

Where does the marine litter come from?

Study on potential land-based sources in Santos, Brazil.



COMBATE ÀS FONTES DE
POLUIÇÃO MARINHA POR
RESÍDUOS SÓLIDOS

CONCEPT AND COORDINATION

Brazilian Association of Public Cleansing and Waste Management Companies (ABRELPE)/(secretaria@abrelpe.org.br).

ABRELPE is a non-profit organization that gathers and represents companies that operate in the urban cleansing services and management of municipal solid waste. Its mission is based on the principles of environmental preservation and sustainable development and its main objective is to promote technical and operational development of the solid waste sector in Brazil.

In an international context, ABRELPE is the representative in Brazil of the ISWA – International Solid Waste Association, the main global entity dedicated to the solid waste matters; it's also the head office of the Regional IPLA Office for South America (International Partnership for the development of waste management services together with local authorities), a well-known program supported by the UN through the UNCRD – United Nations Centre for Regional Development. Moreover, ABRELPE is part of the Municipal Solid Waste Initiative of the CCAC (Climate and Clean Air Coalition), an international partnership for the environment agenda that operates on several fronts to reduce short-lived climate pollutants and fight climate change.

AUTHOR

EcoFaxina Institute - Cleaning, Monitoring and Environmental Education, is a civil non-profit association founded in 2008 in the city of Santos to fight marine pollution in Santos and São Vicente estuary through the elaboration of projects and promotion of public policies for the reduction of plastic waste in the ocean. The main strategy is the recovery of degraded mangrove areas and the reduction of floating solid waste in the estuarine system due to irregular dwellings dumping. To this end, voluntary de-pollution activities are developed in order to warn society about the critical situation of marine pollution and deforestation of mangroves in the estuary. At the same time, volunteers remove as much waste as possible from the coastal ecosystems, especially plastic. The activities are also a tool for research and environmental awareness, which provide a new perspective of the problem for those who participate. So far, EcoFaxina has carried out 97 voluntary activities, involving 2,263 volunteers in the collection of more than 52 tons of solid waste from marine environment.



Figure 1. EcoFaxina Institute volunteers at the end of a waste collection activity. Photo: William R. Schepis.

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The study presents three main groups of land-based sources of marine pollution by solid waste: subnormal dwellings, called stilt houses, located on the riverside of Santos and São Vicente estuary; drainage canals, which cross the more densely urbanized areas of the insular area of the municipality and end up at the beachfront; and the beachfront itself, which, besides the impact caused by the two previous group just mentioned here, is also an area where visitors dispose their waste irregularly. Each solid waste leakage hotspot will be described, as per its environmental characteristics, uses, anthropic occupation and aspects that evidence the impacts of its solid waste pollution in the marine environment.

The **evidence** used to establish these three solid waste leakage hotspots is of **empirical origin** (by photographic record by EcoFaxina Institute with over a decade experience in environmental monitoring and development of voluntary actions in the estuary, partner of the present study) and also **scientific reference** (through hydrodynamic modeling and academic and scientific experience of the professionals involved in the study).

Once the characterizations have been completed, the study concludes with a brief debate on the exposed elements and highlights the need to expand the dialogue between the actions to fight the marine litter subject and key stakeholders to potential solutions.



Figure 2. Intervention carried out by EcoFaxina Institute volunteers in Ponta da Praia using waste collected in the mangrove. Photo: William R. Schepis.

2. LAND-BASED SOURCES OF MARINE POLLUTION

2.1 STILT HOUSES COMMUNITIES

Santos and São Vicente Estuary System (SESS) is located in the Metropolitan Region of Baixada Santista (RMBS), a central portion of the coast of São Paulo state and is influenced by multiple anthropic polluting activities that change its ecological processes. In the 1960s and 1970s, the expansion of the Port of Santos and the Industrial Pole of Cubatão, as well as the increase of tourism in São Paulo's coastal regions, generated an increasing demand for labor, resulting in large migratory flows to the RMBS. Therefore, areas of mangrove and hillside slopes have become places of construction and illegal housing (AFONSO, 2005).



Figure 3. Insular portion of the municipality of Santos (in red) and Permanent Preservation Areas occupied by stilt houses communities (in yellow).

The stilt houses communities represent one of the most concerning issues from the environmental point of view in the region. In Santos, besides destroying the last remaining mangrove areas of its insular portion, they are characterized as one of the main sources of pollution of the estuarine system, due to the illegal disposal of solid waste and sanitary effluents occurring daily in large quantities in the ecosystem.

ECOLOGICAL CHARACTERIZATION

The largest mangrove systems of the RMBS are located in the SESS, on the Itapanhaú River, on the Bertioga Canal and on the Itanhaém river mouth. This ecosystem has been gradually degraded by industrial pollution activities and by the expansion of urban areas, as well as extensive irregular occupations and landings, responsible for the disruption of its function.

Mangrove is defined as a transitional coastal ecosystem between land and marine environments, characteristic of tropical and subtropical regions, susceptible to the tidal regime (SCHAEFFER-NOVELLI, 1995). They typically occur in association with other coastal ecosystems, such as coral reefs, marine algae, mud plains, and sand plains. While mangroves can persist in isolation, their association with other ecosystems reinforces important ecological functions, such as the provision of fish resources and biodiversity balance. Mangroves are linked to adjacent ecosystems through physical, biochemical and biological interactions, which facilitate the presence and maintenance of these associated systems.



Figure 4. Mangrove of Santos and São Vicente estuary. Photo: Tadeu Sampaio.

The position of the mangroves at the boundary between land and sea means that they play an important role in capturing terrestrial sediments. Complex root structures are physical and biological filter and reduce the flow of harmful nutrients and sediments to beds of seaweed, rocky shores, and adjacent coral reefs. This filtering also reduces the turbidity of coastal water, allowing algae and corals to receive the amount of light needed.

