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Using GIS methods to evaluate rhodolith and *Sargassum* beds as critical habitats for commercially important marine species in Bahía Concepción, B.C.S., México

Gustavo HINOJOSA-ARANGO [a*], *Rodolfo RIOJA-NIETO* [b],
Álvin N. SUÁREZ-CASTILLO [c] *& Rafael RIOSMENA-RODRÍGUEZ* [c]

[a] *Centro para la Biodiversidad Marina y la Conservación A.C. Calle del Pirata 420. La Paz, BCS, México. CP. 23090*

[b] *Universidad Nacional Autónoma de México. Unidad Académica-Sisal. Puerto de Abrigo s/n. Sisal, Yucatán, México. CP. 97356*

[c] *Universidad Autónoma de Baja California Sur. Carretera al Sur, Km 5.5, La Paz, BCS, México, CP. 23080*

Abstract – Bahía Concepción was once recognized as a very productive coastal lagoon not only for the Peninsula of Baja California but also for all Mexico. However, lack of proper management has resulted in the closure of various fisheries, such as the Calico scallop, *Argopecten ventricosus*, in 1994. One of the main challenges for the management of coastal resources is the selection of critical habitats for conservation considering the economic activities of the communities associated with them. This study used Geographic Information Systems (GIS) and remote sensing to assess the roll of rhodoliths and *Sargassum* spp. as critical habitats in Bahía Concepción for endangered and commercial species. Underwater surveys, on 72 randomly selected sites within the bay, were conducted to characterize the shallow benthic habitats, fish and invertebrate species abundance and richness during the spring of 2011. Analyses show that rhodoliths are important for the invertebrate assemblages and for at least 4 species protected under the Mexican law, NOM-059, for threatened species. *Sargassum* spp. and seagrass beds are also relevant for diversity but their annual life cycle limits the time when these are available as habitat for other species. GIS tools proved an innovative and effective method to provide essential information to protect critical habitats such as rhodoliths, *Sargassum* spp. and seagrasses, for the recovery and conservation of diversity.

GIS / rhodoliths / *Sargassum* / critical / habitat

Résumé – La méthode SIG pour évaluer les herbiers sous-marins de rhodolithe et de sargasses, des habitats indispensables aux espèces marines d'intérêt commercial en Baie de Conception, B.C.S., Mexique – La baie de Conception a été identifiée comme une zone lagonaire côtière très productive non seulement pour la Basse Californie mais aussi pour toute la côte du Mexique. Cependant, le manque de gestion appropriée a entraîné la fermeture de diverses pêcheries comme celle de la coquille Saint-Jacques, *Argopecten ventricosus* en 1994. Un des principaux défis pour la gestion des ressources côtières est la sélection d'habitats spécifiques dédiés à la consommation, en prenant en compte les

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[*] Corresponding author: gustavo.hinojosa@gocmarineprogram.org

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activités économiques des communautés humaines qui les côtoient. Dans cette étude, les systèmes d'information géographiques (SIG) associés à la télédétection ont été mis en place pour évaluer le rôle des rhodolithes et des sargasses, comme habitats essentiels dans la Baie de Conception, pour les espèces commerciales en danger. Des suivis en plongée sur 72 sites sélectionnés au hasard à l'intérieur de la Baie ont été effectués pour caractériser les habitats benthiques peu profonds et l'abondance des espèces de poissons et d'invertébrés ainsi que la biodiversité au cours du printemps 2011. Les analyses montrent que les rhodolithes sont importants pour les regroupements d'invertébrés et pour au moins 4 espèces protégées selon la loi mexicaine sur les espèces menacées (NOM-059). *Sargassum sp.* et les herbiers sous-marins sont aussi des indicateurs pour la diversité mais leur cycle de vie annuel limite le temps pendant lequel ces habitats sont disponibles pour d'autres espèces. Les outils SIG ont prouvé leur efficacité pour donner des informations essentielles afin de protéger les habitats critiques comme ceux de rhodolithes, *Sargassum sp.* ou les herbiers sous-marins pour la récupération et la conservation de la biodiversité.

GIS / rhodolithes / *Sargassum* / critique / habitat

INTRODUCTION

The Gulf of California has been recognized worldwide for its high biodiversity that supports a wide arrange of recreational and commercial activities (Felix-Pico, 1991; Lluch-Cota *et al.*, 2007). At different times in history, bays on the West coast of the Gulf have played a major role on the economics of the region. For example, the pearls from Bahía de La Paz attracted international attention as early as 1533, reaching the peak of their exploitation by 1880 when Gastón Vives ran a very profitable aquaculture industry until its collapse in 1940 (Martínez-López & Gárate-Lizárraga, 1994). In Bahía Concepción, the extraction of the Calico scallops [*Argopecten ventricosus* (G.B. Sowerby II, 1842)] between 1986 to 1993, used to be the most important commercial fishery until the production declined steadily from 1991 due to the overexploitation of the species, resulting in its closure by 1994 (Felix-Pico *et al.*, 1997). This trend towards the collapse of many fisheries is a common phenomenon worldwide (Bené *et al.*, 2007; Staples *et al.*, 2004; World Bank, 2004) and needs to be addressed by government agencies to ensure sustainable use of marine resources to secure food and economical development for the future.

