FINAL REPORT

Baseline for monitoring changes in corals community structure and nutrients in water at Xcalak National Marine Park

Dr. Hector A. Hernandez Arana
Rufford Small Grant Reference no. 10.06.05
Associate researcher
El Colegio de la Frontera Sur unidad Chetumal. Department of Aquatic Ecology and Systematics. Av. Centenario km 5.5 CP 77900 Chetumal Quintana Roo Mexico.
Tel: 00 + 52 983 8350440 ext 4338 Email: hectorh@ecosur-qroo.mx

Introduction

Xcalak National Marine Park was established as a protected area in 2000, it is one of the less human impacted reef areas in the Mexican Caribbean. Its reef structure is unique among the Mexican Caribbean reef for its extensive and well-defined reef lagoon and a double parallel reef barrier along its southern region that runs in to Belize. The park area has been classified in to a number of zones for different purposes from intensive to restricted and totally protected. This zonation is supposed to allow the main economic activities, mainly boating and commercial fishing, to be carried on as the local population has traditionally done it. However, from year 2000, tourism activities such as snorkelling, diving and recreational fishing have increased due to the operation of a cruise liner terminal 60 km north in Mahahual. There are also plans for developing large tourist resorts on the strip land between Mahahual and the border of Belize (including Xcalak) that will increase the pressure on natural resources including water supply and reef use.

Xcalak reef is naturally strike by hurricanes and in 2005 it was under the thread of Hurricanes Katherine and Wilma. Although no direct damage was caused on the reef, related increased in temperature produced a bleaching event in the area. Similarly, increased precipitation caused an increase in underground runoff and nutrients load discharging in to the reef. Both natural disturbances are considered important reasons for increasing algal cover in reef patches and reef barriers along the Mexican Caribbean. The natural setting at Xcalak National Marine Park, the

related economic activities and the plans for development makes necessary an adequate management of the park, which one of its main goals is to achieve a balance between conservation and sustainable development. Thus, the information gathered and provided by studies of this type are the baseline for the park authorities that allow them to know the overall condition of the natural system, the potential human impacts and how they can be separated from the natural disturbance that occur regularly.

Proposed objectives

1. To know the status of the corals community at the reef lagoon of Xcalak National Park using the spatial and temporal natural community structure of corals and recruits at locations where recreational diving / snorkelling is either permitted or restricted.

2. To estimate the nutrients load in water off the area of urban development.

3. To produce a field guide of stony and soft corals as a tool for the park authorities to strengthen environmental education activities directed to local and tourist users of the reef.

4. To propose a long-term monitoring program to identify changes on the condition of corals within the adequate context of what is due to natural and non-natural impacts.

Departures from the proposed objectives

We proposed to survey two zones to know the status of the corals community at the reef lagoon; instead we surveyed four zones two in the south and two in the north regions of the park. Overall, we surveyed two use and two restricted use zones, doubling the amount of data proposed initially. This gave us a greater area for the baseline information, allowing for a better representation of the corals condition in the reef lagoon.

We offer to surveyed coral recruits but this objective was not possible to achieve due to logistic constrains. Direct observation of recruits in the field is an extremely difficult and time-consuming task because the large amount of algae and the small size of recruits (few millimetres to one

centimetre). Our records estimated none to one recruit per m^2. This result is likely to underestimate coral recruitment in the park. Instead, we use the time planned for the recruit survey to start a parallel but related study of corals establishment within Chetumal Bay through an artificial channel, built from 1999-2004, that communicates the south region of the park with the bay. This study started in April 2006 and ended august 2006. Additionally we started in September 2006 a colonization experiment using carbonate tiles distributed from the reef lagoon through the artificial channel and a small portion of Chetumal bay to study reef organisms' settlement.

We also proposed to measure levels of nutrients in water at the reef lagoon. This objective was change by an explicit demand of the park authorities to measuring nutrients in wells water from the village. This demand is based on the assumption that conditions of nutrients levels in wells water will be a better indicator of the quality of water used in the village as well as an indicator of the quality of underground water that runs in to the reef lagoon.