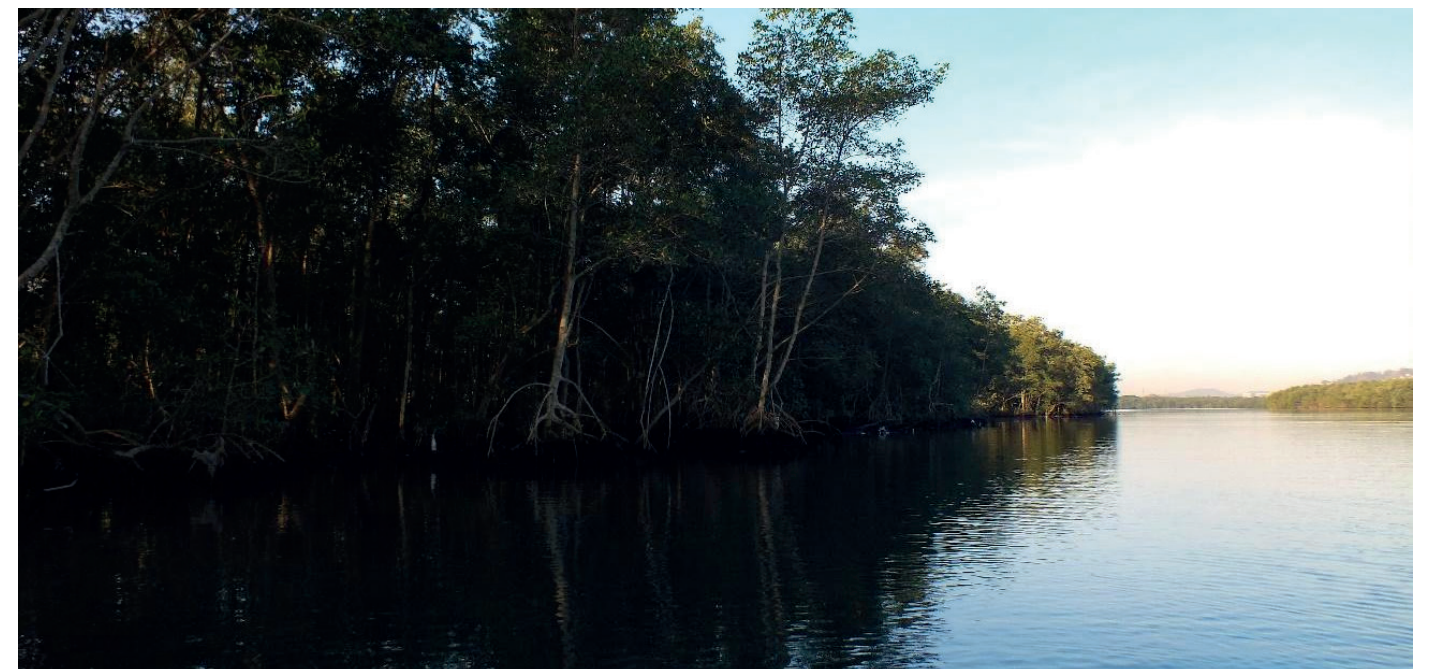


Figure 5. Mangrove of Santos and São Vicente estuary. Photo: William R. Schepis.

In terms of productivity, mangroves are among the most productive ecosystems in the world and have a high potential for storage and export of carbon, which can flow to adjacent systems with tidal currents. This carbon also indirectly enters the food chain of migratory species during high tide, when they feed on organisms associated with the mangroves. These, in turn, can increase the growth and production of a variety of species living in nearby ecosystems.

The occurrence of multiple ecosystems also affects species diversity, with species numbers being larger where mangroves are adjacent to other ecosystems, such as coral reefs. Mangroves can also improve coral resilience, providing a natural refuge from heat stress induced by climate change and ocean acidification.

In the local context, it is possible to list several socioenvironmental benefits derived from ecosystem services provided by the mangrove in Santos estuary. It traps sediments brought by rivers and drainage canals, delaying the silting of navigable canals and reducing dredging expenses. It provides naturally floodable areas that contribute to the macro-drainage of the Northwest Zone and to the reduction of floods, mainly during syzygy¹ tide. They act as a biological filter, purifying thousands of liters of sewage released in the estuarine system and improving water quality. It houses rich biodiversity with many species of commercial value, playing an important role in maintaining fish stocks, increasing productivity and providing food security for thousands of people. The rich biodiversity combined with its natural beauties make the mangrove a touristic attraction with a great potential to be explored.



Figure 6. Fisherman in Santos and São Vicente estuary. Photo: William R. Schepis

8 1 - Period of full or new moon, when the moon and sun are aligned and its gravitational effects add up, producing the highest tides and the lowest tides, called tides of syzygy.

SOLID WASTE

Stilt houses communities occupy a transitional ecosystem between land and sea and remain surrounded by water most of the time, so can also be considered an aquatic source of marine pollution by solid waste.

The solid waste disposed in the mangrove by inhabitants of the stilt houses has equal quantities and characteristics to the municipal solid waste disposed in the urbanized areas of the city. However, it is possible to identify some waste related to the social conditions in these places, such as milk plastic packaging of “Vivaleite” Program, distributed to low-income families by the Government of the State of São Paulo; it is also normally found condoms, contraceptive pill packs and vaginal applicators, distributed by Community Health Agents of the Municipality of Santos in public health posts. Another waste characteristic of the stilt houses communities is wood, used in the construction of the stilt houses, which must be replaced every six months.



Figure 7. Volunteer collecting waste in the mangrove sediment. Photo: William R. Schepis.



Figure 8. Volunteer shows contraceptive pill pack found in the mangrove. Photo: William R. Schepis.



Figure 9. Secretary of Environment of Santos, Marcos Liborio, and EcoFaxina volunteers after a cleanup activity. Photo: William R. Schepis.



Figure 10. Perimeter occupied by stilt houses in Vila Gilda dike.

- **Microregion:**
Northwest Zone of Santos
- **Adjacent neighborhoods:**
Jardim Castelo, Rádio Clube and Bom Retiro
- **Geographic coordinates:**
23°56'30.87"S - 46°23'10.54"W
- **Area:**
24 ha

Table 1. Resident population of stilt houses in Vila Gilda dike.

Neighborhood divisions	Stilt houses	Population	Men	Women	Average
Caminho da Capela	589	1,972	909	1,063	3,4
Caminho São José	1,082	3,770	1,767	2,003	3,5
Caminho São Sebastião	1,264	4,434	2,116	2,318	3,5
Vila Telma	251	973	490	483	3,9
Mangue Seco	165	580	280	300	3,5
Butantã	167	577	280	297	3,5
Total	3,518	12,306	5,842	6,464	3,5

Source: IBGE Census 2010.

Considered the largest stilt houses community in Brazil, this subnormal agglomerate² is located in the northwest region of the island, on a Permanent Preservation Area on the riverside of the Bugres River, which is part of the border with the municipality of São Vicente in 2.7 linear kilometers.

2 - A set of at least 51 houses lacking mostly essential public services, occupying the land owned by others (public or private) and are generally arranged in a disorderly and dense manner (IBGE, 2011).



Figure 11. Aerial view of part of the stilt houses at Vila Gilda dike. Photo: Tadeu Sampaio.

Until the 1950s, the Bugres River was surrounded by an extensive area of mangroves, one of the last remnants of the island, which has been suppressed throughout the time of its occupation. From the 1950s, the first interventions took place in the neighborhoods Rádio Clube and Jardim Castelo, with the construction of a dike and drainage canals throughout its extension by the former National Department of Sanitation Works (DNOS). A large part of the mangrove that covered the entire river basin was suppressed, making it possible to install the first irregular occupations in the 1960s. Much of the mangrove was landed, remaining only 50 meters from the riverside, which was occupied by stilt houses.



Figure 12. Stilt houses among solid waste and sewage in the Vila Gilda dike. Photo: William R. Schepis.



Figure 13. Perimeter occupied by stilt houses in Jardim São Manoel.

- **Microregion:**
Northwest Zone of Santos
- **Adjacent neighborhoods:**
Jardim São Manoel
- **Geographic coordinates:**
23°55'55.97"S - 46°22'51.78"W
- **Area:**
11.6 ha

Table 2 – Resident population of stilt houses in Jardim São Manoel.

Neighborhood divisions	Stilt houses	Population	Men	Women	Average
Caminho da União	479	1,876	960	916	3.9
João Carlos da Silva	354	1,239	604	635	3.5
Total	833	3,115	1,564	1,551	3.7

Source: IBGE Census 2010.



Figure 14. Mangrove fragment near stilt houses community of Jardim São Manoel is one of the areas with the greatest accumulation of solid waste in the estuary. Photo: Ricardo Teles.