One of the main strategies used for the protection and management of marine resources is the establishment of Marine Protected Areas (MPAs). MPAs can increase species diversity and abundance (Lester *et al.*, 2009), and the catch and size of commercially important species (Gell & Roberts, 2003; Sale *et al.*, 2005) if they are properly established and managed. However, one of the main challenges for their implementation is the selection of areas that include those habitats that are necessary for the life cycle of several species (Primack, 1993). The selection of priority areas for conservation should consider identifying those places with unique habitat, in relatively undisturbed conditions that support a diverse community with a high taxonomic richness (Salm & Clark, 2000). The use of spatially explicit tools, such as GIS and remote sensing and tracking technologies, allows for the systematic identification of those areas or habitats that are ecologically important due to their function, therefore increasing the potential benefits of conservation efforts (Malcolm *et al.*, 2012; Pressey & Bottrill, 2009; Rioja *et al.*, 2013; Woodhouse *et al.*, 2000) and reducing the cost of doing so.

Three communities, dominated by primary producers, are considered very important to preserve biodiversity in the Gulf of California: a) rhodolith beds, also know as maerl (Bosence, 1983; Foster, 2001; Hinojosa-Arango & Riosmena-Rodríguez, 2004; Riosmena-Rodríguez *et al*., 2010; Steller & Foster, 1995); 2) seagrass meadows dominated by *Zostera marina* L. and *Ruppia maritima* L. (López-Calderón *et al*., 2010); and 3) *Sargassum* spp. (C. Agardh) forests consisting of *S. horridum* (Stchell & Gardner, 1924) and another 3-4 species of this genus which are present along the West coast of the Gulf of Baja California (Nuñez-López & Casas-Valdéz, 1996; Paúl-Chávez, 2005; Hernández-Carmona *et al*., 2011). Rhodolith beds are sites of high biodiversity, with reports of over 100 species of macroinvertebrates and 72 species of macroalgae (Riosmena-Rodríguez *et al*., 2012) and up to 135 cryptofaunal species associated with them (Foster *et al*., 2007; Hinojosa-Arango & Riosmena-Rodríguez, 2004). Rhodolith beds, included those present in Bahía Concepción, also serve as habitat for the recruitment of commercial species (Riosmena-Rodríguez *et al*., 2010; Steller & Cáceres, 2009; Steller *et al*., 2009) and many others of ecological importance (Riosmena-Rodríguez & Medina-López, 2011). It has been reported that as much as 25% of macroalgal biodiversity depends on rhodolith abundance off of Brazil's Atlantic coast (Amado-Filho *et al*., 2010). The *Sargassum* forest is also relevant to the diversity due to the high richness and abundance of associated fishes and invertebrates (Foster *et al*., 2007; Suárez-Castillo *et al*., in press).

On the other hand, *Sargassum* spp. forests are considered a diversity facilitator in marine communities (Aburto-Oropeza & López-Sagástegui, 2006; Sala *et al*., 2002; Ulloa *et al*., 2006) and a critical habitat for some of the associated species (Aburto-Oropeza *et al*., 2007). It has been reported that more than 160 invertebrate, 90 fish (Avila *et al.,* 2010; Foster *et al*., 2007; Suárez-Castillo *et al*., in press) and 40 macroalgal species (Valdéz-Navarrete, 2009) associated with the Sargassum forests.

The present study uses GIS and remote sensing methods to evaluate the roll of rhodoliths and *Sargassum* spp. as critical habitats for commercially important and endangered marine species in Bahía Concepción by providing detailed information on habitat type and distribution to managers and other stakeholders. Due to the extent and wide distribution of rhodolith beds and Sargassum forest on the West coast of the Gulf of California (Casas-Valdéz *et al*., 1993; Foster, 2001; Foster *et al*., 1997; Hernández-Carmona *et al*., 1990; Pacheco-Ruíz *et al*., 1998; Riosmena-Rodríguez *et al*., 1999), their relevance as critical habitat on the life cycle of commercially important and endangered species is fundamental for developing adequate management strategies. Previous efforts to map the location and extension of rhodolith beds in the past include aerial photographs (Steller & Foster, 1995), the use of remotely operated vehicles (ROV) (Amado-Filho *et al*., 2012a), a combination of side scan sonar and scuba (Amado-Filho *et al*., 2012b), and acoustic seafloor mapping (Halfar *et al*., 2012). In the case of the Sargassum forests, efforts focused on in situ evaluations conducted with the use of SCUBA techniques (Casas-Valdéz *et al*., 1993, 2007; Mafra & Cunha, 2002).

