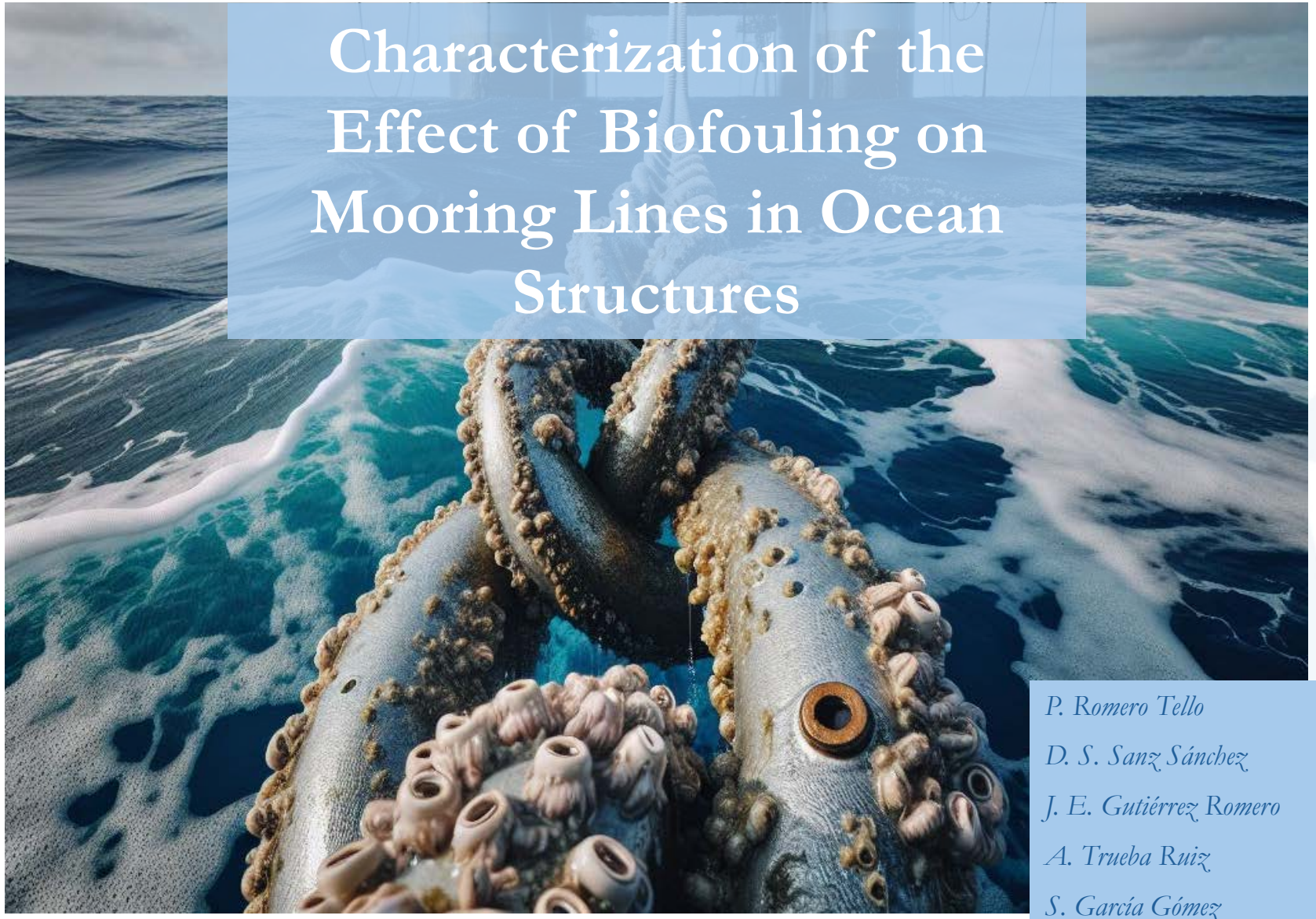
Characterization of the Effect of Biofouling on Mooring Lines in Ocean Structures



64º Congreso Internacional de Ingeniería Naval e Industria Marítima
Gijón 26-28 de marzo de 2025

P. Romero Tello	*E T S de Ingeniería Naval y Oceánica [UPCT]*
D. S. Sanz Sánchez	*E T S de Ingeniería Náutica [UC]*
J. E. Gutiérrez Romero	*E T S de Ingeniería Naval y Oceánica [UPCT]*
A. Trueba Ruiz	*E T S de Ingeniería Náutica [UC]*
S. García Gómez	*E T S de Ingeniería Náutica [UC]*
A. J. Lorente López	*E T S de Ingeniería Naval y Oceánica [UPCT]*

Universidad Politécnica de Cartagena MEMBER OF EUT+ EUROPEAN UNIVERSITY OF TECHNOLOGY