Figure 15. Volunteers of EcoFaxina Institute prepare for the waste collection in a mangrove area near the stilt houses community of Jardim São Manoel. Photo: William R. Schepis.



Figure 16. Perimeter occupied by stilt houses in Vila Alemao.

Table 3 – Resident population of stilt houses in Vila Alemao.

Neighborhood division	Stilt houses	Population	Men	Women	Average
Vila Alemao	858	2,896	1,427	1,469	3.4

Source: IBGE Census 2010.

- **Microregion:**
Northwest Zone of Santos
- **Adjacent neighborhoods:**
Chico de Paula
- **Geographic coordinates:**
23°55'55.97"S - 46°22'51.78"W
- **Area:**
8.91 ha

Vila Alemao occupies both public and private areas and is in the process of land regularization of some of the houses in areas already consolidated. However, there are still hundreds of stilt houses occupying the local mangrove.



Figure 17. Port and stilt houses community sharing space around mangrove areas. Photo: William R. Schepis.



Figure 18. Perimeter occupied by stilt houses in Vila dos Criadores.

Table 4 - Resident population of stilt houses in Vila dos Criadores.

Neighborhood division	Stilt houses	Population	Men	Women	Average
Criadores Village	281	1,029	545	484	3.7

Source: IBGE Census 2010.

- **Microregion:**
Northwest Zone of Santos
- **Adjacent neighborhoods:**
Almoa and Piratininga
- **Geographic coordinates:**
23°55'19.55 "S - 46°23'36.27" W
- **Area:**
15.4 ha

Occupation in the same area of the old municipal landfill. In the place, there is partial water network, electricity, street lighting and telephone lines. There is no sewage network and urban equipment. In the surroundings, there are several cargo terminals of the Port of Santos.

2.2 DRAINAGE CANALS

Santos canals were built to improve sanitation and end the epidemics that affected the municipality. Currently, the canals mainly drain rainwater, but also receive sanitary effluents through clandestine connections in the rainwater drainage system.



Figure 19. Drainage canals in the insular portion of Santos.

HISTORICAL CONTEXT

Between 1890 and 1904, 22,588 people died in Santos, representing more than half the population of that time (about 45,000 inhabitants), due to epidemic diseases such as yellow fever, typhoid, malaria, smallpox and bubonic plague.

The crews from the ships did not want to disembark and preferred to stay off fearing of contracting diseases. The port was about to be closed. The lack of sanitation granted Santos the stigma of “Cursed Port”, which harmed the growth of the city.

In 1905, after many years of controversy, the government decided to implement the new sewage network, and Saturnino de Brito, whose mission was to start the construction of nine drainage canals in the city, developed the project. In 1910, canals 1 and 2 were ready, replacing old rivers and streams that were flooded with rain or tides.

With the installation of sewage networks and rainwater, the outbreaks that caused several diseases in Santos at the end of the nineteenth and beginning of the twentieth century were extinguished, and in 1968, the municipality had 15 canals, according to the following list:

- Canal 01 (1907) - Pinheiro Machado Avenue
- Canal 02 (1910) - Bernardino de Campos Avenue
- Canal 03 (1923) - Washington Luís Avenue
- Canal 04 (1911) - Siqueira Campos Avenue
- Canal 05 (1927) - Almirante Cochrane Avenue
- Canal 06 (1917) - Joaquim Montenegro Avenue
- Canal 07 (1911) - Francisco Manoel Avenue (next to Santa Casa)
- Canal 08 (1912) - Moura Ribeiro Avenue
- Canal 09 (1911) - Barão de Penedo Avenue
- Canal 10 (1968) - Gal. San Martin Avenue (known as Canal 7)
- Canal 11 (1968) - Continuation of Afonso Pena Avenue
- Canal 12 (1968) - Rádio Clube - Hugo Maia Avenue

- Canal 13 (1968) - Santa Maria - Alberto de Carvalho Avenue and Roberto de Molina Cintra Avenue
- Canal 14 (1968) - São Jorge - Eleonor Roosevelt Avenue
- Canal 15 (1968) - Jovino de Melo Avenue

2.2.1 BEACHFRONT CANALS

Throughout Santos beachfront, there are seven drainage canals that flow into the beaches, and in six of them there are flow-holding floodgates located on the beaches. These floodgates usually remain closed and the contents are directed to the Sewage Preconditioning Facility and from there, it is sent to the sea via an underwater emissary along with domestic sewage effluents.

The purpose of the facility is to remove solid and floating materials. After the removal, it receives certain amount of chlorine to eliminate bacteria. The process involves three steps: grating for the removal of coarse and fine solids; sandboxes for removal of fine solids; and chlorination for disinfection.

In periods of higher rainfall, the facility presents reduced capacity, therefore, the floodgates are opened, and the rainwater contained in the canals is released directly into the sea (AMBROZEVICIUS, 2011). During these periods, the waste of the canals, as well as the waste carried by rains, reach the sea and contribute to the pollution of the beaches.

Santos has annual average rainfall between 2000 and 3000 mm, concentrated in the spring-summer period and caused mainly by the cold fronts and high temperatures, with great influence from Serra do Mar mountain chain, a natural barrier.

SOLID WASTE

Solid waste arrives at the canals through rainwater galleries by winds and direct disposal by the population. In the canals, it is possible to find different types of waste, from diapers to televisions. However, the most commonly found wastes are PET bottles, plastic bags, styrofoam, disposable cups and aluminum cans.



Figure 20. Solid waste found on Canal 4. Photos: William R. Schepis.



Figure 21. Solid waste found on Canal 4, between Boqueirão and Embaré neighborhoods. Photos: William R. Schepis.



2.3 BEACHES



Figure 22. Santos beachfront.

The beachfront is part of the coastal zone, delimited by the interface between the mainland and the sea (MMA, 2006). The boundary defined for marine zones is 10 m deep, while in the land zone it is 50 m in urban areas or 200 m in non-urbanized areas, delimited from the high tide line in the direction of the continent (MMA, 2006).

The types of beachfront are evaluated based on two criteria: (1) vulnerability to natural and anthropic processes, such as shape of the beachfront, its position and physical characteristics; (2) occupation level and type at each site, as well as population density at the beachfront (MMA, 2006).

The characterization of Santos beachfront, conducted in the present study, was performed according to the criteria established by the Ministry of the Environment in the Beachfront Project, with general directives of national scope guiding the use and occupation in the coastal zone.

ECOLOGICAL CHARACTERIZATION

The beach is subdivided in seven portions by six drainage canals, coming out of the city and perpendicularly crossing the beach. The seven sectors of the beach, from west to east are José Menino, Pompéia, Gonzaga, Boqueirão, Embaré, Aparecida and Ponta da Praia.

According to the Beachfront Project (MMA, 2006), the beachfront is classified as Class C, with landscapes predominantly anthropized, standing out the urban pattern of occupation, with a medium to high population density, multiplicity of uses and great potential for sanitary and aesthetics pollution.

The beaches of Santos have characteristics of semi-sheltered beachfront. They are presented as low concavity coves and stretches more susceptible to the actions of waves, and beaches more protected due to refraction processes (alteration in the speed of the waves) and diffraction. The diffraction consists of the radial scattering of wave energy due to the interaction with natural obstacles (islands) or civil works (breakwaters) (SOARES et al., 2015).

