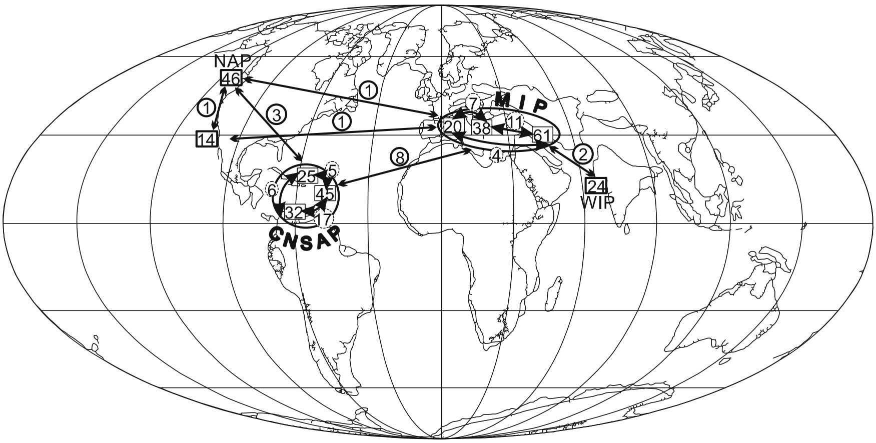

Fig. 2 Global distribution of coral species. Intra- and inter-provincial similarity in number of species are shown

Results and Discussion

Species Level Analysis

1. Twenty Four species have been identified from the locality of Ramania, Kutch, of which only 2 are already known—*Astrocoenia nana* Reuss, 1868 from Greece and Iran, and *Astrocoenia* cf. *bistellata* (Catullo, 1856) from Iran. The rest are new species (Table 2).
2. Data on the global distribution of coral species reveal high degree of similarity among faunas from Italy, Iran and Greece (Table 2; Fig. 2).
3. Substantial similarity also characterises the distribution of corals among Antigua, Venezuela and Puerto Rico, the three localities bordering the Caribbean Sea for which we could gather data (Table 2; Fig. 2). Puerto Rico shares some similarity

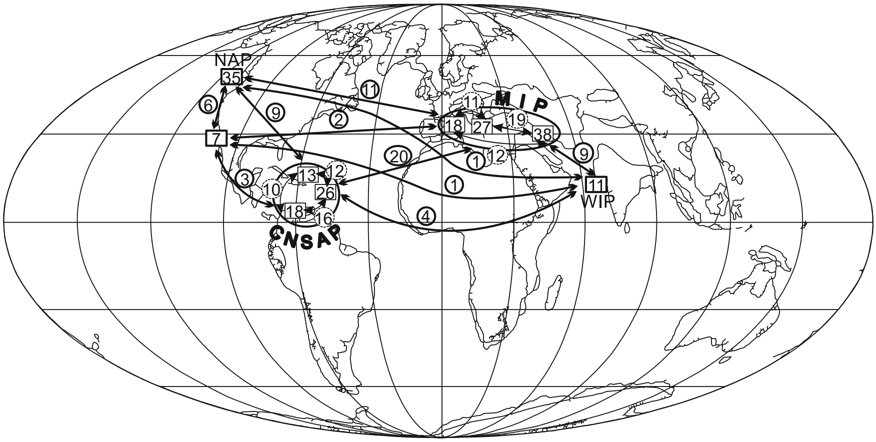

Fig. 3 Global distribution of coral genera. Intra- and inter-provincial similarity in number of genera are shown

with the areas of Europe and Middle East to which Antigua and Venezuela share almost nothing.

4. The state of Washington, USA is the only other area from where substantial number of Oligocene corals are known, almost all of which are endemic (Table 2; Fig. 2).
5. The Oligocene corals are also known from a more tropical part of USA, i.e. California. Only 14 species are known, which also show strong endemism (Table 2; Fig. 2).