MATERIALS AND METHODS

Study area

Bahía Concepción is a 40 km long shallow bay with an average width of 7.5 km, which opens to the Gulf of California at the north end (Fig. 1). The deepest areas range between 50 and 60 m depth at the main channel. A continuous alluvial slope dominates the eastern side of the bay, while the western shore is dominated by steep rocky shorelines. The southern end of the bay is also an alluvial plain that rises towards the southeast (González-Yajimovich *et al.*, 2010). The bay has a semi-diurnal tide that in average ranges 59 cm at the entrance and 75 cm at the head (Obeso-Nieblas *et al.*, 1996).

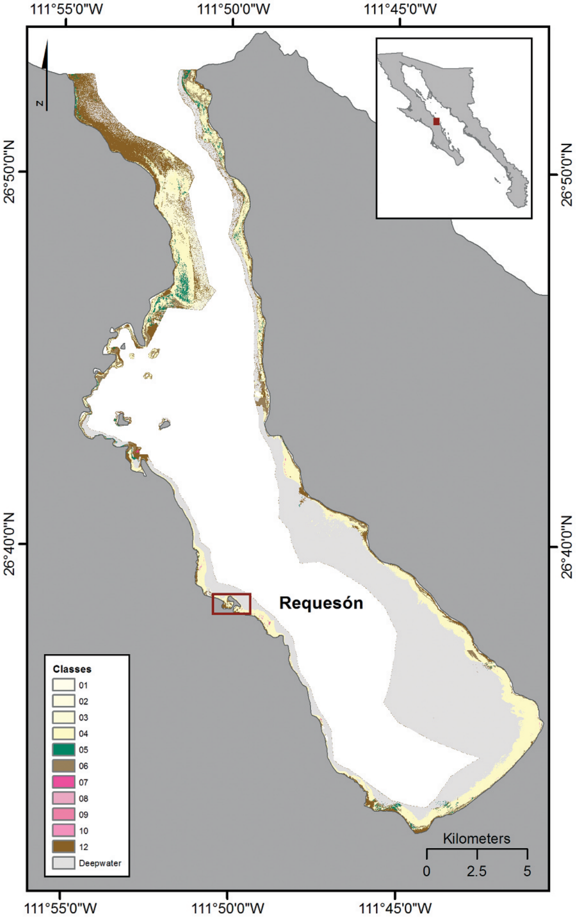

Fig. 1. Thematic map of benthic habitats of Bahía Concepción, Baja California Sur, México, obtained Supervised classification on a Geoeye-1 (RGB) mosaic using 72 training sites gruped with a Bray-Curtis similarity index with a group average linkage method, contextual editing, and similarity on the spectral signature between habitat classes. Rhodoliths are represented in pink, green = seagrass areas, brown = *Sargassum*, yellow = sand, light gray = deep water, darker gray = dry land (the corresponding categories are described on Table I, with the exception of light gray).

In April 2011, we visited 72 randomly selected sites between the 0 and 10 m depth (Fig. 1). At each site, SCUBA was used to place a 30 m long transect perpendicular to the isobaths to gather information on species abundance and diversity for the invertebrates and fish communities. Additionally, quantitative estimates on the percentage of coverage of benthic substrates (seaweeds, seagrass, rhodoliths, *Sargassum* spp., rock, and sand), were recorded by photographs along transects.

Image pre-processing for GIS analysis

A mosaic in natural color (RGB) using four high spatial resolution scenes (2.25 m per pixel) from the Geoeye-1 platform obtained between May-June 2011, period which corresponds with the maximum extent of the *Sargassum* forest for the region (Casas-Valdéz *et al.*, 1993; Muñeton-Gómez & Hernández-Carmona, 1993), was constructed using weighted seam-lines for overlapping areas and histogram matching to reduce differences of brightness and color between scenes. These deep areas (> 10 m) were identified from navigation charts (SEMAR, 2007) and the General Bathymetric Chart of the Oceans (GEBCO 08). These areas in addition to land coverage were masked from analysis to define the Area of Interest (AOI). Atmospheric (Chávez, 1996) and water column (Green, 2000; Lyzenga, 1981) corrections and a 7 ×7 low pass filter were used to enhance contrast and eliminate noise from the mosaic (Schowengerdt, 2007).

