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Adapting the existing coastal Patí a vela fleet for scientic purposes

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ABSTRACT

This paper presents the first results of the Barcelona Institute of Culture's grant for research and innovation projects under the 2019 Barcelona Science Plan entitled "Development of a citizen monitoring program for the Barcelona waters: The Scientific Patí a Vela". The main objective of this project is to develop a small Patí a Vela (PV) fleet that can routinely sample the Barcelona coastal waters and report their observations to an open-access interactive web. The Patí a Vela boat was designed in 1942 by the Mongé brothers. It is a lightweight one- person catamaran with a single Marconi sail and no boom.
The main objective of this contribution is to adapt the Patí a Vela model attaching an on-board platform with scientific instruments (sensors and devices) and determine the new stability characteristics and seakeeping performance. This will allow an adequate sampling of the Barcelona coast waters and the systematic measurements of the essential physical and biogeochemical variables detecting variations along the coast, hence identifying potential sources of contamination. It will also provide the necessary knowledge of natural and anthropogenic seasonality.

1. Introduction.

The low-lying coasts and nearshore communities face vulnerability to the natural disasters and climate change. On one hand, recent events like the powerful Storm Gloria in January 2020 caused severe damages devastating coastal areas along the Mediterranean and beat several historical records of rain, wind and waves(Amores et al., 2020)(Barbier, 2014). On the other hand, coastal marine environments are a major focus of concern regarding the potential impacts of anthropogenic climate change (Harley, 2006) and has implications for marine ecosystems, with far-reaching consequences for human and welfare.
Coastal population densities are nearly three times that of inland areas, and they are increasing exponentially (Field et al., 2014). Monitoring the coastal waters is essential to understand how the planet is changing and how these regions evolve due to natural and anthropogenic effects.

The knowledge of the oceans has improved drastically during the last decades, particularly thanks to satellites remote-sensing and a fleet of and autonomous underwater instruments present in all the oceans far from the coast. However, coastal waters are undersampled both in time and space (Alverson & Baker, 2006). Sample nearshore coastal waters sometimes is difficult from conventional oceanographic platforms. There are different innovative ways of sampling these waters, like attaching sensors to marine mammals as platforms for oceanographic samplings (Mike, 2004). (Brewin et al., 2017) draw attention to the vast number of participants that engage in nautical recreation sports and found that it could be an option to improve the large-scale sampling efforts: for instance, (Brewin et al., 2016) equipped recreational surfers with a temperature sensor to estimate the sea-surface temperature; (Wright et al., 2016) equipped SCUBA divers as oceanographic samplers and (Bresnahan et al., 2016) designed a sensor package to be mounted on paddleboards.

Barcelona's climate is conditioned by the Mediterranean Sea, which acts as a natural regulator to prevent extreme weather conditions. Further, the surrounding sea provides natural resources for local fisheries and a gathering space for local peo-

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ple and visitors, for recreational and social activities. Despite its relevance, the Barcelona marine environment remains very poorly sampled. Apart from the water quality control carried out in summer (Generalitat de Catalunya, 2020) only a systematic year-long offshore sampling has been regularly maintained since 2002 (ICM-CSIC, 2020).

In order to improve this lack of samples, we propose a local strategy for protecting Barcelona coasts and nearshore communities using a recreational boat widely used on Barcelonas' coast and nearby, the Patí a Vela (PV) sailing boat. It is a wooden sailing boat that was born on the beaches of Badalona and Barcelona (Spain) because of the need for swimmers to pass over the polluted nearshore waters. It is a lightweight one-person catamaran with a single Marconi sail and no boom. This boat has the peculiarity of not having a rudder nor a centre-board. The steering is only controlled using the bodyweight of the crew member and the tension in the sail. The Patí a Vela boat was designed in 1942 by the Mongé brothers. Today, the Patí a Vela fleet is distributed over Catalonia, Andalusia and Valencia, but also reaches the French, Belgian and Dutch coasts. According to the International Patin Sailing Association (ADIPAV) data, more than 200 Patí a Vela could directly interact with the samplings. If part of these recreational boats were equipped with the scientific on-board platform with sensors, this could be potential to acquire large volumes of data enhancing the sampling volume of environmental indicators in Barcelona and nearby coast waters.

