Hydrobiologia **260/261**: 197–205, 1993.
A. R. O. Chapman, M. T. Brown & M. Lahaye (eds), Fourteenth International Seaweed Symposium.

Characterization of tidal pool algae in the Mexican Tropical Pacific coast

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Key words: tidal pools, algal characterization, México

Abstract

Tidal pools in the Mexican Tropical Pacific coast have received relatively little attention in spite of their considerable richness in species and wide distribution in the region.

This paper presents the first characterization of the algal flora of this region. It analyzes the number and composition of species of the tidal pools of six localities with regard to geographical distribution and its seasonal variations as well as tidal level. 97 species are reported, 25 Chlorophyta, 23 Phaeophyta, 34 Rhodophyta and 15 Cyanophyta.

Of that total of species, 63% were found in one locality, 23.7% in two, 11.3% in three and 1% in 4 or 5 localities. Not one species was common to all of the pools.

The highest number of species was found on pools of the middle and low intertidal where the Chlorophyta, Rhodophyta and Phaeophyta were the most abundant algae. Cyanophyta was more common in the supralittoral and high intertidal pools.

Introduction

Tidal pools form a widely distributed habitat along the Mexican Tropical Pacific (MTP) littoral, being part of several general habitats such as rocky platforms, rocky points, mounds, etc. (Table 1).

A diverse series of papers has been published about pools, including characterizations using only abiotic environmental characteristics (Klugh, 1924), and characterizations which incorporate information about their biota (Johnson & Skutch, 1928; Davy de Virville, 1934–1935; Daniel & Boyden, 1975; Lubchenco, 1982; Sze, 1982; Femino & Mathieson, 1980; Dethier, 1982; Gallardo & Pérez-Cirera, 1982).

In recent years, more detailed studies have been done, with an evaluation of the abundance of species and their changes in spaçe and time, but most of them have been carried out on temperate coasts either of North America (Daniel & Boyden, 1975; Lubchenco, 1982; Sze, 1982, Femino & Mathieson; 1980; Dethier, 1982) or Europe (Davy de Virville, 1934–1935; Gallardo & Pérez-Cirera, 1982). No study has been published concerning tidal pool algae on the coasts of Mexico.

In this paper we have integrated information from several unpublished professional theses on macroalgae from 6 localities in the Mexican Tropical Pacific (Fig. 1).

Materials and methods

Even though the data come from studies with different orientations, we are endeavouring to

Table 1. General characteristics of tidal pools.

Localities	1	2	3	4	5	6
Geographic	26° 46′ N	20° 52′ N	18° 04′ N	16° 20′ N	15° 44′ N	16° 10′ N
Ubication	105° 33′ W	105° 27′ W	102° 43′ W	98° 35′ W	96° 46′ W	95° 07′ W
General habitat	RO	RO	RP	RP	RP	CR
Tidal level	HI–LI	MI	SL–LI	SL–MI	HI–LI	HI–LI
Isolation at low tide	I	I	I–C	I	I–C	I
Wave exposure	M–L	M	H–M	H–M	M–L	H–M

Localities: 1 = Manzanillas, Nayarit. 2 = Sayulita, Nayarit. 3 = Caleta de Campos, Michoacán. 4 = Punta Maldonado, Guerrero. 5 = Barra Santa Elena, Oacaca. 6 = La Ventosa, Oaxaca. Tidal level: SL = Supralittoral, HI = High Intertidal, MI = Middle Intertidal, LI = Low Intertidal. General habitat: RO = Rocky point, RP = Rocky platform, CR = Crags. Isolation at low tide: I = Intermittent, I–C = Intermittent-continuous. Wave exposure: H–M = High to medium, M–L = Medium to low, M = Medium.

elaborate a first characterization of the flora of this habitat in the region, that will serve as the basic phycofloristic inventory for future studies.

The localities and their collecting dates were: Manzanillas, October 1987 and April 1988; Sayulita, October 1987; Caleta de Campos, August 1990 and May 1991; Punta Maldonado, July 1988, July 1989 and January 1990; Barra Santa Elena, May 1986 and La Ventosa, September 1981.