Habitat characterization and thematic map

Estimates on the percentage of coverage of benthic substrates were obtained from ground-truthed sites by analyzing photographs of 0.25 m^2 quadrats (28 per site) taken every 5 m along the transects. Each photograph was analyzed using the software VIDANA (Developed by The Marine Spatial Ecology Lab at The University of Queensland) to calculate the percentage of coverage of the different substrates and results were averaged per transect. A hierarchical classification analysis between sites was performed to obtain main habitat classes (Mumby & Harborne, 1999; Rioja-Nieto & Sheppard, 2008). Ground-truthed sites were then used as training samples to perform a supervised classification on the Geoeye mosaic with the maximum likelihood algorithm. Using an 80% level of similarity, contextual editing, and similarity on the spectral signature between habitat classes, a classification distinguishing 11 classes (Table I) was obtained to produce the thematic map of the shallow benthic habitats of Bahía Concepción (Overall accuracy = 93%, Kappa = 0.82). Accuracy assessment was estimated using an error matrix to compare habitat predicted types to ground-truthed data (Congalton, 1991). The obtained thematic map was exported to a GIS (ArcMap 10) for analysis (i.e. estimate coverage of habitats). Image pre-processing and classification was performed using ERDAS Imagine 2011.

Sampling of associated invertebrate and fish species

Fish species surveys were conducted in April 2011 at each site by counting along a 30 m long × 2 m wide × 2 m height belt transects parallel to the isobaths. Invertebrate species were recorded for the same transect but only considering a 1 m width. After transects were deployed, surveyors waited for 1 minute to allow fish to settle before commencing the survey. Species were identified *in situ* and all information was recorded on previously prepared formats. Underwater photographs were taken when organisms could not be identified on the field for further analysis in the laboratory. Species were identified to the minimum taxonomic level

Table I. Simplified classes utilized to produce the thematic map of shallow marine habitats of Bahía Concepción. Coverage: presence < 5%, low ≥ 5 ≤ 25%, medium > 25 ≤ 50%, high > 50 ≤ 75% and very high > 75%

Class number	*Main habitat features*
1	Medium cover each of sand and macroalgae with low cover of sponges and presence of rock.
2	Medium cover each of seagrass and sand.
3	Low to very high cover of sand with very high cover of filamentous algae.
4	Low to very high cover of sand, low cover of macroalgae and low cover of filamentous algae.
5	Low to medium cover of hydrozoans with high cover of sand.
6	Medium to high cover of *Sargassum* spp. with medium to very high cover of sand.
7	Low cover of macroalgae, very high cover of rhodoliths.
8	Low to medium cover each of sand and macroalgae, medium cover of rhodoliths.
9	Medium to high cover each of rhodoliths and sand.
10	Low cover of sponges with very high cover of rhodoliths
11	Very high cover of *Sargassum* spp.

according to invertebrate and fish identification guides by Allen & Robertson (1998), Eschemeyer *et al*. (1999), Goodson (1988), Gotshall (1998), Robertson & Allen (2008), and Thompson *et al*. (1979).

Abundance and richness data analysis

Richness and abundance of invertebrate and fish species was calculated as the average per transect for the bay. Species from both taxa that represented 95% of the total abundance were identified and classified according to their abundance. Further comparisons were conducted to analyze the effect of coverage of rhodolith, seagrass and *Sargassum* spp., on the assemblages of fish and invertebrates in shallow areas of the bay by classifying transects according to habitat type.

RESULTS

A thematic map of the shallow benthic habitats in Bahía Concepción was obtained from satellite data (Fig. 1, Table I). A close-up example of a very important area dominated by rhodolith, El Requeson, is shown in Fig. 2. Rhodoliths dominated 4 classes with medium to very high coverage (classes 7-10, Table I). In general a total, of approximately 10.6 ha were covered by living rhodoliths around the islands and predominantly on the western coast of the bay. This represents approximately 0.038% of the total area of the bay (approx. 27.50 ha). Meanwhile seagrass covered 33.74 ha and *Sargassum* spp. dominated 450.93 ha (Fig. 3). Estimations of dead rhodolith coverage were not possible to calculate using the GIS and remote sensing methods due to lack of thalli red pigmentation that makes them very similar to sand-dominated areas.

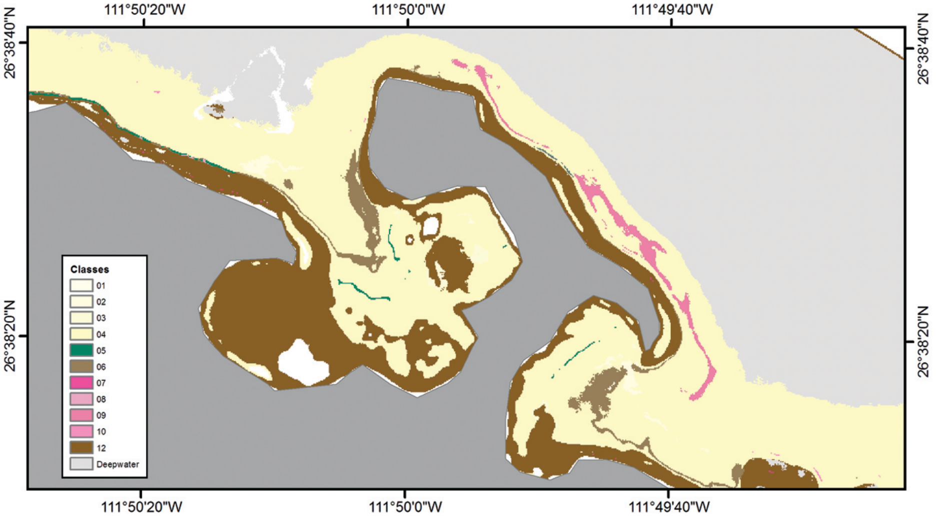

Fig. 2. Thematic map for “El requeson” area, one of the most studied rhodolith sites in Bahía Concepción. Distribution and coverage of *Sargassum*, seagrass areas and rhodoliths are shown in brown, green and pink, respectively.

