We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,300

Open access books available

172,000

International authors and editors

190M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

San Quintin Lagoon Hydrodynamics Case Study

Oscar Delgado-González, Fernando Marván-Gargollo,
Adán Mejía-Trejo and Eduardo Gil-Silva
*Instituto de Investigaciones Oceanológicas,
Universidad Autónoma de Baja California,
Ensenada, Baja California,
México*

1. Introduction

Hydrodynamics at coastal zone determine the way in which water flows and biochemical properties are exchanged. It is important to understand these processes in order to determine the potential effects caused by modifying the flow field as well as the mixing processes. For aquaculture purposes, the flow field distributes food to the organisms, thus by understanding the system hydrodynamic it is possible to determine suitable areas for aquaculture activities.

In México, approximately 2% of the 1.9×10^6 km² which constitutes the national territory corresponds to protected or semi protected coastal areas (Ortiz-Pérez and Lanza-Espino 2006) and is distributed over 11,000 km of coastline; however, norms and guidelines for commercial aquaculture development were not established until the early 1990s, so this activity is currently at an incipient stage in most coastal areas.

San Quintin Lagoon (SQL) is a coastal lagoon located on the northwestern coast of Baja California (Mexico) which is characterized as a semiarid region with a highly productive upwelling offshore. The lagoon covers an area of approximately 42 km² (Figure 1) and is divided in two basins named Bahia San Quintin (BSQ) and Bahia Falsa (BF). The mouth of the lagoon is 1 km wide and has maximum depth of 14 m. The lagoon shows several mud flats, some of them are exposed during low tides and others leave shallow areas which are optimal for aquaculture activities. The tidal regime is mixed semidiurnal with amplitudes as high as 1.6 m above MLLW (Mean Lower Low Water) during spring tides. The oceanic water entering the lagoon is nutrient rich due to upwelling processes associated with the north-south orientation of the coastline which mainly occur during spring and summer (Hernández-Ayón *et al.* 2004). The wind regime changes on a diurnal scale and is a breeze type with its maximum magnitude around 3pm with a dominant direction from the northwest. Due to the orientation of the lagoon and shallowness, the wind plays a very important role in circulation and generation of fetch limited waves. Inside the lagoon, the water column is well mixed (Millán-Núñez *et al.* 1982). The climate is Mediterranean and the lagoon shows as a negative estuary structure due to its net evaporation which makes the lagoon a hyper saline system throughout the year.

Fig. 1. Bahia San Quintin is a coastal lagoon on the northwest coast of Baja California México. The flags at the marine area represent the temperature sensor location, the one at the northwest continental location, marks the site location of the meteorological station.

During the 70s, studies were conducted at SQL to establish its viability for aquacultural activities (Lara-Lara and Álvarez-Borrego 1975, Álvarez-Borrego and Álvarez-Borrego 1982). These studies provided the first biophysical data and, among other findings, it was determined that the system is governed by mixed, semidiurnal tides.

In SQL, aquaculture activities have been conducted continuously for more than 30 years. The Pacific oyster *Crassostrea gigas* is extensively cultured in this area using a rack method. Even though most oyster farms use the same cultivation method, it is common to find differences of more than two months in the time at which organisms attain a commercial size throughout the lagoon (García-Esquivel *et al.* 2000).

The main factors involved in the selection of an area for aquaculture activities are: water, temperature, salinity, depth, and food availability (Héral and Deslous-Paoli, 1991). The conceptual model of factors and processes involved in the distribution of water properties by currents in BF (Delgado-González, 2010), gives an idea of the hydrodynamics and its importance in mixing and carrying food sources from one area to another. Phytoplankton spatial distribution at BF under neap and spring tides, considering oyster consumption, was obtained by using a 2D hydrodynamic model (Delgado-González, *et al.*, 2010) and the results were utilized to determine the most productive areas within BF.

The purpose of this chapter is to present the hydrodynamic regimes at BSQ using a 2D hydrodynamic numerical model that considers the wind effect as well as analyzing food input to the lagoon, residence times and waste production within the lagoon by using a lagrangean tracker method. It is necessary to understand the possible circulation patterns of coastal lagoons like BSQ in order to adequately manage their resources and their water quality, which could be affected as a consequence of the aquaculture activities taking place inside the lagoon.

