Gulf of California Esteros and Estuaries

Analysis, State of Knowledge and Conservation Priority Recommendations

Final Report to the David and Lucile Packard Foundation
by the Arizona-Sonora Desert Museum

March 15, 2006

Richard C. Brusca[1], Richard Cudney-Bueno[2], Marcia Moreno-Báez[3]

1. Principal Investigator and Project Co-Director. Arizona-Sonora Desert Museum, Tucson, AZ

2. Project Co-Director. University of Arizona and Arizona-Sonora Desert Museum, Tucson, AZ

3. GIS Specialist. University of Arizona, Tucson, Arizona

In Collaboration with

Saúl Alvarez-Borrego (CICESE), Tiffany Ash-Cudney (Arizona-Sonora Desert Museum), J. Michael Beman (Stanford University), Rocío Brambilia (CEDO), Luis Eduardo Calderón (CICESE), Mauricio Cervantes (Conservation International, Mexico), Rocío Covarrubias, Meredith de la Garza (University of Arizona), Gustavo Danemann (PRONATURA Noroeste), Richard Felger (Drylands Institute & University of Arizona), Esteban Felix-Pico (Instituto Politécnico Nacional-CICIMAR), Lloyd Findley (CIAD, Guaymas), Manuel Salvador Galindo-Bect (Universidad Autónoma de Baja California), Felipe Galván (Instituto Politécnico Nacional, CICIMAR), Jaqueline Garcia-Hernández (CIAD, Guaymas), Edward Glenn (University of Arizona), Anne Gondor (The Nature Conservancy), Sandra Guido (CIAD, Mazatlán), Patricia González Zamorano (CIBNOR), Ma. Isabel Granillo-Duarte (The Nature Conservancy, Mexico), Osvel Hinojosa-Huerta (University of Arizona), Helena Iturribarria (PRONATURA Noroeste), Shannan Marty (Sonoran Sea Aquarium), Alf Enrique Meling-Lopez (Universidad de Sonora), Eric Mellink (CICESE, Ensenada), Lorayne Meltzer (Prescott College, Kino Bay Center for Cultural and Ecological Studies), Pam Nagler (University of Arizona), Hem Nalini Morzaria-Luna (CEDO), Eduardo Palacios (PRONATURA Baja California Sur & CICESE, Ensenada), Tad Pfister (Prescott College, Kino Bay Center for Cultural and Ecological Studies), Pete Raimondi (Department of Ecology and Evolutionary Biology, UC Santa Cruz), Georgina Saad (PRONATURA Baja California Sur), Jeffrey Seminoff (NOAA-National Marine Fisheries Center, La Jolla), Drew Talley (Department of Environmental Science and Policy, UC Davis), Jorge Torre (COBI), Peggy Turk-Boyer CEDO), Raul Ulloa (COBI & The Nature Conservancy), Carlos Valdes-Casillas (Sonoran Institute), Xicotencatl Vega Picos (PRONATURA, Sinaloa), Albert Van der Heiden (CIAD, Mazatlán)

ARIZONA SONORA DESERT MUSEUM

CONTENTS

EXECUTIVE SUMMARY

Esteros/estuaries are unique, marine, coastal wetlands that provide ecological attributes and economic services not found in any other ecosystems. They often house an extraordinary biodiversity and are home to distinctive communities of animals and plants found nowhere else. They provide critical nursery habitats for a many finfish and shellfish, including most commercial species fished in the Gulf of California. Their primary productivity exceeds that of almost all other marine habitats, and most of this productivity is exported to the open sea as [living or dead] biomass. These wetlands also provide ecological buffers during storms, both from land and sea. Esteros/estuaries provide critical habitat for migratory birds, both waterfowl and song birds, and the Gulf of California's coastal wetlands comprise a key migration route for birds of the Pacific Flyway, providing a corridor of aquatic habitat across nearly 600 km of desert for species moving from South American wintering grounds to North American nesting areas.. These habitats are also highly desirable to humans from a naturalistic point of view.

Despite their importance, esteros/estuaries are the most threatened and least studied coastal ecosystems in the Gulf of California. They have been largely overlooked for conservation efforts while becoming, at an increasing rate, primary sites for human development -- resorts, marinas, salt works and shrimp farms. For example, in the past 10 years over 95% of the mangrove marshes in the northern Gulf of California have already been developed for shrimp farming, and resort/vacation home development is virtually exploding on the Sonoran coast.

This report provides a general overview and state of knowledge of Gulf of California esteros/estuaries, and it recommends conservation priority sites. It is the result of an 18 month study, based on input from over 35 experts from Mexico and the U.S., as well as a review of published and unpublished information on these habitats. This is the first comprehensive analysis that summarizes these important and threatened ecosystems for this region. Although it summarizes all available knowledge, it is important to recognize that large information gaps exist for these ecosystems. In fact, one of the most striking discoveries of this project is the low level of knowledge that exists for virtually all topics investigated. Information is particularly lacking with regard to ecological processes within these habitats, and their relative impact on the adjacent marine environment. Basic information, such as percentage or levels of standing water remaining at low tide and degree of water (tidal) flushing, is lacking for practically all of the Gulf's esteros/estuaries. This information is key to assessing the role that these wetlands play as nursery grounds for marine finfish and shellfish, and the impact they have on the adjacent marine environment via the flow of nutrients (or contaminants) into the open sea. More detailed data and references to specific key works and literature are provided in the Gulf of California Esteros/Estuaries Database (Appendix 1).

Prior to this project, 145 esteros/estuaries had been recorded on official government maps of the Gulf of California. This project added an additional 63, bringing the total number of known esteros/estuaries in this region to 208. Due to their proximity and shared ecological processes, these 208 wetlands can be classified into 93 estero/estuary "systems," and these are what were analyzed for the present study. Of these, 53 are negative estuaries, 22 are positive estuaries, 4 are mixed or seasonal estuaries, and 14 are "unclassified."

The majority of the Gulf's esteros/estuaries are either very small (50 ha or less), or very large (more than 1000 ha). Ejido and federal ownership are the most prevalent types of land tenure surrounding esteros/estuaries in the Gulf of California. A relatively large percentage of these wetlands also have some form of private ownership (37%), or a type of government granted concession right (20%). However, there are still marked gaps in the information regarding estero/estuary land tenure systems. For ~23% of the esteros/estuaries land tenure is unknown or unclear.

The four most widespread uses of esteros/estuaries are: aquaculture, housing, fishing, and recreational tourism. The majority of the Gulf's esteros/estuaries have experienced some medium-level of human impact. However, the number that have experienced very low levels of impact (34) is grater than those that have been subjected to high levels of impact (21). Furthermore, of the low-impacted esteros/estuaries, 56% are larger than 50 ha. Given these somewhat encouraging numbers, combined with the fact that coastal development in this region is rapidly increasing, we believe we are at a unique and critical point in time to devote efforts to conservation and research for these important, but highly threatened ecosystems.

Thus, we provide a list of 41 esteros/estuaries (10 each for regions 1-3, 11 for region 4) that should be considered high conservation priority. In addition, of these 41 esteros/estuaries we identify 22 of "immediate" high priority, based on feasibility and need for conservation within the next 10 years. However, it is important to point out that ALL of the coastal wetlands of the Gulf are of high conservation importance. Equally important, they play different roles. For instance, some estuaries may be of key importance as nursery grounds for endangered and/or commercial species, but do not provide high levels of productivity to the adjacent marine environment. On the other hand, some estuaries with a high degree of tidal flushing are major providers of nutrients to the open sea, but might be of less importance as nursery grounds. Thus, assigning conservation priorities to some esteros/estuaries should not be used as a means to ignore conservation efforts with others. In this regard, we put particular emphasis on maintaining the current state of low-impacted esteros/estuaries, and assessing feasibilities for restoration work on impacted ones that are known to be of high ecological value. Empirically documenting the ecological role of Gulf esteros/estuaries within the context of the larger Gulf ecosystem, and establishing long-term monitoring efforts, will be essential to assess success of conservation measures and to justify, in a robust and scientific way, the development of such measures.

We also recommend that targeted efforts be devoted to the mapping of estero/estuary land tenure systems throughout the entire Gulf of California, paying particular attention to areas in which land purchases for conservation might be feasible and areas where local tenure systems can be aligned with stewardship of the wetlands to provide a buffer against future negative impacts. Local stewardship for protection of coastal wetlands should be enhanced whenever possible. This enhancement should go hand in hand with the development of strategic environmental education campaigns that address not only the ecological value of these coastal systems, but also their cultural and economic legacy. And, finally, as a conservation community we must be more effective in the ways we influence the legal structure that affects the Gulf of California's coastal wetlands.

BACKGROUND

Estuaries are among the most important coastal ecosystems worldwide, providing critical habitat for commercial and non-commercial species, acting as principal sources of nutrients to the adjacent marine environment, and serving as ecological buffers for the seashore. Their importance far outweighs their number and size, yet they are being rapidly degraded and destroyed making them critically important targets for conservation.

In the Gulf of California (Sea of Cortés), Mexico, esteros and estuaries are some of the predominant physical and biological features of the coastline. In this region, the term ***estero*** is typically used to denote coastal lagoons lacking regular freshwater input (these habitats are also known as tidal lagoons, hypersaline lagoons, or negative estuaries). They tend to be saltier at their head than at their mouth, due to high evaporation and lack of freshwater inflow. The term ***estuary***, on the other hand, is typically used for "true" estuaries with perennial (or at least seasonally predictable) freshwater input. Because of this, they are also referred to as positive estuaries. Ecologically, the esteros/estuaries of the Gulf of California can be divided into two types: non-mangrove ecosystems and mangrove ecosystems. The northern Gulf (above the Midriff Islands) has only non-mangrove esteros, whereas the central and southern Gulf (from the Midriff Islands to the mouth of the Gulf) have almost exclusively mangrove esteros/estuaries. The former always lack perennial freshwater input (i.e., no rivers reach the sea in the northern Gulf, aside from small episodic flows of the Colorado River). The latter have increasing freshwater input as one moves southward in the Gulf, with episodic rainy season flows dominating the northern mangrove lagoons, and perennial river flows characterizing the southern Gulf (mainland) mangrove lagoons.

Both esteros and estuaries are rich in biological diversity and high in productivity, transporting large amounts of living and detrital carbon offshore to the open Gulf environment. They also provide critically important nursery habitat for many if not most commercial species of finfish and shrimp in the Gulf.

Despite their ecological and economic importance, esteros and estuaries are undoubtedly the most threatened and least studied coastal ecosystems in the Gulf of California. Except for the Colorado River estuary, the esteros of the northern Gulf are virtually unstudied. In the central and southern Gulf a few estuaries have enjoyed some research and limited conservation activity, but not many (see summary below). Almost no northern Gulf estero/estuary has become a serious target for the conservation community. On the contrary, they have become, at an increasing rate, primary sites for human development -- resorts, marinas, salt works and shrimp farms. Similarly, although a number of studies of Gulf mangrove estuaries have been accomplished, no one has attempted a comprehensive or unified analysis that summarizes all aspects of these important and threatened ecosystems in the Gulf of California.

In April 2004 The Arizona Sonora Desert Museum (ASDM) received funding from The David and Lucile Packard Foundation to prepare a report on the state of knowledge of the esteros/estuaries in the Gulf of California, with particular emphasis on identifying their research and conservation needs. This collaborative effort between the ASDM and over 20 other academic and conservation organizations of Mexico and the U.S. represents the first attempt to obtain an all-encompassing and comprehensive view of the estero/estuary systems of the entire Sea of Cortés. Through this final report, we summarize the activities undertaken in this project and provide a unified perspective of the state of the Gulf's coastal wetlands in the hopes that this will provide a basis to direct future research and conservation efforts. In addition to this report, papers are being prepared for publication in the scholarly literature.

METHODS

The goal of this project was to prepare an up-to-date report on the state of knowledge of the Gulf of California's esteros/estuaries, with particular emphasis on identifying their research and conservation needs.

In order to achieve this goal, we relied upon a mixed methodology that combined qualitative and quantitative data as well as "hard" and "soft" methods for decision making. Our methodological approach is an example of the Delphi process (Phil 1971, Okoli and Pawlowski (2004) combined with a review of baseline information. It utilized an interactive and repetitive process in which experts played a key role to define and refine conclusions. It required the participation of researchers (experts) with vast knowledge of the region, and a system for data filtering as the nature of the process always had an element of subjectivity and individual objectives are not necessarily shared by all parties.

Although not entirely linear, the process to reach our goal included six distinct activities: (a) baseline data collection (b) formation of a "Gulf of California Esteros/Estuaries Working Group" (herein EWG), (c) conducting a first workshop with key experts on various fields pertaining to research and conservation of Gulf of California esteros/estuaries, (d) workshop follow-up and preliminary analysis, (e) conducting a second workshop of the EWG, (f) final analysis and product development.

Baseline Data Collection

One problem related to the identification of research and conservation needs for Gulf esteros/estuaries is that the information, when it exists, is widely scattered among various researchers and institutions in five Mexican states (plus the U.S.), and in addition it is typically discipline- or regionally-specific. Therefore, a necessary first step to reach any informed analysis of Gulf esteros/estuaries was to compile existing knowledge and organize it in a unified way.

Data collection consisted of assembling published and unpublished studies, spatial and tabular data, maps, photographs, and other information sources before and during the first workshop. This collection was done within the environment of a Geographic Information System (GIS) which is a general-purpose technology for handling geographic and tabular data in digital form. We integrated and standardized the data using this technology to develop maps of the Gulf of California esteros/estuaries, and to support decisions throughout the study. Information such as political boundaries, river networks, water bodies, bathymetry and coastline was obtained from Mexican and U.S. agencies including Mexico's National Institute of Statistics, Geography and Computer Science (INEGI), the Environmental Science Research Institute (ESRI), and the U.S. Geological Survey (USGS), among others. The information and maps collected facilitated decision making and information collection during the two workshops with researchers and conservation experts, held on June 17, 2004 and January 25, 2005.

The integration of the esteros/estuaries data included the spatial location of all esteros/estuaries in the Gulf and their categorization by size (surface area), which we calculated as the area enclosed within the highest tide line for each estero/estuary. A geodatabase[1] was created and used as the principal mechanism to store spatial and attribute data within the GIS platform. This allowed for easy storage, editing, analyzing, serving and archiving the inventory and image information containing multiple data formats, such as maps, images and text. The design and development of the geodatabase involved elements of geography, computer technology, database development, data storage, as well as ecological archiving and cartographic expertise.