The main objective of the research project is to develop a first prototype a Scientific Patí a Vela (SPV) that can routinely sample the Barcelona coastal waters using relatively low-cost sensors package (https://atlas-scientific.com/) and report their observations to an open-access interactive web (Camprodon et al., 2019).

To ensure its success, the impact of this recreational activity with the attached sensor package should be minimal, with implications for weight and size requirements. Moreover, the sensor package should be easily accessible and appropriately positioned for good data collection without damaging the crew member activity.

Therefore, the first step of this project is to model a Patí a Vela boat, define the appropriate sensor package and its position and finally evaluate the new stability characteristics and seakeeping performance to hold an on-board platform with scientific instruments. In this contribution, we present the results of this first step. The paper is organized as follows: after the Introduction, Section 1 (methodology) presents the Patí a Vela model considering the official Class Rules. Also, the scientific sensors and devices are described showing the appropriate position of the experimental set-up on-board platform. Section 2 (results) shows the intact stability and seakeeping analysis of four load cases: (1) Patí a Vela without scientific platform (PV), (2) Scientific Patí a Vela (SPV), (3) Patí a Vela with the crew member without scientific platform (PV-crew) and (4) Scientific Patí a Vela with the crew member (SPV-crew). Finally, conclusions are highlighted in the final section (Section 3).

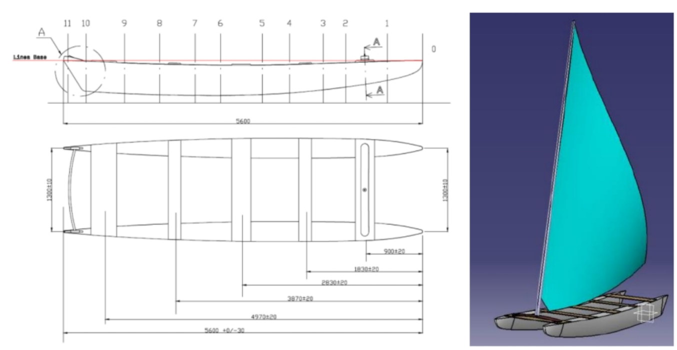
2. Methodology.

The methodology to study the new PV stability characteristics and seakeeping performance to hold a scientific on-board platform is described below. Four load cases have been considered: first, following the body plan attached at the PV Class Rules (ADIPAV, 2018), the 3D model of the Patí a Vela is designed in Catia V5 (PV load case). Then, the experimental set-up on-board platform is described and the scientific devices have been appropriately positioned for good data collection with the minimal impact on navigation (SPV load case). Other two load cases have been considered, the PV load case with the weight and position of the crew member on-board (PV-crew load case) and SPV load case with the weight and position of the crew member on- board (SPV-crew load case).

2.1. PV Load case.

Figure 1 shows the PV model following the body plan attached at the Patí a Vela Class Rules.

Figure 1: Body plan3 (PV Class Rules) and PV 3D model in Catia V5.



Source: Patí a Vela Class Rules (ADIPAV 2018).

To compute the PV lightweight and its centre of gravity, the weight and centre of gravity of each item are considered according the PV Class Rules. The weight and centre of gravity of the hull is determined considering that the construction material is marine plywood with a density of 440 kg/m^3. The thickness of the different parts of the PV is shown in Table 1 and 17 bulkheads are considered:

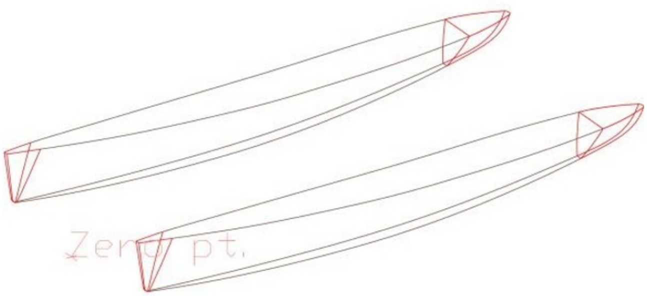
Table 1: Thickness of the different parts of the PV boat.