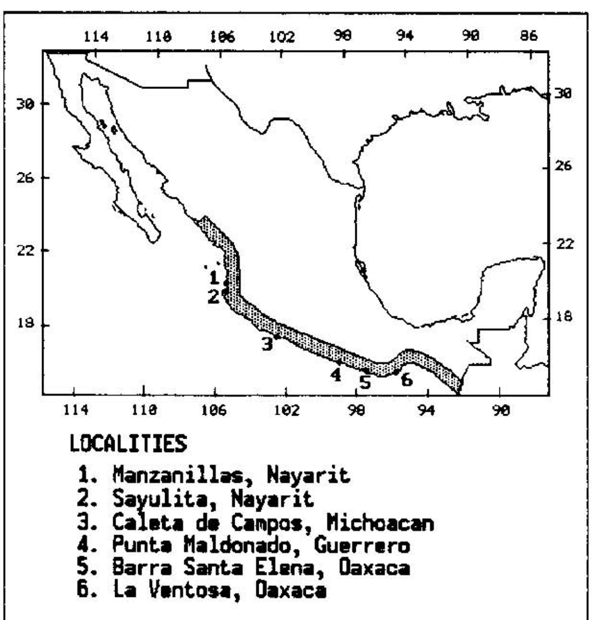

Fig. 1. Study localities on the Mexican Tropical Pacific.

A total of 89 samples was analysed: 9 from Manzanillas, 2 from Sayulita, 16 from Caleta de Campos, 19 from Punta Maldonado, 14 from Santa Elena and 29 from La Ventosa.

Table 1 lists the geographic coordinates and several relevant characteristics (general habitat, tidal level, wave exposure, etc.) of the pools from each locality.

In each locality the tidal pools collected were those which showed the greatest diversity regarding macroalgal flora. Cyanophyta that formed conspicuous mats were collected only at 4 localities, therefore the absence of these species in some localities of Table 2 does not necessarily mean that the species were absent from the locality. Sampling was carried out according to the position of the algae in the tidal pool: margins (MA), walls (WA) or bottom (BO), except in pools where the flora was homogeneous. In this case, only one sample per pool (PO) was collected.

Due to the fact that it was not possible to obtain information about the dimensions, temperature, pH and salinity of every pool, we only establish general correlations between the algal flora and some characteristics of the pools.

The global floristic similarities between pools from different localities were analyzed using presence-absence data with Jaccard's similarity coefficient and the cluster analysis (UPGMA) with the NTSYS program.

Table 2. Distribution of species, pools tidal levels and species locations.

Localities	1		2	3		4			5	6	Pool tidal level	Location in pools
	Oct	Apr	Oct	Aug	May	Jul	Jul	Jan	May	Sep		
Chlorophyta												
Acetabularia parvula Solms–Laub									*		MI–LI	WA
Bryopsis galapagensis Taylor	*			*	*						MI	MA, WA
B. pennatula J. Ag.	*										LI	MA, WA
Caulerpa peltata Lamour. f. *imbricata* (Kjell.) W.-vB. var. *peltata* (Lamour.) Eub.									*		LI	WA
Caulerpa racemosa (Forssk.) J. Ag.	*	*		*	*						LI	PO
Caulerpa sertularioides (S.G. Gmell.) Howe						*	*	*			MI	MA, BO
Caulerpa vickersiae Borg.									*		MI	MA, WA
Chaetomorpha californica Coll.										*	HI	MA
Chlorodesmis hillebrandtii A. & E.S. Gepp				*					*		MI–LI	MA, WA
Cladophora albida (Nees) Kütz.								*		*	HI–LI	MA,WA
Cladophora laetevirens (Dillw.) Kütz.	*										LI	BO
Cladophora microcladioides Coll.									*		MI	WA
Cladophora nigrescens Zanard. ex Frauenf.									*		MI–LI	WA, BO
Codium edule Silva				*	*				*		MI–LI	MA, WA
Codium santamariae Taylor		*		*							MI–LI	PO, BO
Codium setchelli Gardn.				*							MI	WA
Enteromorpha compressa (L.) Nees										*	HI–LI	MA, WA
Enteromorpha lingulata J. Ag.										*	MI–LI	MA, WA
Enteromorpha sp.									*		MI	WA
Halimeda discoidea Dec.	*	*	*				*	*	*		MI–LI	PO, MA, WA, BO
Rhizoclonium riparium (Roth.) Kütz. ex Harvey					*						HI	WA
Struvea anastomosans (Harv.) Picc. & Grün. ex Picc.									*		MI	MA
Ulva californica Wille				*	*						LI	MA
Ulva lactuca L.							*		*	*	LI	MA
Ulva lobata (Kütz.) S. & G.		*									MI	MA
Phaeophyta												
Dictyota bartayresiana Lamour.			*	*	*						MI	PO
Dictyota dichotoma (Huds.) Lamour.									*		MI–LI	WA
Dictyota ? *pfaffi* Schnetter										*	LI	MA
Dilophus pinnatus Daws.	*		*								MI	PO
Diplura simulans Hollenb.									*		MI	WA
Ectocarpus confervoides (Roth) Le Jol. var. *dasycarpa* (Kuck.) Rosenv. & Lund				*						*	HI–MI	MA, WA
Ectocarpus confervoides (Roth) Le Jol. var. *pygmaeus* (Aresch.) Kjell.									*		MI	MA, WA
Feldmannia cylindrica (Saund.) Hollenb. & Abbott										*	MI	PO
Feldmannia elachistaeformis (Heydr.) Pham Hoang									*		MI	WA
Hapalospongidion gelatinosum Saund.				*	*						SL–HI	WA, BO

