

# Water Perspectives in Emerging Countries Integrating Ecosystems in Coastal Engineering Practice (INECEP)

Rodolfo Silva and Valeria Chávez (Eds.)

Summer School in Puerto Morelos, Mexico – September 2017



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Coastlines around the world are facing significant damage from increasing urban development and population density, additional infrastructure of diverse sectors and ecosystem degradation. Engineers are increasingly called upon to provide structures that give protection against wave attack, coastal flooding and erosion. Generally, these protective measures are hard barriers, which are designed with little or no consideration of their impact on ecosystems or possible adaptation to climate and global changes. However, natural solutions have begun to emerge, which replace or are incorporated into conventional protection schemes. Even so, the more conventional structures are those frequently adopted, as there is a lack of knowledge, methodical frameworks, models, analysis tools, and practical guidance for the implementation of more ecologically based schemes.

The Summer School in Puerto Morelos, Mexico, on Integrating Ecosystems in Coastal Engineering Practice (INECEP) held in September 18-30, 2017, organized by Exceed Swindon – Latin America Network was conceived to bridge this gap.

As a response to recent natural disasters, such as flooding and erosion in coastal areas, research and development in ecosystem-based approaches have advanced greatly. Knowledge on the interactions between protection structures and coastal ecosystems, evaluation, modelling and mapping of coastal ecosystem services, methodological frameworks and tools for eco-engineering was provided to the attendees, enabling them to move from conventional coastal protection to nature-based and hybrid coastal protection solutions. The papers in this book are some of the case studies examined during this course.

Editors

Rodolfo Silva and Valeria Chávez



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**Water Perspectives in Emerging Countries**  
**Integrating Ecosystems in Coastal Engineering Practice**  
**(INECEP)**

**Rodolfo Silva and Valeria Chávez**

**Proceedings of the Summer School**

**September 18-30, 2017 – Puerto Morelos, Mexico**

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## PREFACE

In September 2011 and September 2013, the EXCEED-SWINDON Project organised two-week Summer Schools on “Flood Risk Analysis and Management” at Bahir Dar University, Ethiopia, and “Coastal Erosion and Management for Safer Coasts in a Changing Climate” in Tamandare, Brazil, respectively. Given their success, a similar Summer School “Integrating Ecosystems in Coastal Engineering Practice (INECEP)” was organised in Puerto Morelos, Mexico, September 18-30, 2017.

The lecturers in charge of teaching on the course were:

Angel Borja	AZTI, Spain
Andres F. Osorio	UNAL, Colombia
Brigitta van Tussenbroek	ICMYL-UNAM, Mexico
Edgar Escalante	ICMYL-UNAM, Mexico
Edgar Mendoza	Instituto de Ingeniería-UNAM, Mexico
Eleonora Carol	CONICET-UNLP, Argentina
Gladys Bernal Franco	UNAL, Colombia
Hocine Oumeraci	TU Braunschweig, Germany
Ismael Mariño-Tapia	CINVESTAV, Mexico
Katie Arkema	Stanford University, US
Malva Mancuso	UFSM-FW, Brazil
Ma. Luisa Martínez	INECOL, A.C., Mexico
Milton Asmus	FURG, Brazil
Patricia Moreno-Casasola	INECOL, A.C., Mexico
Pedro Pereira	UFPE, Brazil
Rodolfo Silva	Instituto de Ingeniería-UNAM, Mexico
Sheila J.J. Heymans	Scottish Marine Institute, UK
Tjeerd Bouma	Royal Netherlands Institute of Sea Research, NL

The Summer School sessions included class lectures, exercises and discussions. During the classes, the participants from nine countries were equipped with essential state-of-the art knowledge concerning coastal ecosystems, their functioning and interaction with traditional man-made infrastructure, and their evaluation. Modelling concepts and approaches to quantify the degradation and renovation of ecosystems by and after natural disturbances were also covered. The most promising methods/strategies/tools to integrate eco-system engineering solutions for coastal protection at different scales (local to regional) were discussed. The participants also carried out field work in three different ecosystems: beach and dunes, coral reefs, and wetlands. The participants had the opportunity to present and to discuss in group discussions case studies from their own countries with the aim of identifying the most appropriate solutions. Twenty six chapters written by the attendees were selected and are presented in this book.