At high tide, there are currents toward the open sea in the middle portion of the bay; in low tide, there are forcing anticlockwise movements in the region, such as the background geomorphology and the horizontal pressure variations caused by the fluvial discharges of the canals, as well as the tides and the synoptic winds (PONÇANO & FÚLFARO, 1976).



Figure 23. Marine Biology students of Santa Cecília University (UNISANTA) performing analysis of floating solid waste disposed by the sea in Ponta da Praia. Photo: Tadeu Sampaio.

The beaches receive waves from the South, and José Menino beach is the most exposed to them, which loose intensity towards Ponta da Praia beach. However, this one has undergone significant changes after the urbanization of the municipality and the construction of the port, resulting in a process of intensified erosion (ITALIANI, 2014). In order to minimize this process and the increasingly recurrent heavy storms, a pilot project is being carried out for the insertion of barrier of geotextile bags containing sand to minimize erosion and damage caused by extreme storms (SANTOS MUNICIPALITY, 2018).

Winds are predominant east-northeast throughout the year (CASTRO et al., 2006). The frontal systems (cold fronts) are characterized as being the most important synoptic disturbance (CASTRO et al., 2006).

URBAN CHARACTERIZATION

The layout of the beachfront is linear and continuous, and has eight kilometers of extension; it is formed by the following landscape figures: “sea + linear beach + canals + emissary + port”.



Figure 24. Panoramic view of Santos beachfront. Photo: Diego Silvestre.

The urban spatial distribution is continuous, similarly to a corridor. The urban network defines how the occupation is divided and structured, having several uses: housing, commercial and services, with predominance of normal urban network buildings type. In the region near Ponta da Praia, also includes the category of urban port network due to the presence of the Port of Santos canal.

The urbanization is vertical, with predominance of more than nine floors buildings and new constructions that surpass 30 floors.

The access to the beaches are mainly by avenues and sidewalks.

Regarding the landscape diagnosis, the characterization of the beachfront is made based on the observation of morphology elements and of physical attributes: absence of native vegetation, but presence of gardens along its border; presence of drainage canals; presence of urban network; port canal that connects the region of Santos Bay to port, where loading and unloading terminals are located; and presence of stilt houses communities on the opposite side of the canal, located in the municipality of Guarujá.

The landscape configuration of the urbanization varies between the type of common urban beachfront and neighborhood-garden border, being large spaces occupied by gardens, grassy sidewalks, tree-lined avenues and buildings following minimum setbacks required by current urban legislation.

FLOATING POPULATION

The floating population is the difference between permanent and temporary residents, which in turn use means of accommodation, food, goods and equipment, infrastructure, services and commerce available primarily for the permanent resident population (AGEM, 2017).

In the case of Santos, it is observed that the floating population corresponds to 56.5% of the permanent resident population in the Metropolitan region (AGEM, 2017).

It is important to point out that during high season, which lasts from December to March, the increase in the number of beach users is not restricted to the increase of the floating population, being influenced mainly by the permanent resident population. Therefore, the environmental impacts resulting from this increase of visitors cannot be attributed only to tourists.

SOLID WASTE

The solid waste found on the beaches of Santos comes mainly from three sources: stilt houses communities, beach goers and drainage canals.



Figure 26. Floating solid waste disposed by the sea on Boqueirão beach. Photos: William R. Schepis.



3. DISCUSSION ON THE EVIDENCES AND INITIAL CONCLUSIONS

Tons of solid waste reach protected bays in the Dominican Republic, Indonesia, Polynesia, Hawaii and also in the beachfront in Santos, where about 50 tons of solid waste are collected daily (SANTOS MUNICIPALITY). In the Dominican Republic, plastic bottles, bags, styrofoam and other waste that are clogging the beach of Montesinos come from Ozama River, where thousands of people living in informal settlements on the riverside of the river dispose up to 90,000 tons of waste per year (THE NEW YORK TIMES, 2018).

In syzygy conditions, there is a great contrast of intensity of the currents between the São Vicente canal and the Santos canal; in the floods³ (and ebb⁴), there is convergence (and divergence) of the currents in Bertioga and São Vicente canals and currents in a single direction in Santos Port canal. In syzygy, the currents show anticlockwise rotation along the tide cycle. During the quadrature⁵, the surface currents do not have a definite direction of rotation; and in the ebb of the shallow areas, the currents in Bertioga, São Vicente and Santos canals are in a one-way sense (RIBEIRO et al., 2015).



Figure 29. The floating solid waste disposed in the mangrove by stilt houses communities is transported to the sea by tidal currents. Photo: William R. Schepis.

Another land source pollutants are the drainage canals, which contribute with part of the marine pollution on rainy days, when their flow is carried out directly to the beachfront. However, the waste that reach the sea by the canals does not exceed the surf zone, where tidal variation and wave action rapidly transport them to the sand strip and can be mistaken for waste from stilt houses communities because of their household characteristics. It should be noted that some canals do not have floodgates, so the rainwater is released directly into the sea (figure 30).

3 - Period between a low tide and high tide when tide height increases.
4 - Period between high tide and low tide when tide height decreases.
5 - Period of first or last quarter of moon, when the moon and sun are misaligned, and their gravitational effects decrease, producing the smallest tidal amplitudes, called quadrature tides.



Figure 30. Main land sources of marine pollution by solid waste and the influence on their dispersion by tidal currents.

A study conducted by researchers at the Oceanographic Institute of the University of São Paulo (IO-USP) pointed out that the Santos estuary, indirectly contaminating its beaches, is also spreading contaminated material to beaches on the north coast. According to the survey, heavy metals were found in the area, a result of the combination of industrial pole activities and waste disposal in the mangrove areas that flow towards the Santos basin. According to the director of IO-USP, Ana Maria Vaninas, the currents of the region transport the waste. “The materials are transported to the south of São Sebastião, where they are disposed in a strip of hundred meters deep”, says Vanina. According to the research, the disposal causes impacts on the biological processes and on the region ecosystems (JORNAL METRO, 2010).

An emblematic case that brought evidence of the exit of floating solid waste from the bay of Santos and its dispersion along the coast of São Paulo was the accident occurred with the ship Log In Pantanal, on August 11, 2017, when 45 containers fell in the Santos Bay and had products scattered

throughout, reaching several beaches in Guarujá, Santos and São Vicente. On August 19, Peruíbe Municipality located products on Juréia-Itatins beaches. On August 24, thirteen days after the accident, Chico Mendes Institute inspectors found products in the Alcatrazes archipelago, which is 35 kilometers off the coast of São Sebastião. On September 17, 2018, more than a year after the accident, Christmas balls were found on Toque-Toque Grande beach in São Sebastião. In total, about 5 thousand Christmas balls have already been found and collected from the beaches of São Sebastião, Ilhabela, Caraguatatuba and Ubatuba municipalities (G1, 2018).



Figure 31. Beach of São Sebastião after an accident in Santos. Photo: Antônio Marcos da Silva/Vanguarda Repórter.



Figure 32. Products scattered along beaches and rocky shores of Guarujá. Photos: G1.