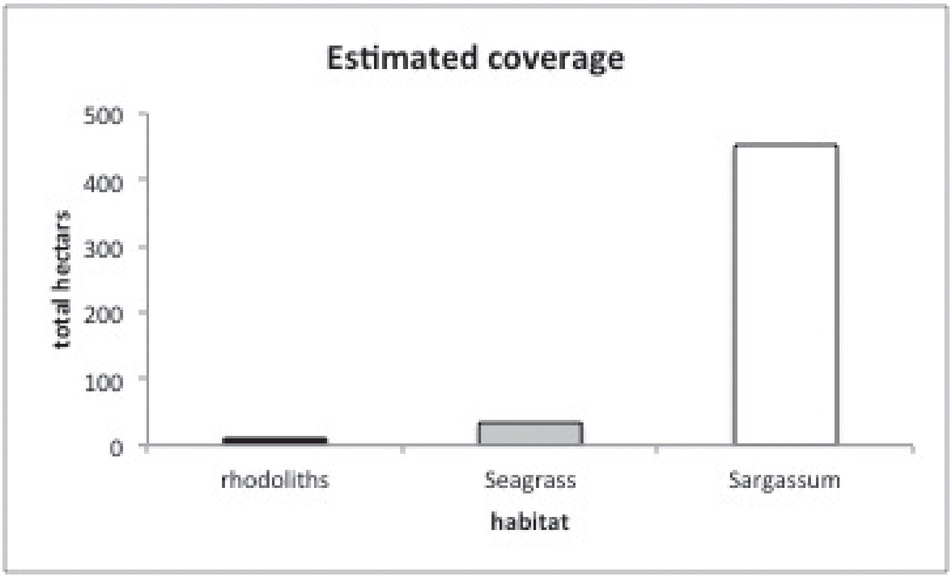

Fig. 3. Estimated coverage of primary producers for shallow benthic habitats in Bahía Concepción, B.C.S., México. Rhodoliths covered approximately 10.6 ha, seagrass 33.74 ha and *Sargassum* a total of 450.93 ha.

Benthic assemblages were dominated in abundance by invertebrates which averaged 209.15 organisms per transect. Fish presented a lower abundance with an average of 32.3 organisms per transect for the sampled sites (Fig. 4). Assemblages were dominated by the anemone *Aiptasia californica* Carlgren, 1952 with mean abundaces of 140 organisms per transect; followed by the sedentary polychaete *Bispira rugosa* Kroeyer, 1856 (43 organisms/transect), both filterfeeder species. Two species of hermatypic corals were within the species representing 95% of the total abundance, *Pocillopora verrucosa* Ellis *et* Solander, 1786 (18 organisms/transect) and *Porites panamensis* Verril, 1866 (2 organisms/transect) (Fig. 5). A total of 15 species of fish dominated in all sites (95% of total abundance), with only four being the most important, *Abudefduf troschelii* (Gill, 1852), *Anisotremus interruptus* (Gill, 1852), *Haemulon maculicauda* (Gill, 1852) and *Eucinostomus* sp. (Baird *et* Girard *in* Bair, 1855). The last three species are commercially extracted but not considered of high economical value for the fisheries of the region (Fig. 6).