Valeria Chávez and Rodolfo Silva – Coordinators of INECEP Summer School  
Instituto de Ingeniería-UNAM, Mexico

# ECOSYSTEM-BASED ADAPTATIONS FOR STEPPED REVETMENTS: AN APPLICATION TO STRAND, SOUTH AFRICA

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**Keywords:** Coastal Structure, Ecosystem-based Adaptations, Stepped Revetment

## **Abstract**

Conventional hard coastal structures such as stepped revetments have significant environmental impacts. This paper investigates how a conventional stepped revetment can be adapted to mitigate or to reduce its environmental impacts. As a first step, the potential environmental impacts of a conventional stepped revetment are identified. Considering these impacts, possible ecosystem-based adaptations are proposed. Since the feasibility of these adaptations will differ from site to site, a case study is selected to investigate the implementation of an ecosystem-based stepped revetment. The study site and its environmental and ecological conditions are described. A discussion on the site selection for the implementation of a possible ecosystem-based stepped revetment is also included. Finally, an ecosystem-based stepped revetment is proposed for the study site.

# COASTAL ECOSYSTEM SERVICES PROVIDED BY CORAL REEFS AT TESORO ISLAND, COLOMBIA

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**Keywords:** Bottom roughness, Coral Reefs, Ecosystem Services, Numerical modelling, Wave damping

## **Abstract**

Coral reefs are coastal environments along a large number of world's coastlines, which constitute protection against sea waves and provide shelter and food for at least 25% of the ocean species. Pressure from tourism, fishing and recreation are among the anthropogenic activities that generate high impacts over the conservation and preservation of these natural habitats. Understanding the ecosystem services provided by coral reefs is fundamental for determining their value and contribution for reducing damages due to human actions combined with the effects of natural extreme events and climate change, which also contributes to coastal erosion and flooding hazards. A lack of knowledge currently exists in Latin American countries for the quantification of ecosystem services provided by coral reefs and the appropriate methodologies to support decision-makers and coastal managers. For this purpose, the current work considers a multidisciplinary approach aiming to combine results from hydrodynamic studies with biological factors, particularly regarding wave-transformation processes and energy dissipation under normal and extreme wave climate conditions. A typical fringing reef from the Colombian Caribbean Sea is selected as case study to quantify specific ecosystem services for practical socio-economic and environmental solutions in those regions, in which coral reefs predominate.

# WAVE ENERGY DISSIPATION ON THE CARIBBEAN INSULAR CORAL REEFS OF COLOMBIA

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**Key words:** Coral Reefs, Degradation, Roughness, Wave dissipation, XBeach

## **Abstract**

The numerical model XBeach was employed to simulate two typical Colombian coral reefs. A fringing and a barrier type reefs under healthy and degraded conditions were compared in terms of their capability to dissipate the wave energy through bottom friction and wave breaking. Laboratory experiments were used to calibrate and validate some modelled results. A significant difference was found between both coral reefs. The bottom friction dissipation is dominated in the fringing reef. By contrast, the barrier reef loses almost all the wave energy by wave breaking.

# ASSESSMENT OF WAVE ATTENUATION PERFORMANCE OF SEAWEED

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**Keywords:** Coastal vegetation, Hydraulic model tests, Seaweed, Wave attenuation, Wave-vegetation interaction

## **Abstract**

Due to the importance of beaches as one of the most important natural resources, many investigations on shoreline protection have been conducted. In addition to beach nourishment and structures such as jetties and breakwaters, which can protect the shoreline by dissipating and reflecting wave energy, the consideration of vegetation for shore protection and related eco-engineering issues has been increasingly addressed in recent publications. Since the interaction processes between hydrodynamics and plants structures are complex, there is an increasing demand for understanding the physical processes taking place in the vegetated areas and improving the current modelling approaches. Therefore, this study aims to improve the understanding of the attenuation of waves by submerged vegetation. For this purpose, hydraulic model tests have been carried out in a wave flume to study the effects of vegetation parameters (density and flexibility) and wave parameters (wave height and period) on wave attenuation using an artificial seaweed meadow subject to different wave conditions. For the effects of wave parameters, it was found that higher dissipation is induced by larger wave heights, and wave attenuation decreases for longer waves. For the effects of vegetation parameters, the results showed that wave attenuation increases with higher density and stiffness of the vegetation.

## INTERACTION BETWEEN REEFS AND BEACH MORPHOLOGY IN PONTAL DO CUPE BEACH, BRAZIL

**Karoline Angélica Martins<sup>1</sup>, Pedro de Souza Pereira<sup>2</sup>, Luciana Slomp Esteves<sup>3</sup>**

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**Keywords:** Beach morphology, Beach profile, Coastal protection, Reef, Ecosystem services.