Strong specific endemism of the Oligocene corals from Kutch necessitates establishment of a palaeobiogeographic province. The Western Indian Province (WIP) was erected by Harzhauser (2007) based mainly on the Oligocene gastropods from Pakistan. Harzhauser et al. (2009) included the Oligocene gastropods from Kutch in this province based on faunal similarity. Contemporaneous mollusc faunas from Kutch and other adjoining areas of western India have long been known to bear strong similarity with the Pakistan fauna (Sowerby 1840; D'Archiac and Haime 1854; Vredenburg 1925, 1928) and were always considered together with the latter. Corals are not known from the Oligocene deposits of Pakistan. Here we designate the Oligocene corals from Kutch to the same palaeobiogeographic unit, i.e. the WIP in order to avoid multiplication of similar unit names.

Large sharing of species between Iran, Greece and Italy evinces close biogeographic relationship. Italy shares 35% of its coral species with Greece and Greece shares about 29% with Iran. This pattern of specific similarity of the coral faunas correspond to that of the Oligocene gastropods. Harzhauser et al. (2002) erected the Mediterranean Iranian Province (MIP) to include basins of northern Italy, Greece and central Iran based on the specific similarity of Oligocene gastropods. Here, we upheld the same province name for contemporaneous coral faunas.

Significant specific similarity exists among Antigua, Venezuela and Puerto Rico. Puerto Rico shares 20% and 24% of its species with Antigua and Venezuela respectively. About 53% of Venezuelan coral species are also known from Antigua. We erect here the Caribbean-Northern South American Province (CNSAP) to include these three areas based on similarity of the Oligocene coral faunas.

Very strong endemism of the coral fauna from Washington necessitates erection of a new faunal province. We christen this province as the Northwestern American Province (NAP). Strong endemism of the Californian fauna also suggests the presence of a separate biogeographic province. However, the information from this area is relatively poor and only 14 species are known. Hence, we refrain from establishing a formal biogeographic unit based on such poor data and refer to the Californian fauna informally.

Genus Level Analysis

1. The 24 species that we have so far identified from Kutch, western India belong to 11 genera. Most of the genera are known from Italy, Iran and Greece. The Kutch assemblage also shows some generic similarity to the faunas from Antigua, Venezuela and Puerto Rico (Table 3).
2. Intraprovincial generic similarity among the basins is expectedly very high (about 70–90%) (Table 3). Interestingly, interprovincial generic similarity is also quite high. The CNSAP and the WIP share about 69% and 82% of their genera with the MIP respectively. The WIP bears about 36% generic similarity with the CNSAP (Table 4).
3. The NAP shows descent similarity with the MIP (about 31%) and the CNSAP (about 26%). It has only one common genus with the WIP (Table 4). Generic similarities among the CNSAP, the MIP and the WIP are, however, much higher.
4. Out of 7 genera that were recorded from California, 6 are also known from the NAP. California also shares about 43% of its genera with the CNSAP and about 29% with the MIP. One genus is common between California and Kutch.

The strong generic similarity between the WIP and the MIP parallels the trend shown by contemporaneous gastropod molluscs (Harzhauser et al. 2009). This trend reflects Tethyan heritage and indicates that considerable connectivity still existed between these provinces during the Oligocene. These provinces were included in the Western Tethys Region of the Tethys Realm based on benthic mollusc fauna (Harzhauser et al. 2002 and references therein).

The strong Tethyan affinity of the Oligocene coral fauna from the CNSAP is worth noticing. The relationship between the CNSAP and the Tethyan provinces, especially the MIP lying on the other shore of Atlantic, has never been adequately explored (see Harzhauser et al. 2002). Harzhauser et al. (2002) showed significant commonness in the gastropod composition of the Caribbean and adjacent tropical areas with that of the MIP. Hence, the CNSAP should be considered as the western fringe of the Tethys Realm.

The Washington coral fauna appears to be unique in composition. It shares relatively less with any of the other provinces. The California fauna, which shares majority of its genera with the NAP, has little in common with the latter when specific composition is considered. The uniqueness of the NAP calls for its inclusion in a different region or even realm. The question of affinity of the California fauna remains unresolved because of the relatively poor nature of information. Unfortunately, we could not access information on the faunas from Indo-Pacific basins like Java and Borneo (Gerth 1921, 1923, 1925). This information can be crucial in delineating palaeobiogeographic relationship of the NAP and deciphering possible routes of dispersal of its constituent corals.