We designed the database (Figure 1, Appendix 1) to be useful during and after our workshops, for both data entry and data analysis, and to compile and sort both qualitative and quantitative data. The database was organized by the following categories:

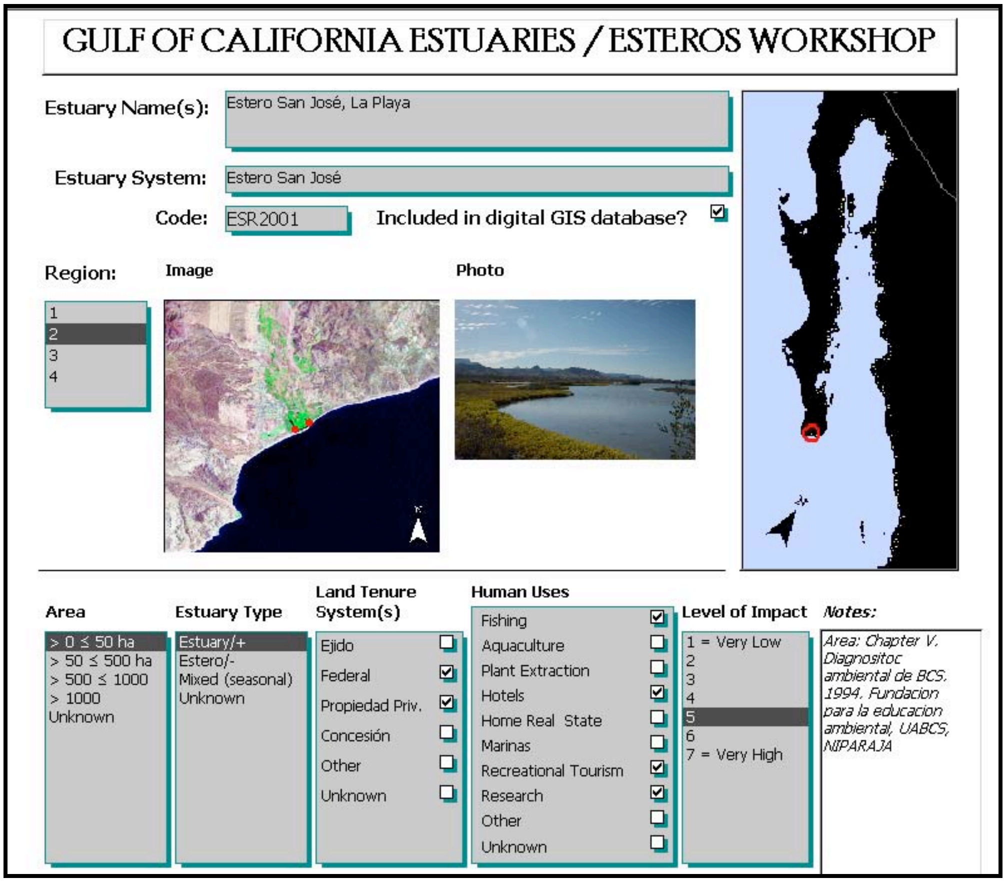
1. General Information about an estero/estuary:
    a. Estero/estuary name
    b. Estuary system name
    c. Estero/estuary type
        i. Positive (with freshwater influence)
        ii. Negative (perhaps with historical past freshwater influence, but no significant flow today)
    d. Estero/estuary area
2. Biological information
    a. Dominant vegetation
3. Human use
    a. Land tenure systems (ejido, federal, private property, concession, other, unknown)
    b. Principal types of human uses (fishing, aquaculture, plant extraction, hotels, home real estate, marinas, recreational tourism, research, other, unknown)
    c. Level of anthropogenic impact: ranked/estimated based on a Likert scale of 1 to 7. Number 1 being esteros/estuaries in "pristine" condition, and 7 being those where practically all their area and their "natural" biophysical processes had been heavily modified. By "pristine" and/or "natural" we refer to the state of the esteros/estuaries immediately prior to a large

[1] A geodatabase, short for "geographic database," represents geographic features and attributes as objects and is hosted inside a relational database management system such as GIS.

human presence on the coastline of the Gulf (i.e., late 19th century/early 20th century). However, we recognize that their "state" has been highly dynamic in geological terms and that there was some slight human impact prior to this time period.

4. Level of knowledge: A ranking of 1 implies that "practically no studies have been conducted on the estero/estuary for the given subject matter," whereas a ranking of 7 implies that "many studies have been conducted on the estero/estuary and there is little left to learn for the given subject matter." The subject matters addressed were:
    a. Biodiversity
    b. Community ecology
    c. Nursery and reproductive habitat
    d. Primary productivity
    e. Overall influence on the Gulf of California
5. Open ended questions
    a. Key biological significance of the estuary
    b. Major information gaps
    c. Major known current and future threats
    d. Current research and conservation efforts
    e. Key people to contact who are knowledgeable about the estero/estuary regarding human use, property rights, and biophysical processes

Figure 1. Example of the Gulf of California Esteros/Estuaries Working Group Database Entry Layout



To increase the coordinate precision of the geodatabase, and to facilitate discussion and analysis, we divided the Gulf of California in four discrete geographic regions. These regions largely represent ecologically distinct coastal wetland types.

Region 1. Upper Gulf non-Mangrove Esteros/Estuaries. That region comprising all non-mangrove esteros/estuaries of Sonora and Baja California.

Region 2. Baja California Mangrove Esteros/Estuaries. That region comprising all esteros/estuaries from Bahía de los Ángeles to the southern tip of the Baja California Peninsula (Cabo San Lucas).

Region 3. Sonoran Mangrove Esteros/Estuaries. That region comprising all esteros/estuaries from El Sargento (Midriff Island region) to Yavaros (southern Sonora).

Region 4. Sinaloa-Nayarit Mangrove Esteros/Estuaries. That region comprising all esteros/estuaries from Bahía Agiabampo to Cabo Corrientes.

These four regions also served as the basis for the organization of working groups during and after our workshops. In addition, in collaboration with Drs. Edward Glenn and Pam Nagler from the Environmental Research Lab of the University of Arizona, we developed the first aerial photographic atlas of the esteros found in the northern Gulf, from Guaymas (Sonora) and Bahía de Los Angeles (Baja California) to the Colorado River Delta (Appendix 2). This atlas served as an important detailed reference for experts assigned to work on Regions 1 and 3 during our workshops (Glenn et al. 2006).

Formation of Gulf of California Esteros/Estuaries Working Group (EWG)

Between March and June (2004) we identified key experts in various research and conservation fields related to Gulf esteros/estuaries in order to form an "Esteros Working Group" (EWG) that would help us address research and conservation needs of the Gulf's coastal wetlands. We paid particular attention to identifying people who, as a group, would not only give us a wide range of research and conservation expertise, but also the broadest geographical coverage possible. This group included 36 researchers and conservation practitioners from 25 Mexican and U.S. institutions (Table 1).

Table 1. List of Esteros/Estuaries Working Group Participants.

Participant's Name	Institutional Affiliation
Saúl Alvarez-Borrego	CICESE
J. Michael Beman	Stanford University
Richard C. Brusca	Arizona-Sonora Desert Museum
Luis Eduardo Calderón	CICESE
Mauricio Cervantes	Conservation International, Mexico
Richard Cudney-Bueno	University of Arizona & Arizona-Sonora Desert Museum
Gustavo Danemann	PRONATURA Noroeste
Richard Felger	Drylands Institute & University of Arizona
Esteban Felix-Pico	Instituto Politécnico Nacional-CICIMAR
Lloyd Findley	CIAD (Centro De Investigacion En Alimentacion Y Desarrollo), Guaymas
Felipe Galván	Instituto Politécnico Nacional, CICIMAR
Jaqueline Garcia-Hernández	CIAD (Centro De Investigacion En Alimentacion Y Desarrollo), Guaymas
Edward Glenn	Environmental Research Lab, University of Arizona
Anne Gondor	The Nature Conservancy
Sandra Guido	CIAD (Centro De Investigacion En Alimentacion Y Desarrollo), Mazatlán
Osvel Hinojosa-Huerta	School of Natural Resources, University of Arizona
Patricia González Zamorano	Centro de Investigaciones Biológicas del Noroeste, CIBNOR
Shannan Marty	Sonoran Sea Aquarium

Alf Enrique Meling-Lopez	Universidad de Sonora
Eric Mellink	CICESE
Lorayne Meltzer	Prescott College, Kino Bay Center for Cultural and Ecological Studies
Hem Nalini Morzaria-Luna	CEDO (Intercultural Center for the Study of Deserts and Oceans)
Pam Nagler	Environmental Research Lab, University of Arizona
Eduardo Palacios	PRONATURA Baja California Sur & CICESE
Tad Pfister	Prescott College, Kino Bay Center for Cultural and Ecological Studies
Pete Raimondi	Department of Ecology and Evolutionary Biology, UC Santa Cruz
Jeffrey Seminoff	NOAA-National Marine Fisheries Center, La Jolla
Drew Talley	Department of Environmental Science and Policy, UC Davis
Jorge Torre	COBI (Comunidad y Biodiversidad A.C.)
Peggy Turk-Boyer	Intercultural Center for the Study of Deserts and Oceans (CEDO)
Raul Ulloa	Comunidad y Biodiversidad A.C.(COBI) & The Nature Conservancy
Carlos Valdes-Casillas	Sonoran Institute
Albert Van der Heiden	CIAD (Centro De Investigacion En Alimentacion Y Desarrollo), Mazatlán
Xicotencatl Vega Picos	PRONATURA, Sinaloa
Manuel Salvador Galindo-Bect	Universidad Autónoma de Baja California
Ma. Isabel Granillo-Duarte	The Nature Conservancy, Mexico

First Workshop of the Gulf of California Esteros/Estuaries Working Group

On June 17 2004, we conducted a workshop at the Westward Look Resort in Tucson, Arizona as a continuation of the Gulf of California Conference held from June 13-16, 2004. The workshop objectives were to:

1. Obtain baseline data on the state of knowledge, the main threats, and existing conservation opportunities of the Gulf of California esteros/estuaries.
2. Reach consensus within the Esteros Working Group on future working activities.

Prior to the workshop, we assured that the objectives and methodology to follow were clear to all participants. These were again reinforced at the beginning of the workshop. Some months prior, we had asked participants to gather specific information on the various topics we would be discussing according to their regional and topical areas of expertise, and to bring this information to the workshop.

Given the size of the area to be covered, during this first workshop we followed a rapid appraisal approach that allowed us to obtain, in a systematic way, general yet critical information on most of the esteros/estuaries of the Gulf within an eight-hour period. For this, workshop participants were divided into the four regional working groups we had previously identified.

Each group was responsible for completing a digital database spreadsheet on the state of knowledge of the coastal wetlands in their region. The database was designed in a way that it could be completed easily and quickly (10-20 minutes per estero/estuary). We then incorporated this information into the geodatabase to be integrated with the spatial component.

Each working group was given printed maps of the region that they were to focus on, which highlighted categories of esteros/estuaries according to their size. Each group was instructed to first begin working on the larger estuaries, and then move to smaller and smaller wetlands. For every working group, we assigned a facilitator and an assistant in charge of entering all presented information into the database, and to answer any methodological questions as needed (Table 2).

Table 2. Workshop organizers and facilitators

Workshop Organizers and Facilitators	Institutional Affiliation
Richard (Rick) C. Brusca	Arizona-Sonora Desert Museum
Richard Cudney-Bueno	University of Arizona; Arizona-Sonora Desert Museum
Tiffany Ash-Cudney	Arizona-Sonora Desert Museum
Marcia Moreno - Báez	University of Arizona & Arizona-Sonora Desert Museum
Rocío Covarrubias	Independent Contractor
Meredith De la Garza	University of Arizona
Rocío Brambilia	CEDO
Georgina Saad	PRONATURA Baja California Sur
Helena Iturribarria	PRONATURA Noroeste

Workshop Follow Up and Preliminary Analysis of Results

FTP Site and Information Sharing

At the end of the workshop, we gathered as a group to define future work and assign working responsibilities. We established an FTP site (on an Arizona-Sonora Desert Museum server) to upload and share large files for the project. Leaders for each of the working groups were assigned responsibility for compiling additional (post-workshop) information on their region (with the input of all other participants) and uploading this information to the FTP site.

Assignation of Preliminary Conservation Priority Ranking Scores

In preparation for our second workshop, we assigned a preliminary "conservation priority ranking score" to all esteros/estuaries in the Gulf of California. This score was used during our second workshop as a means to facilitate discussion within the various regional working groups when fine-tuning the selection of research and conservation priorities. During the second workshop, participants were given the opportunity to change/modify the information in the database if considered necessary. This ultimately changed the final ranking scores of some esteros/estuaries. It is important to clarify that we were dealing with a system for which a great deal of information is currently lacking. Therefore, we conducted our ranking in the most systematic way possible with the information available to all participants. Ranks were assigned as follows:

We used five variables that were known or confidently estimated for all estuaries: (1) Level of [Anthropogenic] Impact, (2) Estero/Estuary Area, (3) Level of Knowledge, (4) Previous Recognition as a Conservation Priority Area, (5) Current Protected Status.

Level of Impact: The current level of impact for a natural system is an important variable in the assignment of conservation priorities. On one hand, areas that are highly impacted may be in need of urgent conservation and/or restoration measures in order to assure their existence if they are still at a "salvageable" stage. On the other hand, systems that are in relatively "pristine" condition should also be given important attention in order to maintain them in a healthy state, or improve their health, and ensure their environmental value. For the purpose of this preliminary analysis, we assigned a higher weight to those estuaries that were less impacted than those that were highly impacted. Based on the 1-7 Likert scale, esteros/estuaries with a 6-7 value (highly impacted) were weighed as "1". Those with a 3-5 value were assigned a "2" and the low impacted ones (1-2) were assigned a "3".

Area: Larger esteros/estuaries were assigned a higher weight value. Those comprising an area of 0-50 Ha were assigned a "1," followed by those between 50-1000 Ha which were assigned a "2," and those > 1000 which were assigned a "3."

Level of Knowledge: We assigned a higher weight value to those esteros/estuaries for which there was an overall higher level of knowledge. For each estuary, we obtained an average knowledge ranking score which consisted of the sum of the 1-7 Likert scale values assigned to each of the 5 knowledge topics divided by 5. Given that our highest level of knowledge ranking score was 5.4, we grouped the esteros/estuaries in three categories. Those with an average knowledge value of 0-2 were weighed as "1," followed by those with an average value greater than 2 and less than 4 (assigned a weight value of "2"), and those with an average knowledge value ≥ 4 (assigned a weight value of "3").

Previous Recognition as a Conservation Priority Area: There have been important previous collaborative efforts to identify and assign conservation priority areas in the Gulf of California. For the purpose of our esteros/estuaries initiative, we considered five of these efforts: *Taller Para el Establecimiento de Prioridades de Conservación de la Biodiversidad del Golfo de California* (Coalición para la Sustenabilidad del Golfo de California 2004), Priority Sites Portfolio of the Sonoran Desert (Marshall et al. 2000), Terrestrial Priority Regions established by Mexico's National Commission on Biodiversity (CONABIO), Marine Priority Regions established by Mexico's National Commission on Biodiversity (CONABIO), and *Áreas de Importancia para la Conservación de las Aves* (AICAS) established by the *Sección Mexicana del Consejo Internacional para la Preservación de las Aves* (CIPAMEX).

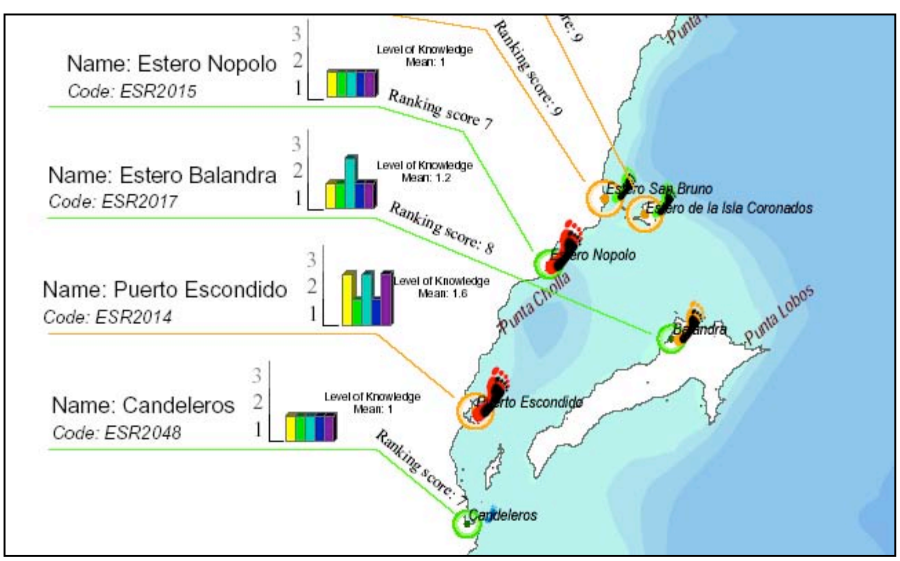
Initially, we identified if a particular estero/estuary had been included in any of these efforts. However, after accounting for all these efforts practically every single estero/estuary had been selected as a conservation priority in one way or another! Although this is clearly indicative of the biological and socio-economic significance of the Gulf's coastal wetlands, this aggregated information did not allow us to distinguish one estero/estuary from another in terms of their overall significance. Given this, we decided to only use the results of the *Taller Para el Establecimiento de Prioridades de Conservación de la Biodiversidad del Golfo de California* (sometimes referred to as "the Mazatlán workshop") as a basis for assigning of weight values. All esteros/estuaries that belong to an area already identified in that analysis as a priority area were assigned a weight value of "3," all others were assigned a weight value of "1."