### **Abstract**

Reefs provide substantial protection to the coast by reducing wave energy before it reaches the shore, which is also considered an ecosystem service of coastal protection. Wave transformations over reefs influence the beach morphology, which is primarily determined by wave breaking height, wave peak period and sediment size. Pontal do Cupe Beach, located in the Brazilian northeast, at Pernambuco state was taken as a model to evaluate the reef's influence over the beach morphology. This beach is characterized by the presence of a parallel reef line in certain parts of the coast, often covered by corals, calcareous algae and molluscs. A Principal Component Analysis confirmed the existence of five beach profile clusters, distinguished by their morphology. One cluster represents the morphology of beaches right in front of the reef lee, another denotes the morphology of beaches under the influence of wave diffraction, and the other three clusters indicate the beaches with less influence of the reef's protection. Through clusters mean profiles it was possible to identify morphological features associated with wave transformation gradients, such as the existence of berm on exposed profiles and a marked low tide terrace on protected profiles.

# CHANGES IN COASTAL ECOSYSTEMS' ROLE AGAINST HURRICANE AND STORM SURGE AT ANA MARIA GULF, CUBA

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**Keywords:** change of covers, coastal exposure, ecosystems' role, human activities, natural habitat's ranking

## **Abstract**

The Terrain Categorization (TERCAT) tool from ENVI identified change of covers from 1975 to 2014. The covers include Sand, Mud, Rocks, Seagrass, Dry Crops, Green Crops, Inland Water Bodies, Mangrove, Natural Vegetation, and No Vegetation. Natural habitat's ranking and drag coefficient assigned to each cover represent a measure of coastal exposure. Crops and No Vegetation express if human activities have induced coastal exposure changes. Results show an increment of Natural Vegetation and decrement of covers related to crops and no vegetation. The study area has a highly coastal exposure due to the natural habitat's ranking 5, which is the most representative one. Changes in covers do not generate great changes in coastal exposure. The reduction of covers identified with human activities and the increase of Natural Vegetation prove that human activities do not affect the coastal exposure. The cover profiles near to Palo Alto harbor and Júcaro town have less mangrove width than those long away, making it more exposed to coastal flooding. It is possible to identify two different zones taking into account changes of both natural habitats ranking for coastal exposure and drag coefficient from 1975 to 2014.

# WAVELET AS ROUGHNESS INDICATOR FOR CORAL REEF BATHYMETRIC PROFILES

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**Keywords:** Coral-Reef, Roughness, Structural-Complexity, Wavelet

## **Abstract**

Coral reefs are complex, productive and fragile systems, which are affected by multiple variables acting at several scales. However, properly evaluating and measuring roughness in these systems represent technical and logistic challenges, including water motion (breaking waves), shallowness, and coral fragility. Therefore, selection of a suitable method within the variety of existing possibilities is very important. The present work compares different analysis tools for roughness evaluation on bathymetric profiles: Rugosity Index (RI), Standard Deviation (SD), Spectral Analysis (Fourier Analysis), and Wavelet Analysis. Cross-reef bathymetric profiles were performed in the Puerto Morelos reef system in Quintana Roo, Mexico. A pentamaran (dim: 2 x 1.5 m) was equipped with an ADCP used as an echosounder (~30 cm resolution) and a differential GPS. The Wavelet analysis was the only one capable of evaluating roughness height, length at different scales (0.3 to 30 m) and its spatial location along the profile. Thus, this tool is adequate to find relations between roughness and phenomena at different scales through profiles.

# RIP CURRENTS IN AN INTERMEDIATE BEACH WITH A NATURAL SUBMERGED ROCKY BANK

**Francisco F. Criado-Sudau, Douglas D. Nemes, Marcos N. Gallo**

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**Keywords:** Risk scale, Surf zone, Morphodynamic Variability

## **Abstract**

Rip currents are strong transverse seaward directed flows, part of the hydrodynamic of oceanic beaches, being the main reason for lifeguard rescues efforts and drownings all over the world. To obtain in situ measures in the surf zone is a challenge due to the high energy, which is typical of these environments. A significant dataset was created during 25 field experiments (01/2015–01/2016) under low and high wave energy conditions. Eulerian and lagrangian surveys were carried out by an ADCP and human drifters, respectively. The Reserva Beach presented three zones considering the rip currents' frequency and intensity, two lateral zones classified like "risk zones" and a central, classified as safety zone. The largest rip currents speeds were typically observed during high and shore-normal wave conditions. A threshold for significant wave height was identified (1.5-2) that determines the highest rip current velocities, from them on higher waves do not increase rip currents intensity. This study aims to characterize the rip currents of Reserva Beach in order to support a rip current forecast scale for the beaches of Rio de Janeiro, considering the wave parameters, tide influence, and the beach morphodynamic. The analysis of the in situ measurements should help in the calibration and validation of a hydrodynamic numerical model meaning to extend the risk scale along the coast of Rio de Janeiro.

