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ANALYSIS EVOLUTION OF THE CENTRAL BEACH OF BLANES LINKED TO THE ENLARGEMENT OF ITS PORT

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Contents

1. ABSTRACT

The enlargement of Blanes port, necessary to improve the operational problems of it and the needs of the users who run it, can cause certain impacts on the beach where it is supported.

Blanes beach, has 630 meters long, is a limited beach between Punta de Sa Palomera and the port, which may undergo changes in its coastal dynamics due to the construction and enlargement of said port.

It is for this reason, the object of the work, by means of the measurements of three selected sections, the same for each photo taken weekly from 2009 to the present. It will try to determine the changes that occurs in the coastline after the port expansion (areas where the beach recedes and areas where sand accumulates for different reasons that in this study will be the main focus) and see which regions are more vulnerable to wave action in each season of the year. In order to contribute to the impact study of the port from a post-construction point of view and the investigation of beach morphodynamics.

2. INTRODUCTION

Beaches of Blanes (Girona) are one of the main sociological actives of the village, both as they are located in front of the urban center (S'Abanell and Blanes center) and the four beaches situated to its cliff areas (Sa Forcanera, San Franciso, S'Agulla and Treumal). Historically, the space between Palomera and the promontory of the Convent and the Punta de Santa Anna (the beach of Blanes center) from actually a natural bay for boats anchoring and unloading, as well as for their construction, while S'Abanell beach in its great extension was dedicated to fishing themes. The dedication changes at the beginning of the 20th century when the first tendencies of Blanes port construction in 1914 are seen, which will be developed during the thirties and the end of 1946. With the awakening of tourism, the beaches become the pole of recreational activities and the port change its purpose to have markedly fishing character that along the time also increase the activities related to the recreational boating. Blanes port will be extended in period of 1977-1986 and will continue in this way until 2010.

On December 26, 2009 a large maritime storm that affected all of Catalonia causes serious damage to main dike of the Port of Blanes. Generalitat de Catalunya is currently accelerating a project to expand and modify the port that it already had prepared, which will be carried out mainly in 2010. The Environmental Impact Study (EIA) associated with this extension explained the socioecological impacts of this expansion to the environment and towards the

population of Blanes. The report opted for a modification of one of the constructive alternatives that solved the problems of reinforcement and protection of the current dike and, in turn, responded to the demand of those interested in expanding the port. The report specified the different impacts and in relation to the impact on the beaches commented on page 152 that *the alternatives proposed have no effect on the beaches of Blanes;* in particular, on the beach of Blanes center it was commented; *The beach of Blanes is a pocket beach between Cap de Sa Palomera and Santa Anna. The construction of the new dike will not increase the barrier effect to the longitudinal transport that constitute the existing obstacles.* However, and as a compensatory measure to the expansion, the promoter, since it would place a new jetty on the side of the port to prevent the entry of the sand, it was committed to making a contribution of aggregates to the beach in the northern zone touching the port.

In the subsequent public procedure of the EIA, the Center for Advanced Studies of Blanes (CEAB-CSIC) would object to some of the comments of the EIA and in particular on its affectation to the beach of Blanes center commented; *In situations of east wind (NE, E and SE), a medium or strong storm could displace the negative effects on the beach to the right of it (looking out to sea). If now the beach suffers in the center, its subsequent sufferings will move towards the Palomera so the new structure after a possible extension will damage the Palomera walk and, perhaps, in exceptional situations to the subsequent buildings, will affect the shore of the population and in exceptional situations to Cataluña square and its parking. On the other hand, it will cause a greater balance of the beach, which will force more frequent works. Apart from thinking only of an initial regeneration linked to the work is to think little, other regenerations that are necessary should also be paid by the promoter if it is evident that they are a consequence of the extension.*

In order to evaluate the previous comment, the CEAB developed a small study later together with the Polytechnic University of Catalonia (UPC) to obtain a better knowledge of these affectations. The beach of Blanes center (Figure 1) is a 630 m long between two obstacles: the set of outer harbor, dike and Punta de Santa Anna of the port; and the Punta de Sa Palomera.

Figure 1. Blanes bay with the location of Blanes center beach.

The work specified that; *the beach of Blanes center is a beach in equilibrium that can undergo seasonal changes in a short period under the action of storms or years with dominant directions of waves different from those of the average year. Being a pocket beach between two obstacles, these short-term changes will manifest as accumulations of sediment on both sides of the beach (a storm of SSW component will accumulate sediment on the NE side of the beach and vice versa), but that they will not change the form of balance to which the beach will tend again once these extraordinary waves episodes are over.*

The work was carried out applying an oceanographic model that determined that in a temporary situation:

- *The results of the model showed three clearly differentiated zones. In the area to the north, you can see an accumulation of sand produced by the diffusion of the port that reaches up to approximately 14 meters at the point closest to the dike.*

- *In the central section of the beach the sand is lost producing a 15 m shoreline recession at the most unfavorable point, although in reality it is not like that, the model does not take into account the existence of a submerged dike, it does not matter, you can take the medium to the left of the dike (3.5 m) and the medium to the right (5.5 m) as a recession.*
- *In the area near Punta de Sa Palomera, there is an accumulation of sand up to 9 m.*

Taking advantage of all this knowledge and with the determination to evaluate the final impact of the expansion, the CEAB, starting in January 2009, a year before the expansion project began, initiates a series of weekly photographs on the evolution of the beaches of Blanes from the promontory of Sant Joan. These photographs should be able to determine whether all comments previously made about the impact were correct or not.