Item	Thickness (mm)
Hull	5
Deck	7
Bulkhead	5

Source: Authors.

The frame of reference considered is presented in Figure 2, the positive x axis is forward, the positive y axis is starboard and the positive z axis is up.

Figure 2: PV Frame of reference.



Source: Authors.

Finally, the weights and centre of gravity of the lightweight condition is shown in Table 2:

Table 2: Weights and Center of Gravity (CGx: longitudinal, CGy: transversal, CGZ: vertical) (PV load case).

Item	Weight (t)	CGx (m)	CGy (m)	CGz (m)
Hull	0.089	2.87	0	0.35
Mast	0.009	4.51	0	3.1
Rigging	0.001	3	0	2
Sail	0.002	3.27	0	3

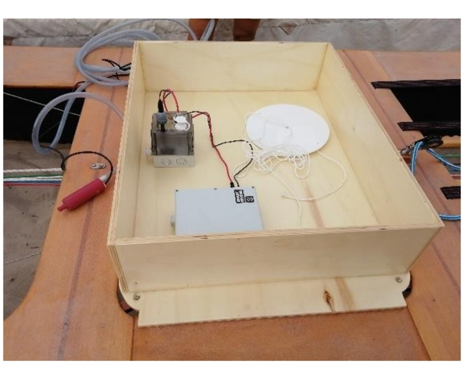
Source: Authors.

The total weight for the PV load case is 101 kg and the position of the centre of gravity is CGx=3.03 m, CGy= 0 m and CGz=0.664 m.

2.2. *Scientific Patí A Vela (Spv Load Case).*

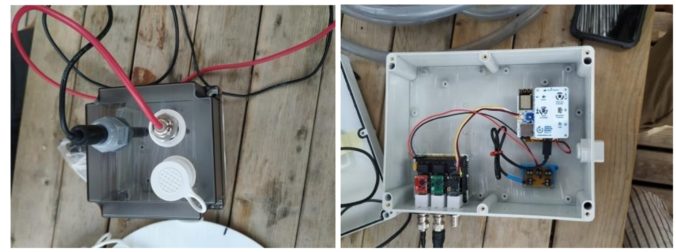
To adapt the PV model, the scientific equipment includes: a sensor box with a sea surface temperature sensor and a conductivity sensor, an electronic box that must be connected with the sensor box, a 12 V battery, a water collector/evacuated tube with pump connected with the sensor box and a Sechhy disk (Figure 3 and Figure 4). All this equipment will be well suited into a platform with a waterproof box and data will be transferred via wireless or mobile data upload with charging capabilities and cloud-based data storage.

Figure 3: Experimental scientific platform.



Source: Authors.

Figure 4: Sensor Box (left) and Electronic Box (right).



Source: Authors.

Table 3 shows the size and the weight of the experimental scientific equipment:

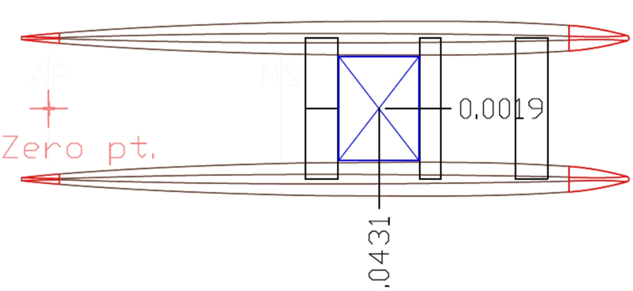
Table 3: Size and weight of the Experimental Scientific Equipment.

Item	Dimensions (cm) [height (z)· depth (x) · width (y)]	Weight (kg)
Battery (12V)	9.2·9.4·14.4	3.94
Electronic Box with Battery (5V)	8 · 17.5 ·22	0.92
Sensors Box (without water)	13 · 13 · 13	0.55
Water Collector/Evacuated tube with pump	-	0.4/0.17
Waterproof Equipment Box	20 · 96 · 74	10

Source: Authors.

Then, the position of the scientific devices has been appropriately positioned for good data collection with the minimal impact on navigation. The platform and the waterproof box must be placed between the second and third beds from the bow, since it is the position with minimum interference with the crew member to trim the PV (Figure 5).