# OCEANOGRAPHIC CONDITIONS LINKED TO THE ARRIVAL AND DEPARTURE OF *SARGASSUM SPP.* ON A FRINGING REEF LAGOON IN PUERTO MORELOS, QUINTANA ROO

**Diana Berriel-Bueno<sup>1</sup>, Ismael Mariño-Tapia <sup>1</sup>, Elena Ojeda-Casillas <sup>2</sup>,  
Cecilia Enriquez-Ortiz<sup>3</sup>, Tonatiuh Mendoza-Ponce<sup>2</sup>, A. David García-Barrera <sup>2</sup>**

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**Keywords:** Atypical *Sargassum* influx, Coastal video-monitoring, Fringing reef lagoon, *Sargassum* dispersion, *Sargassum* modelling

## **Abstract**

Massive atypical influx of *Sargassum spp.* has been reported from 2011 to 2016 across the Caribbean Sea and Gulf of Mexico's coasts. It is believed that this atypical influx was originated in the North Equatorial Recirculating Region (NERR), and because of the tropical characteristics of the surrounding water the *Sargassum* reservoir found the ideal conditions for establishing and growing. Under normal conditions, *Sargassum*'s role as a nutrient input source benefits the benthic community and the coastal vegetation, while in contrast, huge accumulations of *Sargassum* lead to anoxic conditions resulting in the eutrophication of the environment. In the Mexican Caribbean, the coastline of Quintana Roo was the most affected one. Around 9,700 m<sup>3</sup> of *Sargassum* were removed monthly per kilometer of beach, and at Puerto Morelos fringing reef lagoon, more than 6,600 m<sup>3</sup>/km washed ashore. Wave and wind forces are the main drivers of the circulation of the reef lagoon, so the coupled wave-hydrodynamic Delft3D-SWAN model was used to simulate *Sargassum* inflow and outflow oceanographic conditions in the lagoon. Additionally, cover areas of *Sargassum* were obtained from imagery analysis from a fixed coastal video monitoring system installed during the massive arrival event.

# LONG-TERM BEACH AND COASTAL DUNE DYNAMICS IN RESPONSE TO NATURAL AND HUMAN-MADE FACTORS

**M. Luisa Martínez<sup>1</sup>, Rosario Landgrave<sup>1</sup>, Rodolfo Silva<sup>2</sup>, Patrick Hesp<sup>3</sup>**

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**Keywords:** Breakwaters, Coastal Dunes, Mexico, Mobile Dune Stabilization, Urbanization

## **Abstract**

This study took place in Playa Chachalacas, located in the central region of the Gulf of Mexico. The goal of this study was to understand the long-term consequences of modifying sediment dynamics through the combined effect of dune stabilization and the construction of breakwaters for shoreline protection. With aerial images from different years, the following items were analyzed: (a) stabilization of the mobile dune; (b) shoreline dynamics and changes at the river mouth, located down-drift from the dunefield; and (c) urbanization along the shoreline. Data show that the cover of grasses and shrubs increased rapidly. In some points, there was intense erosion along the shoreline and accretion in others. The breakwaters promoted accretion but exacerbated erosion down-drift, with notable changes in the inlet. Finally, urbanization has occurred at a fast rate, and mostly parallel to the shoreline. The results indicate that different factors affect sediment dynamics: (a) warm and wet climate promoted vegetation growth and sediment stabilization; (b) the breakwaters solved the erosion problem locally, but generated intense erosion down-drift; and (c) urbanization along the coast resulted in ecosystem loss and increased risks to flooding. Indeed, management and development plans for coastal environments need to consider the dynamic nature of the coastline.

## MORPHODYNAMIC VARIABILITY OF BEACHES IN COSTA VERDE, COLOMBIA

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**Keywords:** sediment transport model, coastal erosion, statistical parameters, morphology, dynamic equilibrium, SANDY®

### Abstract

The stability of coastal ecosystems depends greatly on the sediment balance, so understanding the sediment fluxes and their spatial distribution is a key issue for understanding the stability of a dune beach system. This research considers the analysis of statistical parameters of grain size distribution on the Costa Verde coast, Colombia in order to determine its stability status. Theoretical and numerical models are used to predict the sediment transport direction and volume. The physical processes of the coastal zone are evaluated based on combined analyses of the coastline evolution, the geomorphology, the effect of hydrodynamics, and the anthropogenic impacts. The results show that better management policies must be developed in order to reduce beach erosion and to promote a sustainable use of the coastal zone.