The work presented below evaluates the behavior of the Blanes center beach for a space of 10 years. That is why, a series of weekly photographs has been studied between January 1, 2009 and December 31, 2018. The final objective of the work is how the beach has evolved after the expansion of the port and if the comments are made in the works cited previously were or not correct. Basically we wish to know if the beach has remained stable in terms of its volumetry and if only the balancing processes are observed in the dynamics of their sands that later can be worked artificially with beach machinery.

3. METHODOLOGY

3.1. The study area

The study area referred to this work is the beach of Blanes, a beach of 630 meters of length that is located between S'Abanell beach and Blanes Port. (Figure 1).

Blanes center beach is a balanced beach that can suffer seasonal changes in a short period of time in the action of temporary times or years with dominant directions of different waves from the average year. As a beach between two obstacles, these short-term changes are manifested as sediment accumulations on either side of the beach (a temporary SSW component will accumulate sediment on the NE side of the beach and vice versa), but that will not vary the form of equilibrium to which the beach will tend again once these extraordinary waves episodes are over.

By the enlargement of the port of Blanes, the obstacle that this represents for the swell will cover much more length, so that the area where the waves are affected by diffraction will be greater and therefore there will be a longer length where the beach will tilt.

On the other hand, in the area exposed to the waves where diffraction does not affect and where sediment transport is basically induced by the longitudinal current, the shoreline of the beach will be parallel to the wave train. (Ros et al., 2011)

3.2. Beach evolution

Beach width (BW)

Since January 2009, weekly photographs of Blanes center beach have been obtained from an elevated coastal point in the "Muntanya de Sant Joan" (Figure 2). This point of observation is located at 180 m above sea level and 1 km from the northernmost end of the beach. Photographs are taken with a reflex camera and always from exactly the same geographical point with the same angle and zoom. We have weekly data from 2010 until today and less frequently (but at least monthly) from 2009, the beginning of the series. The photographs were used to measure beach width. Measurements relied on in this work were taken only from photographs in which the shoreline was clearly defined. The rest of the images, where incidental waves did not allow us to trace the coastline accurately, were discarded from the analysis.

Beach width measurements were initially obtained in three transects spatially distributed across the beach. Photographs were analyzed using photo processing software (ImageJ®) on a weekly basis. Visual references were used to adjust the measurements taken. A calibration between "in situ" measurements and photo processing showed a possible error of between 1 and 3 m. All pictures and measures have been analyzed by the same person to minimize further cumulative errors.

Figure 2. Aerial vision area of the study (A). And a map locating Blanes (B).

Beach width (BW) is normally considered a key indicator in beach management processes (Sardá et al., 2015). Moreover, BW is used in the Beach Quality Index (Ariza et al., 2010), a composite index (BQI) able to measure the three main ecological functions of a beach (recreational, natural and protective). The BQI can be used as a balance tallying tool for modern beach management processes (Sardá et al., 2015). To further assist management schemes, we designed a graphic display aiming for a better visual interpretation of BW measures. The measurement taken from the photographs was placed on top of a four-colored layer that qualifies the protective function of the beach: a) blue; good status, higher than 30 m; b) orange; pre-alert status, between 26 and 30 m; c) red; alert status, between 10 and 26 m and; d) black; critical status, less than 10 m width.