Current Conservation Status: We identified all the esteros/estuaries that currently fall into one of the protected areas of the Gulf of California recognized by Mexico's Commission of Protected Natural Areas (CONANP). As with the previous variable, all the esteros/estuaries that were located within a protected area were assigned a weight value of "3" while those that did not were assigned a "1".

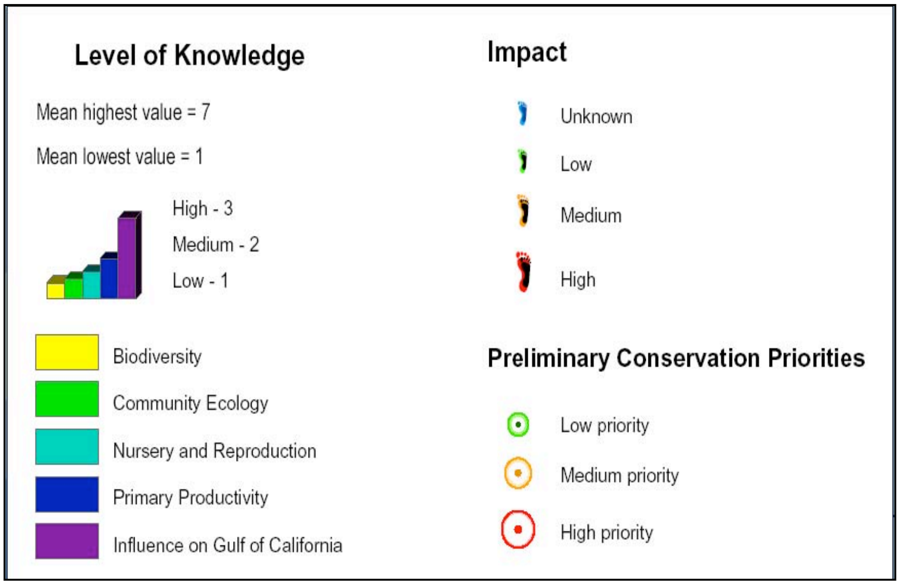
Once we had obtained weight values for each variable, we summed these and obtained a ranking score for each estero/estuary. These values ranged from 6-14. Based on the distribution of ranking scores, we recognized three conservation priority categories: Lower (ranking score values of 5-7), medium (ranking score values of 8-10), and high (ranking score values of 11-14). This information was then incorporated into the production of 4x8 ft regional maps. These maps included the ranking scores with each estero/estuary color-coded according to its preliminary conservation priority category. They were used extensively during our second workshop in order to facilitate the discussion amongst regional experts (Figure 2).

Figure 2. Examples of type of information included in the EWG estero/estuary conservation priority maps. Figure (a) comprises a section of the map for region II. Figure (b) represents the explanatory legend for the different variables included in the maps.

(a)



(b)



Second Workshop of the EWG

On January 25, 2005 we conducted a second workshop of the EWG in Tucson. The objectives of this workshop were to: (a) fine-tune the information gathered prior, during, and after our June 2004 workshop, and (b) to select key esteros/estuaries as conservation priorities.

Participants worked within the same regional working groups as assigned during our first workshop, but they were also allowed to move freely among other regional groups if considered desirable. We provided each group with the Gulf of California esteros/estuaries database and with a map of their region showing the preliminary conservation priority ranking scores. In addition to other activities, each group was asked to identify, to the best of their knowledge, ten of the most important estuaries in their region in terms of: (a) overall biodiversity, (b) nursery habitat, (c) level of productivity exported to the Gulf. Once these esteros/estuaries were selected, each group was asked to select 5 of these in terms of realistic conservation feasibility, opportunities, and needs within the next ten years. Their

discussion on this matter took into account, but was not limited to, the following questions:

a) Are there known plans to develop this estero/estuary? Would it be possible to work around those plans?

b) Are there reasonable possibilities of conducting land purchases?

c) Are there currently any conservation efforts taking place in this area?

d) Are there plans in place to establish a protected area?

e) Is there current interest from adjacent communities and/or the government to protect this site?

f) Is it feasible to conduct effective restoration work?

For each of these esteros/estuaries, workshop participants were asked to identify pressing research needs and recommendations, and to outline why it was selected.

As a means to not stunt the creativity and experience of the experts, we did not set *a priori* quantifiable methods of selection other than providing the preliminary conservation priority ranking scores as a guide. Each group was therefore asked to engage in an open discussion, and each was free to come up with conservation priorities different from those of the preliminary ranking scores. Participants were also asked to modify information in the database and existing maps if they considered it appropriate.

Final Analysis and Product Development

After our second workshop, we combined and analyzed all information gathered to date. This implied updating and modifying the initial database and maps as well as condensing and standardizing all the information obtained across regional groups. The following is a summary of the results of these efforts.

RESULTS

Prior to our initial workshop, we had identified 145 esteros/estuaries in the Gulf of California (excluding those found on islands) through existing databases and maps. After our two workshops, however, this number increased to 208. To our knowledge, many of these additional esteros/estuaries have not been recognized on any official maps or in any existing databases. Given their proximity and connectivity, as well as their shared ecological characteristics and processes, the working groups opted to join some of these 208 into "estero/estuary systems" for ease of discussion and analysis. We incorporated all of the esteros/estuaries, and "estuary/estuary systems," into our geodatabase and produced new maps with this refined and expanded information. In all, the EWG identified a total of 93 esteros/estuaries, or "estuary systems," in the Gulf of California. We will use this number (93) as the basis for all of our subsequent analyses.

As expected, a majority (53) of these systems were identified as "negative estuaries," or esteros. Next most common were positive estuaries (22) and mixed or seasonal estuaries (4). For 14 esteros/estuaries our working group was unable to determine presence or absence of freshwater input. The majority of the esteros/estuaries were either very small (area = 50 ha or less) or very large (area = >1000 ha) (Figure 3).

In terms of the prevalence of human activities in these coastal systems, various forms of housing development, fishing, recreational tourism and mariculture were the most widespread uses (Figure 4). Although 38 percent of the esteros/estuaries were reported as having some kind of recent research activities in them, this figure is a bit misleading. Many of these were reports of only one or two small projects or much of the work focused on one small segment of the system (e.g., specific pollutants, bird surveys, etc.). Furthermore, in terms of research in the esteros/estuaries, almost none of the work has actually been published. Many esteros/estuaries have already been totally destroyed to make way for shrimp farms, boat marinas (e.g., Cabo San Lucas, San Carlos), power plants (e.g., Puerto Libertád), or other forms of "development." In addition to the direct habitat loss, these developments pollute the coastal and maritime environment (e.g., the Puerto Libertád power plant emits between 67,000 and 100,000 tons of sulfur into the air annually).

By far, the greatest immediate threat to the Gulf's esteros/estuaries is the explosive growth of shrimp farms being built in them, or adjacent to them, especially in cases where mangrove ecosystems are threatened. For a period of time, mangroves were afforded some protection by federal law, but in 2004 this protection was essentially rescinded (under pressure from coastal developers) and now there is little to stop the destruction of these critically important ecosystems. Already, 90 percent of Mexico's cultivated shrimp comes from the Gulf of California, most of it from farms that replaced (or are contiguous with and impact) mangrove lagoon habitats.

The first shrimp farms were constructed in coastal Sonora in the 1980s, but in the 1990s new farm construction took off in the region and by 2003 97% of Mexico's shrimp aquaculture was taking place on the shores of the Sea of Cortez. As of May 2004, more then 115 shrimp farms had been built along the Sonoran shoreline alone, covering an area of 24,000 ha. And the relatively small state of Nayarit has over 140 coastal shrimp farms. Sinaloa, however, has taken the brunt of this coastal mariculture development with over 150 shrimp farms (encompassing nearly 20,000 hectares), with over a quarter of these (4,800 hectares) in Bahía Santa María. By 2004, farmed shrimp production in the Sea of Cortez had grown to exceed the wild catch, leading to tension between shrimp fishers and shrimp farmers (there is also tension between the industrial and small-scale fishers, and between the commercial fishers and the sport fishers – all of whom compete for the same diminishing fish stocks). Today, Mexico is the second largest producer of farm-raised shrimp in the Western Hemisphere.

In addition to outright habitat destruction, Mexico's coastal shrimp farms flush to the open sea, and they generate huge nutrient loads from uneaten food, shrimp feces, and dead shrimp that wash out to the coast – along with antibiotics, added vitamins and hormones, and other chemicals used in the ponds, and also often introduced (exotic) microorganisms (or exotic shrimp strains) from other localities that are imported with the shrimp postlarvae that are introduced into the ponds. The highly crowded shrimp ponds are susceptible to invasions by broad spectrum of parasitic/pathogenic protists, fungi, bacteria and viruses. Páez-Osuna et al. (1997; also see 1998, 1999, 2003) estimated that the farms of Sinaloa alone discharge an annual pollution load corresponding to the untreated sewage generated by 56,200-192,750 and 43,500-149,170 people, in terms of nitrogen and phosphorus respectively.

Figure 3. Distribution and Size of Individual Esteros/Estuaries (and Systems) found in the Gulf of California, Mexico

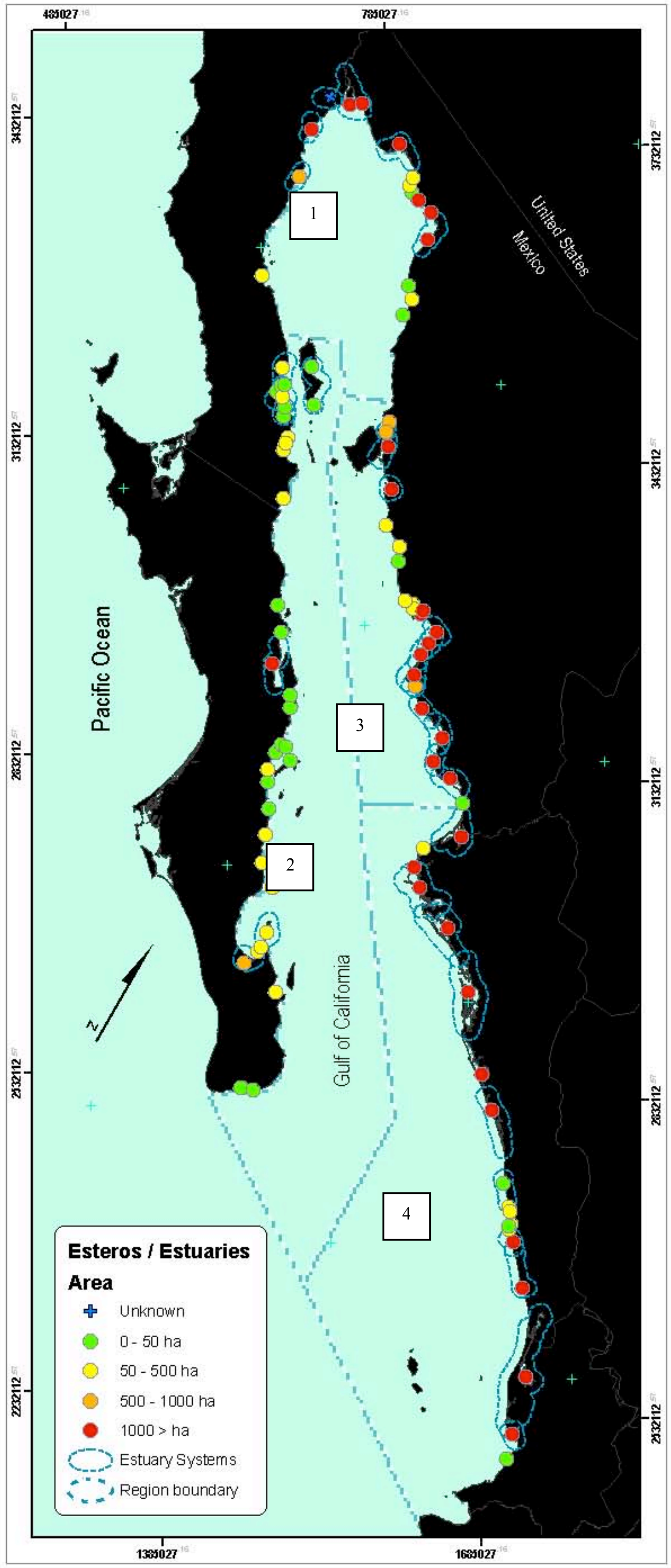
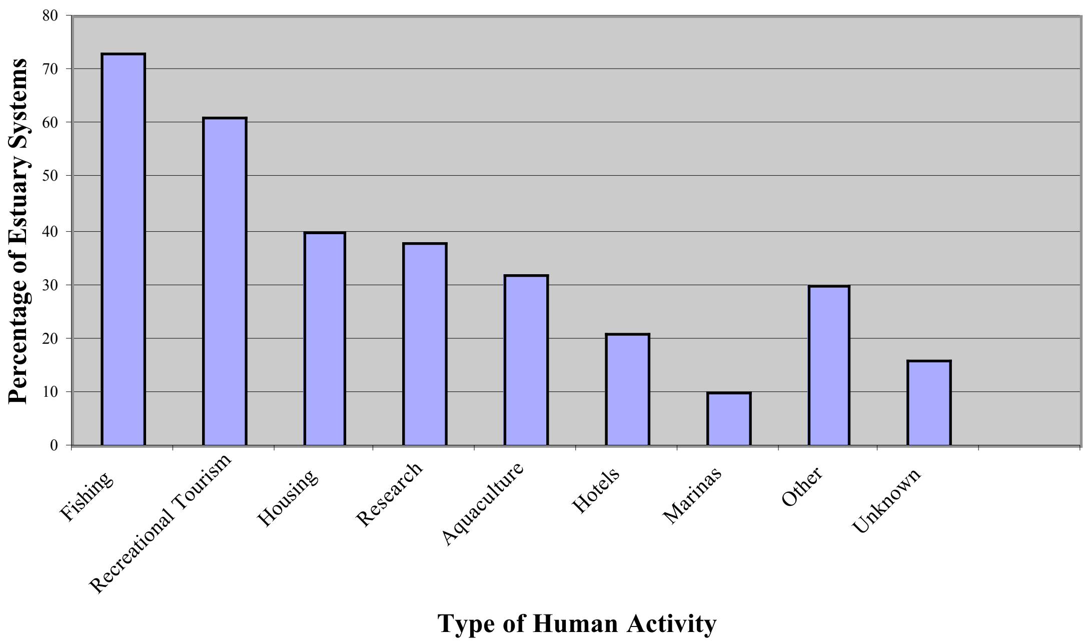


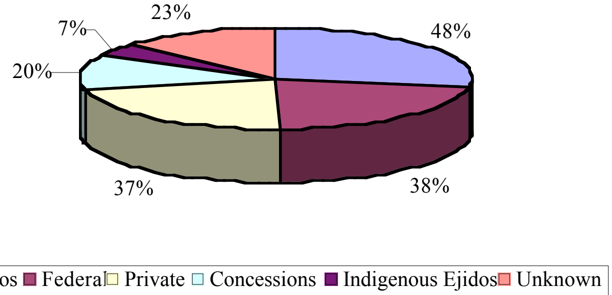
Figure 4. Percentage of Esteros and Estuaries in the Gulf of California with Various Types of Human Activities



* Other = hunting, road construction, drug trafficking hideouts, gravel extraction, salt mining, ranching, agriculture.