## SALINIZATION OF MARSHES IN ARGENTINA: NATURAL VS. ANTHROPOGENIC FACTORS

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**Keywords:** Argentinian coast, coastal wetland, embankment, salt marshes, soil salinity

### **Abstract**

In the littoral zone of Argentina, marsh environments under arid, semi-arid and humid conditions are numerous. In this work, salt marshes located in Río de la Plata Estuary, Bahía Blanca Estuary, San Antonio Bay, and San Jorge Gulf were studied aiming at understanding the processes that determine the occurrence of evaporates in salt marshes, and analyzing the importance of natural and anthropogenic factors. QuickBird and Google Earth images were used to identify the geomorphologic, anthropogenic and hydrological characteristics, and selected samples were examined under a binocular magnifying glass, through X-ray diffraction (XRD) and scanning electron microscopy (SEM). The four studied marshes are located along a latitudinal gradient on the Argentina Atlantic coast, where the climatic conditions are wet in the northern sector and arid in the marshes of the southern sector. The tidal conditions change from north to south as micro-tidal in Ajó marsh, meso-tidal in Bahía Blanca, and macro-tidal in San Antonio and Fracasso marshes. In each area, contrasting climatic conditions, tidal and anthropogenic influence and hydrological characterization were studied both the anthropogenic and the natural factors condition the soils marshes salinization. Although it is expected that a greater amount of salts occur in arid marshes soils, it was observed that salt development in altered marshes with humid climates are more important. This shows the high negative influence that an anthropogenic modification can have over sensitive ecosystems as the marshes.

# MODELLING AND MANAGEMENT OF STORM-DRIVEN SALTWATER INTRUSION IN FRESHWATER AQUIFERS: THE CASE OF NEAR BREMERHAVEN, GERMANY

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**Keywords:** Aquifers contamination; Coastal floods; Seawater intrusion; Storm surge; Wave overtopping.

## **Abstract**

Coastal floods represent a significant humanitarian and socioeconomic hazard. Therefore, coastal barriers such as dunes, dykes and other engineered structures are often required as structural mitigation measures against coastal flooding. However, during extreme conditions (e.g., extreme storm surges), overtopping waves and/or floods resulting from breaching of coastal barriers may still be a threat. In fact, they can induce, in addition to direct physical damages, further types of long-term damages. The most important long-term effect of coastal floods is saltwater intrusion (SWI) into coastal aquifers induced by the vertical infiltration of the salt water behind the overtopped and/or breached coastal barriers. Such vertical SWI increases the salinity of the originally fresh groundwater, which indeed represents a major decrease of the water quality, possibly with significant environmental effects that can hinder possible sustainable development in coastal zones. This paper, therefore, highlights this problem through a case study in northern Germany, where coastal floods from the North Sea might represent a real threat to freshwater aquifers. Moreover, through the case study, the paper attempts to briefly summarise the state-of-the-art in modelling and mitigating storm-driven saltwater intrusion.

# **SUBMARINE GROUNDWATER DISCHARGES AND THEIR INFLUENCE ON BENTHIC COVER AND REEF RUGOSITY AT PUERTO MORELOS REEF LAGOON**

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**Keywords:** Bathymetry, Benthic Cover, Coral, Macroalgae, Rugosity

## **Abstract**

The present study shows evidence of continental inputs of water flowing directly into the reef crest through Submarine Groundwater Discharges (SGD) and its effect on the ecosystem in reef lagoon of Puerto Morelos, Quintana Roo. Using oceanographic instrumentation, high resolution bathymetric profiles were obtained to characterize reef rugosity, videotransects to estimate benthic cover through morpho-functional groups (stony corals, gorgonians, macroalgae, sponges, seagrass, and substrate), and salinity and temperature measurements to determine the influence of SGD. In addition, a CTD Diver was installed fixed on the sea bottom to study the dispersion of SGD on the reef and its lagoon. Measurements show consistent decrements of salinity with one month duration (during October-November 2016) reaching minimum values of 9.4 psu at sites influenced by SGD. These sites show contrasting effects as compared with the reference sites (i.e., Limones), such as a macroalgae-dominated benthic cover and reduced rugosity, especially where the macroalgae is present. Evidence of this is observed in the rugosity index obtained for the reference profiles. The results corroborate the negative influence of SGD on the reef, which could strengthen the demand for better sewage treatment practices in the area.

# GROUNDWATER ECOSYSTEMS SERVICES FOR INDUSTRIAL USE IN COASTAL AQUIFER

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**Keywords:** Aquifer Barrier Marine, Groundwater, Hydrodynamics, Industrial exploitation, Wetlands.