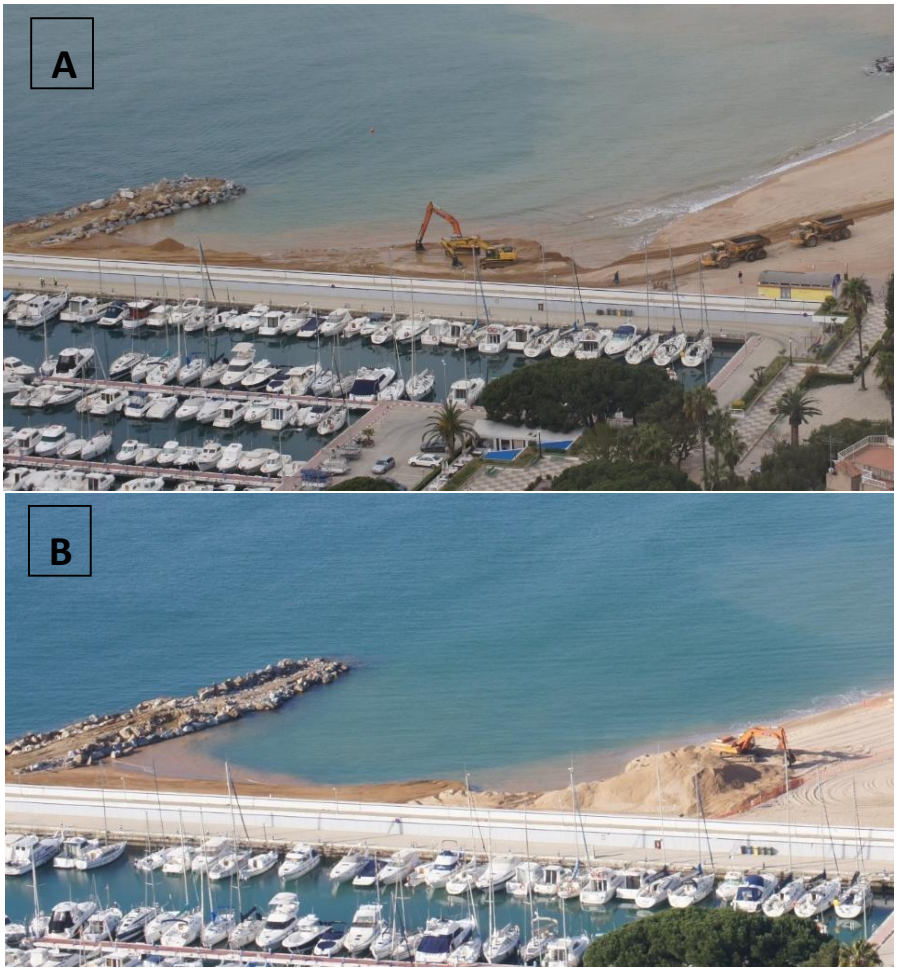

Figure 3. Artificial nourishment of 13 of April (A) and 23 of March (B) 2011.

Transect 3 was placed at the northernmost part of Blanes center beach. The enlargement of the port experienced at the port caused transect 3 to be the most drastic changes of the coast, reaching the most pronounced trend curve, experiencing growth since 2009. A new process was then developed to study the coastal evolution of the beach in this particular area (Figure 3). Because an entrance of water in the area, leaving it without a beach. From there it was observed in detail all the procedures that have been done. Especially on every month of April and May, sand trucks arrive leaving the beach prepared for the summer season and fulfilling with the mitigation measure proposed by the EIA study.

Protection Partial Index (IPP)

The protection partial index (IPP) is a sub-index used in the BQI (Ariza et al., 2010). The IPP measures beach capacity to dissipate wave energy and to prevent structural damage to promenades and maritime facilities. The IPP is comprised of three different sub-measures: (i) the effective beach width (EBW), which is the distance between existing infrastructures

and the shoreline; (ii) the storm reach (SR), which is the beach width potentially eroded by a storm of a given return period; and (iii) the minimum beach width (MBW), which is the minimum width of operative beach required for protection purposes (i.e. for beach infrastructures to be protected from storm impacts). The IPP is measured using the following formula:

$$IPP = \frac{L(IPP1 > 1)}{Ltotal}$$

Where,

$$IPP1 = \frac{EBW}{SR} + MBW$$

Where IPP1 is the partial protection index for a particular point of the beach, and IPP is the partial protection index for the whole beach. The IPP measures the percentage (from 0: no protection to 1: full protection) of the beach with the length of IPP1>1 in relation to the total length of the beach. Previous calculations have shown that the protective function of S'Abanell will disappear if the width of the beach decreases to less than 26 m (Ariza et al., 2010). We will use the same parameters for Blanes center beach.

Pluviometry data, swell and beach dynamics

Pluviometry (daily total rainfall) data were obtained from the meteorological station of Malgrat de Mar (Meteorological Service of Catalonia-Meteocat - XEMA). The station of Malgrat de Mar was the only meteorological station of the Tordera river basin that has a series of data long enough to evaluate variations in the pluviometry regime over the last sixty years. We used these data as an indirect measure of precipitation for the entire Blanes beaches. Due to the relatively small size of the Blanes center beach, there were no significant differences between average pluviometry at different sites of the whole zone.

Swell dynamics data were obtained from the SIMAR network (point 2118140) of the Spanish Agency "Puertos del Estado" (Puertos del Estado, 2016). Data were obtained from a numerical prediction model, WAM model (TW Group, 1988), with a temporal cadence of 1 hour based on REDEXT buoy network, REDMAR tide gauge network and directional wind data (Puertos del Estado, 2016). These types of data are suitable for calculating swell regimes (de Farias et al., 2012). The time series of significant wave height and predominant wave direction have been obtained from these data and compiled in a Microsoft Excel database.

3.3. Fieldwork

In order to correctly perform the beach width calculations of three sections, three beach measurements were made.

Figure 4. Calibration of the beach on February 26, 2019 with the three sections (1st, 2nd, 3rd) indicated with a red line.

These transects allows to take the measurements of all the other images from 2009. Since they are needed for the ImageJ program and thus be able to work in real scale.

3.3.1. Beach calibration

First, all weekly images were introduced in a Power Point and the same lines in red (figure 4) were drawn in each of them, with the same proportions and reference points. In addition to adding other lines to define the work better.

Then, the transects were measured for ten years with the ImageJ program, so that all the measurements of the beach are taken at the same reference points and can be established precise comparisons. These measurements were worked thanks to the previous calibration measurements.

3.3.2. Microsoft Excel database

As the images were analyzed, the values were put in an Excel, besides, every change that was appreciated on the beach, such as constructions, sand extractions, accumulations, beach extensions, modifications for tourist use, etc. Was discussed.