Remarks

The Oligocene coral species are seldom found beyond province boundaries. Most of them are also often endemic to a single basin. In contrast, majority of the genera appear to migrate great distances beyond province territories, often even crossing significant geographic barriers. This strong specific endemism and large generic pandemism indicate wide migration followed by rapid allopatric speciation.

The global distribution of the Oligocene corals clearly shows wide longitudinal vis-a-vis relatively restricted latitudinal occurrence mainly within palaeo-tropics and subtropics. Present day reef corals are known to be strongly sensitive to climatic factors and restricted to the tropical zone. Apparently, this attribute was already acquired by the Oligocene corals. The diverse coral fauna from Washington, USA, which flourished in higher latitudes, however is an exception. Presence of corals there perhaps indicates that the prevailing climate of the Oligocene was warmer and more equable than the present day. Palaeo-temperature data suggests the same (Hansen et al. 2013). However, the unique nature of the composition of the Washington fauna with large specific as well as generic endemism indicates the presence of a strong climatic barrier to the dispersal of the tropical corals to higher latitudes. Only more cold-tolerant genera could permeate into the higher latitudes and survive.

The presence of a seaway connection and regular migration between the WIP and the MIP during the Paleogene has been known for a long time in relation to the molluscs (Eames 1951, 1952; Iqbal 1969a, b, 1972; Halder 2012; Halder and Sinha 2014; Halder and Bano 2015; Harzhauser et al. 2002, 2009). The migration took place through the relict Tethys seaway. It may be pointed out that many early Paleogene molluscs of western India appear in younger strata of the Mediterranean Europe. However, Iqbal (1969a, b) declined to consider a westward migration of the fauna in the absence of more definitive evidences. Harzhauser et al. (2002) demonstrated the presence of an easterly surface current in the Tethys that bathed the western shores of the Indian Peninsula during the Paleogene (see also Popov 1993). The information analysed in the present study is not adequate for the reconstruction of possible direction of migration of the coral fauna between the WIP and the MIP.

The presence of a coral fauna in the Western Atlantic CNSAP, similar to that of the MIP and the WIP, indicates an extension of the Tethyan faunal influence across the Atlantic Ocean and hence, the presence of a trans-Atlantic current system. The direction of migration, again, cannot be inferred from the present dataset. An analysis of the information on the contemporaneous gastropods also could not conclusively reveal the migration direction. However, a westward current from the MIP to the CNSAP appears to be the stronger possibility in terms of the gastropod distribution (Harzhauser et al. 2002). The relatively lower similarity between the WIP and the CNSAP may be attributed to the large geographic distance between these provinces and the relatively weak present state of the knowledge on the western Indian fauna.

It is more difficult to understand the relationship of the Pacific coastal basins of the USA with other provinces in the absence of data from other Pacific basins. California, however, having about 43% generic similarity with the CNSAP perhaps got its coral fauna from the latter. Presumably, this migration had taken place through the connection that existed at that time between the Caribbean Sea and the Pacific Ocean. The Isthmus of Panama severed this tie later. Washington, in spite of its unique faunal composition, might have got early settlers from California. Relatively cold-tolerant forms from the latter area perhaps migrated to Washington and flourished there in a relatively unusual setting as opportunist taxa. Data from the western Pacific archipelago is required to assess if and to what extent faunal similarity existed between the two shores of the Pacific. However, a migration route across the huge Pacific Ocean is difficult to perceive in the absence of hopping sites.

Conclusion

The global distribution of the Oligocene coral faunas indicates an almost circum-tropical occurrence in nearly all coastal basins including the western Pacific. Significant absence of corals was from the tropical African countries. Whether it was real or reflects lack of study is not known. The distribution shows very strong Tethyan affinity of most of the provinces—including that on the western shore of the Atlantic and even the tropical eastern Pacific—elucidating a trans-Atlantic surface current and possible passage through the sea between the two American continents. However, strong endemism of the coral species to the provinces and even to the basins reflects rapid speciation was operative in allopatry.