Table 2. (Continued)

Localities	1		2	3		4			5	6	Pool tidal level	Location in pools
	Oct	Apr	Oct	Aug	May	Jul	Jul	Jan	May	Sep		
Hincksia breviarticulata (J. Ag.) Silva				*	*						MI	MA, WA
Lobophora variegata (Lamour.) Womers.				*	*						HI–MI	MA, WA
Padina caulescens Thivy		*	*								LI	PO, WA
Padina aff. *concrescens* Thivy				*	*						MI	MA, WA, BO
Padina durvillaei Bory	*		*	*	*			*	*		MI–LI	MA, WA, BO
Padina gymnospora (Kütz.) Sonder	*					*		*	*		HI–MI	PO, WA, BO
Ralfsia confusa Hollenb.				*	*				*		HI–MI	MA, WA
Ralfsia expansa (J. Ag.) J. Ag.	*	*	*	*	*						LI	MA, WA
Ralfsia integra Hollenb.		*									MI	WA
Sargassum howellii Setch.	*	*	*								MI	PO, WA, BO
Sargassum liebmanii J. Ag.				*	*				*		MI–LI	MA, WA, BO
Sphacelaria rigidula Kütz.			*					*	*		HI–MI	PO, MA, WA, BO
Sphacelaria tribuloides Menegh.									*		HI–MI	MA, WA
Rhodophyta												
Ahnfeltia concinna J. ag.		*									MI	MA
Amphiroa beauvoisii Lamour.	*										MI–LI	PO, MA, WA, BO
Amphiroa brevianceps Daws.							*	*	*		MI, LI	WA
Amphiroa dimorpha Lem.				*						*	LI	MA, BO
Amphiroa mexicana Taylor				*	*		*	*		*	MI–LI	MA, WA, BO
Amphiroa misakiensis Yendo			*								MI	PO, WA
Amphiroa rigida Lamour.				*							LI	BO
Amphiroa valonioides Yendo	*	*	*								HI–LI	PO, MA, WA
Asparagopsis taxiformis (Delile) Trevisan	*			*					*		MI	MA, WA
Centroceras clavulatum (C. Ag.) Mont.			*	*							MI	PO, MA
Chondria arcuata Hollenb.									*		MI	MA, WA
Chondria dasyphylla (Woodw.) C. Ag.			*								LI	PO
Galaxaura fastigiata Dec.								*			MI	BO
Galaxaura rugosa (Ell. & Sol.) Lamour.									*		MI	BO
Gelidiella hancockii Daws.			*								HI	MA, WA
Gelidiopsis tenuis S. & G.	*		*						*		MI–LI	WA, BO
Gelidium pusillum (Stack.) Le Jol.									*		HI–MI	MA
Grateloupia versicolor (J. Ag.) J. Ag.										*	LI	MA, WA, BO
Herposiphonia secunda (C. Ag.) Ambr.										*	MI–LI	MA, WA, BO
Hildenbrandia rubra (Sommerfelt) Meneg.		*		*	*						SL–HI	MA, WA, BO
Hypnea cervicornis J. Ag.						*		*		*	MI–LI	BO
Hypnea pannosa J. Ag.			*	*	*	*	*	*			MI	MA, WA
Hypnea spinella (C. Ag.) Kütz.				*	*				*		MI–LI	MA, WA
Jania pacifica Aresch. ex J. Ag.									*	*	HI–LI	MA, BO
Jania tenella (Kütz.) Grün.			*	*	*		*	*			MI	PO, MA, BO
Laurencia decidua Daws.						*	*	*			MI	BO
Laurencia lajolla Daws.									*		MI–LI	MA, WA