Main results

The survey was carried on during 2005 and 2006 on the following regions, localities and stations (Figure 1 and Table 1). Overall 347 transects were surveyed for 6,960 linear metres of reef patches within the reef lagoon. This is the largest data set at present for Xcalak National Park and constitutes a valuable baseline for future monitoring. Our results are presented in a summarize form pooling together the data of the two samplings per region in order to show the general patterns on corals distribution and composition, as well as the general tendencies on hard coral linear cover and the overall size distribution of soft corals. We registered, only for the reef lagoon, 44 species of soft and hard corals, which correspond to nearly 60% of the overall species list for the whole park.

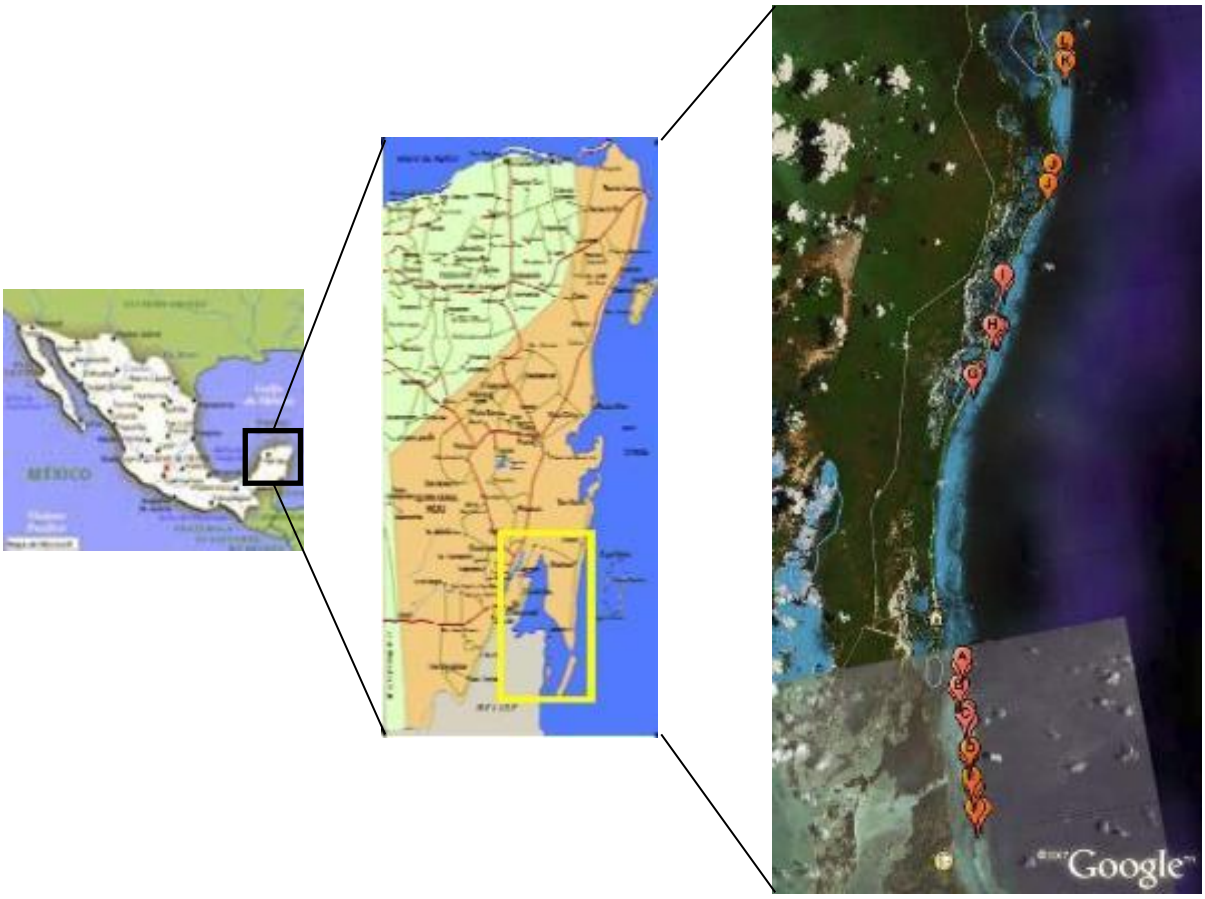

Figure 1. Xcalax within the context of the Mexican Caribbean, and the approximate location of surveyed regions, zones and localities on the reef lagoon at Xcalak National Marine Park.

Table 1. Summarized description of the survey design applied for the study of soft and hard corals community structure at Xcalak Reef National Park.

Sampling date	Region	Zone	Localities	Station	Transects (20 m)
July 2005 Nov 2005	South	Public use	A	a-c	15 15
July 2005 Nov 2005		Public use	B	d-f	15 15
July 2005 Nov 2005		Public use	C	g-i	15 15
July 2005 Nov 2005		Restricted use	D	j-l	14 14
July 2005 Nov 2005		Restricted use	E	m-o	15 13
July 2005 Nov 2005		Restricted use	F	p-r	15 15
April 2006 July 2006	North	Public use	G	a-c	15 15
April 2006 July 2006		Public use	H	d-f	11 15