It is interesting to note that several of the Oligocene coral genera are still extant. The Oligocene corals had a climate controlled distribution mainly in the tropical and the subtropical areas. They were generally associated with fairly shallow water shelf sediments (Bosellini 1998). They also had longitudinally wide geographic distribution. All these features correspond to the distribution of the present day reef corals (Veron 2016). Shallow water occurrence of the present day corals in the tropical zone is known to be controlled by the symbiotic association with photosynthetic organisms. Protracted planktotrophic larval ontogeny of majority of the reef corals is responsible for their wide geographic distribution (Veron 2013). Apparently, these modern aspects of the coral biology had been attained by the reef corals already during the Oligocene.

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Appendix 1

Global distribution of Coral species reported from different basins/provinces of the Oligocene

Global distribution of Coral species reported from different basins/provinces of the Oligocene

Sl. no.	Species name	MIP			CNSAP			WIP	California	NAP
		Greece	Italy	Iran	Antigua	Venezuela	Puerto Rico	Kutch		Washington
1	*Astrocoenia nana*	√		√				√		
2	*Astrocoenia* cf. *bistellata*			√				√		
3	*Astrocoenia* cf. *zitteli*			√						
4	*Astrocoenia portoricensis*				√	√				
5	*Astrocoenia guantanamensis*				√	√				
6	*Astrocoenia sp. B*				√					
7	*Agathiphyllia sp. 1*			√						
8	*Agathiphyllia sp.2*			√						
9	*Agathiphyllia gregaria*	√	√				√			
10	*Agathiphyllia tenuis*				√	√	√			
11	*Agathiphyllia hilli*				√		√			
12	*Agathiphyllia browni*				√					
13	*Agathiphyllia splendens*				√					
14	*Agathiphyllia antiguensis*					√	√			
15	*Agathiphyllia anguillensis*						√			
16	*Agathiphyllia bosniaca*						√			
17	*Agathiphyllia robusta*						√			
18	*Agathiphyllia sp. 3*				√					
19	*Antiguastrea cellulosa*				√	√	√			
20	*Antiguastrea elegans*						√			
21	*Antiguastrea alveolaris*						√			
22	*Antiguastrea sp.*			√						
23	*Antiguastrea lucasiana*	√	√							
24	*Actinacis rollei*		√	√						
25	*Actinacis sp. A*				√					
26	*Astreopora stellaris*			√						
27	*Astreopora meneghiniana*	√		√						
28	*Astreopora tecta*		√							
29	*Astreopora decaphyllia*	√								
30	*Astreopora antiguensis*				√					
31	*Astreopora goethalsi*					√				
32	*Alveopora sp.*			√			√			
33	*Alveopora? sp.*			√						
34	*Alveopora tampae*				√	√				
35	*Alveopora sp. A*				√					
36	*Alveopora rudis*		√							
37	*Astrangia persica*			√						
38	*Acanthastrea sp.*			√						
39	*Asterosmilia sp.*			√						
40	*Acropora saludensis*				√	√				