HYDRODYNAMIC MODELING

In order to corroborate the field observations and previous research data, a hydrodynamic modeling of the estuary in a scenario of syzygy was made by the Hydrodynamic Research Center of the Santa Cecília University (NPH/UNISANTA). The obtained data show how the tidal currents act in the dispersion of the solid waste in the estuarine system.

The movements were estimated from numerical hydrodynamic model results based on “Princeton Ocean Model - POM ”(BLUMBERG; MELLOR, 1987). The POM is a non-linear three-dimensional model with the complete hydrodynamic equations (for sea level, currents, temperature, salinity and density), which solutions are obtained in a sigma coordinate system (accompanying the submarine relief), considering the separation of modes and second order turbulent closure (MELLOR, 1998).

In the high tide and low tide chart for August 28, 2018, it is possible to see that the first high tide was at 3:08 a.m. and the next high tide at 15:34 p.m. The first low tide was at 9:43 a.m. and the next low tide was at 21:29 a.m.

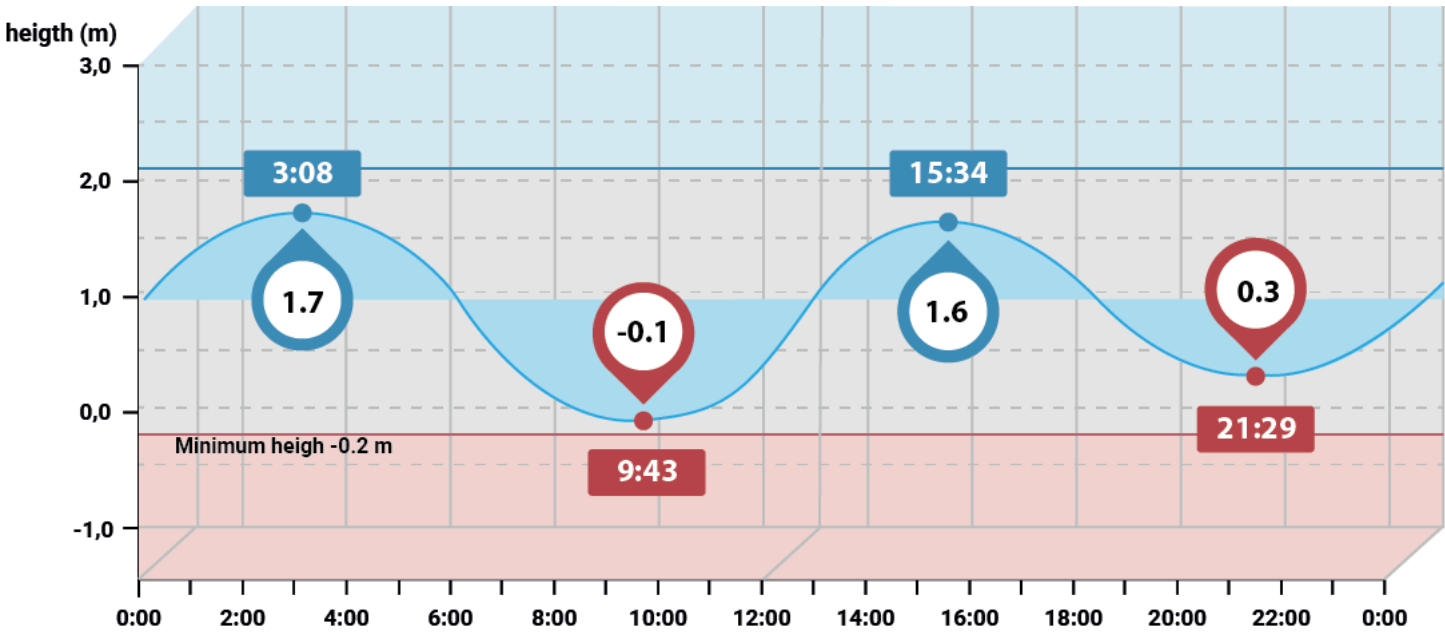


Figure 33. Tidal coefficient on August 28. Adapted from tabuademares.com.br.