Table 2. (Continued)

Localities	1		2	3		4			5	6	Pool tidal level	Location in pools
	Oct	Apr	Oct	Aug	May	Jul	Jul	Jan	May	Sep		
Lomentaria hakodatensis Yendo						*					HI	MA
Peyssonnelia dawsonii Denizot	*										LI	BO
Peyssonnelia mexicana Daws.	*								*		MI–LI	MA, WA
Pleonosporium squarrulosum (Harv.) Abb.						*					HI	MA
Polysiphonia scopulorum Harv.	*										LI	WA, BO
var. *villum* (J. Ag.) Hollenb.												
Pterocladia caloglossoides (Howe) Daws.	*		*								HI	PO, MA, WA, BO
Rhodymenia pacifica Kylin						*	*	*			MI	BO
Cyanophyta												
Anabaena oscillarioides Bory						*		*			SL	PO
Anabaena sp.									*		HI–MI	WA, BO
Aphanocapsa littoralis Hansg.						*		*			SL	PO
Calothrix contarenii (Zanard.) Born. et Flah.									*		HI	MA
Calothrix crustacea Thuret						*			*	*	SL–MI	MA
Hydrocoleum glutinosum Gom.									*		MI	WA
var. *vermiculare* Gom.												
Hydrocoleum lyngbyaceum Kütz. ex Gom.									*		MI	MA
Lyngbya confervoides C. Ag. ex Gom.									*		MI	MA
Lyngbya majuscula Harney						*		*	*	*	SL–HI	MA, WA
Lyngbya semiplena (C. Ag.) J. Ag. ex Gom.										*	SL–HI	MA, WA
Microcoleus chtonoplastes Thuret										*	HI	MA
Microcoleus tenerrimus Gom.									*		HI	MA
Oscillatoria chalybea Mert.										*	MI	MA
Oscillatoria corallinae (Kütz.) Gom.									*		HI	MA
Plectonema aff. *wollei* Feldm. ex Gomont					*						HI	WA, MA

Localities: 1 = Manzanillas, Nayarit. 2 = Sayulita, Nayarit. 3 = Caleta de Campos, Michoacán. 4 = Punta Maldonado, Guerrero. 5 = Barra Santa Elena, Oaxaca. 6 = La Ventosa, Oaxaca.
Tidal level: SL = Supralittoral, HI = High Intertidal, MI, Middle Intertidal, LI = Low Intertidal.
Location in pools: Margin = MA, Walls = WA, Bottom = BO, Pool = PO.

Results

A total of 97 species (Table 2) was determined, including 25 Chlorophyta (24.8%), 23 Phaeophyta (23.7%), 34 Rhodophyta (35%), and 15 Cyanophyta (15.5%) (Table 3).

61 species (63%) were found in the tidal pools of only one locality; 23 (23.7%) were present in two localities; 11 (11.3%) were present in 3 localities; and 1 (1%) in 4 or 5 localities. Not one species was common to all of the pools (Table 3).

Table 2 lists the distribution of tidal pool algae with respect to tidal level. The majority of species of Cyanophyta (11 species) were recorded in pools located at the highest levels of the littoral zone, whereas species of Chlorophyta (23 species), Rhodophyta (29 species) and Phaeophyta (22 species) were recorded mainly for the middle and low intertidal zones.

With regard to the distribution of species in different portions of the pools (Table 2) we have found that the Cyanophyta showed a tendency to be found on the margins (11 species), whereas Chlorophyta (15 species), Rhodophyta (18 species) and Phaeophyta (19 species) were more common on the walls, but the proportions found in the bottom and margins are not so contrasted as in Cyanophyta species.

Figure 2 shows the dendrogram resulting from the application of the similarity index to species composition between localities. The values oscillate between 0.072 and 0.258.