Figure 5: Platform and waterproof box position (SPV load case).



Source: Authors.

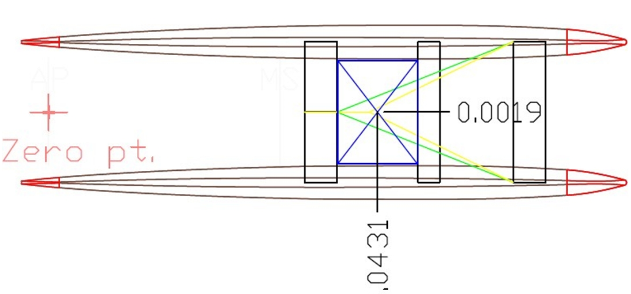
The sampling water will be obtained through the water collector. The box sensor will be filled of sea water and then will be drained through the evacuation tube. For a good data collection, the water must be collected with the minimum turbulences, so the pump must be placed as forward as possible. The collector tube will pass through the waterproof box on the side parallel to the water. It must be taken into account that in this area, there are also the cables to trim the sail (Figure 6).

Figure 6: PV trimming cables.

Source: Authors.

The sail can be trimmed to forward or to aft, therefore the tube collector must be positioned in a location that does not disturb the movement of the cables to trim the sail. As can be seen in Figure 7, the cables to trim the sail are positioned in the maximum forward position (yellow line) and in the maximum aft position (green line). Both configurations have been analyzed in order to decide the position where the tube collector will go through the waterproof box and the position of the different elements that make up the final scientific equipment position at the PV.

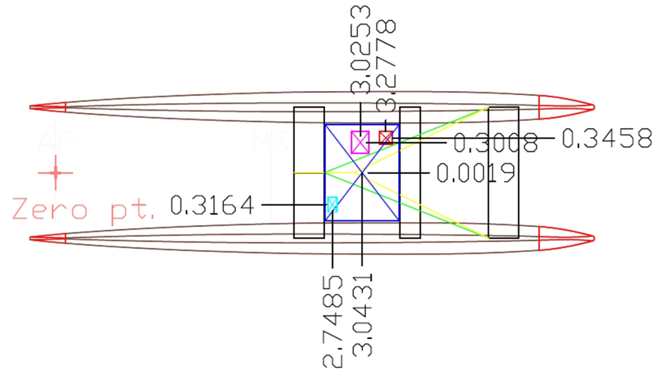
Figure 7: Cables to trim the sail in forward position (yellow line) and aft position (green line).



Source: Authors.

The configuration of the scientific instruments described in Table 3 is presented in Figure 8. The sensor box (red item), is situated in a side, as forward as possible and without interfering with the movement of the trimming cables. The electronic box (pink item) is positioned behind the Sensor Box and in the same side. In order to keep the center of gravity of the PV boat in the plane of symmetry, the position of the Battery (light blue item) is positioned on the other side and as aft as possible.

Figure 8: Scientific instruments configuration.



Source: Authors.

Finally, the centre of gravity and weights for the new load case are shown in Table 4:

Table 4: Weights and Center of Gravity (CGx: longitudinal, CGy: transversal, CGZ: vertical) (SPV load case).

Item	Weight (t)	CGx (m)	CGy (m)	CGz (m)
Lightship	0.101	3.03	0	0.664
Platform and Waterproof Box	0.010	3.043	0.002	0.6
Sensor Box	0.003	3.278	0.346	0.565
Electronic Box	0.001	3.025	0.301	0.540
Battery	0.004	2.749	-0.316	0.572

Source: Authors.

The total weight for the SPV load case is 119 kg and the position of the centre of gravity is CGx=3.023 m, CGy= 0 m and CGz=0.652 m.

2.3. *Pv with crew (Pv-Crew Load Case).*

A new load case has been considered the PV with the crew member on board. The weight of the crew member is 69 kg and it is positioned at CGx=0.5m, CGy=0m and CGz=1m in the fifth bed (see Figure 9). In this case we have considered the crew member is situated in the centreline but, in function of the wind direction, the position of the crew member will change at the starboard or port site.