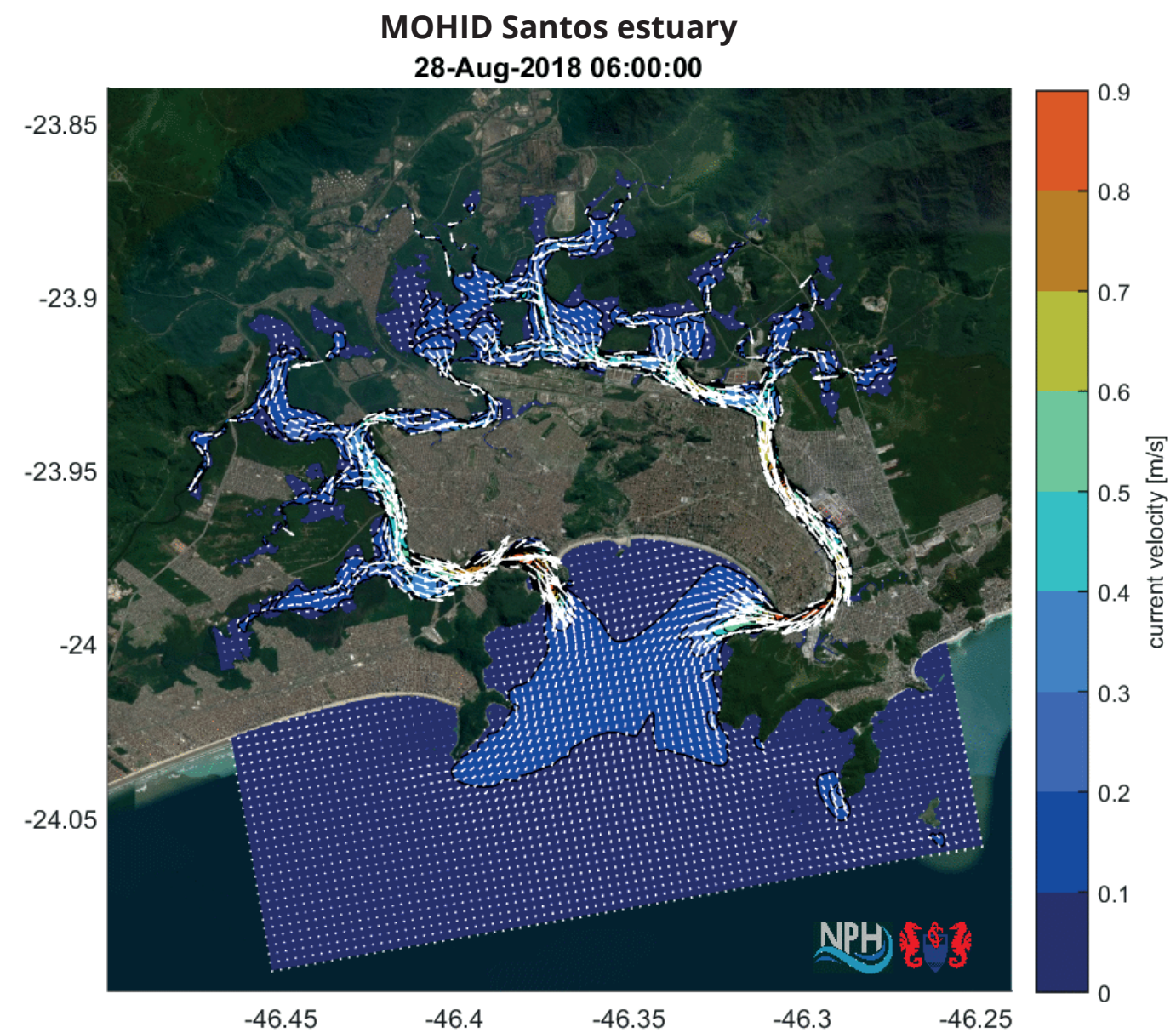
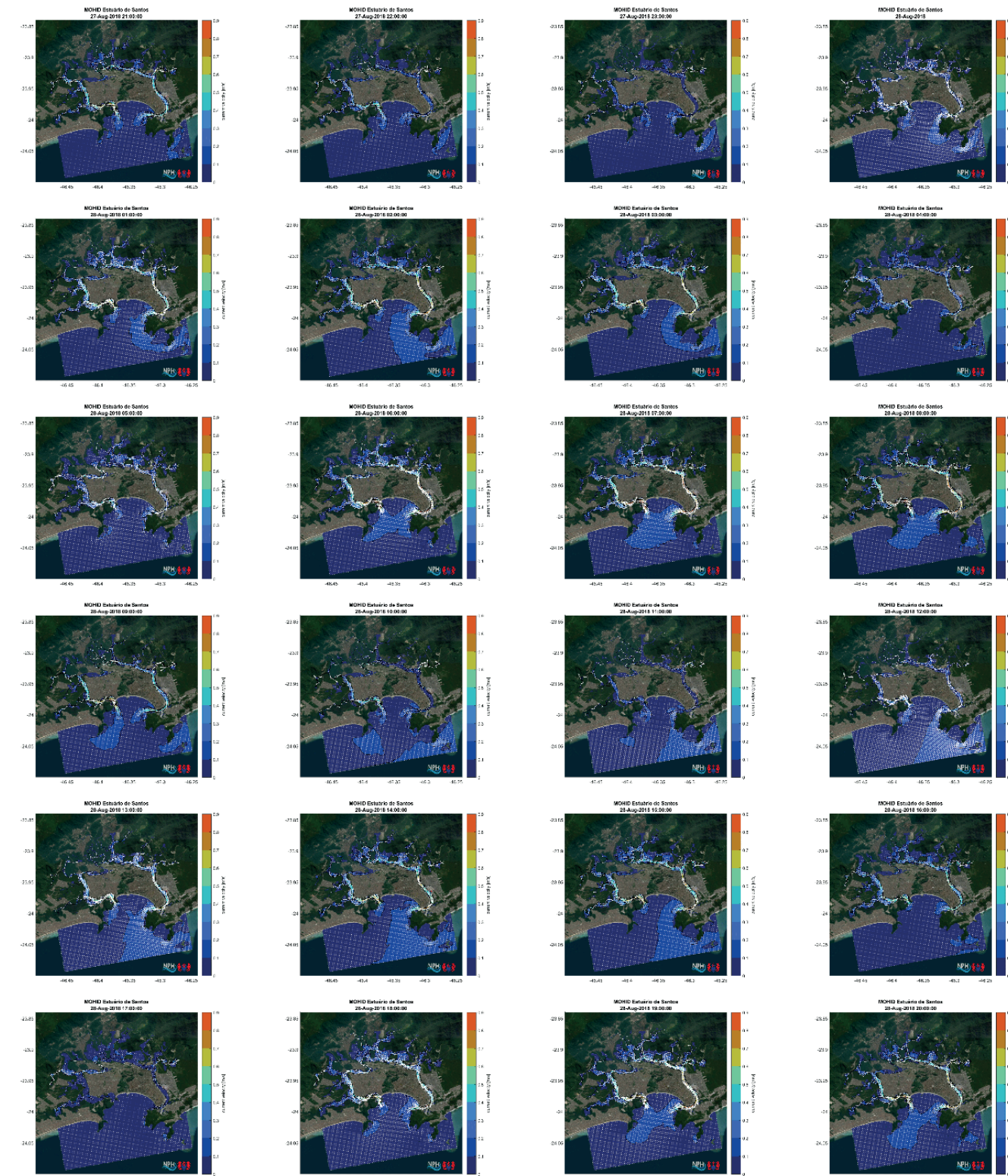


Figure 59. Hydrodynamic Modeling at 6 o'clock on 08/28/2018, in a moment of intense syzygy ebb in the SESS. Source: NPH-UNISANTA.

Figures 34-58. The sequence of hydrodynamic modeling images in syzygy scenarios shows the direction and velocity of the flooding and ebb surface currents (m/s) in the canals of the SESS, with a high contrast of intensities between the streams of the São Vicente and Santos canals during ebb tide, when the most intense surface currents present 20.2 crn/s in the coastal area and 74.3 crn/s in the shallow areas (estuarine canals). Frames hourly in the period from 27/08-21h00 to 28/08-20h00. Source: NPH-UNISANTA.