Ejido and federal ownership are the most prevalent types of land tenure on the coasts surrounding the Gulf's esteros/estuaries. A relatively large percentage of the Gulf's esteros/estuaries have some form of private ownership (37%) or a type of government granted concession right (20%). Indigenous exclusive territorial rights also exist for at least 7% of the esteros/estuaries (Figure 5 – NOTE: percentages total >100% because many esteros/estuaries have more than one type of land tenure).

Figure 5. Percentage of Esteros and Estuaries in the Gulf of California in Relation to Types of Land Tenure



One of the most striking discoveries of our work is the low level of knowledge that exists for the various topics we addressed. Comparing estuaries for which there is a low level of knowledge (ranking of 1 or 2 for a given topic) to those for which there is a high level of knowledge (ranking of 6 or 7), we found that important information is greatly lacking for most esteros/estuaries in the Gulf (Figure 6). This is particularly true for information regarding ecological processes within the esteros/estuaries and the role that they play in the adjacent marine environment. Of the five research topics we addressed, the one that has been best studied, often across several esteros/estuaries, is biodiversity. However, even in the case of biodiversity studies there is still a paucity of accomplished research. Esteros/estuaries with the highest level of knowledge are those found in the southern and central region of the Gulf (Figure 7).

Figure 6. Percentage of Gulf of California Esteros/Estuaries in Relation to Estimated Scientific Level of Knowledge

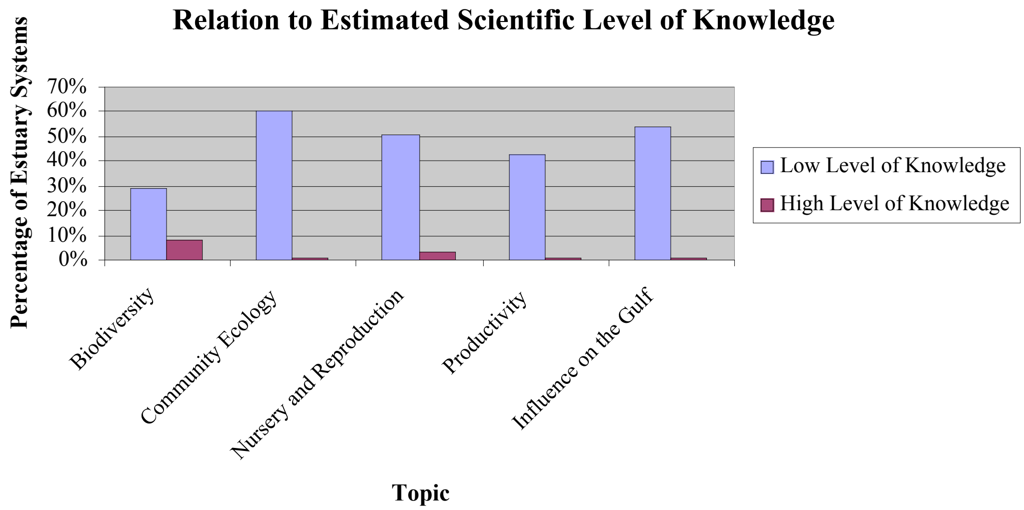
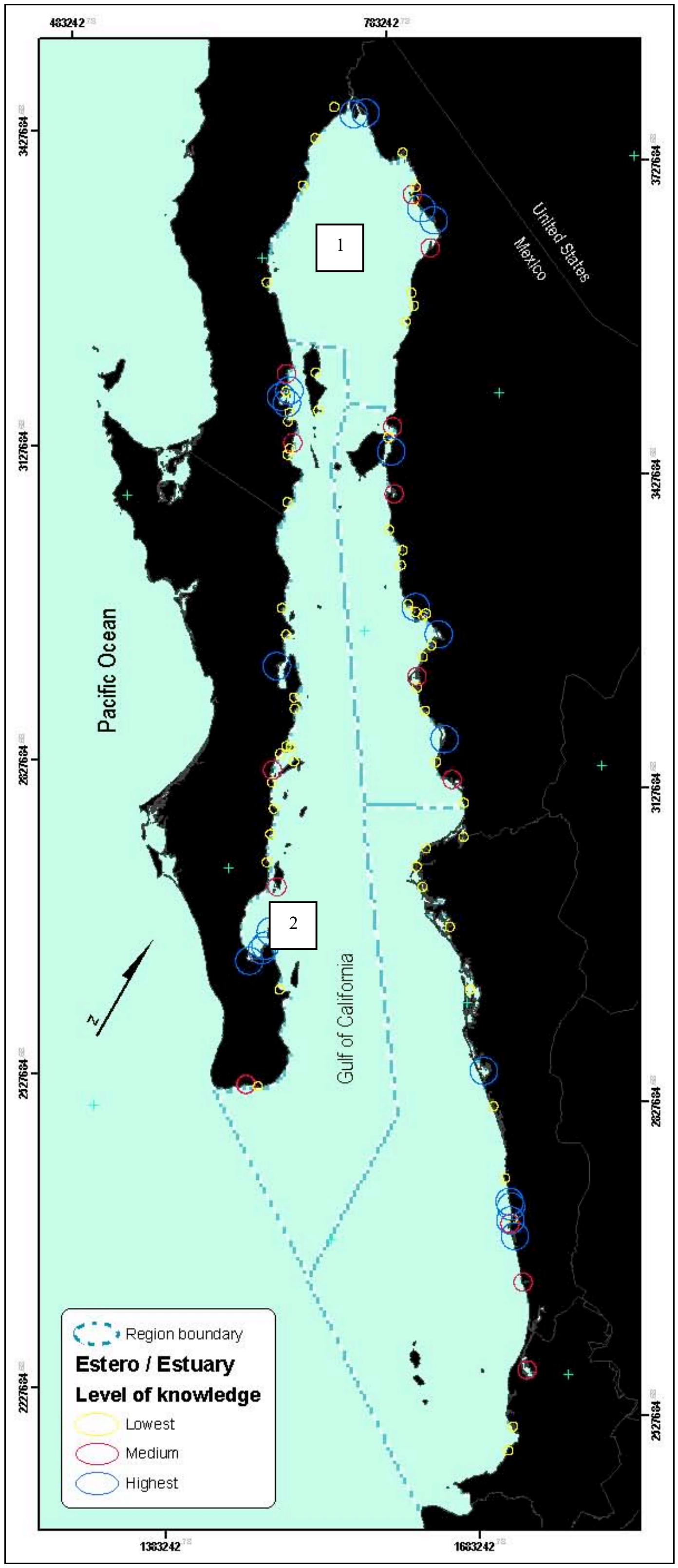


Figure 7. Distribution of Individual Esteros/Estuaries (and Systems) in the Gulf of California According to Estimated Level of Knowledge



Finally, we also found a surprisingly high number of esteros/estuaries that are currently in "somewhat pristine" condition. As in the previous example, we combined estuaries ranked 1-2 (low level of impact), 3-5 (medium level of impact), and 6-7 (high level of impact). The majority of esteros/estuaries are at some medium impact level. However, the number of esteros/estuaries that have experienced very low levels of impact (34) is greater than those that have been subjected to high levels of impact (21). Of these low-impacted esteros/estuaries, 56% are larger than 50 ha. It is important to remember that these numbers reflect some estuaries that have been combined into systems and, therefore, the overall number of low-impacted individual esteros/estuaries is actually somewhat higher (Tables 3 and 4, Figure 8).

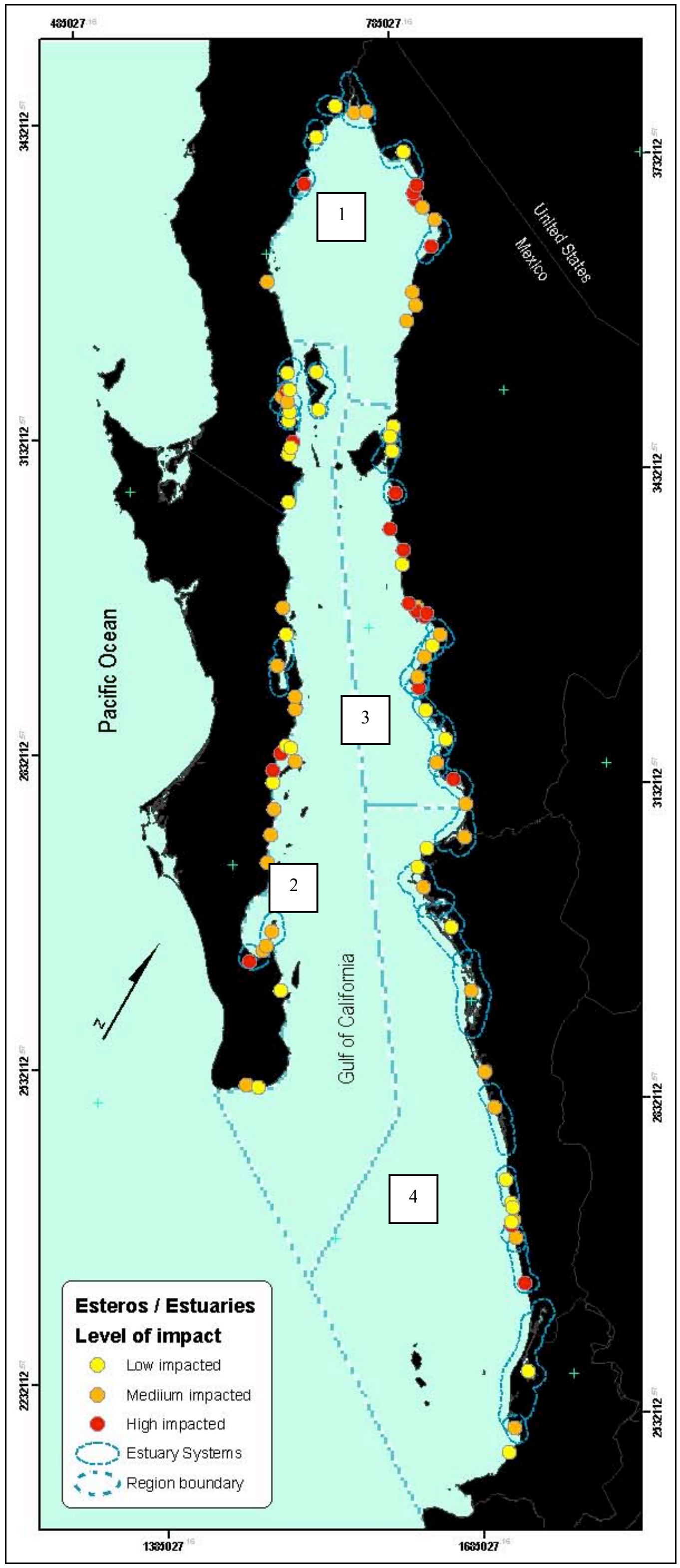
Table 3. Highly-impacted esteros/estuaries (ranked 6 or 7 on a scale of 1-7) of the Gulf of California, Mexico.

Estero/Estuary Name	Region	Area (Ha)
Estero Peñasco	1	1-50
Estero el Porvenir	1	50-1000
Cerro Prieto	1	50-1000
Estero la Salina	1	>1000
La Cholla	1	50-1000
Estero Nopoló	2	1-50
Estero Punta la Gringa - Grande	2	1-50
El Zacatal (FIDEPAZ)	2	50-1000
Puerto Escondido	2	50-1000
Río Mulegé	2	50-1000
Estero Cardonal	3	50-1000
Estero Miramar	3	50-1000
Estero el Rancho	3	>1000
Estero del Cochori	3	>1000
Estero Tastiota	3	50-1000
Estero los Algodones	3	50>1000
Estero el Mezquite	3	50>1000
Estero Santa Cruz	3	>1000
Estero Santa Barbara	3	>1000
Estero el Sábalo	4	50-1000
Laguna Caimanero	4	>1000

Table 4. Low-impacted esteros/estuaries (ranked 1 or 2 on a scale of 1-7) of the Gulf of California, Mexico.

Estero/Estuary Name	Region	Area (Ha)
Estero Ometepec	1	1-50
Esteros Ramada (Segundo)	1	>1000
Complejo Adair	1	>1000
El Bledito	2	1-50
Estero Mulegé	2	1-50
Vibora y Estanque	2	1-50
Estero La Palmita	2	50-1000
Estero Candeleros	2	1-50
Estero Santa Teresa	2	1-50
La Bocana	2	50-1000
Estero Punta María	2	50-1000
Estero San Bruno	2	1-50
Estero de la Isla Coronados	2	1-50
Las Ánimas Medio-Centro	2	1-50
Las Ánimas Norte	2	1-50
Estero de en Medio (Guadalupe Sur)	2	50-1000
Estero San Rafael	2	50-1000
Estero Coronado	2	1-50
Punta Perla	3	50-1000
Estero del Sargento	3	50-1000
Las Cocinas	3	1-50
Estero la Tortuga	3	>1000
Estero San José	3	>1000
Canal del Infiernillo	3	>1000
Estero Siaric	3	>1000
Estero Custodio	4	1-50
Estero Chicura Viva	4	50-1000
Estero el Colorado	4	>1000
Estero del Yugo	4	1-50
Estero el Hincha Huevos	4	1-50
Estero el Colorado	4	>1000
Estero el Caracol	4	>1000
Estero Agua Grande	4	>1000
Estero del Verde Camacho	4	50-1000

Figure 8. Distribution of Individual Esteros/Estuaries and Systems in the Gulf of California According to Level of Impact



CONSERVATION PRIORITIES

General Overview

Results of our preliminary analysis to obtain various levels of conservation priorities for esteros/estuaries using five variables (area, impact level, knowledge level, current conservation status, previous recognition as a conservation priority area) are shown in Tables 5 and 6. We identified 38 esteros/estuaries (individual esteros and systems) as having a high conservation opportunity ranking score (score values of 11-14), 38 with a medium ranking score (score values of 8-10), and 15 with a low ranking score (5-7).

Table 5. Conservation ranking scores obtained for all estero/estuaries and systems studied in regions I and II of the Gulf of California. Ranking scores are based on five variables: area, estimated level of impact, estimated level of knowledge, previous recognition as a conservation priority site, and current formal protection status.

Estero/Estuary or System Name	Database Code	Conservation Priority Ranking Score
REGION I		
El Desemboque del Norte (Río de la Concepción)	ESR1011	6
Puerto Lobos o Cabo Tepoca	ESR1013	6
Estero Peñasco	ESR1008	7
Los Tanques	ESR1012	7
Complejo Estero Percebú	ESR1001	8
Cerro Prieto	ESR1006	8
Sistema Ometepec	ESR1003	9
San Luis Gonzaga	ESR1014	9
Almejas - Sistema La Salina	ESR1010	10
La Cholla	ESR1007	11
Sistema Morúa - La Pinta	ESR1009	12
Esteros Ramada (Complejo La Bolsa)	ESR1002	13
Complejo Adair	ESR1005	13
Esteros del Delta del Rio Colorado	ESR1004	14
REGION II		
San Juanico	ESR2016	6
Estero San José	ESR2001	7
El Bledito	ESR2002	7
Estero Mulegé	ESR2019	7
Isla Angel de la Guarda	ESR2033	7
Agua Verde	ESR2009	8
Puerquitos	ESR2017	8
Estero San Lucas	ESR2020	8
Estero La Palmita	ESR2021	8
Corredor	ESR2006	9
Estero Candeleros	ESR2010	9

Estero Nopoló	ESR2012	9
Región Bahía de los Ángeles Norte	ESR2029	9
Isla Angel de la Guarda	ESR2032	9
La Bocana	ESR2003	10
Ensenada La Paz	ESR2005	10
Estero Balandra	ESR2014	10
Estero Punta Marúa	ESR2022	10
Estero Punta Arenas	ESR2028	10
Sistema Balandra-Pichilingue	ESR2004	11
Sistema de Esteros Isla Espíritu Santo	ESR2007	11
Puerto Escondido	ESR2011	11
Estero San Bruno	ESR2013	11
Estero de la Isla Coronados	ESR2015	11
Río Mulegé	ESR2024	11
Región Las Ánimas	ESR2025	11
Región Las Ánimas	ESR2026	11
Región Agua Amarga	ESR2031	11
Estero Isla san José (La cocina)	ESR2008	12
Sistema Bahía Concepción	ESR2018	12
Estero San Rafael	ESR2023	12
Región Bahía de los Ángeles Sur	ESR2027	13
Estero Coronado (Bahía de los Ángeles)	ESR2030	13

Table 6. Conservation ranking scores obtained for all estero/estuaries and systems studied in regions III and IV of the Gulf of California. Ranking scores are based on five variables: area, estimated level of impact, estimated level of knowledge, previous recognition as a conservation priority site, and current formal protection status.