Discussion

Analyzing Fig. 2 the low values of similarity between localities reflect the fact that few species are shared by different localities. Considering species present in two or more localities (Tables 2 and 3) it is clear that floristic affinity has a tendency to increase when the localities are closer (Figs 1 and 2), as a result of the differential geographical distribution of algal species in the region. On one hand we have species common to pools of the northwestern portion of the region such as *Bryopsis galapagensis*, *Codium santamariae*, *Padina caulescens*, *Sargassum howelli*, *Amphiroa valonioides*, *Pterocladia caloglossoides*, and on the other species common to pools of the southeastern part such as *Ulva lactuca*, *Amphiroa brevianceps* and *Jania pacifica*. Species with the widest distribution in pools of 4 or 5 localities are *Padina durvillaei*, *Padina gymnospora*, and *Halimeda discoidea*.

Analyzing Tables 2 and 4 it is evident that the algal flora of tidal pools of the 6 localities varies greatly, both in number and in species composition. It seems that the differences in the number of species per locality is the result of a combination of factors, including the diversity of physiographic characteristics, number and place of the pools in the littoral zone, as well as the type of general habitat and environmental heterogeneity present at each locality.

In general we found that pools located in the

Table 3. Percentages of shared species among localities.

Division	Total # of species	Exclusive species	Spp common to 2 localities	Spp common to 3 localities	Spp common to 4 localities	Spp common to 5 localities
Chlorophyta	25	17	6	1	1	–
	(24.8%)	(68%)	(24%)	(4%)	(4%)	–
Phaeophyta	23	12	7	3	–	1
	(23.7%)	(52.3%)	(30.4%)	(13%)	–	(4.3%)
Rhodophyta	34	19	10	5	–	–
	(35%)	(55.9%)	(29.4%)	(14.7%)	–	–
Cyanophyta	15	13	–	2	–	–
	(15.5%)	(86.7%)	–	(13.3%)	–	–
Totals	97	61	23	11	1	1
	(100%)	(63%)	(23.7%)	(11.3%)	(1%)	(1%)

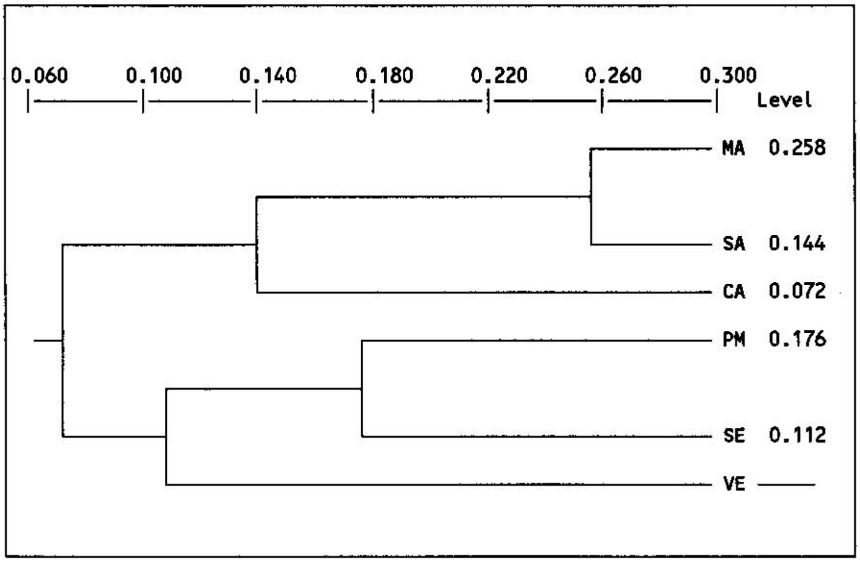

Fig. 2. Floristic affinity of algae from tidal pools of different localities. Jaccard's similarity coefficient. Method = UPGMA. MA: Manzanillas, Nayarit; SA: Sayulita, Nayarit; CA: Caleta de Campos, Michoacán; PM: Punta Maldonado, Guerrero; SE: Santa Elena, Oaxaca; VE: La Ventosa, Oaxaca.

middle and low intertidal have the highest number of species. Therefore, those localities where these types of pools predominate are the most diverse, such as Barra Santa Elena and Caleta de Campos with 40 and 28 species, respectively. On the other hand, at Punta Maldonado with pools located mainly on the supralittoral fringe and high intertidal, only 21 species were present (Tables 1 and 4). Similar results have been reported by Johnson & Skutch (1928), Sze (1982) and Gallardo & Pérez-Cirera (1982). Sayulita with few and very homogeneous pools, was the locality with the lowest number of species (17).