41	*Acropora sp. A*					√				
42	*Acropora sp.*	√	√	√						
43	*Colpophyllia eocaenica*			√						
44	*Colpophyllia longicollis*			√						
45	*Colpophyllia maeandrinoides*	√								
46	*Colpophyllia willoughbiensis*				√	√				
47	*Caulastrea pseudoflabellum*	√								
48	*Caulastrea sp.*	√					√			
49	*Caulastraea farsis*			√						
50	*Caulastrea fusinieri*		√							
51	*Caulastraea portoricensis*				√					
52	*Cyathoseris sp.*	√	√							
53	*Cyathoseris* cf. *appennina*	√								
54	*Cyathoseris hypocrateriformis*	√								
55	*Ceratotrochus (Conotrochus) sp.*			√						
56	*Cricocyathus annulatus*			√						
57	*Ceriosmilia iranica*			√						
58	*Cereiphyllia tenuis*		√							
59	*Diploastrea coronata*			√						
60	*Diploastrea costata*			√						
61	*Diploastrea crassolamellata*				√	√				
62	*Diploastrea magnifica*				√	√				
63	*Diploastrea nugenti*				√					
64	*Diploastrea sp. T*				√					
65	*Diploastrea sp.*					√				
66	*Diploria antiguensis*				√					
67	*Diploria sp.*	√								
68	*Euphyllia caliculata*	√								
69	*Favites insignis*			√						
70	*Favites cf.inaequiseptata*			√						
71	*Favites macrocalyx*	√								
72	*Favites oligocenia*	√								
73	*Favites polygonalis*				√					
74	*Favites ambigua*	√								
75	*Favites sp.*			√			√			
76	*Fungophyllia sp. A*				√					
77	*Favia sp. 2*	√								
78	*Favia sp. 1*	√								
79	*Gardinoseries? sp.*			√						
80	*Goniopora* cf. *nodulosa*	√		√						
81	*Goniopora sp.*	√					√			
82	*Goniopora sp. 2*	√		√						
83	*Goniopora sp. 3*			√						
84	*Goniopora sp. 4*			√						
85	*Goniopora rudis*		√							
86	*Goniopora imperatoris*				√	√				
87	*Galaxea sp.*			√						
88	*Goniastrea canalis*				√	√				
89	*Hydnophora solidior*			√						
90	*Hydnophora* cf. *inaequalis*			√						
91	*Hydnophora* cf. *rudis*			√						
92	*Hydnophora pulchara*	√								
93	*Hydnophora sp.*			√						
94	*Hydnophora sp. A*				√					
95	*Heliopora sp. A*				√					
96	*Ilariosmilia subcurvata*			√						
97	*Leptoseries irregularis*			√						
98	*Leptoseries* cf. *dinarica*									
99	*Leptoseris sp. C*				√					
100	*Leptoseris portoricensis*				√					
101	*Leptoseris alternas*			√						
102	*Leptoria* cf. *concentrica*			√						
103	*Leptoria bithecata*	√								
104	*Leptoria sp.*	√		√						
105	*Leptomussa variabilis*	√		√						

106	*Leptomussa sp.*		√	√						
107	*Montipora sp. A*			√	√					
108	*Montastrea sp.*	√		√						
109	*Montastraea canalis*				√	√	√			
110	*Montastraea endothecata*				√		√			
111	*Montastraea imperatoris*					√	√			
112	*Montastraea limbata*					√	√			
113	*Montastrea endothecata*						√			
114	*Montastraea sp.*					√				
115	*Montastrea guettardi*		√							
116	*Pironastraea antiguensis*				√					
117	*Pindosmilia brunni*	√								
118	*Porites regularis*				√					
119	*Porites macdonaldi*				√					
120	*Porites portoricensis*				√	√				
121	*Porites microscopica*				√					
122	*Porites reguiaris*				√					
123	*Porites baracoaensis*				√	√				
124	*Porites trinitatis*					√				
125	*Porites waylandi*					√				
126	*Pocillopora arnoldi*					√				
127	*Porites sp.*	√	√	√			√			√
128	*Plocophyllia bartai*		√							
129	*Pavona bronni*	√	√							
130	*Platycoenia iranica*	√		√						
131	*Plesiastrea sp.*	√		√						
132	*Placosmiliopsis fimbriatus*			√						
133	*Placosmiliopsis multisinuous*			√						
134	*Rhizangia sp.*	√								
135	*Siderastrea conferta*				√	√				
136	*Siderastrea (Siderofungia) sp.*			√						
137	*Solenastrea sp. B*					√				
138	*Stephanocyathus (Odontocyathus) sp.*			√						
139	*Stephanocoenia duncani*				√	√				
140	*Stylophora affinis*					√				
141	*Stylophora granulate*					√				
142	*Stylophora undata*					√				
143	*Stylophora imperatoris*				√					
144	*Stylophora minor*				√					
145	*Stylophora sp. C*				√					
146	*Stylophora sp.*	√	√				√			
147	*Stylophora thirsiformis*			√						
148	*Stylofora conferta*	√								
149	*Stylophora cf. sokkohensis*			√						
150	*Acanthastrea n. sp.1*							√		
151	*Acanthastrea n. sp. 2*							√		
152	*Stylaster antiquus*		√							
153	*Tethocyathus persicus*	√								
154	*Trachyphyllia sp.*					√				
155	*Turbinaria sp.*	√								
156	*Turbinaria* cf. *sitaensis*			√						
157	*Tarbellastrea carryensis*			√						
158	*Pavona n. sp. 1*							√		
159	*Pavona n. sp. 2*							√		
160	*Pavona n. sp. 3*							√		