3.3.3. Graphics

Next, Excel data was transferred in Sigma Plot program, and they were plotted, with an X axis that represents the natural days, segmented by vertical lines all the summer seasons (July-August) to be able to observe and differentiate all the changes produced. And with a Y axis that represent the meters for the beach width (trasects 1, 2, 3) and square meter for the area. In addition, the monthly and annual means of all the data were made.

3.3.4. Areas study

To complement the results, the same measurement process was performed with the ImageJ program, but measuring the total beach areas of all the same photographs. The monthly averages were made and of them, the annual averages to be able to obtain more precise measurements. (Figure 5).

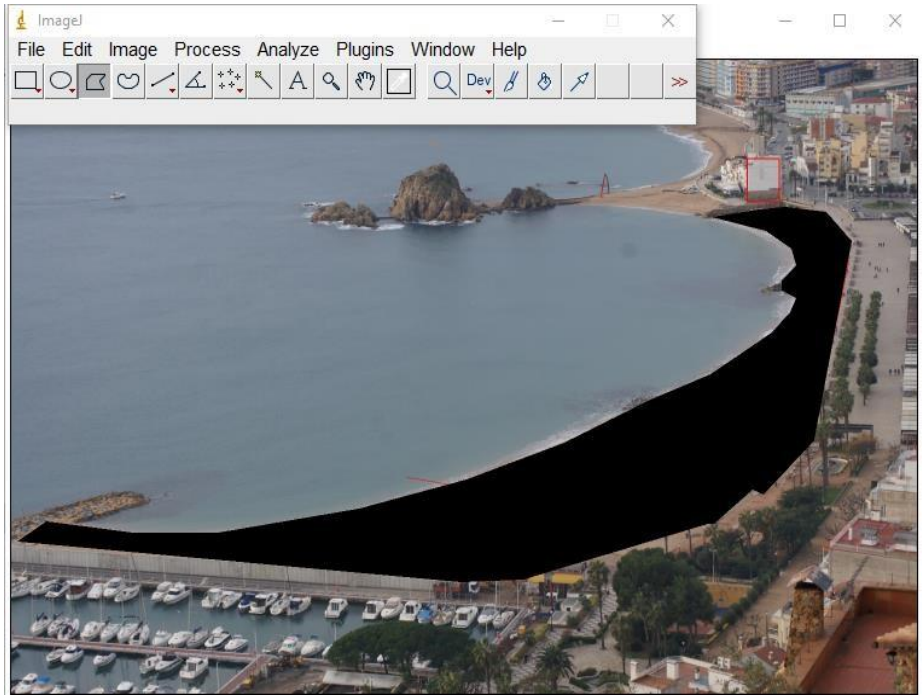

Figure 5. Area study process with ImageJ.