Concerning the physiographic characteristics of the pools, we found that the shallower the pool the lower the number of its species, but this generalization does not hold true.

Analyzing differences in species composition in the different localities, it is evident that in spite of the fact that the greatest number of species was found in only one locality, the said species do not necessarily have a restricted distribution but in-

Table 4. Number of species per locality.

Division	Total of species	Localities					
		1	2	3	4	5	6
Chlorophyta	25	7	1	8	4	11	5
Phaeophyta	23	7	7	10	3	10	3
Rhodophyta	34	10	9	9	10	10	6
Cyanophyta	15	–	–	1	4	9	5
Totals	97	24	17	28	21	40	19

Localities: 1 = Manzanillas, Nayarit. 2 = Sayulita, Nayarit. 3 = Caleta de Campos, Michoacán. 4 = Punta Maldonado, Guerrero. 5 = Barra Santa Elena, Oaxaca. 6 = La Ventosa, Oaxaca.

stead are fairly common in other habitats in a considerable number of localities of the MTP region. Such is the case of *Dictyota dichotoma*, *Chondria arcuata*, *Gelidium pusillum*, *Enteromorpha compressa*, *Struvea anastomosans*, *Bryopsis pennatula*, *Caulerpa sertularioides* or *Amphiroa beauvoisii* (Dawson, 1961; González-González, 1992).

Seasonal variation in species composition of pools was not clearly evident in two of three localities for which we have this kind of information (localities 1, 3 and 4: Table 2). Changes in composition were conspicuous in Sayulita (19 out of 24 species changed) where this habitat is poorly represented, whereas changes in proportion of species (personal observations) occur in Caleta de Campos (9 out of 28 species changed), where the habitat is widely represented and diverse. In Punta Maldonado we observed two types of changes: a seasonal one with 13 species in common and 8 that changed and an interannual one with 4 species in common and 13 that changed.

An additional cluster analysis was made with a matrix of presence-absence of species of 89 samples on one hand, and environmental conditions on the other. The results obtained have not allowed the recognition of exclusive groups of species due to the fact that the information gathered is too general and we lack additional data such as abundance of the species. However, from our personal field observations we have been able to describe the growth forms that are present in tidal pool algae. The said forms can be defined not so much by species composition as by their growth forms and the predominance of certain species. In other words species can be found in pools with different conditions but may be conspicuous only in some of them, being larger, more numerous or with different degrees of intertwining between species (for example in 'mats'). Following is a description of the most common growth forms and their environmental conditions:

Filamentous and crustose forms (*Hildenbrandia rubra*, *Anabaena oscillarioides Calothrix crustacea*, *Lyngbya majuscula Aphanocapsa litoralis*) characteristic of the supralittoral and margins of pools of the high mesolittoral.

Short mats (*Pterocladia caloglossoides*, *Sphacelaria rigidula*, *S. tribuloides*, *Bryopsis galapagensis*, *Caulerpa sertularioides*, *C. vickersiae*, *Enteromorpha lingulata* and *Gelidium pusillum*), present on walls of high mesolittoral pools and margins of those of the mid mesolittoral.

Long mats (*Acetabularia parvula*, *Hypnea pannosa*, *Laurencia lajolla*, *Cladophora microcladioides*, *Codium edule*, *Amphiroa* species), found on walls and margins of tidal pools located in the mid and low mesolittoral respectively.

Erect thallus forms (*Codium santamariae*, *Amphiroa rigida*, *Hypnea cervicornis*, *Laurencia decidua*, *Rhodymenia pacifica*, *Halimeda*, *Padina* and *Sargassum* species), present either on the bottom, on walls or margins of tidal pools located in the mid or low mesolittoral. The specific composition shows that pools are one of the most diverse habitats in the littoral zone. The phycofloristic composition and number of species in tidal pools were found to be correlated with geographic distribution of localities, the position within the littoral zone and microhabitat heterogeneity of the pools.

In order to obtain a better understanding of tidal pool algae in the MTP region, the incorporation of both more detailed information and new localities, uniformity in the data gathered and equivalent units of comparison that consider both the algal associations and related environmental conditions are necessary. This applies not only to the species or associations and conditions present in this habitat but also to those of other habitats that are present at the same locality.

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