April 2006 July 2006		Public use	I	g-i	10 15
April 2006 July 2006		Restricted use	J	j-l	15 15
April 2006 July 2006		Restricted use	K	m-o	15 15
April 2006 July 2006		Restricted use	L	p-r	15 15
Total					347

Coral community structure

The spatial distributions of coral species averaged by locality within the regions are presented in Figure 2. All localities in the south region had a higher number of species in average than those at the north region; however, the standard deviation, which is bigger for the north than for the south region, does not allow being conclusive regarding the differences between regions. There are not clear differences in number of species among localities within regions, neither between public and restricted use zones.

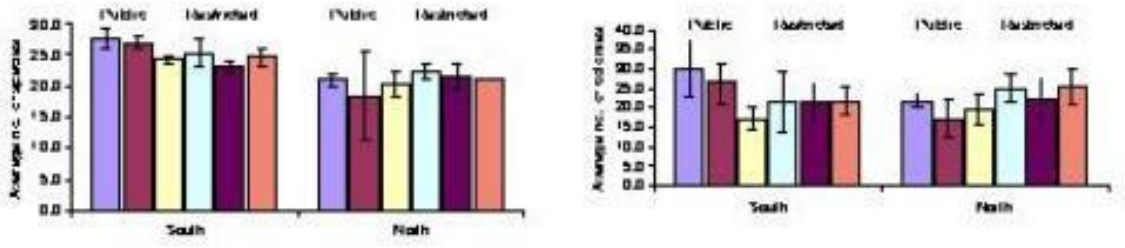

Figure 2. Average number of species and average number of colonies (± 1 SD) per locality by zones and region of hard and soft corals sampled in Xcalak Reef National Park during 2005 and 2006.

We observed the same pattern of spatial distribution for the average number of colonies of hard and soft corals and linear cover of hard corals by locality per zones and region (Figures 2 and 3). No marked differences are apparent between regions and no clear differences among localities within regions and between public use and restricted use zones. It is important to note the larger variability, represented by the standard deviation, recorded for number of colonies and linear cover. This variability reflects the patchy distribution of corals in the reef lagoon; it changes from zone to zone and region to region.