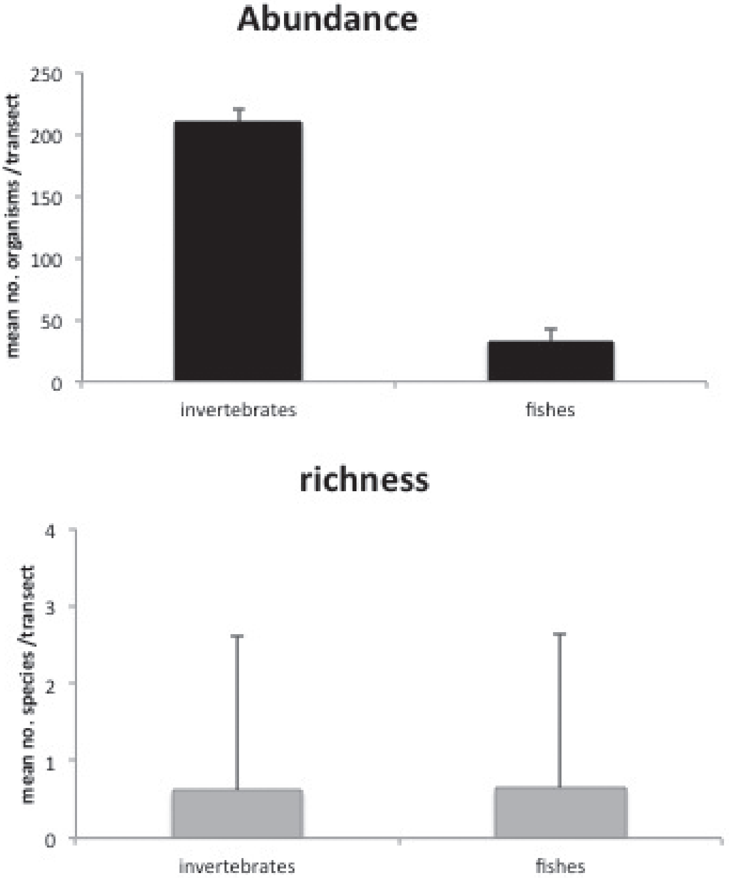

Fig. 4. Overall abundance and richness of fish and invertebrate species recorded for shallow benthic habitats in Bahía Concepción. Invertebrate abundance was higher than fish abundance (upper graph). Richness was similar when data from all transects was analyzed together for both taxa (lower graph).

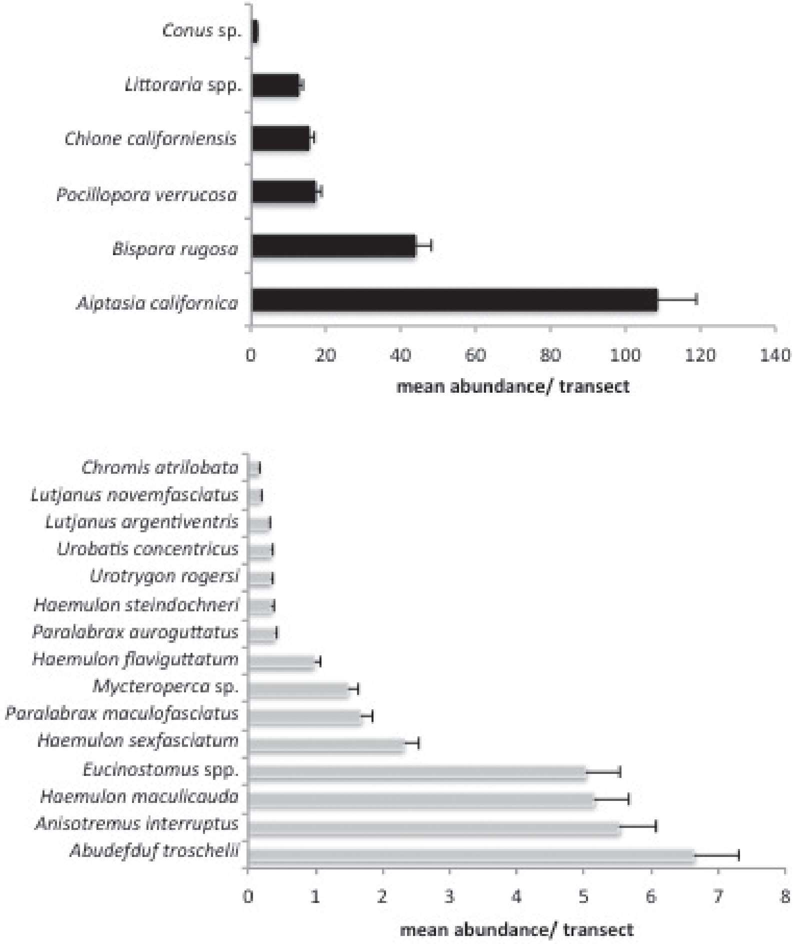

Fig. 5. Mean abundance of species that represented 95% of the total abundance for invertebrates (upper graph) and fish (lower graph). The anemone *Aiptasia californica* dominated shallow benthic assemblages in the study area; followed by the polychaete *Bispira rugosa*, both species are filter feeders.

Abundance of fish and invertebrates was analyzed by transect to explore possible patterns on shallow benthic assemblages in the bay. Invertebrates showed higher abundances for those transects (1-14) with high rhodolith coverage, with an average of 741.3 organisms per transect. These abundances were matched just in two occassion for transects dominated by *Sargassum* spp. (Fig. 6), the second most important habitat for the invertebrate assemblages, with an average of 165.3 organism per transect. For fish species, the importance of both habitats was inverted, with higher number of fish in *Sargassum* spp. (85.45 organisms/transect) followed by rhodolith beds (21.61 organisms/transect). One transect, dominated by seagrass followed the pattern described previously for *Sargassum* spp., with higher abundance of fish and lower presence of invertebrates (transect # 43, Fig. 7).