Estero/Estuary or System Name	Database Code	Conservation Priority Ranking Score
REGION III		
Estero Cardonal	ESR3006	6
Estero Miramar	ESR3011	6
Las Bocas	ESR3023	6
Estero el Rancho	ESR3012	7
Estero del Cochori	ESR3013	7
Estero Tastiota	ESR3007	8
Estero los Algodones	ESR3009	8
Estero el Mezquite - Zona de la Salina	ESR3018	8
Estero el Soldado	ESR3010	9
Sistema de Esteros del Canal del Infiernillo	ESR3025	9
Punta Perla y Palo Fierro	ESR3002	10
Sistema de Esteros Santa Cruz	ESR3005	10
Sistema Siuti	ESR3016	10
Sistema Aquiropo	ESR3021	10
Sistema Yavaros	ESR3022	10
Estero del Sargento	ESR3001	11
Sistema de Esteros del Canal del Infiernillo	ESR3003	11
Las Cocinas	ESR3008	11
Sistema Algodones	ESR3015	11
Sistema Lobos	ESR3017	11
Los Melagos - Sistema San José	ESR3019	11

Sistema de Esteros del Canal del Infiernillo	ESR3024	11
Las Guásimas	ESR3014	12
Sistema de Esteros del Canal del Infiernillo	ESR3004	13
El Tobari	ESR3020	13
REGION IV		
Estero Custodio	ESR4020	7
Estero el Sábalo	ESR4009	9
Estero la Escopama	ESR4013	9
Sistema Estuarino Agiabampo	ESR4001	10
Sistema Topolobampo-Ohuira	ESR4002	10
Complejo Lagunar Bah_a Santa Mar_a	ESR4004	10
Sistema Bahía de Ceuta	ESR4006	10
Estero Chicura Viva	ESR4010	10
Sistema de Huizache y Caimanero	ESR4014	10
Sistema San Blas	ESR4017	10
Bahía de Navachiste	ESR4003	11
Estero del Yugo	ESR4007	11
Meseta de Cacaxtla	ESR4008	11
Sistema Topolobampo-Ohuira	ESR4012	11
Estero el Caracol	ESR4018	11
Ensenada de Pabellones	ESR4005	12
Teacapan-Agua Brava-Marismas Nacionales	ESR4015	12
Estero del Verde Camacho	ESR4016	12
Sistema Estrero de Urias	ESR4019	12

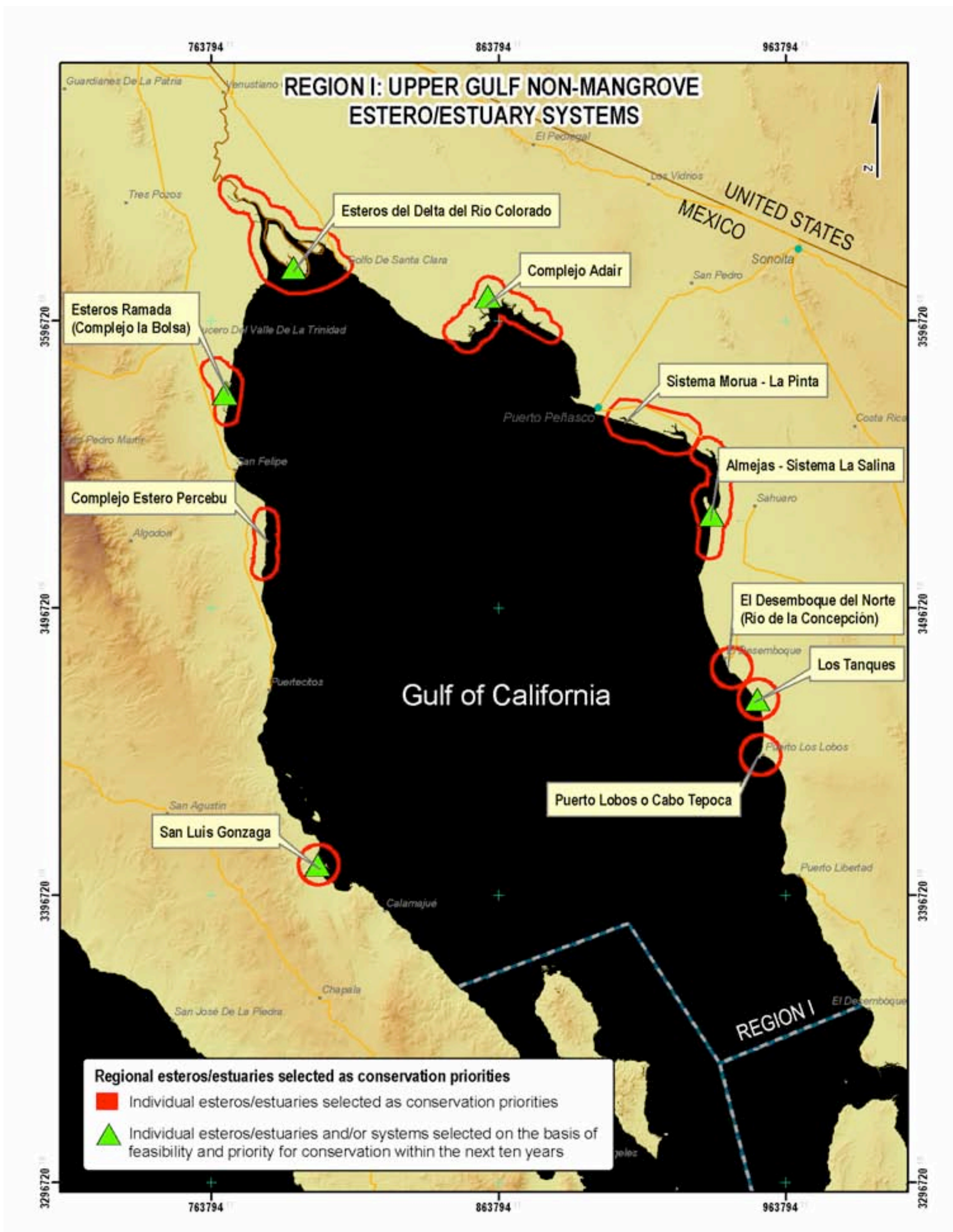
Based upon this information, and consideration of overall biodiversity, importance as a nursery habitat, and level of productivity exported to the Gulf, the EWG identified 41 estero/estuary systems for which high conservation priority should be recognized. Table 7 summarizes these by region (10 each in Regions 1-3, 11 in Region 4). The majority of these have a medium impact level (58%), and only 15% are smaller than 50 Ha. In the following section of the report we provide maps showing the location of these esteros/estuaries, as well as summaries of the 22 (5-6 per region) that were selected by the EWG on the basis of realistic conservation feasibilities, opportunities, and needs within the next 10 years.

It is important to note that ALL of the coastal wetlands of the Gulf are of high importance. They all play critical ecological roles and they are all threatened, to a greater or lesser degree, with development of one kind or another. Thus, the assigning of conservation priorities should not be used as a means to ignore conservation efforts at other esteros/estuaries in the Gulf.

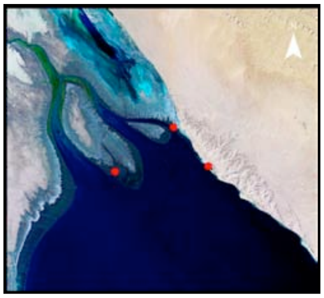
Table 7. Esteros/estuaries of the Gulf of California selected as conservation priority areas by the Gulf of California Esteros/Estuaries Working Group.

Esteros/Estuaries	Area (Ha)	Level of Impact
Region 1: Upper Gulf Non-Mangrove Estero/Estuary Systems		
Esteros del Delta del Río Colorado	>1000	Medium
Complejo Adair	>1000	Low
Almejas - Sistema La Salina	>1000	High
Esteros Ramada (Complejo La Bolsa)	>1000	Low
Sistema Morúa - La Pinta	>1000	Medium
Los Tanques	50-1000	Medium
Complejo Estero Percebú	50-1000	High
San Luis Gonzaga	50-1000	Medium
Puerto Lobos o Cabo Tepoca	<50	Medium
El Desemboque del Norte (Río de la Concepción)	<50	Medium
Region 2: Baja California Mangrove Estero/Estuary Systems		
Ensenada La Paz	50-1000	High
Corredor San Cosme Punta Mechudo	50-1000	Medium
Isla Espíritu Santo	50-1000	Medium
Estero Isla San José (La cocina)	50-1000	Medium
Puerto Escondido	50-1000	High
Estero Nopoló	<50	High
Sistema Bahía Concepción	>1000	Medium
Rio Mulegé	50-1000	High
Corredor Costero La Asamblea-San Francisquito	<50	Medium
Estero San José	<50	Medium
Region 3: Sonoran Mangrove Estero/Estuary Systems		
Sistema Lobos	>1000	Medium
El Tóbari	>1000	Low
Sistema de Esteros del Canal del Infiernillo	>1000	Low
Sistema Yavaros	>1000	High
Sistema de Esteros de Santa Cruz	>1000	High
Sistema Siuti	>1000	Medium
Estero El Soldado	50-1000	Medium
Sistema Algodones	>1000	Low
El Sargento	50-1000	Low
Las Guásimas	50-1000	Medium
Region 4: Sinaloa/Nayarit Mangrove Estero/Estuary Systems		
Sistema Lagunar San Blás	>1000	Medium
Teacapán-Agua Brava-Marismas Nacionales	>1000	Low
Sistema Estero de Urias	>1000	Medium
Estero el Verde Camacho	50-1000	Low
Meseta de Cacaxtla	<50	Low
Sistema Bahía de Ceuta	>1000	Medium
Ensenada de Pabellones	>1000	Medium
Complejo Lagunar Bahía Santa María	>1000	Medium
Bahía de Navachiste	>1000	Low
Sistema Estuarino Agiabampo	>1000	Medium
Sistema Topolobampo-Ohuira	>1000	Medium

REGION I: UPPER GULF NON-MANGROVE ESTERO/ESTUARY SYSTEMS



Esteros del Delta del Río Colorado



Database code: ESR1004

Esteros/estuaries included: El Challo, El Muelle Viejo, and Estero Golfo de Santa Clara

Estuary type: negative

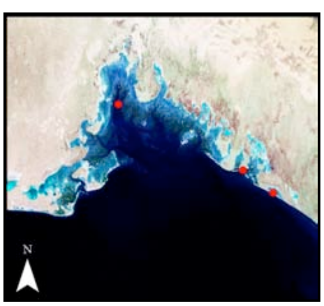
Main Reasons for Selection

- Harbors a high biodiversity
- High levels of productivity and export of detritus
- Unique habitat and nesting area for resident and migratory birds
- Important boundary for various neo-tropical and coastal birds
- Spawning site for various commercial and non commercial fishery species
- Largest concentration of endemic salt grass, *Distichlis palmerii,* in the Gulf of California
- The area already has an important conservation status being part of the Upper Gulf of California and Colorado River Delta Biosphere Reserve
- Strong presence of community & NGO involvement in conservation efforts

Pressing Research Needs

- Assess levels of fishing effort and overall impact of fishing activities
- Better understand local oceanographic processes and their effects on larval retention and dispersal
- Assess the effects of the presence, absence, and timing of Colorado River freshwater flows on fisheries and the marine ecosystem as a whole
- Assess levels of productivity within the system and exported throughout the year
- Assess variations in water quality throughout the year and processes determining such variations
- Conduct a hydrological characterization of the area

Complejo Adair



Database Code: ESR1005

Esteros/estuaries included: Estero Las Lisas, Estero San Judas, and Estero Animato

Estuary Type: negative

Main Reasons for Selection

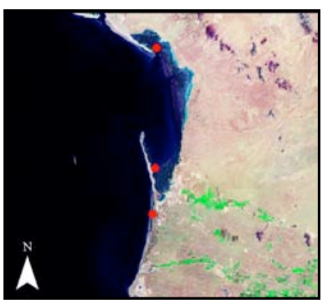
- Second most important population of *Distichlis palmerii* and associated halophyte plants in the Gulf of California
- Known important nursery ground for shrimp and other commercial fishery species

- Presence of unique, coastal, freshwater springs ("pozos") & associated Colorado River delta refugial plant communities
- Presence of numerous archaeological sites (these could provide additional incentive to protect the area)
- High primary productivity
- Important nesting area of least tern and snowy plover
- Key importance for shorebirds such as avocets and sanderlings
- Ejidos have not sold their land to developers and may be interested in conservation
- Coastal development has yet to reach this point in the coast
- There are possibilities for land purchases/conservation easements before new proposed coastal highway is constructed

Pressing Research Needs:

- Conduct thorough assessment of archaeological sites
- Assess the influence of Colorado River freshwater flows
- Obtain a better understanding of the biology of existing halophyte communities and their influence on the marine environment
- Conduct thorough studies on primary productivity and biomass productivity
- Understand ecological community structure
- Conduct a hydrological characterization of the area
- Conduct thorough study of the area's role as a prime nursery ground for shrimp and other commercial species

Almejas - Sistema La Salina



Database Code: ESR1010

Esteros/estuaries included: Estero Almejas (La Pitaya), La Salina, and San Francisquito

Estuary Type: negative

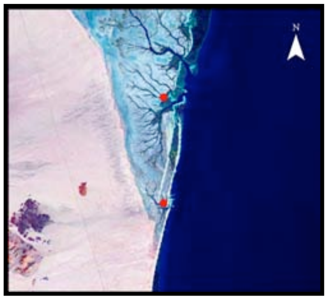
Main Reasons for Selection:

- Two major habitat types, large shallow subtidal region and marshland
- Known to be an important area for fishery purposes
- Likely to have high biodiversity and productivity
- Deeper waters than other esteros in the region, with permanent standing water that serves as key nursery grounds for fish and invertebrates
- Relatively undeveloped but likely to be developed soon

- Pressing Research Needs
- Estimate levels of productivity throughout the year and its influence on the adjacent marine environment
- Understand the ecological community structure and trophic interactions of the system
- Determine essential habitat for species of particular importance
- Characterize amount of biological and physical exchange of water

- ➢ Conduct a hydrological characterization of the area

Esteros Ramada (Complejo La Bolsa)



Database Code: ESR1002

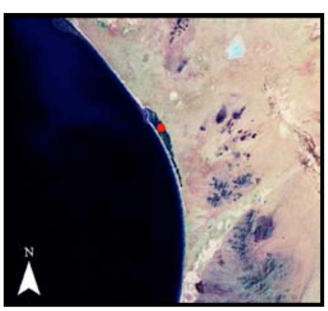
Esteros/estuaries included: Estero La Ramada Primero and Estero La Ramada Segundo

Estuary Type: negative

Main Reasons for Selection
- ➢ The largest estuary complex in the northern Baja California region
- ➢ Very important fishing grounds adjacent to the system
- ➢ Very likely to be of key importance as a nursery ground for various commercial and non-commercial species
- ➢ Provides extensive habitat for various shorebirds
- ➢ The system has a key research value as well, as it is composed of three estuaries that range in impact from highly impacted to pristine
- ➢ There are good opportunities for purchasing land for conservation purposes
- ➢ The system is already recognized as an important conservation area, and some management structure exists via the Upper Gulf of California and Colorado River Delta Biosphere Reserve