Table 5: Weights and Center of Gravity (CGx: longitudinal, CGy: transversal, CGZ: vertical) (PV-crew load case).

Item	Weight (t)	CGx (m)	CGy (m)	CGz (m)
Lightship	0.101	3.025	0.000	0.664
Crew member	0.069	0.500	0.000	1.000

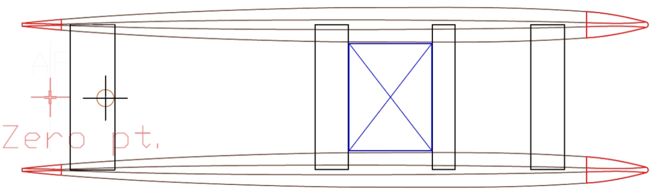
Source: Authors.

The total weight for PV-crew condition is 170 kg and the position of the centre of gravity is CGx=2 m, CGy= 0 m and CGz=0.9 m.

2.4. *Scientific Pv with crew load case (Spv-Crew).*

Finally, a last load case (PV with both scientific platform and crew member on-board) has been considered.

Figure 9: Position of the crew member (orange circle) and position of the waterproof box (blue rectangle) for SPV-crew load case.



Source: Authors.

The total weight for the SPV-crew load case is 188 kg and the position of the centre of gravity is CGx=2.097 m, CGy= 0.001 m and CGz=0.78 m.

3. Results.

Once the design has been modelled, the hydrostatics, stability and the seakeeping performance of described four load cases (PV, SPV, PV-crew and SPV-crew) have been assessed using Maxsurf stability analysis module.

Table 6 shows the hydrostatics particulars of the three described conditions.

Table 6: Hydrostatics particulars (PV: Patí a Vela; SPV: Scientific Patí a Vela; PV-crew: Patí a vela with crew member; SPV-crew: Scientific Patí a Vela with crew member).

Hydrostatics	PV	SPV	PV-crew	SPV-crew
Draft Amidships m	0.109	0.122	0.199	0.210
Displacement t	0.1010	0.1186	0.170	0.188
Heel deg	0.0	0.0	0.0	0.0
Draft at FP m	0.253	0.267	-0.142	-0.173
Draft at AP m	-0.035	-0.023	0.255	0.248
Draft at LCF m	0.167	0.180	0.197	0.207
Trim (+ve by stern) m	-0.288	-0.290	0.114	0.075
WL Length m	4.290	4.449	4.302	4.48
Beam max extents on WL m	1.491	1.499	1.511	1.518
Wetted Area m^2	2.347	2.611	3.487	3.723
Waterpl. Area m^2	1.207	1.298	1.340	1.430
Prismatic coeff. (Cp)	0.558	0.559	0.635	0.629
Block coeff. (Cb)	0.105	0.108	0.120	0.124
Max Sect. area coeff. (Cm)	0.188	0.193	0.198	0.204
Waterpl. area coeff. (Cwp)	0.189	0.195	0.206	0.210
LCB from zero pt. (+ve fwd) m	3.061	3.059	1.982	2.068
LCF from zero pt. (+ve fwd) m	3.000	2.994	2.208	2.299
KB m	0.118	0.126	0.123	0.129
BMt m	5.200	4.766	3.434	3.316
BML m	13.348	13.036	8.805	9.114
KMt m	5.306	4.882	3.556	3.445
KML m	13.436	13.133	8.925	9.241
Immersion (TPc) tonne/cm	0.012	0.013	0.014	0.015
MTc tonne.m	0.003	0.003	0.003	0.004
RM at 1deg = GMt.Disp.sin(1) tonne.m	0.008	0.009	0.008	0.009
Max deck inclination deg	3.8418	3.8738	1.5219	1
Trim angle (+ve by stern) deg	-3.8418	-3.8738	1.5219	1