## **Abstract**

Protection of groundwater resources involves the conservation of water quality and quantity in order to save it for the future generations, based on the incorporation of management and planning measures aiming at the conservation of systems and the appropriate use of lands. Thus, it is ensured that potentially impacting activities should not be installed in places that present higher hydrogeological risk. The beverage industry demands large volumes of water in the production process. When groundwater is used to supply the industry, a productive aquifer with good physical-chemical and bacteriological water quality can minimize the production costs. This study aims to develop a conceptual hydrodynamic model for Coxilha das Lombas Aquifer and to estimate the area needed to supply groundwater to the brewing company. The hydrodynamic study indicated the presence of an unconfined and a semi-confined aquifers. Regional groundwater flows from NW to SE. Groundwater withdrawal by the industry is 3.2 times greater than the natural recharge that infiltrate into the aquifer in the company's property. There is risk of reduction on groundwater discharge to the adjacent and non-adjacent wetlands ecosystems.

# GROUNDWATER FLUCTUATIONS AND THEIR INTERACTIONS WITH RIVERS AND WETLANDS IN COASTAL ZONES

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**Keywords:** Flooding, Groundwater-surface water interaction, Wetlands

## **Abstract**

Groundwater and surface interactions affect recharge and discharge processes, and are of great ecological importance and affect humans. This study was carried out on the coastal plain of the state of Veracruz, Mexico in order to understand seasonal variation in groundwater, its interaction with surface water and with the vegetation of flooded areas. Piezometer data were used with historical data from hydrometric stations and land use data from remote image analysis. Five ways that groundwater, surface water and vegetation interact are: (1) groundwater reflects the river's behaviour and the presence of riparian vegetation, (2) the area with river discharge, influence from the sea and groundwater has mangroves, (3) where the contribution of the river is superficial, but the contribution of groundwater flow is in the opposite direction, a discharge zone is formed, (4) the watershed discharging into the sea and groundwater flowing in the opposite direction indicates that the dune lakes are fed by groundwater, and (5) the aquifer rises where soil is mainly sandy (urban coastal zone). The region's management plan should take into account that flooding in the area results from groundwater and surface water, so solutions should include implementing both engineering and environmental solutions together.

# THE MULTI-CHANNEL ESTUARINE SYSTEM OF THE AMAZON AND PARÁ RIVERS

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**Keywords:** Amazon River; Multi-channel estuaries; Numerical modelling; Straits of Breves; Tide

## **Abstract**

Tides play an essential role in estuarine hydrodynamics, being important for navigation, water management and the sustainable use of natural resources. This study aims to analyze the behavior of the tidal propagation along the main two channels and the inner straits of the Amazon estuary in terms of water levels and flow velocities. The Amazon River with an average discharge of  $1.7 \times 10^5 \text{ m}^3/\text{s}$  flows through two main branches, North and South, towards the ocean. The Tocantins River, of which the average discharge is  $1.3 \times 10^4 \text{ m}^3/\text{s}$ , flows to the Para River. Around Marajo Island, the Amazon South channel meets the Para River at the mouth and they are also connected through a set of channels, the Straits of Breves. Tidal propagation along this multi-channel system is modulated by the incident tidal amplitude and phase, and the amplitude and phase of the rivers' discharges. However, the tidal response could be more complex due to the exchange between the two hydrographically distinct estuaries, which are connected by tidal channels. A numerical model (Delft3D) and available data from several tidal gauges are used to investigate the tidal propagation. The results show: (a) the formation of a tide convergence zone, and (b) a greater influence of the Amazon River in flow velocity directions than that of the Para River. An analysis of the levels and currents (H-v diagrams) of tides at the convergence zone is also presented to understand the wave tide behavior.

## EROSION OF PUERTO COLOMBIA COAST BY MARITIME ACTIVITIES

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**Keywords:** coastal processes, hard structures, Puerto Colombia coast, ecosystems, wave climate

### **Abstract**

In this article, coastal processes are analysed using Landsat Satellite images to assess conditions caused by the construction of coastal works. The littoral cells were implemented according to geomorphological and hydrological factors and the use of regressive models such as the Digital Shoreline Analysis System (DSAS), an extension of ArcGIS 10.3, in order to estimate the changes in the coastline such as erosion and sedimentation rates. The results of this study show that the equilibrium of the system was lost given that the natural conditions allow the natural generation of soft sandy beaches has been irreversibly altered by human activities.