Pressing Research Needs
- ➢ Conduct a thorough characterization of essential habitat for commercial and non-commercial species
- ➢ Conduct comparisons of "pristine" versus highly impacted regions within the system
- ➢ Conduct a hydrological characterization of the system
- ➢ Analyze its role in productivity in the adjacent marine environment
- ➢ Conduct a thorough analysis of land tenure and ownership

Los Tanques



Database Code: ESR1012

Esteros/estuaries included: Los Tanques

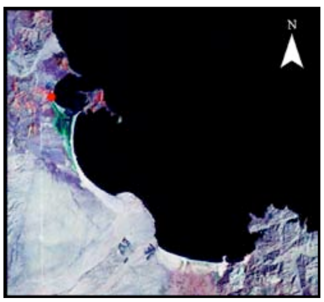
Estuary Type: negative

Main Reasons for Selection
- ➢ Small, isolated and relatively pristine estuary

- One of the most southern marsh estuaries (no mangroves)
- Given its location, it is likely of significant biological importance in terms of connectivity of marine populations
- Provides an excellent “control site” to conduct comparisons with other marsh esteros of the Sonoran coast

Pressing Research Needs
- Characterize essential habitats
- Conduct comparisons between this low impacted estero and other, more highly impacted esteros of the northern Sonoran coast
- Conduct a hydrological characterization of the area
- Conduct basic inventory studies

San Luis Gonzaga



Database Code: ESR1014

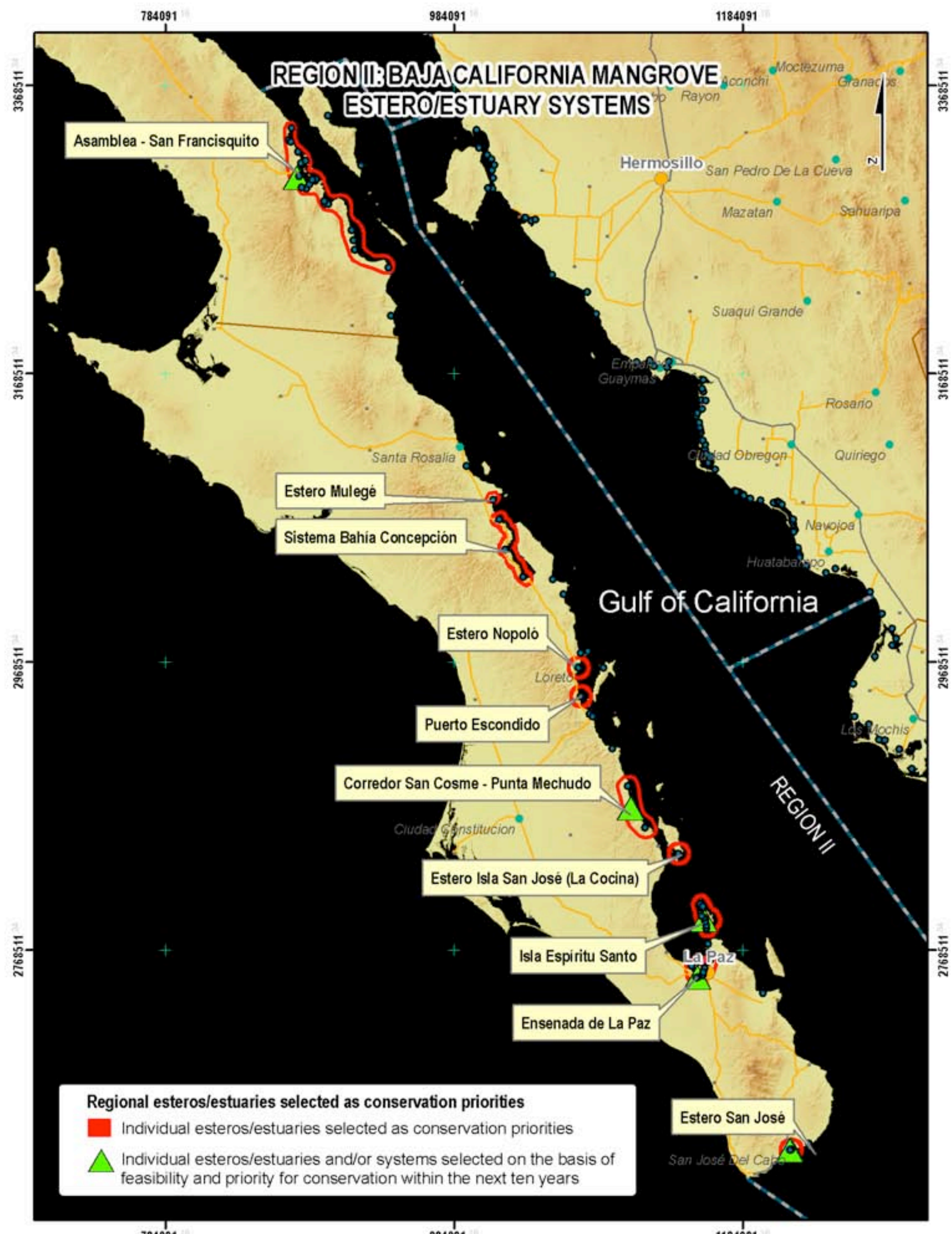
Esteros/estuaries included: San Luis Gonzaga

Estuary Type: negative

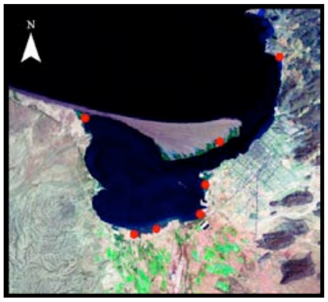
Main Reasons for Selection
- One of the most isolated esteros on the Baja California coast
- Likely to be of significant importance in a chain connecting estero systems along the Baja coast
- Future threats are likely minimal

Pressing Research Needs
- Conduct an assessment of fishery activities within and in the surrounding waters of the estero
- Analyze the estero’s existing land ownership status
- Conduct basic biological inventory studies
- Assess variations in water quality throughout the year
- Conduct a hydrological characterization of the area
- Use as comparison with other more impacted esteros of the northern Baja coast

REGION II: BAJA CALIFORNIA MANGROVE ESTERO/ESTUARY SYSTEMS



Ensenada La Paz



Database Code: ESR2005

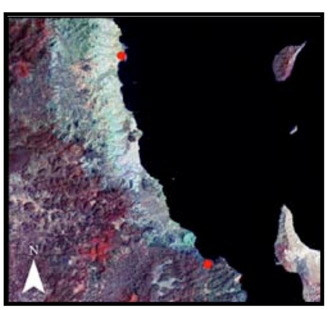
Esteros/estuaries included: Enfermeria, El Conchalito, El Zacatal (FIDEPAZ), Chametla, Centenario, Estero Zacatecas, and Manglares el Mogote

Estuary Type: negative

Main Reasons for Selection
- ➢ High biodiversity
- ➢ Currently being strongly impacted by urban growth
- ➢ Plans exist for significant continued development

Pressing Research Needs
- ➢ Conduct an assessment of primary and secondary productivity within the system and in its surrounding waters
- ➢ Conduct an ecological economics evaluation
- ➢ Assess levels of pollution
- ➢ Map land use
- ➢ Generate baseline data for management tools (there is an existing preliminary land use planning document)
- ➢ Assess fishing activities, particularly in terms of fishing effort and overall fishing impact on the ecosystem
- ➢ Conduct ecological systems studies
- ➢ Assess coastal oceanographic processes

Sistema San Cosme-Punta Mechudo



Database Code: ESR2006

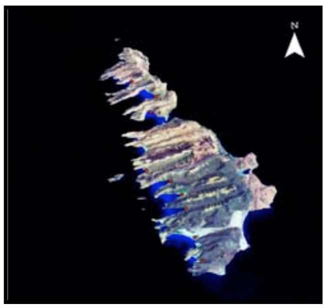
Esteros/estuaries included: El Gato and Bahía Falsa

Estuary Type: Negative

Main Reasons for Selection
- ➢ High biodiversity
- ➢ Area currently threatened by human impacts
- ➢ There are plans for future development projects

Pressing Research Needs
- Conduct an assessment of primary and secondary productivity within the system and in its surrounding waters
- Conduct an ecological economics evaluation
- Assess levels of pollution caused by existing sewage and power plants
- Map land use
- Generate baseline data for management tools
- Assess fishing activities, particularly in terms of fishing effort and overall fishing impact on the ecosystem
- Conduct ecological systems studies
- Assess coastal oceanographic processes

Isla Espíritu Santo



Database Code: ESR2007

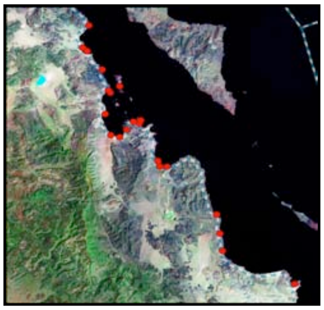
Esteros/estuaries included: nine island esteros

Estuary Type: Negative

Main Reasons for Selection
- High biodiversity
- Current strong interest in conservation (national and international)
- The terrestrial component of the island is already protected under CONANP's guidelines
- Marine area surrounding the island likely to be recognized as a protected area in the near future
- Many archeological sites

Pressing Research Needs
- Primary and secondary productivity research
- Ecological systems studies
- Ecological economics valuation
- Conduct carrying capacity studies as they relate to human use of the island's esteros for tourism
- Survey and assess coastal archeological sites

La Asamblea-San Francisquito Coastal Corridor (LASFCC)



Database Code: The corridor includes three systems: ESR2027, ESR2029, ESR2031

Esteros/estuaries included: 21 small esteros[2]

Estuary Type: Negative

Main Reasons for selection

- High biodiversity
- Small wetlands and sandy beaches in the coastal corridor function as a bridge for energy flow between the high productive marine ecosystem and the arid desert ecosystem
- The corridor likely acts as an important connectivity site for marine fish and invertebrates given its isolation in relation to northern and southern esteros/estuaries
- Sea turtle, whale shark, and seabird foraging habitat
- Spawning habitat for halibut and likely other commercial species
- Roosting habitat for threatened birds
- Designated within marine and terrestrial conservation priority regions in Mexico, and within a priority region for conservation of birds
- Designated as a Wetland of International Importance by the Ramsar Secretariat
- Included in the proposed "Bahía de los Ángeles" Biosphere Reserve
- High landscape value
- Wetlands currently in healthy condition, but individually threatened by proposed marina projects (the area is a key site for the *Escalera Náutica* project) and intensive coastal development
- Substantial research and conservation efforts initiated in 2002 by Pronatura Noroeste, and continuing at the present time; Guadalupe and Las Ánimas already conserved to perpetuity by easements (*servidumbres ecológicas*); San Rafael and El Rincón proposed as core zones in the Biosphere Reserve
- Local community supports wetland conservation; legal defense of the Punta Arenas marsh halted the construction of a marina at that site

Pressing Research Needs

- Continue bio-ecological descriptions
- Conduct an assessment of energy flows through the coastal wetlands in the corridor
- Evaluate commercial fish recruitment in the area
- Conduct an ecological economics evaluation
- Assess coastal oceanographic processes

---

[2] This corridor includes three estero systems totalling 21 small esteros. Following coastline from Northwest to Southeast: Punta Remedios, Venado, En Medio, Guadalupe, El Cardón, Las Caguamas (on Coronado Island), La Gringa, Robertón, Punta Arenas, Muñoz, El Rincón, La Mona, Puerto Don Juán, El Neto, El Quemado, Las Ánimas Norte, Las Ánimas Centro, Las Ánimas Sur, Punta María, Campo de la Cooperativa, San Rafael.

Estero San José

Database Code: ESR2001

Esteros/estuaries Included: Estero San José and La Playa

Estuary Type: Positive

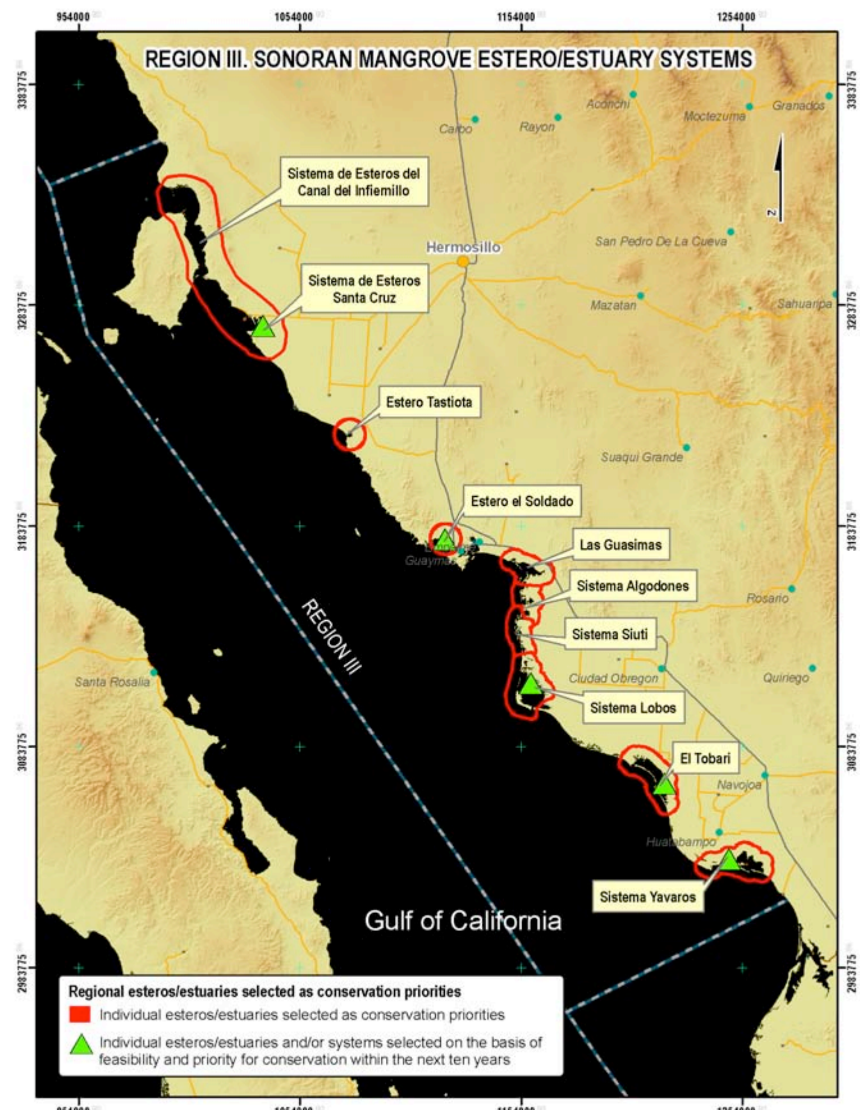
Main Reasons for Selection

- This is a small (<50 Ha) estuary (i.e., easier to protect) yet of very high biological value
- Provides critical habitat for many species
- Its location at the southern tip of the Baja California peninsula may play a key role in connectivity of various species
- Currently a proposed site for the *Escalera Náutica* initiative
- Likely to be highly developed in the near future if no action is taken

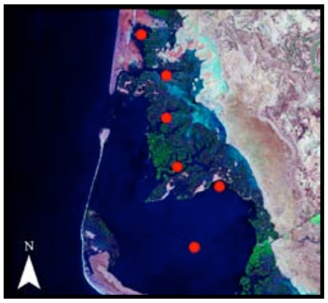
Pressing Research Needs

- Conduct an assessment of primary and secondary productivity within the system and in its surrounding waters
- Conduct an ecological economics evaluation
- Conduct ecological systems studies
- Conduct basic biodiversity inventories
- Assess levels of pollution caused by sewage and power plant
- Map land use
- Assess fishing activities, particularly in terms of fishing effort and overall fishing impact on the system
- Assess human impact related to tourism development
- Search for mechanisms to provoke changes in the development of the *Escalera Náutica*

REGION III. SONORAN MANGROVE ESTERO/ESTUARY SYSTEMS



Sistema Lobos



Database Code: ESR3017

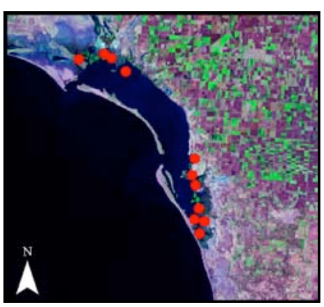
Esteros/estuaries included: Estero La Culebra, Estero Gauicari, Estero las Piedritas, Estero La Pitahayita, Estero San Francisquito, and Bahía Lobos - Estero Las Piedritas

Estuary Type: Positive

Main Reasons of Selection
- The system is large
- The system forms part of Yaqui territory, providing *de facto* and legal forms of protection
- There is a high abundance of waterfowl, especially colony-forming water birds, shore birds, and marsh birds
- Important shrimp nursery ground
- Feeding ground for Pacific green sea turtles, *Chelonia mydas agassizii*

Pressing Research Needs
- Assess land use and ownership
- Conduct studies on primary and secondary productivity, and assess nutrient transport
- Determine the distribution and abundance of birds
- Conduct studies on hydrological dynamics
- Evaluate urban development and the effects of La Salina
- Assess the impacts of agricultural runoffs
- Understand the perception of the Yaqui tribe in terms of use, development, and conservation of the area.