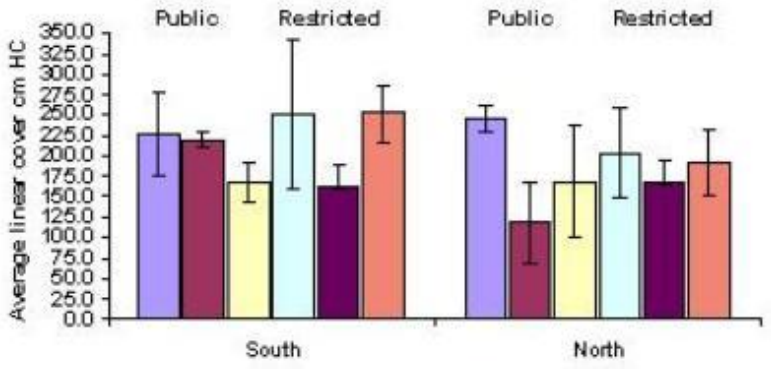

Figure 3. Average linear cover (± 1 SD) per locality by zones and region of hard corals sampled in Xcalak Reef National Park during 2005 and 2006.

The size distribution of soft corals between zones within regions has the same shape. Soft corals in the range of 15 to 30 cm high are numerical dominant. The main difference is related to the number of colonies present within the zones. Looking at the south region, the public use zone had more colonies of soft corals than the restricted use and it is the opposite for the north region (Figure 4).

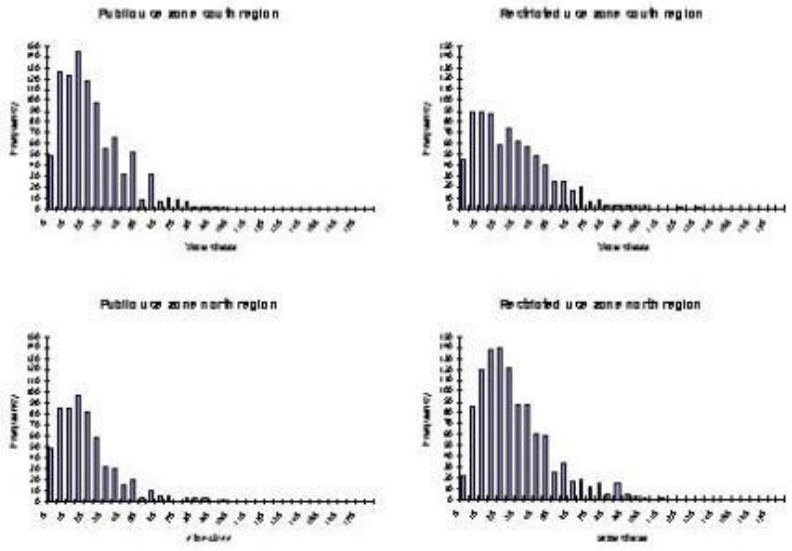

Figure 4. Size distribution of soft corals by zone and region. Total number of colonies for the south region = 1708 and for the north region = 1656

One of the main objectives of this survey was to represent the overall condition of hard and soft corals within the reef lagoon. Based on the sampling effort at different spatial scales we can state that corals are relatively well distributed along the reef lagoon, with minor differences between localities, zones, and regions. This spatial structure of corals composition makes easier the design of a long term monitoring program for the reef lagoon. There are a number of options for a proper design, one is to keep the sampling effort and do yearly surveys of composition and linear cover. Due to the lack of differences based on the baseline data, then it would be expected that large-scale natural disturbances would influence equally the south and north regions. On the contrary, smaller scale disturbances such as human influences would be expected to have local impacts at the locality or even at the station level, thus any major differences between zones could be related to differences in the use type.