# METHODOLOGY FOR THE DETERMINATION OF EROSION AND DECREASE OF COASTAL VULNERABILITY

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**Keywords:** beach, Campeche, coast, erosion, vulnerability

## **Abstract**

For more than three decades, the tourism development at the coast of Campeche has lacked a management plan that considers its conservation and sustainability. As a result, several areas feature tourist and urban infrastructure that is severely pressing the coastal system. Specifically Chenkan, which is a RAMSAR site dedicated to the conservation of the sea turtle, is suffering chronic erosion problems and increased vulnerability due to anthropogenic interventions in the coast. The present study analyzes data from a survey of 10 beach profiles with an average spacing of 300 m in longitudinal direction and 60 m in transversal direction for the calculation of erosion/deposition volumes and the grain size distribution, and statistical values of 330 sediment samples. In addition, Quickbird images from 2009 to 2013 were used in order to evaluate the coastline evolution. The results obtained so far show the seasonal variability of the coastline and of the sediment grain size.

# COASTAL EROSION CONTROL IN FRINGE MANGROVES AFFECTED BY LOGGING IN THE COLOMBIAN CARIBBEAN

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**Keywords:** Caribbean, Disturbance, Ecosystem services, Erosion rates, Fringe mangroves

## **Abstract**

Fringe mangroves are able to reduce erosion by wave dissipation, sediment retention and soil development. Indicators of mangrove ecosystem integrity and reported erosion/accretion rates were analyzed to identify the relation between potential erosive predictors and reported erosion rates. Two of the three sites studied had mangrove tree mortality levels (23% and 30%) above the expected threshold (13% and 14%, respectively) due to natural mortality and logging; a result that indicate a suboptimum condition of ecosystem integrity. Relatively high erosion rates of -9 m/yr are found in a highly exposed location with suboptimum ecosystem integrity. Accretion rates of +0.2 m/yr are found in a protected location with an acceptable condition of ecosystem integrity. In Punta Las Playitas, a location with relatively low exposition to waves, high exposed setting and suboptimum ecosystem integrity, erosion rates are between -0.2 and -1.5 m/yr. It is concluded that Interaction between ecosystem integrity, wave energetic conditions and sediment delivery may define sediment balance in mangrove vegetated shores, it is necessary to identify acceptable thresholds of logging intensity and river sediment delivery to improve coastal adaptation, mangrove persistence and to establish soft engineering solutions to erosion using mangroves.

## DESIGN OF STRATEGIES FOR THE CONTROL OF BEACH EROSION WITH AN ECOSYSTEM-BASED MANAGEMENT APPROACH

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**Keywords:** coastal erosion, anthropization

### **Abstract**

Coastline evolution was studied in Sabancuy beach through the use of satellite images, from which the areas of beach erosion and accretion were determined in a period of 10 years (2004 - 2014). The beach at the east side of the access channel was found to have a growth area of 129,109 m<sup>2</sup>, while the beach in the west side of the channel shows an area loss of -23,790 m<sup>2</sup>. The degree of anthropization of the study area was determined to evaluate the effect of the transformation by human action on the different biological systems. It was found that 50% of the study area is covered with natural vegetation, 36% is occupied by agricultural areas, 8% corresponds to secondary vegetation, and lastly, 6% corresponds to urban settlements. Based on this information, a first proposal of possible strategies for beach erosion control is presented.

## IDENTIFYING MULTIFUNCTIONAL RESTORATION AREAS FOR COASTAL LANDSCAPE CONSERVATION IN MEXICO

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**Keywords:** sandy beaches, coastal dunes, biosphere reserve, Marismas Nacionales, perturbation, restoration

### Abstract

Overpopulation and inadequate management of the world's coastlines have seriously degraded numerous sandy beaches that provide valuable ecosystem services to society. The recovery of coastal ecosystem services is one potential adaptation strategy to address both current threats and future threats from climate change. However, the implementation of restoration projects is a complex process that involves multiple variables (i.e., ecological, geomorphological, and socio-economic variables) that vary widely per site. In the present study, the ReDune index was applied in Marismas Nacionales, a UNESCO-designated Biosphere Reserve located on the Mexican Pacific Coast, in order to identify sandy beaches that require restoration and can be feasibly restored. The results highlight the flexibility and versatility of the ReDune index, which can be applied in sites with differing sedimentary, ecological, and human pressures and characteristics. Also, the index clearly distinguished between locations, where restoration is urgent, and those, where it is not. Further research is required to choose the appropriate strategies for restoring the indicated sites. Ultimately, the considered restoration alternatives should be flexible and enhance the resilience of the complex beach systems of Marismas Nacionales.