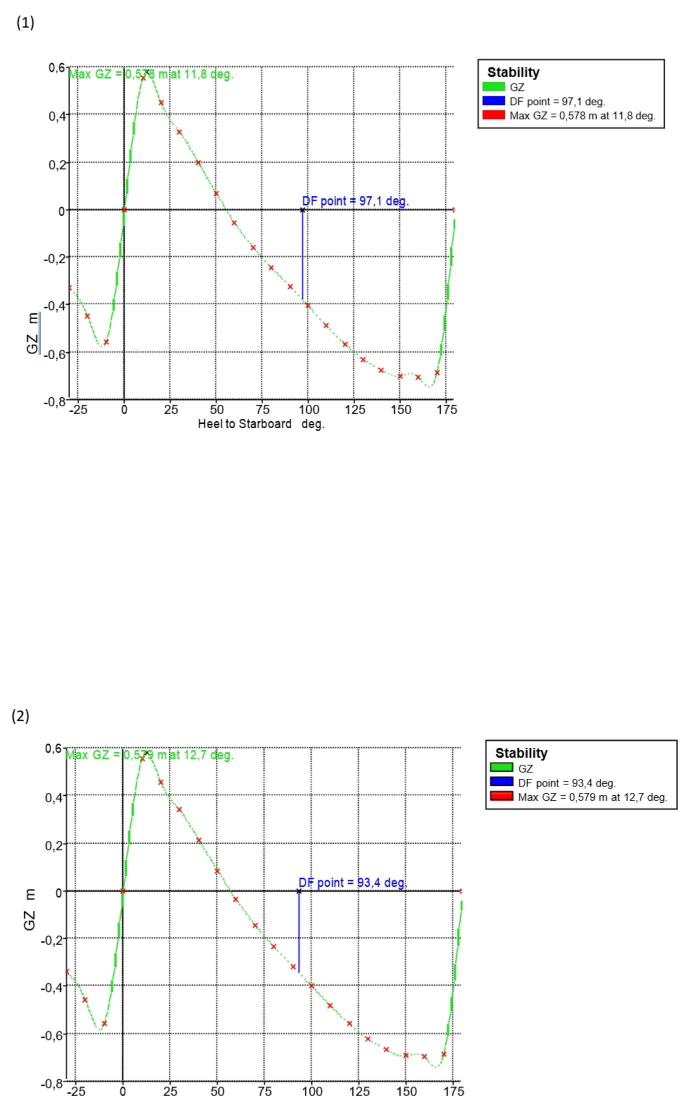
Source: Authors.

Later, the stability criteria (**??**) has been applied to ensure the compliance with the class requirements. The ISO 12217-3:2017 specifies methods for evaluating the stability and buoyancy of intact boats of hull length less than 6 m, whether propelled by human or mechanical power. One important parameter related on initial static stability is the metacentric height (GM). The GM of the four described load cases are calculated as the distance between the vertical centre of gravity and its metacentre being:

$GM_{PV} = 4.642m$, $GM_{SPV} = 4.23m$, $GM_{PV-crew} = 2,756m$ and $GM_{SPV-crew} = 2.665m$.

Another important stability parameter is the statical stability curve (GZ). This curve is a plot of righting arm or righting moment against angle of heel for the given loading condition. Figure 10 shows GZ curve for the four conditions described above.

Figure 10: Statical stability curve (PV: Patí a Vela (1); SPV: Scientific Patí a Vela (2); PV-crew SPV-crew (3): Scientific Patí a Vela with crew member (4)).



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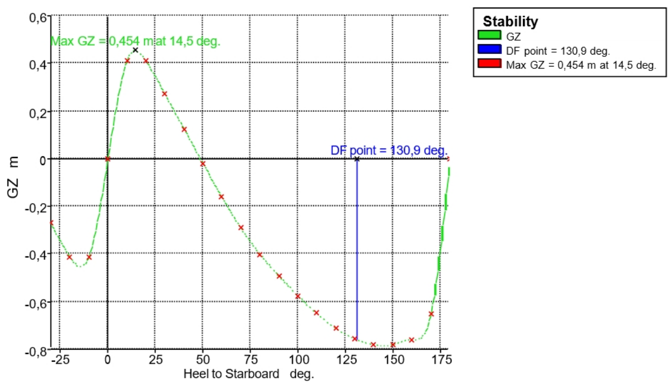
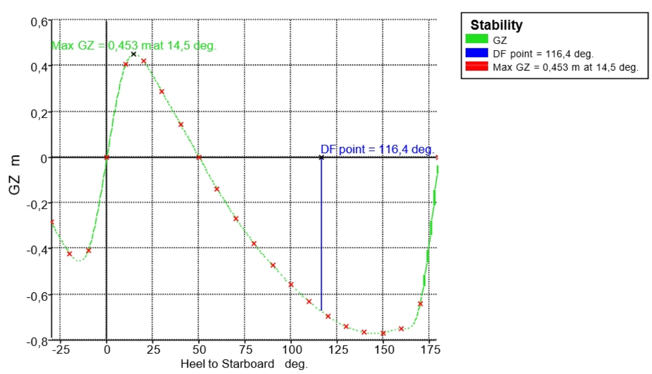