Nutrients in well water at Xcalak village

This data is the first baseline information of nutrients levels in wells water at Xcalak. The purpose of this data is to place in to context the levels of nutrients in wells compare to those registered in the reef lagoon, Chetumal Bay and some control wells out of the village. All nutrients in wells water have higher concentration than those registered for the reef lagoon and Chetumal Bay, with

ammonium and O-Phosphates being relatively higher in Xcalak village wells (Figure 5). Ammonium is considered an indicator of recent organic contamination; under natural conditions ammonium levels in underground water increases during the rainy seasons. However, in villages such as Xcalak where there are not drainage system for sewage, leakage from septic wells is likely to occur. According to Mexican regulations on the quality of water for human use, the nutrients load in wells from Xcalak village is too high for human use. Inhabitants of Xcalak rarely use well water because its brackish nature, thus the risk for diseases via well water is relatively low. There is also the potential of long-term environmental impact on the reef lagoon due to higher nutrients load in underground water that runs in to the reef system. This impact is reflected in the amount of algae growing on the reef that in turn changes the dominance pattern from corals to macroalgae. Excessive nutrient load is not the only cause for changes in the dominance pattern from corals to algae, but it is a potential thread for reef systems under tourist pressure, which is the case for the reefs systems in the Mexican Caribbean.

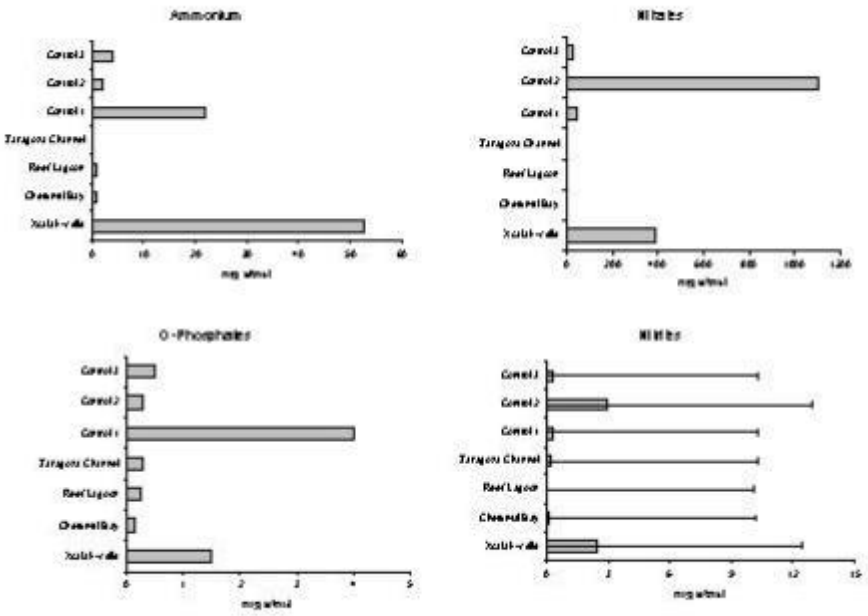

Figure 5. Concentration of nutrients in wells water at Xcalak village compared with levels of nutrients at the reef lagoon and some sites at Chetumal Bay.

Main products obtained

Database of hard and soft corals. This study has produced a comprehensive database of linear cover and species composition of soft and hard corals for the reef lagoon of Xcalak National Park. The database comprises more than 8,500 records, along nearly 7,000 m of linear patch reefs direct observations. It is expected that this database become a quantitative reference of community composition and general condition of patch reefs at Xcalak.

Data base of nutrients levels in wells water. This study has produced the first database of nutrients levels in wells water at Xcalak village. The database comprises approximately 300 records of six different nutrients.

Field guide of hard and soft corals. We have recorded approximately 3,000 digital photographs of hard and soft corals for all the species present at the surveyed sites in the reef lagoon. 50% of the photographic record has been checked for correct identification of hard corals by a recognize expert in the field. Although one of the objectives of this study was to produce a field guide of hard and soft corals, at present we have not completed the id checking for the soft corals, which is a difficult group to id directly in the field. We have made progress on the selection of photographs of hard corals to be included in the field guide and we are working in a join proposal with The Mesoamerican Barrier Reef Project (MBRS). The proposal seeks to use the field guide for Xcalak as a pilot project for similar guides on the other protected areas within the MBRS (Appendix A).