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161	*Tarbellastrea hamedanii*	√		√						
162	*Tarbellastrea* cf. *distans*			√						
163	*Balanophyllia elongate*								√	
164	*Stylophora ponderosa*									√
165	*Stephanocyathus holcombensis*									√
166	*Flabellum hertleini*									√
167	*Archohelia weaveri*									√
168	*Astrangia clarki*									√
169	*Balanophyllia fulleri*									√
170	*Caryophyllia woodmanensis*									√
171	*Favia n. sp. 1*							√		
172	*Favia n. sp. 2*							√		
173	*Favia n. sp. 3*							√		
174	*Favia n. sp. 4*							√		
175	*Favia n. sp. 5*							√		
176	*Favia n. sp. 6*							√		
177	*Favia n. sp. 7*							√		
178	*Favia n. sp. 8*							√		
179	*Favia n. sp.9*							√		
180	*Paracyathus sp.*									√
181	*Stylaster milleri*									√
182	*Trochocyathus townsendensis*									√
183	*Tubastrea nomlandi*									√
184	*Dendrophyllia hannibali*									√
185	*Caryophyllia blakeleyensis*									√
186	*Balanophyllia teglandae*									√
187	*Montastrea n. sp. 1*							√		
188	*Eusmilia bainbridgensis*									√
189	*Paracyathus sp.*									√
190	*Platycyathus? sp.*									√
191	*Siderastrea washingtonensis*									√
192	*Flabellum rhomboideuui*									√
193	*Plesiastrea n. sp. 1*							√		
194	*Turbinolia insiguitica*									√
195	*Steriphonotrochus pulcher*									√
196	*Oculiua aldrichi*									√
197	*Oculiua harrisi*									√
198	*Balanophyllia caulifera var. nuiltigrauosa*									√
199	*Trochocyathus californianus*								√	
200	*Stylophora minutissima*									√
201	*Astrocoenia pumpellyi*									√
202	*Flabellum remoudianum*								√	
203	*Flabellum califonicum*								√	
204	*Trochocyathus striatus*								√	
205	*Trochocyathus zitteli*								√	
206	*Trococyatbus stantoni*								√	
207	*Pocillopora damicornis*								√	
208	*Pocillopora meandrina*								√	
209	*Siderastrea californica*								√	
210	*Astreopora occidentalis*									√
211	*Astreopora sanjuanensis*									√
212	*Goniopora n. sp. 1*							√		
213	*Pocillopora verrucosa*								√	
214	*Siderastrea clarki*								√	
215	*Pocillopora sp. 1*									√
216	*Hydnophora n. sp. 1*							√		
217	*Hydnophora n. sp. 2*							√		
218	*Colpophyllia sp.*						√			√
219	*Montipora schencki*									√
220	*Pavona sp.*		√						√	

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221	*Turbinolia sp.*								√	√
222	*Platycoenia sp.*									√
223	*Astrangia sp.*									√
224	*Platytrochus sp.*									√
225	*Discotrochus sp.*									√
226	*Madracis sp.*									√
227	*Dichocoenia sp.*									√
228	*Stephanocoenia sp.*									√
229	*Spenotrochus sp.*									√
230	*Leptoria n. sp. 1*							√		
231	*Endopachys sp.*									√
232	*Eupsammia sp.*									√
233	*Euphyllia sp.*		√							
234	*Galaxea sp.*		√							
235	*Montipora sp.*			√						
236	*Rhabdophyllia sp.*			√						
237	*Stylocoenia sp.*			√						
238	*Pocillopora sp.*				√	√				
239	*Siderastrea sp.*						√			
240	*Astreopora sp.*						√			
241	*Flabellum sp.*						√			√
242	*Astrohelia sp.*									√
243	*Eupsammid sp.*									√
244	*n. gen. 1 n. sp. 1*							√		
245	*n. gen. 2 n. sp. 1*							√		
Total		**38**	**20**	**61**	**45**	**32**	**25**	**24**	**14**	**46**

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