The hydrodynamics regimes and waterborne particle transport was obtained using the Coastal Modeling System Flow (CMS) Flow in conjunction with the Particle Tracking Model (PTM). Both models are embedded within the SMS user interface. CMS is a two-dimensional finite volume numerical model developed by the US Army Corps of Engineers which is based on a rectangular grid allowing for grid refinement as well as telescoping grids. PTM (Particle Tracking Model) is a lagrangean particle tracker designed to trace the fate and pathways of sediment and other waterborne particles. It was designed jointly by the Coastal Inlets Research Program (CIRP) and the Dredging Operations and Engineering Research (DOER). Particles are transported by the flow field and it takes into consideration a logarithmic current profile for their advection.

2. Data collection

2.1 Tides

Tides in the north Pacific coast are the primary hydrodynamic forcing agent for coastal lagoons with a constant water exchange with the open ocean such as SQL. (Fischer *et al.*, 1979). The tides at SQL are mixed with a semidiurnal predominance (Figure 3). The tides exhibit a well-defined fortnightly modulation for which the range during spring tides is approximately 2.5 m and 1.0 m for neap tides. Using these values in combination with the surface area of the basin and the mouth cross-sectional area, for a linear-frictionless tidal wave, according to Stiegebrandt (1977), the amplitude of the tidal currents should be:

$$u_0 = \alpha Y \sigma / 2A$$

where α is the tidal range, Y is the surface area of the basin ($42 \times 10^6 \text{ m}^2$), A is the cross-sectional area at the entrance (7500 m^2) and σ is the frequency of the main tidal forcing ($2\pi/12.42 \text{ h}$). Thus, for spring tides u_0 should be approximately 0.98 m/s and for neap tides it should be around 0.31 m/s, which are similar to the observed values reported in this work.

The most intense tides occur during spring tides in December and January whilst the less exchange occurs during neap tides around the year (Delgado-Gonzalez, *et al.*, 2010). There is a 40 minute tidal lag between the lagoon mouth and the head in BSQ, located in the inner part of the right arm of SQB (Ocampo-Torres 1980).

2.2 Wind

Wind, in many places, is responsible for producing surface currents as well as vertical mixing under special conditions (Fischer *et al.*, 1979). In the particular case of San Quintin the wind is generally strong and the direction does not change very much thus being also an important forcing agent for the lagoon hydrodynamics. Due to the lagoon configuration, wind is more important at BF than at BSQ mainly due to the primary axis of BF which coincides with the predominant wind direction and the fact that volcanoes shelter BSQ.

The wind data presented in this chapter was registered in the northwest area of BSQ (Figure 1). The wind hodograph shows the time of the day and magnitude for local and synoptic winds recorded at this station. This station also records air temperature and atmospheric pressure (Figure 2). The ellipse shape of the hodograph and its northern relative position from intersection of the West-East (u) and South-North (v) components can be used to identify the hourly characteristics for the local wind and the synoptic effect, respectively.

Drifters from September 10th, pink color (Figure 4a), were deployed at the central zone of BSQ. The five drifters finished out of the lagoon and most of the time their trajectories remained at the central part of the main tidal channel. Just at the mouth area, the drifters were closer to the east part rather than to the central part of the channel and ended at the shoaling region of the tidal delta. Drifters from November 4th, 2010 and April 14th, 2011, black and gold color (Figure 4a), followed the central area of the channel until they reached the delta part, where they started to move away from each other following curved trajectories, which indicates the balance between the lagoon water and the oceanic waters. Drifters from August 26th, 2010, red color (Figure 4a) located at the inner part of BSQ moved slower, but followed the central area of the tidal channel.

Drifters from April 13th, 2011, red color (Figure 4b) were located outside the bay in order to determine if they would be suctioned inside. However the wind component was strong enough to move them away from the bay entrance. On June 21st, 2011, black color (Figure 3b), the drifters were deployed 4 hours after the flooding tide started to fill the lagoon, reducing the possibility of seeing the full expected trajectories and the drifters were forced by the wind stress to curve into the sand bar.

Fig. 4. During ebb tide conditions the mean velocities of drifters were 0.4m/s with maximum values around .8 m/s at the mouth area. During the experiments in flood conditions, the wind stress at the surface moved the drifters away when these were deployed outside San Quintin bay and to the coast when were deployed at the mouth. The initial time (To) is shown to represent the initial position in each experiment. The black arrow represents the outflow from and inflow to San Quintin Bay.