Human resources. Throughout the duration of the study we have trained undergraduate students on field techniques for reef surveying. This training has been achieved through collaboration between El Colegio de la Frontera Sur and the University of Plymouth, UK. At present three students from the University of Plymouth and two from Mexican universities have collaborated within the project and received hands on training on corals id, reef surveying and the analysis of nutrients in wells water. Because of this collaboration program, there has been one BSc dissertation of Mr. Hylton Calder pots for an environmental science degree from the University of Plymouth (Appendix B). There was also a poster presented at the first meeting of the Mexican Ecological Society during last November, this poster is part of a BSc in biology of a Mexican student (Appendix C). It is expected to have, in the near future, one BSC dissertation from a Mexican student for a Biology degree and one BSc dissertation from another UK student for a coastal Ecology degree

Technical report. At present there is a technical report being written for the park authorities that includes a detail description of species composition and condition of the corals community structure in four zones of the park and first information related to levels of nutrients in wells water from Xcalak village. The report also includes a proposal for a long term monitoring program of the four zones surveyed during 2005-2006.

Other products. Derived from the first results obtained during this study, a proposal was written and submitted for funding to The National Commission for Biodiversity (CONABIO) in Mexico. The proposal offers to build a bathymetric chart and a habitat mapping of the entire park; it was accepted for funding and started operating in January 2007. Information related to the approved project can be found on the following link project number DM015 "Caracterización del ANP Parque Nacional Arrecifes de Xcalak y formulación de un programa de monitoreo"
http://www.conabio.gob.mx/institucion/restauracion/doctos/Proy_Aprob.pdf

Linkages established with the park authorities of Bacalar Chico in Belize to start a collaboration programme for continuing working in the area of influence of the artificial channel build from 1999-2004.

What red spots or information needs we observed?

1) Artificial channel that facilitates colonization of marine fauna in to Chetumal Bay, the discharge of lower salinity water and nutrients into the reef lagoon and the potential development for marina and tourist resorts.

2) High levels of nutrients in underground water from the village wells. Is this load of nutrients reaching the reef lagoon?

3) Need of experimental observations for coral recruitment in collaboration with researchers from other institutes in México.

Financial report

Equipment and consumables	Cost in Sterling
Digital camera including housing for a permanent record of local Species.	550.00
GPS for site positioning and relocation	300.00
Plastic chains, lead, ropes, buoys, water proof paper. Materials required for the transect surveys and in situ recording of species composition, percentage of cover and general condition of corals	200.00
Materials for quadrat construction. This will be used to estimate recruits density	100.00
Fuel for ground transportation. Xcalak is located approximately 230 km from the research centre.	400.00
Expenses for 4 persons. This correspond to 45 days at the field	1,000.00
Reagents and consumables for water samples analyses	1,500.00
Edition of booklet for corals field guide*	NOT FINISHED
Electric vacuum pump. For filtering water samples	250.00
Maintenance of equipment (not considered initially)	200.00
Total	**4,500.00**

* The field guide is in the process of edition and the remainder 500 sterling pounds from the original budget received will be used for preparing the draft. The final publication will be done in collaboration with the MBRS project. A photograph of the equipment bought with the grant is included in Appendix D.


STONY AND SOFT CORALS
Of the reef lagoon of Xcalak Reef National Park
Hector A. Hernandez Arana
Humberto Bahena Basave
Aurora U. Beltrán torres

Size, Abundance and Composition of Hard and Soft Corals, in Free and Restricted Use Reef Lagoons in Xcalak's National Park, Mexico.

Hylton Calder-Potts
285871
E0E3215
Tutor: Dr Paul Ramsay

Size, Abundance and Composition of Hard and Soft Corals, in Free and Restricted Use Reef Lagoons in Xcalak's National Park, Mexico.

Disclaimer

The research presented in this thesis is original and has been carried out by the undersigned, except where otherwise stated.