El Tobari



Database Code: ESR3020

Esteros/estuaries included: Estero Siaric, Estero el Conchalito, Estero La Pitahaya, Estero el Diablo, Camora, Estero Jiamora, Estero la Liebre, El Tobari, Estero Cubuja, And Estero Tobarito

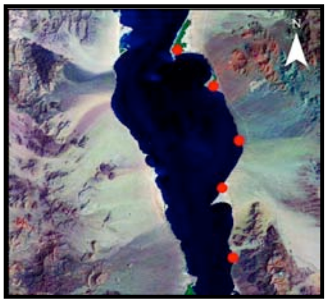
Estuary Type: Mixed

Main Reasons for Selection
- Strong community participation in conservation
- High tourism potential, particularly Isla Huivulai
- Important nursery area for shrimp
- Important area for nutrient cycling
- Key area for colony-forming water birds, marsh birds, waterfowl, and shore birds

Pressing Research Needs

- Conduct basic biological inventories
- Assess levels of contaminants
- Conduct studies on primary and secondary productivity and assess nutrient transport
- Understand the effects of shrimp aquaculture on the bay
- Assess the effects of sedimentation
- Assess levels of pollution of freshwater inputs and their impact on wildlife
- Conduct studies on hydrological dynamics

Sistema de Esteros del Canal del Infiernillo



Database Code: ESR3003

Esteros/estuaries included: Punta Arenas, Punta Víboras, Punta Onah, Punta Tortuga, El Sargento, and Santa Rosa

Estuary Type: Negative

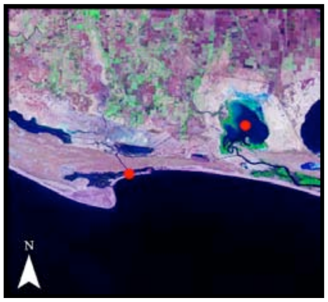
Main Reasons for Selection

- Most important area in the Gulf for certain sea grass species, Brandt's geese, and sea turtles
- Human impact on the region has been minimal (in Seri Land)
- The entire channel is "regulated" by the Seri people as a community-based and government recognized conservation resource
- It is currently protected as part of the exclusive fishing zone of the Seri community
- It is one of the only marine territories in Mexico granted exclusive fishing rights (to the Seri)
- There is a strong institutional presence already supporting conservation and research
- There is interest within the local Seri communities (Punta Chueca and Desemboque) to conserve the area
- Seri are already involved in biological monitoring efforts

Pressing Research Needs

- Conduct an analysis of primary and secondary productivity
- Assess local hydrodynamics and level of export of nutrients to oceanic waters outside the Channel
- Conduct biodiversity surveys
- Understand the relationship between local fishing activities and the stability of sea grass beds
- Conduct paleoecological studies
- Include Seri paraecologists in research
- Long-term biodiversity monitoring

Sistema Yavaros



Database Code: ESR3022

Esteros/estuaries included: Estero Santa Bárbara and Moroncarit

Estuary Type: Positive

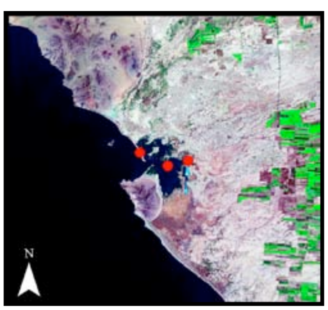
Main Reasons for Selection

- High biological diversity
- Historically an important calving area for gray whales
- Key site for vegetation: geographical boundary for many southern and northern plant species
- Large size (>1000 Ha) and diversity of habitats
- Close to Mayo Indian tribal land
- Possibilities to capitalize on tourism in terms of increasing environmental awareness and providing income to the local community

Pressing Research Needs

- Conduct an analysis of pollution levels
- Assess existing land use patterns and tenure system
- Assess population levels of birds and key marine biota
- Conduct biodiversity inventories
- Study the system's relationship with freshwater flows
- Assess effects of discharge of sardine plant, aquaculture, and agricultural drainage
- Understand the conditions that have led to massive mangrove die-offs in recent years

Sistema de Esteros Santa Cruz



Database Code: ESR3005

Esteros/estuaries included: Estero Santa Cruz, Estero Kino, and Salina Santa Cruz

Estuary Type: Negative

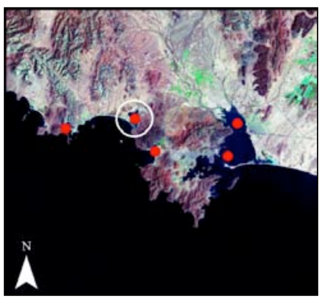
Main Reasons for Selection

- Known to be of high biological importance
- Does not drain completely, thus serves as an important nursery ground for fishes and invertebrates by providing permanent water and shelter
- Sustains threatened sea bird populations that also make use of neighboring Isla Alcatraz
- Highly productive, likely to strongly enhance fisheries production

- The only large estuary in the Midriff Islands region
- Currently at high risk of being destroyed due to increasing development and aquaculture use
- There exists a social and political momentum for conservation; current conservation interest from local government

Pressing Research Needs
- Assess local hydrodynamics
- Long term monitoring of birds and marine biota
- Assess pollutant levels
- Assess existing land use patterns and tenure systems
- Research zoning and development plans

Estero el Soldado



Database Code: ESR3005

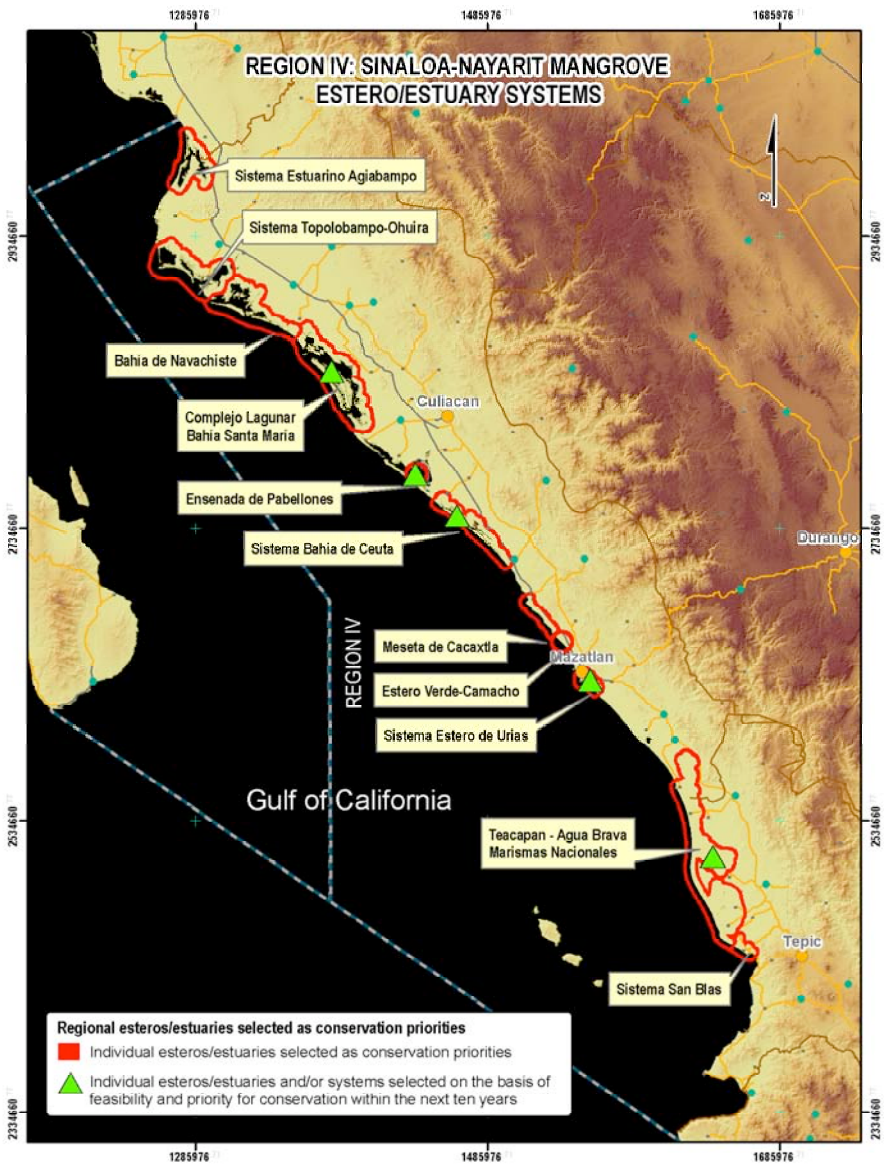
Esteros/estuaries included: Estero el Soldado

Estuary Type: Negative

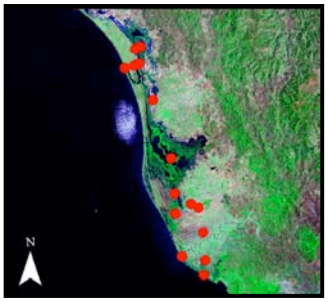
Main Reasons for Selection
- One of the best studied esteros in the Gulf
- Presence of academic and conservation organizations near by
- High level of stability of the system
- Good opportunities for environmental education efforts with the communities of Guaymas and San Carlos
- Disproportionate high diversity levels compared to other esteros found nearby
- Important stopover for neotropical birds and other waterfowl
- Current protection efforts have slowed development, but the estero is threatened by a new (adjacent) San Carlos-Miramar-Guaymas highway and future development in the area (e.g., increasing human traffic, sewage, small boat use, etc.)

Pressing Research Needs
- Long term monitoring of birds and marine biota
- Assess effects of current urban and tourism development
- Feasibility study for increased protection

REGION IV: SINALOA-NAYARIT MANGROVE ESTERO/ESTUARY SYSTEMS



Teacapán-Agua Brava-Marismas Nacionales



Database Code: ESR4015

Esteros/estuaries included: Agua Grande, El Maiz, Rueda del Rio, Teacapán, Auta, Toluca, Grande, Mezcal, El Coco, Laguna Agua Brava, and Estero la Lima

Estuary Type: Positive

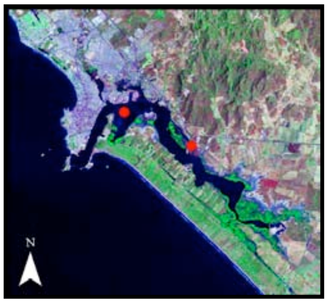
Main Reasons for Selection

- Largest mangrove system in the entire Eastern Pacific
- It is the most important area for the conservation of migratory birds in the region
- The system supports important flagship species, such as the jaguar (*Panthera onca*), American crocodile (*Crocodylus acutus*), and American avocet (*Recurvirostra americana*)
- Strong influence on productivity of adjacent fisheries, particularly shrimp
- Given its size, diversity of environments, and permanent standing water, it is likely to provide key nursery habitat for numerous commercial and non-commercial species
- High ecotourism potential

Pressing Research Needs

- Monitor quality and quantity of freshwater flows
- Monitor variations in salinity, temperature, oxygen and key nutrients
- Assess the state of its natural resources
- Conduct studies on water circulation processes, including the transport of suspended and dissolved organics and nutrients (e.g., carbon, nitrogen, phosphorous)
- Conduct basic biological inventory studies
- Assess the population dynamics of flagship species (jaguar, crocodile, avocet, etc.)
- Map land use and ownership patterns
- Assess the feasibility of land acquisitions
- Assess the impact of fishing activities on the system
- Assess impacts of mangrove and adjacent jungle deforestation on the productivity of fisheries
- Conduct an economic evaluation of local biodiversity
- Characterize the social and economic consequences of wetland transformation

Sistema Estero de Urias



Database Code: ESR4019

Esteros/estuaries included: Estero La Sirena and Estero de Urias

Estuary Type: Negative

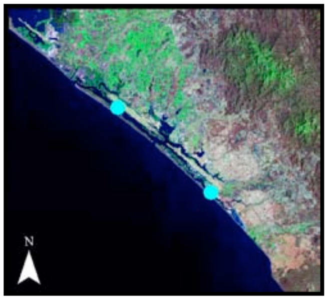
Main Reasons for Selection

- Large mangrove system with a variety of habitats
- Important habitat for migratory birds
- Nursery ground for various commercial and non-commercial species
- System is close to a large urban site, producing a gradient of highly impacted areas to areas that are in near “pristine” condition
- Close to an urban center, offering the opportunity to teach different population sectors aspects of estuarine ecology and the negative consequences of degradation
- Being close to important academic institutions could result in the development of research studies at relatively low cost
- Active presence of NGO’s working on various education, community involvement, and overall conservation projects

Pressing Research Needs

- Monitor freshwater flows
- Monitor variations in salinity, temperature, oxygen and key nutrients
- Assess the state of its natural resources
- Conduct studies on water circulation processes, including the transport of suspended and dissolved organics and nutrients (e.g., carbon, nitrogen, phosphorous)
- Conduct basic biological inventory studies
- Map land use and ownership patterns
- Assess the feasibility of land acquisitions
- Assess the impact of fishing activities on the system
- Assess the impact of mangrove and adjacent jungle deforestation on fisheries productivity
- Conduct an economic evaluation of local biodiversity
- Characterize the social and economic consequences of wetland degradation
- Research the most effective education means to affect decision makers and the general public regarding the value of the wetland

Sistema Bahía de Ceuta



Database Code: ESR4006

Esteros/estuaries included: Estero Agua Amarga and Laguna Quevedo (Ceuta)

Estuary Type: Positive

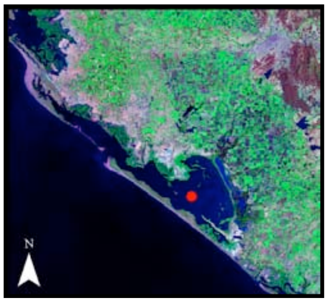
Main Reasons for Selection

- Large system, with a variety of habitat types
- Provides key habitat for shore birds
- Nesting site for various species at risk, including birds and sea turtles
- There is high potential for conservation of private lands (over 1000 Ha), which include Sinaloa's most important nesting area for birds with high conservation priority