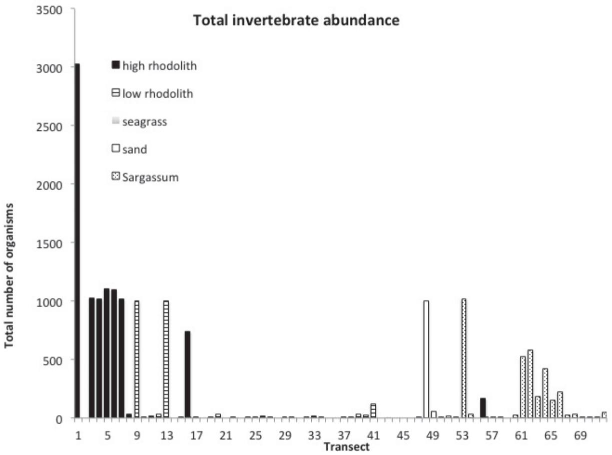

Fig. 6. Total abundance of invertebrates by transect. Overall, invertebrates were more abundant on benthic substrate dominated by high densities of rhodoliths (transects 1-14).

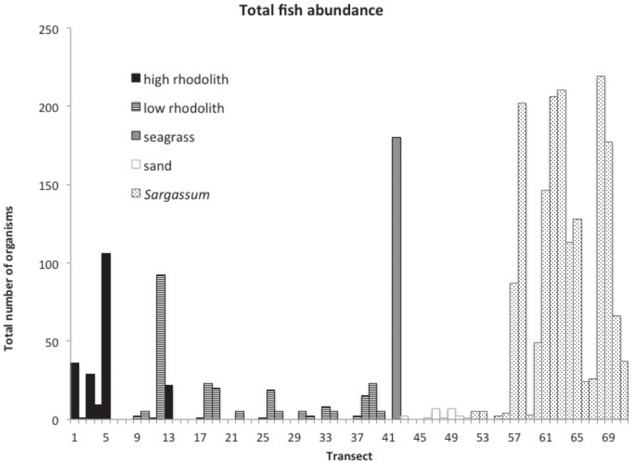

Fig. 7. Total abundance of fish by transect. Fishes were more abundant on those habitats dominated by *Sargassum* spp. (transects 57-72). Seagrass showed high abundance of fish (transect 41).

Four species included in the Official Mexican Standard and Environmental law published in 2010 for the protection of native and endangered species (NOM-059) were recorded during our surveys. Three were the bivalves *Pteria sterna* (Hanley, 1856), *Pinctada mazatlanica* (Gould, 1851), and *Spondylus calcifer* (Carpenter, 1857). The other species was the sea cucumber *Isostichopus fuscus* (Ludwig, 1875). All four species were observed during dives on rhodolith beds, even though observations were not registered as the specimens were outside transect boundaries. *P. mazatlanica* was recorded only for a *Sargassum* spp. dominated transect.

DISCUSSION

The method used in this study allows a more precise and extensive mapping of the area of interest with significant reduction of time in the field. Combining in situ observations with remote sensing data allows a more accurate mapping not only for one component of benthic communities such as rhodoliths, but other critical habitats such as Sargassum forest and seagrass beds at the same time. Previous studies have tried to map the presence of rhodolith, seaweed and seagrasses beds in the bay by direct and indirect methods. For example, direct evaluations of *Sargassum* spp. forest extension (Casas-Valdéz *et al.*, 1993, 2007), aereal surveys of rhodolith beds (Steller & Foster, 1995) or remote operated vehicles and side scan sonar (Amado-Filho *et al.*, 2012a, 2012b). The limitation of resources both technological and financial have limited the precision when mapping different marine habitats, not only for the presence of rhodoliths but also other habitats such as *Sargassum* spp. and seagrass beds. Given these limitations and the need for cost-effective tools for management planning, the application of coupled methodologies, such as the one proposed here, are essential.

The analysis of satellite photographs carried out during the present study showed that areas shallower than 10 m and close to the shore are dominated by *Sargassum* spp. during the spring time with an estimated 450.93 ha covered by this species. Suárez-Castillo *et al.* (personal communications) estimated 264.1 ha using *in situ* approach. Our estimations are 45 times higher for *Sargassum* spp. and just over 10 ha of live rhodoliths in the bay. While overall spatial coverage is low, rhodoliths are present all year long, making rhodolith beds a long-lived and persistent habitat (Foster *et al.*, 2007). Due to their hard 3-dimensional structure rhodolith beds can harbor many species of invertebrates and fish. This abundance and richness is enhanced by non-living rhodolith sediments and other foundation species such as *Sargassum* spp., that also harbour a diverse associated community (Foster *et al.*, 2007; Hinojosa-Arango *et al.*, 2009; Steller & Foster, 1995). The assemblages associated with living rhodolith beds are so diverse that have been compared to those observed in coral reefs and giant kelp forests (Austin *et al.*, 1980; Cabioch, 1969; Patton, 1994). On the other hand, *Sargassum* spp. and seagrasses are seasonal communities, which limits the time that they are available as habitat for fish and invertebrates. As reported by Foster *et al.* (2007), *S. horridum* in Cabo Machos, at the mouth of Bahía Concepción, directly affects fish and invertebrate diversity by providing shelter when fully developed thalli are present. It also can have an indirect effect as a source of food.