# ELEMENTS INDUCING COASTAL SQUEEZE ON THE COAST OF SABANCUY, CAMPECHE, MEXICO

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**Keywords:** coastal squeeze, coastal ecosystems, hard structures, land use change, sea level rise

## **Abstract**

The term coastal squeeze describes the process, in which rising sea levels and other factors, such as increased storminess and coastal subsidence, push coastal habitats landward. Also, the presence of hard structures along coastlines can create static, artificial margins between the land and the sea, restricting coastal habitats to a narrowed zone. Rising ground levels with respect to the coastal plain, which may be caused by impeded hydro-sedimentary flow, can also form additional natural barriers. In particular, the coast of Mexico is vulnerable to increasing sea levels, yet other more rapidly occurring processes could be inducing coastal squeeze to a greater extent, such as coastal subsidence, extreme hydro-meteorological phenomena, land use changes and erosion stemming from the retention of sediments in upper coastal basins. The objective of this study was to analyze coastal squeeze along the coast of Sabancuy in the state of Campeche, Mexico, through identifying the variables for the first time that are determinative of coastal squeeze in this area. The processes examined land use changes, storm incidence and the presence of hard structures, among other factors, which have rapidly increased in the study area in recent years and have caused the loss of coastal ecosystems. Ultimately, one of the goals is to create a methodology that can quantitatively measure the effects of coastal squeeze in different coastal zones. This study presents the first steps: the identification of variables that influence coastal squeeze and an assessment of their importance. The resulting methodology would serve as a tool for decision makers and for the sustainable management of coasts.

## CHALLENGES AND STRATEGIES TO MODEL MARINE LITTER IN THE GUANABARA BAY

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**Keywords:** analytical-numerical 3D model, floating macro marine litter, Guanabara Bay, modeling marine litter, particle tracking model

### **Abstract**

The problem of floating macro marine litter (FMML) in Guanabara Bay was globally evidenced when the 2016 Olympic Games were held in the city of Rio de Janeiro. This problem also occurs on the beaches of *Ilha do Fundão*, where the campus of the Federal University of Rio de Janeiro is located, which is part of the bay. When it is required to evaluate the dynamics, transport and spatial distribution of the FMML in this particular sector, and in the bay in general, certain challenges present themselves. That is, the modeling of flows between the coasts and the interface with the ocean, the monitoring, distribution and quantification of floating litter on the beaches, and when they are in the marine environment, the scale problems of the processes, which the numerical models cannot represent, as well as the validation of the results with limited data from surveys, among others. This work discusses the challenges for FMML modeling in coastal areas and, likewise, evaluates possible strategies for solving them. For that, some strategies for modeling were proposed, such as the use of a 3D analytical-numerical hydrodynamic model, coupled to a Lagrangian particle tracking model, combined with observed experimental data.

# DESALINATION PLANTS – THE ENVIRONMENTAL IMPACT ON CORAL REEFS IN THE NORTHERN RED SEA

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**Keywords:** Coral Reefs, Desalination, Numerical Modeling, SWRO

## **Abstract**

Desalination techniques could be a solution to face the problems of water scarcity. In 2015, 300 million people could be supplied with freshwater by desalinated water as well as a huge capacity of industry waters. Nevertheless, the technique comes with a variety of disadvantages. This paper examines the emissions of desalination plants and their environmental impacts on the marine organisms of corals. Basis of this paper is a case study about chemical loads of desalination plants in the northern Red Sea. It was found that the brine that is lead into the ocean can heavily influence the marine ecosystem. In this paper, the idea of an assessment tool is extended. The paper is structured as a literature research and combines the existing issues with the idea of a numerical tool as guidance within the planning of new plants. The objective of this guide should be to optimize the system in order to decrease environmental impacts. Central of the discussion is that for each plant a holistic and individual solution has to be found. Combining all aspects in one assessment approach is complex, but this challenge should be seen as a chance to preserve nature.

## ECONOMIC VALUATION OF MANGROVE AREAS A STUDY CASE IN NORTHEAST OF BRAZIL

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**Keywords:** ecosystem services, mangroves, opportunity cost, replacement cost, valuation

### **Abstract**

Brazil has the second largest mangrove area on earth with high socioeconomic and ecological importance. However, these forests are suffering a decline due to sea level rise, human occupation and lack of preservation policies, putting at risk the quality of several ecosystem goods and services that they provide, such as carbon storage service that contribute to the climate change mitigation. A way to avoid more degradation and to promote the preservation of mangroves is doing an economic valuation of their ecosystem services. Through this study case, performed in the Ponta do Tubarão Sustainable Development Reserve - RDSPT (Rio Grande do Norte), it was aimed to estimate the opportunity and replacement costs associated with the carbon storageservice, and the dynamics of loss and gain of mangrove areas as a consequence of the coastline progression and human perturbation over 30 years. It was found that an increase of mangrove areas from 1984 to 2014 occurred, leading to a higher carbon storagecapacity. Carbon storageservice of the RDSPT mangroves also affords 75% more profit than the wind energy sector. It was found that the restoration of the lost areas would cost approximately 377 million Euro by reforesting the core areas and patches near the beach strip.