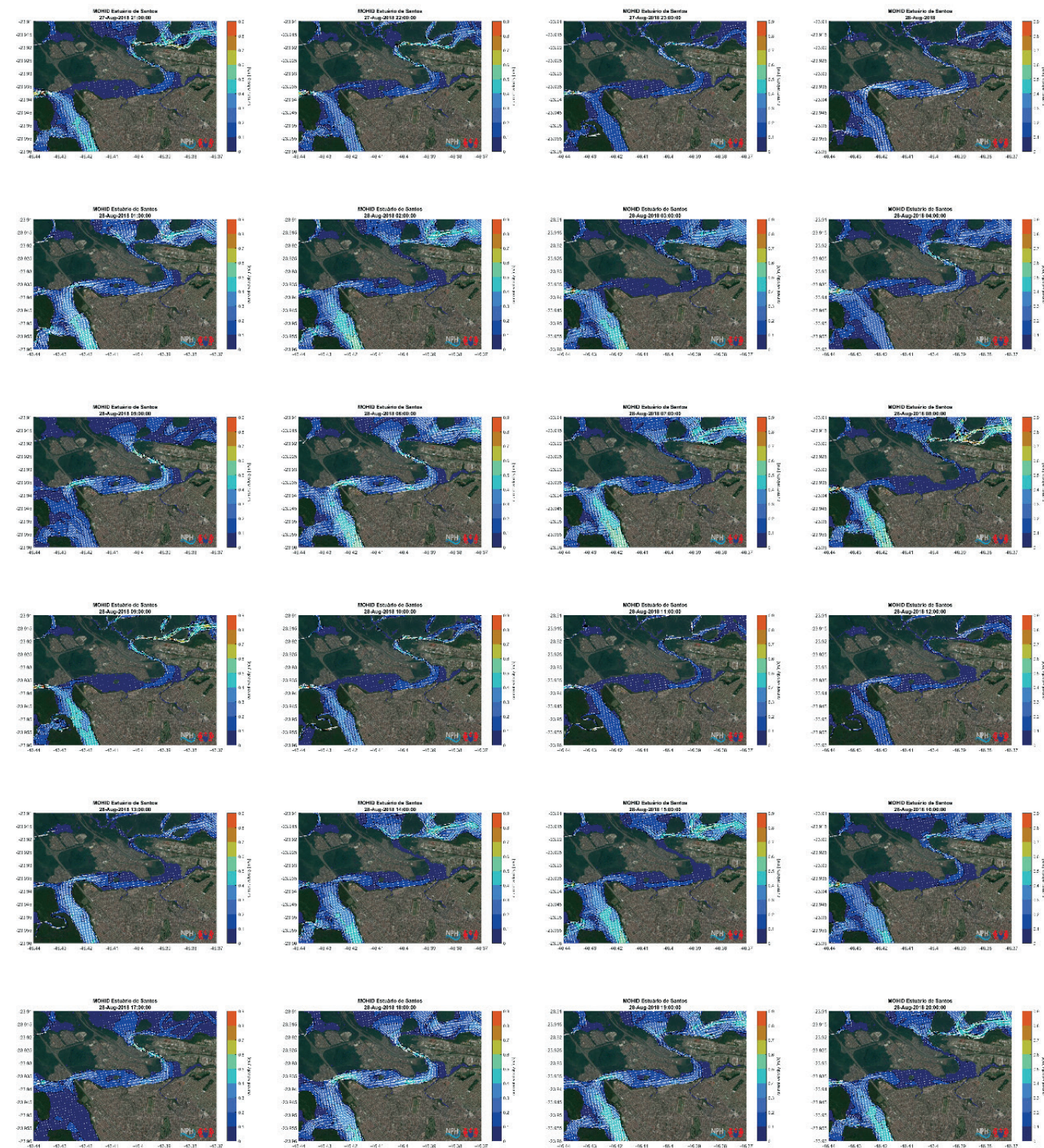


Figure 60 to 83. Hydrodynamic modeling in the region of the estuary where the stilt houses communities are located. Frames hourly in the period from 27/08-21h00 to 28/08-20h00. Source: NPH-UNISANTA.

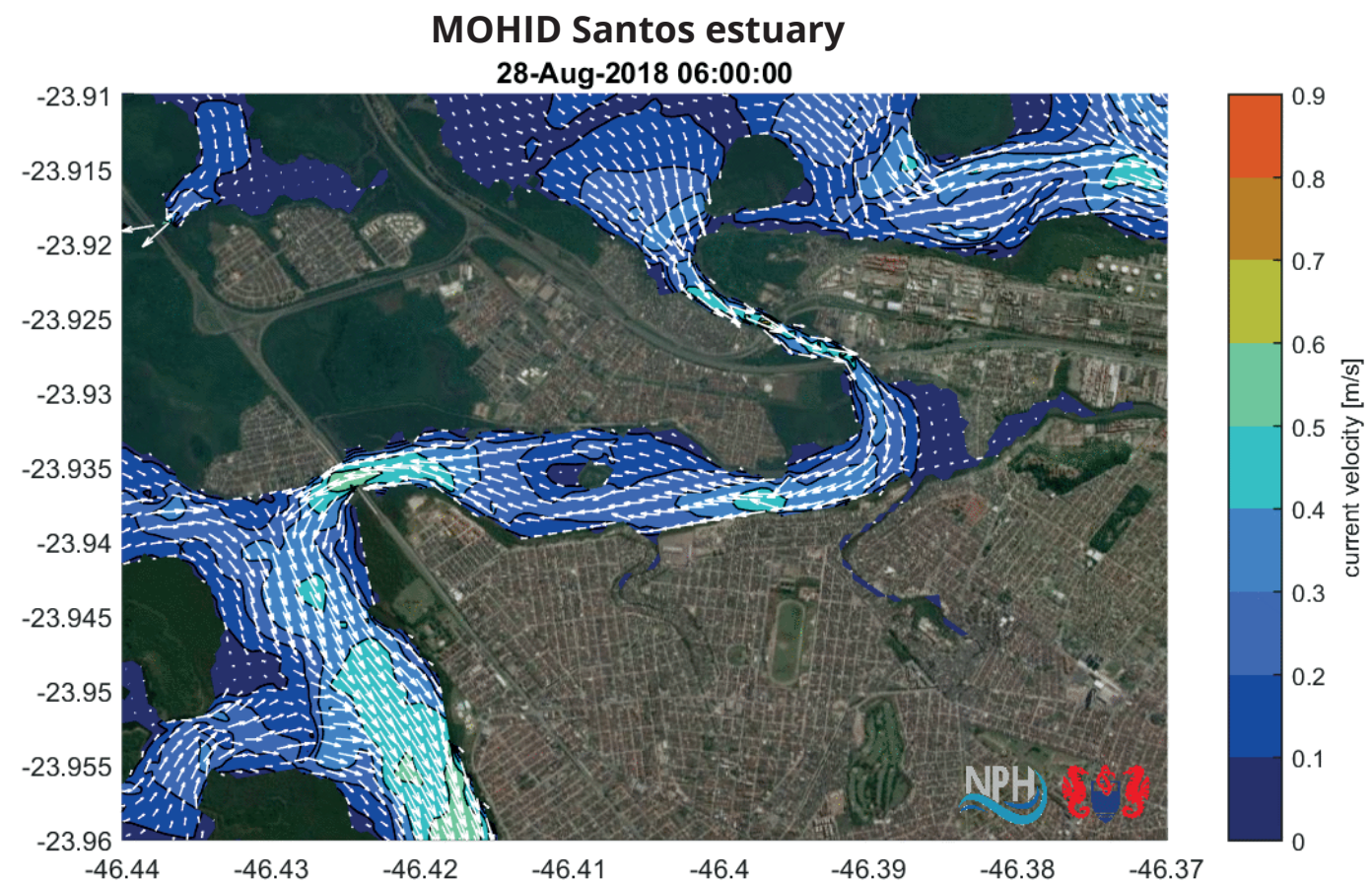


Figure 84. Hydrodynamic modeling of the region where the stilt houses communities are located at 6 o'clock on 08/28/2018, moment of intense syzygy ebb in SESS. During the ebb, the waste disposed in the mangrove is transported by the surface currents to São Vicente canal. Source: NPH-UNISANTA.

Based on the above considerations, the data presented in this report confirm the hypothesis raised in the previous report that there is a solid waste leakage to the marine environment from areas with failures in the coverage of collection services. These, in turn, as demonstrated by hydrodynamic modeling, are subject to the tide regime, which act in the dispersion and transport of solid waste in that environment.

Therefore, with the recognition of the main land-based sources of marine pollution by solid waste in the municipality of Santos and the elements that interfere in its dispersion in the marine environment, the project will now focus on identifying what leaks: types of materials inadequately disposed that move around the island; georeferenced orthographic mapping of stilt houses communities and image records (with drone aid to identify areas of disposal); number of stilt houses; updated population estimate of each community; and amount of waste disposed daily in the estuary. This survey will be carried out along the beachfront and on the remaining mangrove of the island, which will allow to obtain more information and point out mitigating actions for the Action Plan to be developed in sequence.

4. REFERENCES

AFONSO, C.M. Transformação ambiental e paisagística na Baixada Santista, SP. Paisagem Ambiente: ensaios (20): 85-130p. São Paulo, 2005.