4. RESULTS

4.3. Beach width

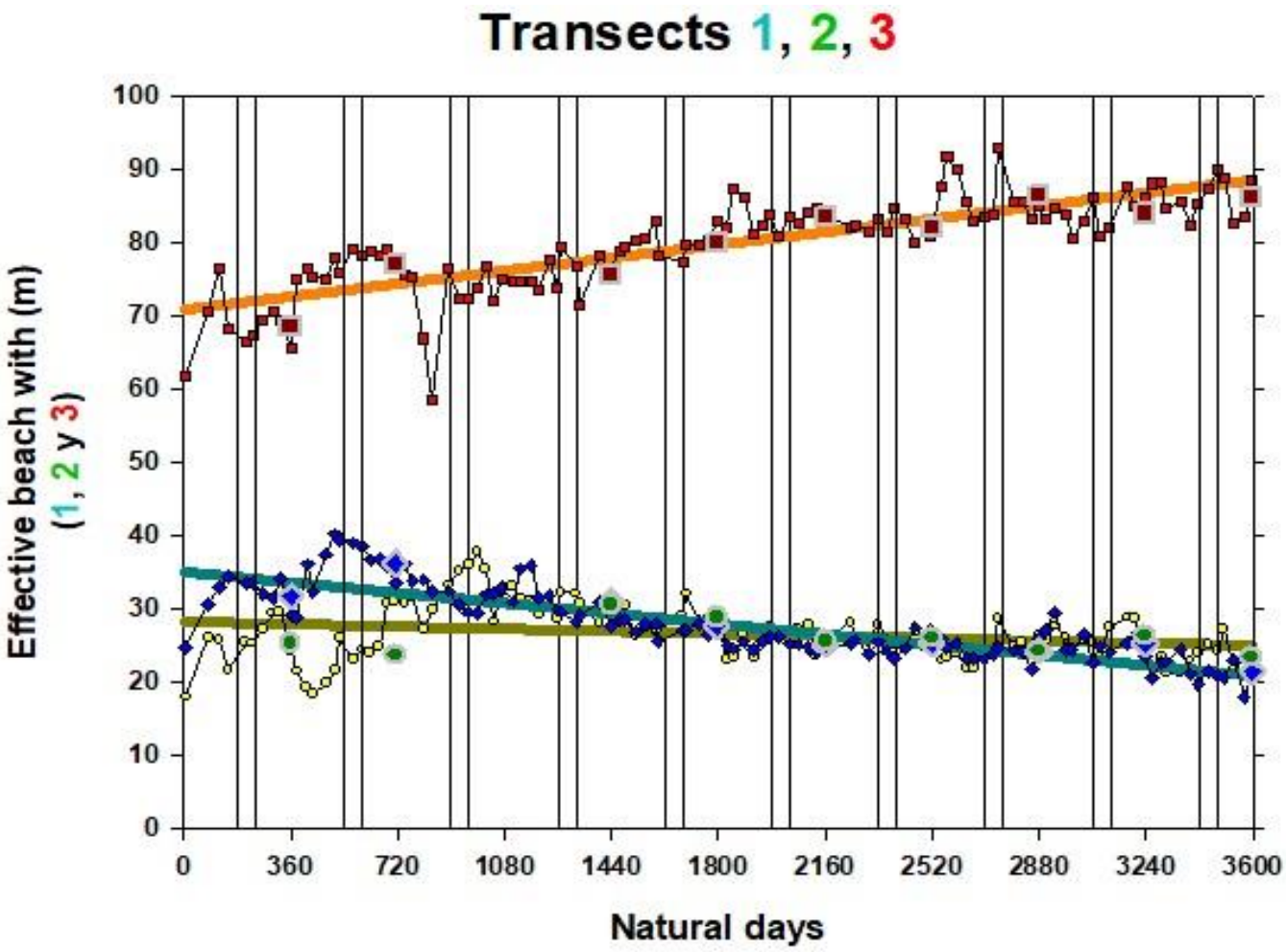

Figure 6. Graph of the trends of each transect with monthly and annual averages.

In this figure 6 all the data obtained from the monthly means were plotted, which all red squares (transect 3), yellow points (transect 2) and blue diamonds (transect 1). Those that are larger and less frequent are the annual average, which we will not give greater importance. In this graph we want to give importance to the trends of each beach, and also the vertical lines delimit each summer of each year (July-August), in every month of May, in transect 3 near the port, it happens a regeneration of beach, increasing its width for tourist purposes. The general trend of transect three the beach growth. The trend of the other transects decreases, with a greater accentuation in transect 1, at the other end of the beach, next to

Punta de Sa Palomera. Observing a strong regression of the beach. While the middle transect has a small descent.

During the last decade, the three stretches of Blanes Center beach studied have evolved differently. While the northern part (Transect 3) next to the port, showed accretion, the area of the beach near the Punta de Sa Palomera continued to erode. The weekly evaluation of three transects are presented in Figure 7. The sporadic large width values over the 10 years (transect 3) correspond to principal cause to the enlargement of the port, concretely in 2011 (January to April) de width experimented a strong erosion, correspond after to the first artificial nourishment carried out on the beach (Figure 7). Following a period of stability after nourishment, an improvement became evident in this transect.