_____

Hylton Calder-Potts

W**ord count 3,851**

CAMBIOS EN LA DIVERSIDAD MACRO Y MEGABÉNTICA EN EL SURESTE DE LA BAHÍA DE CHETUMAL PRODUCIDOS POR LA APERTURA DEL CANAL DE ZARAGOZA

*Ameneyro Ángeles Brenda y Hernández Arana Héctor A..
El Colegio de la Frontera Sur Unidad Chetumal. Departamento de Ecología Acuática y Sistemática. Av. Centenario km 5.5 C.P. 7700 Chetumal, Quintana Roo hectorh@ecosur-qroo.mx

INTRODUCCIÓN

Una perturbación produce cambios estructurales en los patrones comunitarios. Estos cambios han sido descritos usando como modelo a la fauna béntica, ya que los organismos son relativamente sedentarios con tiempos generacionales comparativamente largos (Thouzeau *et al.*, 1991 en Araski, E. 2004). Idealmente los diseños de muestreo para detectar cambios demandan de información previa y posterior a la perturbación (Eberhardt and Thomas, 1991). En ausencia de información previa a la perturbación, se deben de utilizar otras alternativas, como lo es incluir las principales fuentes de variabilidad especial y temporal (Hernandez Arana, 2005) a la escala en la que ocurren los posibles cambios en una comunidad (Underwood, 1994). El objetivo de este trabajo es analizar los patrones espaciales en la biodiversidad establecida en zonas específicas que nos proporcionen información del sistema en general, para evaluar los cambios producidos en la comunidad béntica por la apertura del Canal de Zaragoza.

Figura 1. Bahía de Chetumal; el recuadro señala el área de studio

MATERIAL Y MÉTODO

La zona de estudio es la región sureste de la Bahía de Chetumal entre los 18.20335º N, 87.8619º W y 18.17112º N, 87.8928 W (Figura 1 y 2). En abril del 2006 hicimos un estudio prospectivo para identificar las principales Fuentes de variabilidad por la influencia directa de los Canales de Zaragoza y Bacalar Chico. Usamos un diseño ortogonal de dos factores fijos, localidad y fechas. Cuatro niveles para localidad y tres niveles para fechas abarcando la temporada de lluvias del 2006 (Figura 2).

Figura 2. Localidades muestreadas: desembocadura del canal de Zaragoza, desembocadura de Bacalar Chico, Control 1 y 2.

En cada localidad se distribuyeron aleatoriamente diez cuadros (repeticiones) de 10m x 1m sobre sustrato rocoso, tres fijos para comparar cambios temporales. Los siete restantes se distribuyeron aleatoriamente en cada fecha de muestreo. Dentro de cada cuadro se anotó presencia de cada especie y se resaltó la presencia de corales como indicadores de cambio. Se llevó un registro fotográfico de cada especie observada. Se utilizó el paquete estadístico PRIMER 6 & PERMANOVA 2006 para el análisis de similitud entre muestras, el análisis de varianza multivariado por permutaciones, la representación gráfica por medio de Análisis canónico de ejes principales y el análisis de similitud por porcentaje para identificar las especies que discriminan entre grupos (Figura 4).

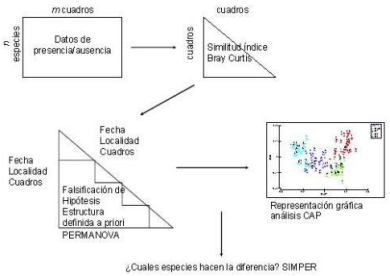

Figura 4. Estrategia para el análisis de datos multivariados modificado de Anderson (2001), Clarke y Warwick (2001).

RESULTADOS

El término de interacción fecha por localidad es significativo (Tabla 1). Los factores principales no son independientes, aunque sí hay diferencias entre fechas y localidades, es necesario analizarlos en conjunto.