2.3.3 Water temperature

Water temperature at San Quintin Lagoon shows a clear seasonal signal, a clear variation between BF and BSQ and throughout a tidal cycle, and within its shallows areas the water temperature closely tracks air temperatures even with the constant effects of wind mixing processes.

Three HOBO Water Temp Pro v2 Data Logger sensors were deployed at BSQ during the 6 months (Figure 1). These sensors were located at aquaculture buoys and situated at a depth of approximately 1.5 m. The instrument recorded temperature at a rate of 15 minutes (Figure 5). The role of tides in the temperature oscillations during the August-November months and the upwelling index is well observed; it is possible to observe that during spring tides the water temperature inside the lagoon drops 3 or 4 °C, and most of the times this drop shows visual correlation with the upwelling index, and during neap tides the system increase its temperature. However, during the last days of November the spring tides reduce the temperature and the system does not return to the original warm temperatures, marking the beginning of winter inside the lagoon (Figure 5).

Fig. 5. The temperature time series at three stations in BSQ showed similar behavior, only two are presented. During summer months mean temperatures in the two inner is $19.0\text{ }^{\circ}\text{C} \pm 1.44$ and $14.8\text{ }^{\circ}\text{C} \pm 0.95$ during winter months. The fortnightly tide has an important role in the main fluctuations observed.

In order to see the relationship between spring and neap tides and temperature changes, the first fifteen days of August and October (Figure 6). During neap tides, first 6 days of August (Figure 6a) the mean temperature is around $19\text{ }^{\circ}\text{C}$ and during the spring tide the mean temperature remains around $17.5\text{ }^{\circ}\text{C}$, mainly because of the different hydrodynamics associated with these two tide conditions.

Fig. 12. (Top) Ebbing tide for a spring event, 3.5 hours after high water and (Bottom) flooding tide for a spring event, after 2.5 hours from low water.

Fig. 13. (Top) Ebbing tide for a neap event, 1.75 hours after high water and (Bottom) flooding tide for a Neap event after 4 hours from low water.

shows that the flushing time from BSQ is much faster than for BF, especially the upper section of this basin. Also the Sonora Channel plays an important role in flushing BF as can be observed from source 5 and the main channel connecting to BSQ flushes the eastern mud flats represented by sources 2 and 3.

3.4 Detritus inflow

Due to the fact that aquaculture is a very important activity inside BF basin, the model was set to simulate detritus inflow from open water into the lagoon. To do so, four point sources were specified just beyond the mouth delta. Figure 16 shows these sources as well as the advection of such particles during a flooding time frame.

From Figure 16a it can be observed that sources 1 and 2 are mainly transported into BF through the Sonora Channel, at the left side of BF, as well as over the central mud flat and a smaller fraction from this sources goes into SQB. For source 3 there is not much transported into the lagoon as the bulk stays outside and finally source 4 is transported through the main channel mostly into BSQ as well as the eastern mudflats from BSQ basin and just a very small fraction enters into BF basin.

Fig. 16. a) Modeled detritus inflow point sources and b) chlorophyll levels during a flooding period.

Water Resources Management and Modeling

Edited by Dr. Purna Nayak

ISBN 978-953-51-0246-5

Hard cover, 310 pages

Publisher InTech

Published online 21, March, 2012

Published in print edition March, 2012

Hydrology is the science that deals with the processes governing the depletion and replenishment of water resources of the earth's land areas. The purpose of this book is to put together recent developments on hydrology and water resources engineering. First section covers surface water modeling and second section deals with groundwater modeling. The aim of this book is to focus attention on the management of surface water and groundwater resources. Meeting the challenges and the impact of climate change on water resources is also discussed in the book. Most chapters give insights into the interpretation of field information, development of models, the use of computational models based on analytical and numerical techniques, assessment of model performance and the use of these models for predictive purposes. It is written for the practicing professionals and students, mathematical modelers, hydrogeologists and water resources specialists.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Oscar Delgado-González, Fernando Marván-Gargollo, Adán Mejía-Trejo and Eduardo Gil-Silva (2012). San Quintin Lagoon Hydrodynamics Case Study, Water Resources Management and Modeling, Dr. Purna Nayak (Ed.), ISBN: 978-953-51-0246-5, InTech, Available from: <http://www.intechopen.com/books/water-resources-management-and-modeling/san-quintin-lagoon-hydrodynamics-case-study>

INTECH
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.