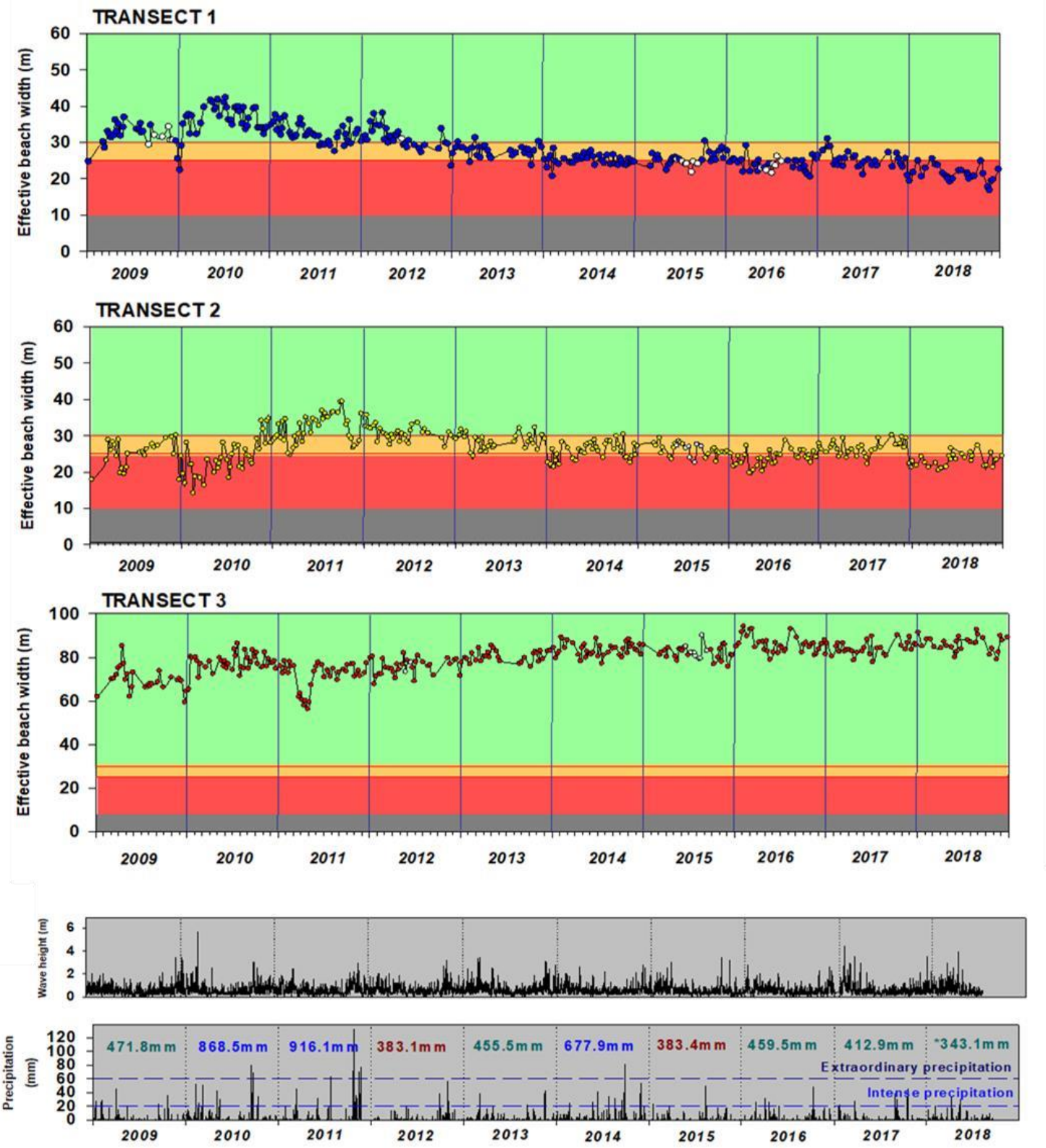

Figure 7. Graph of al weekly data of three transects, wave height and precipitation.

In addition, observing what is happening in the south transect, next to Punta de Sa Palomera (T-1), it appears in the red danger zone, when the beach is less than 26 m (Protection Parcial Index, IPP), the beach is in danger, and consequently in situations of storm, the beach does not fulfill its protection function. in the graph (Figure 7) it is observed that it descends so a beach balance also occurs, that the lost sand goes to the other end of the beach (in this case in the north zone, T-3).

The evolution of the IPP index for the three analyzed transects is shown in Figure 7. Except for the first and second transect, the other transect 3 showed a progressive improvement in the IPP that matches the accretion process shown on this stretch of the beach. The lower beach width graph of Figure 7 shows the recovery of beach width, as indicated by the IPP. The upper graph of Figure 7 indicates the value of the IPP index for the southern and central parts. In 2010 (T-1), northern part of the beach had a width greater than 26 m and for T-2 was in 2011, what allowed it capable of carrying out its protective function in this part of the Mediterranean Sea in a short part of time.