Tabla 1. Resultados del análisis multivariado de varianza por permutaciones

Fuente	df	SS	MS	Pseudo-F	P(perm)
Fechas	2	13115	6557.7	5.7974	0.001
Localidades	3	1.0139e5	339797	29.8175	0.001
FxL	6	20883	3480.5	3.0769	0.001

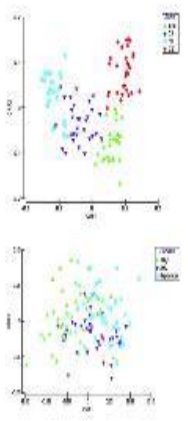

Figura 5. Ordenación de repeticiones por a) localidad y b) fecha.

La representación gráfica del efecto de fecha y localidad sobre la composición comunitaria se muestra en las figuras 5a y 5b. Las diferencias entre fechas fueron significativas aunque se observa mucha variabilidad dentro de cada fecha. Se observa un gradiente temporal de cambio en la composición comunitaria atenuado por esta variabilidad. Las diferencias entre localidades fueron significativas y se observa claramente un gradiente espacial desde los canales natural y artificial hacia las localidades control, representativas de las condiciones de Bahía de Chetumal.

Se observa también una mayor influencia de Bacalar Chico hacia el Control 1 y éste a su vez se traslapa con el Control 2. El Canal de Zaragoza se agrupa independientemente, reflejando una composición de especies diferentes, *e.g.* presencia de corales por la influencia marina. El análisis de similitud para identificar especies que discriminan entre localidades demostró que a) *Acetabularia crenulata* se encuentra en las localidades cercanas a los canales, b) *Penicillus capitatus* en el área de influencia del Canal de Zaragoza y c) *Brachiodontes sp.* en las localidades control. d) *Chondrilla nucula* está presente preferentemente en Bacalar Chico y los corales escleractinios (e-i) se distribuyen exclusivamente en el área de influencia marina, excepto *Siderastrea radians* presente también en Bacalar Chico. (Figura 6 a-i. Fotografía H. Bahena y H. Hernández).

DISCUSIÓN

Los resultados de PERMANOVA muestran que el efecto de fecha depende de la localidad. El patrón espacial de diferencias entre localidades es una característica constante durante la época de lluvias. EL patrón espacial de la composición comunitaria muestra que el Canal de Zaragoza influye al facilitar el ingreso y establecimiento de especies marinas *e.g.* corales los cuales no se encontraron en el canal natural (excepto una especie) a pesar de ser una comunicación histórica constante. Este resultado muestra claramente que sí es posible detectar cambios derivados de la construcción del canal artificial aun cuando no tenemos información previa. Esto fue posible por que el diseño de muestreo incorporó las principales fuentes de variación en el sistema (Underwood 1994; Hernández Arana *et al*. 2005).

BIBLIOGRAFÍA

Anderson,M.J., 2001. A new method for non-parametric multivariate analysis of variance. Austral Ecology 26, 32-46.
Araski E., Muniz P., Pires-Vanin A.M. 2004. A Functional Analysis of the Benthic Macrofauna of the São Sebastião Channel (Southeastern Brazil). U.S.A. Marine Ecology. Vol. 25 (4):249-263.
Eberhardt,L.L. and Thomas,J.M., 1991. Designing environmental field studies. Ecological Monographs 61(1), 53-73.
Hernandez Arana,H.A., Warwick,R.M., Attrill,M.J., Rowden,A.A., and Gold Bouchot,G. 2005 Assessing the impact of oil-related activities on benthic macroinfauna assemblages of the Campeche shelf, southern Gulf of Mexico. Marine Ecology Progress Series 289, 89-107.
Underwood,A.J., 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbance. Ecological applications 4(1), 3-15.

Agradecimientos: Financiamiento; ECOSUR, Rufford Foundation. Fotografia; H. Bahena, H. Hernández. Apoyo en Campo; R. Herrera, A. Batún. Identificación de organismos: Corales; A. Beltrán, M. Ruiz. Algas; L. Quan. Esponjas; P. Gomez. Moluscos; R. Caicedo, E. Gonzalez