Differences in habitat structure are obvious between rhodoliths and the other two analyzed habitats, *Sargassum* spp. and seagrasses. The thalli of seaweeds and the blade of seagrasses seem to allow for the development of a more abundant fish community; while invertebrates are more abundant in association with rhodoliths (Fig. 6). The use of *Sargassum* spp. forest and seagrass by fish species during their developmental stages have been previously described (Aburto-Oropeza *et al.*, 2009), which can use all levels of the canopy due to their higher mobility. In the case of the invertebrate assemblages, with many sedentary species, hard-stable substrates facilitate their development. Rhodoliths have been widely recognized for their importance for invertebrate assemblages both in Bahía Concepción (Foster *et al.*, 1997, 2007; Steller *et al.*, 2003; Hinojosa-Arango & Riosmena-Rodríguez, 2004; Riosmena-Rodríguez *et al.*, 1999) and around the world (Amado-Filho *et al.*, 2010; Foster, 2001; Foster *et al.*, 2007; Gagnon *et al.*, 2012; Hall-Spencer *et al.*, 2003).

Management of foundational habitats such as rhodoliths and Sargassum forests, could help to prevent fisheries collapses such as the one described for the Calico scallop in Bahía Concepción in 1994 (Felix-Pico *et al.*, 1997) and the general detrimental trend on fisheries (Bené *et al.*, 2007; Staples *et al.*, 2004; World Bank, 2004). The GIS and remote sensing coupled methodologies used in this study allow for multispecific habitat detection with higher precision than previous methodologies that facilitate mapping and consequently management planning.

The Use of GIS for the management of rhodolith and Sargassum *spp. associated species*

Specific cases of fisheries collapse are already known for Bahía Concepción (Felix-Pico *et al.*, 1997). During the study close attention was paid to those species listed on the NOM-059, to determine which habitats could play an important role for such species in the bay. We found 4 species of invertebrates included in this list associated with rhodolith and *Sargassum* spp. beds during dives. All species were of commercial importance until their numbers decreased and their fishery became not profitable (Felix-Pico *et al.*, 1997). Signs of human impact on the benthic community in Bahía Concepción can also be appreciated on the composition of rhodolith beds assemblages. We found two species of filter feeders that have been used as disturbance indicators around the world and at different scales depending on their abundances, *Aiptasia californica* (Geller *et al.*, 2005) and *Bispara rugosa* (Thiel, 2008). They were the most abundant species in our study but further studies are needed to determine if they can be used to monitor disturbances related to fisheries in Bahía Concepción.

The use of GIS coupled with remote sensing provided a critical tool for the mapping and management planning in the area. We were able to calculate, with an overall accuracy of 93% and kappa = 0.82, the area covered not only by rhodoliths but also for other type of habitat like Sargassum forests and seagrass beds which are mainly composed of species considered foundational for their role in providing habitat, and biodiversity support (Crowder, 2005; Shelton, 2010). Rhodoliths have already been considered in management plans elsewhere, such as in The Special Areas Conservation act (SACs) in the UK, the European Community Council Directive in the European Union, as part of the Great Australian Bight Marine Park, and the Kapiti Marine Reserve in New Zealand (Riosmena-Rodríguez *et al.*, 2010). In the case of Sargassum forest, it has been considered as a critical habitat in the south Atlantic of the USA (Connolly, 2002; Laffoley *et al.*, 2011) and an essential habitat for the management plans of barracuda and magi-magi (Connolly, 2004).

In most studies, selected taxa have been used as indicators of priority areas due to the high diversity associated with them to design both types of protected areas, terrestrial (Howard *et al.*, 1998; Kremer *et al.*, 1999) and marine (Sala *et al.*, 2002; Ward *et al.*, 1999). Nevertheless, methods such as the one used here that allow for a study at a “seascape” scale of the different benthic habitats, are necessary to design management strategies that benefit both, natural systems and the users.

CONCLUSION

GIS spatial tools combined with remote sensing information have increased our capacity to map larger areas that include a precise location of important species, in this case rhodoliths, seagrass and *Sargassum* spp., for their conservation and management. While the importance of all three groups is evident, rhodoliths – both dead and alive – play a major role not only because of their presence throughout the year, but also because they harbor species included on the NOM-059 of threatened species. Consequently, rhodolith beds should be considered in management plans as critical habitats for the survival and possible recovery of endangered and other commercially important species.

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