4.4. Areas

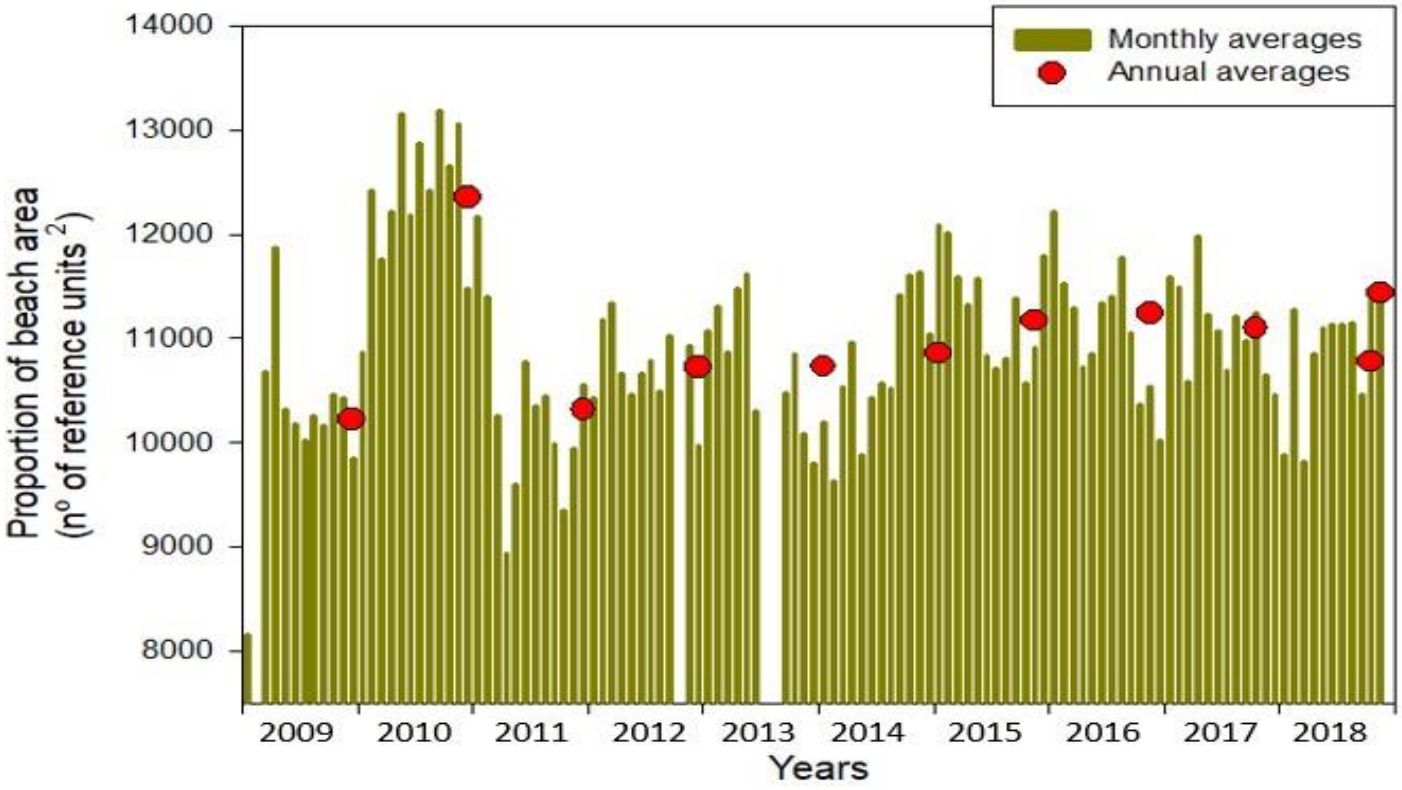

Figure 8. Monthly and annual areas averages.

In the study of the total surface of the beach, it is observed that the area does not decrease, it remains stable, it could even be said that the beach increases in surface area (Figure 8), this is due to the fact that the sand does not disappear but is balanced, transported in sediment to one to the other side of the beach, accumulating on the beach next to the port (T-3), after the build of enlargement the port, the highest red point is observed, which coincides with the beach regeneration explained previously, besides that every year sand is added in the month of May.

But the regeneration did not have much impact, in 2010 it managed to regenerate all the lost beach, but after 2010 the beach still has the same surface.

5. DISCUSSION

The central beach of Blanes is a pocket beach between obstacles, vulnerable to natural forces and subject to pressures produced by human interventions. The beach is a highly tourist sector, as well as being constantly changing due to the effects of waves as well as storms and the enlargement of the port. Its northern end is the one with the most changes in the last ten years, with constant sand nourishments to mitigate the impacts. While the southern zone, near Punta de Sa Palomera, in the Environmental Impact Study (EIA), it was said that no changes would be observed because of the enlargement, for this reason there are no beach regenerations and mitigate actions, and with the data obtained it is observed that area is in a critical situation, below 26 meters: the width required for the beach to exercise its protective function against a 10-year return period storm (Ariza et al., 2010). According to the SBEACH (Larson y Kraus, 1989). From 2011 to the present the values have entered the orange and red zone, as a result of a great problem of erosion, in which the urban part of the beach is subject to a risk exposure to adverse weather conditions.

In transect 2 in central area, it remains a little more stable but also within the range of precaution, orange zone, slowly decreasing to the red zone of danger, between 2016 and 2018 there are more values in red than orange zone. Ad an addition, during the years of this study (2007-2018) the region did not undergo extreme storms whose effects could have been negative for the recovery process (Durán et al., 2016; Mendoza y Jiménez, 2008). However, negative trends continue to be observed in T-2 and T-1. And only taking precautionary measures and regeneration in T-3.

In the study of EIA and UPC (Universidad Politécnica de Catalunya), they had not anticipated these negative effects in the other areas of the beach, while the study of the ‘Centro de Estudios Avanzados de Blanes’ (CEAB-CSIC), had anticipated these impacts, objecting some comments of EIA, commenting: *In situations of east wind (NE, E and SE), a medium or strong storm could displace the negative effects on the beach to the right of it (looking out*

to sea). If now the beach suffers in the center, its subsequent sufferings will move towards the Palomera so the new structure after a possible extension will damage the Palomera walk and, perhaps, in exceptional situations to the subsequent buildings, will affect the shore of the population and in exceptional situations to Cataluña square and its parking. On the other hand, it will cause a greater balance of the beach, which will force more frequent works. Apart from thinking only of an initial regeneration linked to the work is to think little, other regenerations that are necessary should also be paid by the promoter if it is evident that they are a consequence of the extension. Said in the introduction of this work.

6. CONCLUSION

During the last decade, the Blanes beach center has shown a trend for improvement in its physical conditions (Figure 9), as a direct consequence of the artificial beach actions and the abandonment of previous human-based pressures. Improvements were evident in the northern part of the beach but not in the southern part, near la Punta de Sa Palomera, where the situation is still critical. Our time series analysis also served to identify areas where the modification of essential processes is compromising beach resilience; The ecological balance of the sediment and the awareness of all the artificial changes that are made in the area, with all mitigations of possible impacts the situation of Maresme beaches, are critical to improving the erosion / accretion balance. In order to recover IPP (26m minimum) functionality in the future, the region has created a governance structure ("Taula de la Tordera") to facilitate implementation of an ecosystem-based management process, using its basic principles to redress the problems caused by past fragmented coastal management frameworks. This governance structure is created for the S'abanell Beach and the region of Tordera delta, but this work is next to these areas and the data obtained, will be utilized to crate the same governance structure but with Blanes central beach characteristics. In addition, this project will be presented in the future to the municipality of Blanes, to make known what is really happening in the area.