Pressing Research Needs

- Monitor freshwater flows
- Monitor variations in salinity, temperature, oxygen and key nutrients
- Assess the state of its natural resources
- Conduct studies on water circulation processes, including the transport of suspended and dissolved organics and nutrients (e.g., carbon, nitrogen, phosphorous)
- Conduct basic biological inventory studies
- Map land use and ownership patterns
- Assess the feasibility of land acquisitions
- Assess the impact of fishing activities on the system
- Assess the impact of mangrove and adjacent jungle deforestation on fisheries productivity
- Conduct an economic evaluation of local biodiversity
- Characterize the social and economic consequences of wetland degradation
- Research the most effective means to educate and affect decision makers and the general public regarding the wetland's value
- Research and learn from the effects of wetland degradation in the Mazatlán area in order to prevent similar situations from occurring in Bahía de Ceuta, as there is currently high potential for urban and tourism development in the area

Ensenada de Pabellones



Database Code: ESR4005

Esteros/estuaries included: Ensenada de Pabellones

Estuary Type: Positive

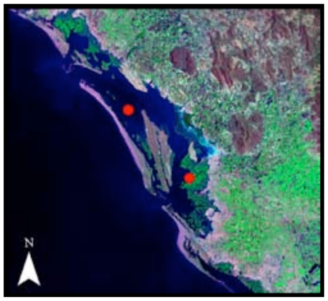
Main Reasons for Selection

- The system has been recognized as an area of conservation priority for migratory birds
- Has strong influence on the productivity of the adjacent oceanic zone, particularly affecting local important commercial fisheries such as shrimp
- Has a high potential for the development of tourism as part of the Esclera Náutica initiative
- The Lucenilla Peninsula is the only private coastal reserve in the Gulf of California and perhaps the largest private coastal reserve in Latin America
- The Lucenilla Peninsula offers unique opportunities for conservation, restoration, and education for the adjacent coastal communities and the state's capital

Pressing Research Needs

- Monitor freshwater flows
- Monitor variations in salinity, temperature, oxygen and key nutrients
- Assess the state of its natural resources
- Conduct studies on water circulation processes, including the transport of suspended and dissolved organics and nutrients (e.g., carbon, nitrogen, phosphorous)
- Conduct basic biological inventory studies
- Map land use and ownership patterns
- Assess the feasibility of land acquisitions
- Assess the impact of fishing activities on the system
- Assess the impact of mangrove and adjacent jungle deforestation on fisheries productivity
- Conduct an economic evaluation of local biodiversity
- Characterize the social and economic consequences of wetland degradation

Complejo Lagunar Bahía Santa María



Database Code: ESR4004

Esteros/estuaries included: El Tule and Bahía Santa María

Estuary Type: Positive

Main Reasons for Selection

- Recognized as a conservation priority area for migratory birds
- Important foraging area for Pacific green sea turtles (*Chelonia mydas agassizii*)
- The bay is known to be a sporadic nursery area for gray whales (*Eschrictius robustus*)
- Known to strongly influence productivity of adjacent oceanic waters
- Fisheries of high commercial value take place within the Bay and in its adjacent waters
- High potential for tourism development, especially with Esclera Náutica initiative
- The bay includes the most important area for the conservation of shore birds in northwestern Mexico
- Private lands within this area (350 Ha) are in the process of being purchased to conduct restoration projects in the adjacent wetlands with funds from Mitsubishi and NAWCA
- The purchase of an additional 750 Ha would guarantee the conservation of all core biological areas

Pressing Research Needs

- Monitor freshwater flows
- Monitor variations in salinity, temperature, oxygen and key nutrients
- Assess the state of its natural resources
- Conduct studies on water circulation processes, including the transport of suspended and dissolved organics and nutrients (e.g., carbon, nitrogen, phosphorous)
- Conduct basic biological inventory studies
- Map land use and ownership patterns
- Assess the feasibility of land acquisitions
- Assess the impact of fishing activities on the system
- Assess the impact of mangrove deforestation on fisheries productivity
- Conduct an economic evaluation of local biodiversity
- Characterize the social and economic consequences of wetland degradation

GENERAL CONCLUSIONS

This report provides a general overview and state of knowledge of Gulf of California esteros/estuaries, and recommends specific conservation priority targets. The report is based on input from over 35 experts from Mexico and the U.S., as well as a review of published and unpublished reports on these coastal wetlands. Although a number of important studies have been conducted in the past, until now a comprehensive/unified analysis that summarizes key aspects of these important and threatened ecosystems had never been attempted. This said, it is important to emphasize that our study only attempts to summarize available knowledge, but large information gaps exist for these critically important ecosystems. When available, however, more detailed data and references to specific key works or literature are provided in the Gulf of California Esteros/Estuaries Database (Appendix 1).

We identified 208 esteros/estuaries in the Gulf of California. Many of these are not recognized on any official maps or databases. Given their proximity and connectivity, as well as their shared ecological processes, the Gulf of California Esteros/Estuaries Working Group (EWG) joined some of these into "estero/estuary systems" for ease of identification and analysis. In total, we recognize (and analyze) 93 esteros/estuaries, or estero/estuary systems.

The vast majority of these coastal wetlands are "negative estuaries," or *esteros* as they are commonly called in Mexico (coastal marine wetlands lacking perennial or predictable freshwater input). The others are positive estuaries and mixed or seasonal estuaries. Esteros have been the least studied coastal wetlands throughout the Gulf.

The majority of esteros/estuaries are either very small (area = 50 ha or less) or very large (area = >1000 ha). Housing development, fishing, shrimp faming, and recreational tourism are the most widespread forms of human activities in these ecosystems.

As of May 2004, more then 115 shrimp farms had been built along the coast of Sonora (covering an area of 24,000 ha), 140 shrimp farms along the Nayarit coast, and 150 farms along the coast of Sinaloa (the latter encompassing nearly 20,000 hectares). These farms produce more market shrimp tonnage than does the wild catch in Mexico. Coastal shrimp farms in Mexico are virtually unregulated, and they flush out to the adjacent estuaries, or to the open sea, huge nutrient loads from uneaten food, shrimp feces, and dead shrimp, as well as antibiotics, added vitamins and hormones, and other chemicals used in the ponds, and also often introduced (exotic) microorganisms (or exotic shrimp strains) from other localities that are imported with the shrimp postlarvae that are introduced into the ponds.

Ejido and federal ownership are the most prevalent types of land tenure systems surrounding the esteros/estuaries. A relatively large percentage of these wetlaneds also have some form of private ownership (37%), or a type of government granted concession right (20%). However, there are still marked gaps in the information regarding estero/estuary land tenure systems. For at least 23% of the esteros/estuaries land tenure is unknown/undocumented.

Gaps in information extend to most of the topics addressed in our study. One of the most striking findings of this assessment is the low level of knowledge that exists for these important coastal features. With the exception of the Colorado River delta and estuary, the esteros of the northern Gulf are virtually unstudied. Similarly, although a number of studies of southern Gulf mangrove estuaries have been accomplished, these have usually covered a limited number of topics and have lacked a framework to understand the systems in a more holistic manner.

Information gaps are particularly true regarding ecological processes within these habitats, and the roles they play in the adjacent marine environment. For instance, basic information such as percentage or levels of standing water remaining at low tide, and degree of water flushing, has been lacking for practically all of the Gulf's esteros/estuaries. This information is key to assessing the role that an estero or estuary plays as a nursery ground for marine finfish and shellfish, and the impact they have on the adjacent marine environment via the flow of nutrients or contaminants into the open sea.

An important finding of our study is that a surprisingly large number of esteros/estuaries are currently in somewhat "pristine" conditions, and the majority are at a medium impact level. More importantly, the number that have been subjected to very low levels of impact is greater than those that have been subjected to high levels of impact. Of the low-impacted esteros/estuaries, 56% are larger than 50 ha. Given these somewhat encouraging numbers, combined with the fact that development along the coast of the Gulf of California is clearly increasing, we believe we are at a unique and critical point in time to devote efforts to conservation and research. Esteros/estuaries are clearly the most threatened and least studied coastal ecosystems in the Gulf of California. They have also been largely overlooked for conservation efforts while becoming, at an increasing rate, primary sites for human development -- resorts, marinas, salt works and shrimp farms.

Keeping the above in mind, the Gulf of California Esteros/Estuaries Working Group believes that the time is ripe to engage in targeted research and conservation efforts to ensure the future of these key coastal ecosystems of the Gulf. In this regard, we provide a list of 41 esteros/estuaries that should be considered of high conservation priority. In addition, we identify 22 esteros/estuaries (5-6 per geographic region) based on feasibility and need for conservation within the next 10 years. However, it is important to point out that ALL of the coastal wetlands of the Gulf are of high conservation importance. They all serve unique ecological roles and they are all threatened, to a greater or lesser degree, by "development." Equally important, they play different roles. For instance, some estuaries may be of key importance as nursery grounds for endangered and/or commercial species, but be of little value in terms of providing high levels of productivity to the adjacent marine environment. On the other hand, some estuaries with a high degree of tidal flushing are major providers of nutrients to the open sea, but be of less importance as nursery grounds. Thus, assigning conservation priorities to some wetlands should not be used as an excuse to ignore conservation efforts on other esteros/estuaries in the Gulf.

In this regard, we put particular emphasis on maintaining the current state of low-impacted esteros/estuaries, and assessing feasibilities for restoration work on impacted ones that are known to be of high ecological value. Furthermore, empirically documenting the ecological role of Gulf esteros/estuaries within the context of the larger Gulf ecosystem and engaging long-term monitoring efforts will be essential to assess impact of conservation measures and to justify, in a robust and scientific way, the development of such measures. In this same vein, specific efforts should also be devoted to conducting a thorough mapping of estero/estuary land tenure systems throughout the entire Gulf of California, paying particular attention to areas in which land purchases for conservation might be feasible and areas where local tenure systems can be aligned with stewardship of the wetlands to provide a buffer against future negative impacts. At the same time, local stewardship for protection of coastal wetlands should be enhanced whenever possible. This enhancement must go hand in hand with the development of strategic environmental education campaigns that address not only the ecological value of these coastal systems, but their cultural and economic legacy as well.

Finally, as a conservation community we must be more effective in the way we influence the legal structure that affects, for better and for worse, the Gulf of California's coastal wetlands and in the way in which we convey our conservation message to other constituencies. We must take a more holistic approach to conservation and research efforts with these systems; anything else will prove futile amidst the wave of future development that awaits the Gulf of California's coastline.

PRIMARY REFERENCES

Brusca, R. C. and G. C. Bryner. 2004. A Case Study Of Two Mexican Biosphere Reserves: The Upper Gulf of California/Colorado River Delta and Pinacate/Gran Desierto de Altar Biosphere Reserves. Pp. 21-52 in N. E. Harrison and G. C. Bryner (eds.), *Science and Politics in the International Environment.* Rowman and Littlefield, New York.

Brusca, R. C., L. T. Findley, P. A. Hastings, M. E. Hendrickx, J. Torre Cosio and A. M. van der Heiden. Macrofaunal Biodiversity in the Gulf of California. Pp. 179-203 *in* J.-L. E. Cartron, G. Ceballos, and R. Felger (eds.), *Biodiversity, Ecosystems, and Conservation in Northern Mexico.* Oxford University Press, NY.

Brusca, R.C. In Press. Invertebrate Biodiversity in the Northern Gulf of California. In, R. Felger and W. Broyles, *Dry Borders II.* University of Utah Press. 92 pp.

Okoli, C. and S. D. Pawlowski. 2004. The Delphi method as a research tool: an example, design considerations and applications. Information and Management 42: 15–29.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). 1998. Regiones Prioritarias Marinas. Escala 1:4 000 000. México. Financiado por -USAID-PackardFoundation-CONABIO-WWF-FMCN.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). 2004. Regiones Terrestres Prioritarias. Escala 1:1 000 000. México.

Danemann, G., H. Morzaria Luna, S. Barocio, H. Batché, B. Casillas, J. Castillo, A. González, S.Muñoz, F. Ochoa and M. Vargas. 2005. Inventario de los Humedales del Corredor Costero La Asamblea - San Francisquito, Baja California. Technical Report for the U.S. Fish and Widlife Service, Division of Habitat Conservation (4401 North Fairfax Drive, Room 730, Arlington, Virginia 22203, EUA). Pronatura Noroeste, Dirección de Conservación en Baja California. Ensenada, Baja California, México. 45 pp.

Glenn, E. P., P. L. Nagler, R. C. Brusca and O. Hinojosa-Huerta. 2006. Coastal wetlands of the northern Gulf of California: inventory and conservation status. Aquatic Conservation: Marine & Freshwater Ecosystems 16: 5-28.

Hendrickx, M. E., R. C. Brusca, and L. T. Findley (eds.). 2006. *A Distributional Checklist of the Macrofauna of the Gulf of California, Mexico. Part I. Invertebrates. [Listado y Distribución de la Macrofauna del Golfo de California, México, Parte I. Invertebrados].* Arizona-Sonora Desert Museum and Conservation International. 429 pp.

Marshall, R.M., S. Anderson, M. Batcher, P. Comer, S. Cornelius, R. Cox, A. Gondor, D. Gori, J. Humke, R. Paredes Aguilar, I.E. Parra and S. Schwartz. 2000. Análisis Ecológico de las Prioridades de Conservación en la Ecoregión del Desierto Sonorense. Prepared for The Nature Conservancy (Arizona Chapter), Sonoran Institute, and Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora, with the assistance of the Legacy Program U.S. Department of Devense. 157 p

Nagler, P., E. Glenn and R. C. Brusca. 2004. *Photographic Atlas of Esteros and Other Coastal Wetlands of Conservation Interest in the Northern Gulf of California.* Arizona-Sonora Desert Museum. 147 pp.

Páez-Osuna, F., S. R. Guerrero-Galván, A. C. Ruiz-Fernández, and R. Espinosa-Angulo. 1997. Fluxes and mass balances of nutrients in a semi-intensive shrimp farm in northwestern Mexico. Marine Pollution Bulletin 34: 290-297.

Páez-Osuna, F., S. R. Guerrero-Galván and A. C. Ruiz-Fernández. 1998. The environmental impact of shrimp aquaculture and coastal pollution in Mexico.. Marine Pollution Bulletin 36: 65-75.

Páez-Osuna, F., S. R. Guerrero-Galván and A. C. Ruiz-Fernández. 1999. Discharge of nutrients from shrimp farming to coastal waters of the Gulf of California. Marine Pollution Bulletin 38: 585-592.

Páez-Osuna, F., A. Flores-Verdugo, L. P. Lyle-Fritch, R. Alonso-Rodirguez, A. Roque and A. C. Ruiz-Fernandez. 2003. Shrimp aquaculture development and the environment in the Gulf of California ecoregion.. Marine Pollution Bulletin 46: 806-815.

Pill, J. 1970. The Delphi method: substance, context, a critique and an annotated bibliography. Socio-Economic Planning Science 5: 57-71

Sección Mexicana del Consejo Internacional para la Preservación de las Aves CIPAMEX – Comisión Nacional para el Conocimiento y Uso de la Biodiversidad CONABIO. 1999. Áreas de Importancia para la Conservación de las Aves. Escala 1:250 000. México. Financiado por CONABIO–FMCN–CCA.

Whitmore, R. C., R. C. Brusca, J. L. León de la Luz, P. González-Zamorano, R. Mendoza-Salgado, E. S. Amador-Silva, G. Holguin, F. Galván-Magaña, P. A. Hastings, J.-L. E. Cartron, R. S. Felger, J. A. Seminoff, and C. C. McIvor. 2005. The ecological importance of mangroves in Baja California Sur: Conservation implications for an endangered ecosystem. Pp. 298-333 *in* J.-L. E. Cartron, G. Ceballos, and R. S. Felger (eds.), *Biodiversity, Ecosystems and Conservation in Northern Mexico.* Oxford University Press, NY.