AGEM. Plano Regional de Gestão Integrada de Resíduos Sólidos da Baixada Santista. Etapa 2 – Panorama dos Resíduos Sólidos na RMBS (versão para oficinas microrregionais). Agência Metropolitana da Baixada Santista. Região Metropolitana da Baixada Santista, São Paulo, 48p. 2017.

ALLSOPP, M.; WALTERS, A.; SANTILLO, D. & JOHNSTONE, P. Plastic Debris in the World's Oceans. 43p., Greenpeace, Amsterdam, Netherlands, 2006.

AMBROZEVICIUS, A.P. Poluição aquática em Santos (SP): Uma abordagem interdisciplinar. Dissertação de Mestrado. Interunidades em Ciência Ambiental. Universidade de São Paulo, São Paulo, 123p., 2010.

BLUMBERG, A.F. & MELLOR, G.L. A description of a three-dimensional coastal ocean circulation model, Three-Dimensional Coastal Ocean Models, N. Heaps (ed), Am. Geoph. Union, 208p., 1987.

CASTRO, B.M.; LORENZZETTI, J.A.; SILVEIRA, I.C.A. & MIRANDA, L.B. Estrutura termohalina e circulação na região entre o Cabo de São Tomé (RJ) e o Chuí (RS). In: ROSSI-WONGTSCHOWSKI, C. L. B., MADUREIRA, L. S-P. (Eds.). O ambiente oceanográfico da plataforma continental e do talude na região sudeste-sul do Brasil. 1. ed. São Paulo: EDUSP, 2006.

COHAB-ST. Projeto Integrado de Urbanização do Dique Vila Gilda, Companhia de Habitação da Baixada Santista, 2007.

DIÁRIO DO LITORAL. Santos é a cidade mais verticalizada do Brasil, aponta pesquisa. Diário do Litoral, 2018. Available in <http://www.diariodolitoral.com.br/cotidiano/santos-e-a-cidade-mais-verticalizada-do-brasil-aponta-pesquisa/117399/>.

FABIANO, C. & MUNIZ, S. Regularização Fundiária - Dique Vila Gilda: caminhos para a regularização. Boletim Eletrônico, BE 3370, ANO VIII, Editor: Sérgio Jacomino. São Paulo, 2008.

G1. Contêineres que afundaram na costa de SP devem ser retirados do mar em até 30 dias. G1 Santos e Região, 2018. Available in <https://g1.globo.com/sp/santos-regiao/porto-mar/noticia/containers-que-afundaram-na-costa-de-sp-devem-ser-retirados-do-mar-em-ate-30-dias.ghtml>.

G1. Enfeites de Natal ainda chegam às praias do litoral norte de SP mais de um ano após queda de contêineres no mar. G1 Vale do Paraíba e Região, 2018. Available in <https://g1.globo.com/sp/vale-do-paraiba-regiao/noticia/2018/09/17/enfeites-de-natal-ainda-chegam-as-praias-do-litoral-norte-de-sp-mais-de-um-ano-apos-queda-de-containers-no-mar.ghtml>.

G1. Resíduos de contêineres que caíram de navio são encontrados a 100 km de local do acidente na costa de SP. G1 Santos e Região, 2018. Available in <https://g1.globo.com/sp/santos-regiao/porto-mar/noticia/residuos-de-containers-que-cairam-de-navio-sao-encontrados-a-100-km-de-local-do-acidente-na-costa-de-sp.ghtml>.

GODINHO, R.E. Nova metodologia de projeção da população flutuante. Anais. Associação Brasileira de Estudos Populacionais. 13p., 2016.

HARARI, J. & CAMARGO, R. Modelagem numérica da região costeira de Santos (SP): circulação de maré. Revista Brasileira de Oceanografia, 46(2), 135-156p., 1998.

IBGE. Censo demográfico 2010. Aglomerados subnormais - Primeiros resultados. Instituto Brasileiro de Geografia e Estatística, 2011.

IMO. "International Convention for the Prevention of Pollution from Ships (MARPOL), annex V prevention of pollution by garbage from ships". International Maritime Organization. London, 1988.

ITALIANI, D.M. Resposta morfodinâmica à alimentação artificial da Ponta da Praia, Santos, SP. Dissertação de Mestrado. Instituto Oceanográfico, Universidade de São Paulo, São Paulo, 2014.

JORNAL METRO SANTOS. Praias escondem lixo do estuário. Jornal Metro Santos, 187(1), 2p, 2010. Available in <https://www.scribd.com/document/37856000/Jornal-Metro-Santos-17-09-2010>.

LAIST, D.W. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Marine debris - Sources, Impacts and Solutions. Springer Series on Environmental Management (eds Coe, J.M. & Rogers, D.B.) 99-139p. Springer, 1997.

MELLOR, G.L. Users Guide for a Three-Dimensional, Primitive Equation Numerical Ocean Model. Princeton Ocean Model, 1998.

MMA. Projeto Orla: Fundamentos para Gestão Integrada. Ministério do Meio Ambiente. Ministério do Planejamento, Orçamento e Gestão. Brasília, 73p., 2006.

OLIVEIRA, A.S. Interações entre sistemas frontais na América do Sul e a convecção na Amazônia. 115p. Dissertação de Mestrado - INPE/SJC, São José dos Campos - SP, 1986.

PIRES-VANIN, A.M.S. A influência do complexo estuarino da baixada santista sobre o ecossistema da plataforma adjacente (ECOSAN), 2004.

PONÇANO, W.L. & FÚLFARO, V.J. 1976. Sedimentação atual nas adjacências da Ponta de Itaipu e Baía de Santos: implicações na escolha de locais de lançamento de material dragado. In: Congresso Brasileiro de Geologia de Engenharia, 1. Rio de Janeiro, 1976.

PREFEITURA DE SANTOS. Instalado primeiro bag do projeto piloto contra ressaca e erosão na Ponta da Praia. Prefeitura de Santos, Santos, 17 fev. 2018. Available in: <http://www.santos.sp.gov.br/?q=noticia/instalado-primeiro-bag-do-projeto-piloto-contrar-ressaca-e-erosao-na-ponta-da-praia>.

PREFEITURA DE SANTOS. Serviço: Limpeza de praias. Available in: <http://www.santos.sp.gov.br/?q=servico/limpeza-das-praias>.

RIBEIRO, R.B.; SAMPAIO, A.F.P.; LEITAO, P.M.C.F.L.; LEITAO, J.M.C.F.L. & PUIA, H.L. Modelagem numérica operacional do nível do mar e correntes para o Estuário de Santos. XI Simpósio sobre Ondas, Marés, Engenharia Oceânica e Oceanografia por Satélite, Arraial do Cabo, 2015.

SCHAEFFER-NOVELLI, Y. Manguezal ecossistema entre a terra e o mar. Caribbean Ecological Research, 1995.

SCHMIDT, C; KRAUTH, T. & WAGNER, S. Export of Plastic Debris by Rivers into the Sea. Environmental Science & Technology, 2017.

SOARES, S.B. & CHACALTANA, J.T.A. Refração e difração de ondas em regiões costeiras. II Congresso sobre Planejamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa, Universidade Federal do Espírito Santo, 2015.

THE NEW YORK TIMES. Wave After Wave of Garbage Hits the Dominican Republic. The New York Times, 2018. Available in <https://www.nytimes.com/2018/07/23/world/americas/dominican-republic-garbage.html>.





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