Figure 9. First image (A) 8 January 2009 and the last image (B) 26 February 2019.

7. ACKNOWLEDGEMENT

First, I would like to acknowledge the person who gave me the opportunity to be part of this working and passionate ecosystem protection team, Rafael Sardà, who works on this project every week by ten years, a constant person and very aware of the changes that humans cause in the environment. He supports me along this project and he is a great person, very nice and fun to work with, and I really liked his point of view as a scientific professional, a whole learning, because he loves the natural environment, and the knowledge of anthropic changes that produce unknown effects and thanks to this, possibly in the future the laws will take more stringent measures for the conservation of Tordera river and Blanes beaches.

I gratefully acknowledge the support and companionship, every person who works in the center, treated me very well, as one more of the team. And Rafael, whose exigence has made me accomplish a project that too many times I thought it was not going to be possible, and for being close enough to be able to talk with confidence.

I also appreciate his confidence to let me work away from the center, in my family house (2 hours away), and go to the center and make video calls whenever I needed it, to keep moving forward. After my stay in Gran Canaria and Chile, being able to finish the career next to my family is completely a gift.

To my friends, who besides being so far, warmed me up every time I need.

And finally, to ULPGC and CEAB-CSIC and all the administrative employers of both institutions that made me possible this nice work.

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Descripción detallada de las actividades desarrolladas durante la realización del TFT

En este apartado se expondrán y comentarán todos los conceptos relacionados con la realización del TFT. Se explicará brevemente el proceso de cada actividad realizada, así como la formación recibida y el nivel de integración e implicación dentro del departamento y relaciones con el personal.

Área de estudio

El área de estudio se centra en la playa central de Blanes, Cataluña. Se trata de una zona de playa encajada entre dos obstáculos, Punta de Sa Palomera y la ampliación del puerto. Esta playa es realmente importante para la región de Blanes, ya que es la playa central de la ciudad, altamente turística y de uso pesquero. Durante todos estos años de estudio y de recopilación de información, se han llegado a identificar cuáles son realmente los impactos negativos que se producen, y cuáles son las zonas de erosión que ponen la playa en peligro.

Recopilación de datos bibliográficos

Durante estos meses de trabajo se han ido recopilando los trabajos del Estudio de Impacto Ambiental por parte del Puerto, el trabajo de la Universidad Politécnica de Catalunya relacionada con la ampliación del puerto, las objeciones que ponía el CEAB-CSIC ante estos estudios y lo más importante, la recopilación de las fotografías tomadas des del año 2009 al 2019 (actualmente se siguen tomando).

Análisis de fotos

La recopilación de todas las fotografías semanales, nos han permitido elaborar una serie de datos y un análisis completo de los cambios producidos después de las modificaciones de la playa y además tener un seguimiento de todos los aportes de arena artificiales que se han ido haciendo. Lo programas utilizados son: Microsoft Excel, ImageJ, SigmaPlot, PowerPoint. Se trabajó en ello varios meses con perseverancia y dedicación, para poder analizar cada una de las fotografías con detalle, minimizando los posibles errores de medición.

Formación recibida

Durante la realización del TFT la formación recibida se basó en las técnicas y metodologías para seguir una evaluación de impacto ambiental precisa. Me compartieron todas las herramientas y conocimientos posibles para poder seguir el trabajo con precisión. Además de solucionar errores fotográficos que impedían el buen seguimiento de estudio.

Nivel de integración e implicación dentro del departamento y relaciones con el personal

El nivel de integración des del primer día ha sido realmente agradable, la implicación para poder seguir este trabajo, ha sido la precisa para ir avanzando de una forma constante, siempre había disponibilidad para ayudarme y explicarme cualquier duda durante el proceso. Además de querer enseñarme, como es la vida profesional en este sector y explicarme todos los demás

trabajos que se están realizando en el centro. Permitiéndome observar un abanico de posibilidades para continuar con el estudio del mundo marino.

Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT

La experiencia ha sido muy positiva y agradable, el aprendizaje y el desarrollo del trabajo han sido gratificante. El proceso de investigación ha ido cambiando, con diferentes fases de trabajo, unas requerían más dedicación que las otras, por ejemplo, el análisis de las fotografías ha sido realmente largo, pero obtener los resultados ha sido de mucha satisfacción.

Valoración personal del aprendizaje conseguido a lo largo del TFT

El aprendizaje adquirido durante este tiempo ha sido tanto personal como profesional. Poder evaluar los impactos de una playa con técnicas que desconocía, ha sido sorprendente, porque no sabía que me gustaría tanto este campo de las ciencias del mar. Ya que, con estos estudios, completan las evaluaciones de impacto ambiental realizadas por las empresas, que, en este caso, no era tan detallada y precisa. Con este trabajo, es posible cambiar y regular las leyes de costa y poder proteger las playas del Maresme que se encuentran en una situación similar a la de Blanes. Con ello, me llevo las ganas de seguir aprendiendo y perfeccionándome en este ámbito. La valoración personal del aprendizaje ha sido un 10.