(4)



Source: Authors.

The new stability characteristics according to the metacentric height and large angle stability have been assessed. As can see, the metacentric height is slightly higher in initial PV load case without scientific platform nor crew member on-board and lower in the SPV-crew condition, but this value remains positive and high in the four load cases. Also, from Figure 10, the variation in GZ values are similar in the four load cases and the stability characteristics according the stability criteria ISO 12217-3:2017 are ensured.

Table 7 presents some of the significant parameters related on the stability and seakeeping performance of a ship and also the variation between PV and SPV load cases (with and without crew member). In general terms, these parameters can be described as:

- Metacentric Height (GM): higher metacentric height indicates higher initial static stability.
- Length/Displacement ratio (L/Dis): for a given length, the less the displacement, the better the seakeeping quality is.
- Length/Beam ratio (L/B): the pitch motion increases slightly with an increase of the L/B.
- Longitudinal Centre of Gravity (CGx). The effect of CGx position on ship motion is not so clear. For the head sea condition an increase in heaving motions is observed when the CGx position is located forward. When CGx is moved forward, both pitching motion and relative bow motion are slightly decreased.
- Longitudinal Centre of Buoyancy position (LCB) minus Longitudinal Centre of Flotation position (LCF): Seakeeping response are sensitive to LCB-LCF.

Table 7: Significant parameters on the stability and seakeeping performance for 4 load cases (PV, SPV, PV-crew and SPV-crew).

Parameter	PV	SPV	Variation SPV/PV	PV-crew	SPV-crew	Variation SPV-crew/PV-crew
GM (m)	4.642	4.230	-0.412	2.756	2.665	-0.091
L/Dis (m/t)	42.475	37.513	-4.963	25.306	21.277	-4.029
L/B	2.877	2.968	0.091	2.847	2.635	-0.212
CGx (m)	3.030	3.023	-0.007	2.000	2.097	0.097
LCB-LCF (m)	0.061	0.065	0.004	-0.226	-0.231	-0.005

Source: Authors.

As can be seen in the above table (Table 7), the values between PV and SPV load cases (with and without crew member) are similar, indicating that the stability characteristics and seakeeping performance for all load cases are not affected by the attached scientific platform on-board.

Conclusions.

In the past few years, some recreational activities have been used for data collection and environmental sampling. Thanks to low cost environmental sensors, there is scope to expand the range of environmental indicators that could be measured. In the first stage of this project, physical environmental indicators like temperature, salinity and turbidity will be analysed. Further research will analyse other chemical environmental indicators like oxygen and pH.

In this contribution the first prototype of the Scientific Patí a Vela with an on-board platform with the scientific instruments is presented. Main hydrostatic parameters have been assessed to ensure the stability and seakeeping performance for new three load cases (with crew member and scientific platform on-board). Also, the position of the scientific devices has been appropriately positioned for good data collection with the minimal impact on navigation. Results indicate that the stability and seakeeping performance will not be affected with an on- board platform with scientific instruments. However, the attachment of the scientific on-board platform would also influence the ship manoeuvrability. Therefore, manoeuvring prediction of these load cases should be taken into account during the Scientific Patí a Vela design step in further research.

Next steps of this project will show the first observations taken with the Scientific Patí a Vela from a Barcelona coastal zone, which will be about 4-5 km long and between 0.4 and 2.4 km wide. All data will be freely available thanks to the development of an open-access interactive web where data will be incorporated and retrieved.

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