CONTENTS

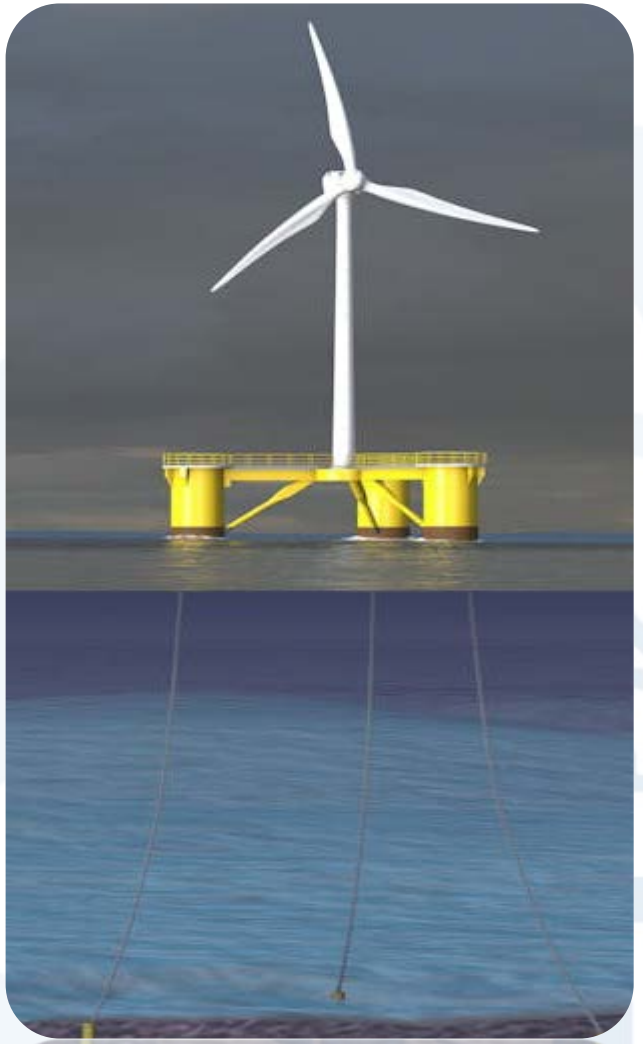
I. INTRODUCTION

- Marine growth, known as biofouling, is a common phenomenon on moored offshore platforms.
- This process involves the accumulation of marine organisms such as algae, mollusks, and crustaceans on submerged surfaces, which can significantly impact the operation and maintenance of these structures.
- This accumulation alters various hydrodynamic parameters of the structure and the mooring itself.

- This study examines how biofouling will affect the mooring system of the HiPRWind platform.

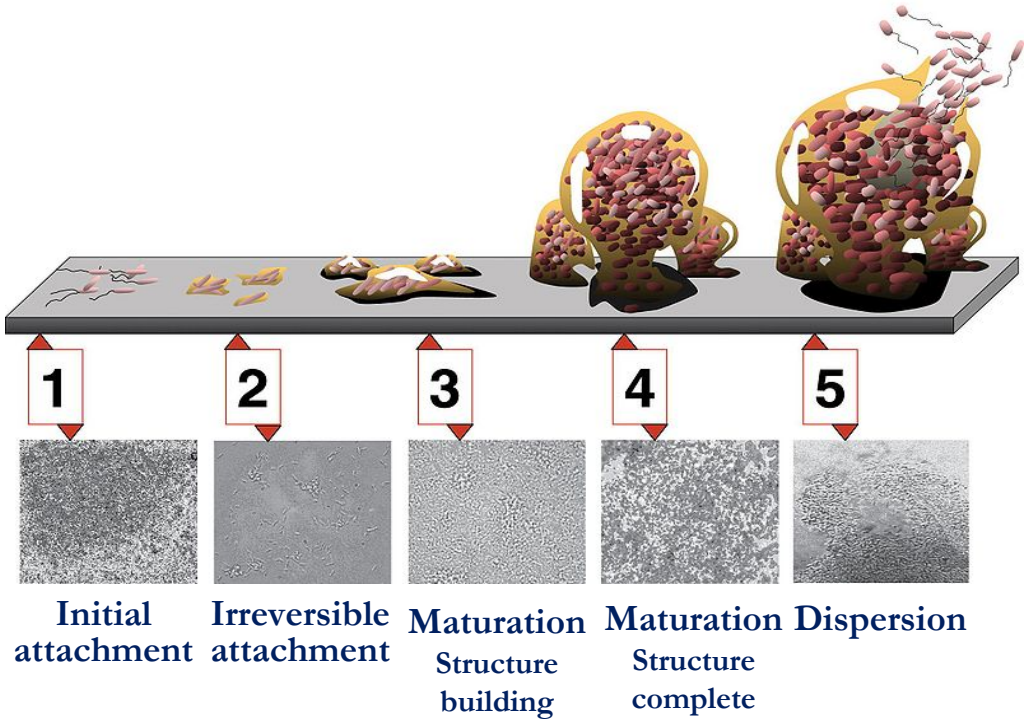
II. OBJECTIVES

- **Evaluate** the increase in mass and sectional area in both the mooring system and the platform.
- **Analyze** the variation in the drag coefficient of the chain due to biofouling.
- **Stress analysis** under two wave conditions, survival and operational, for different levels of biofouling growth.
- Determine the **maximum excursions** under both wave conditions, survival and operational, according to the degree of biofouling growth.



III. METHODOLOGY

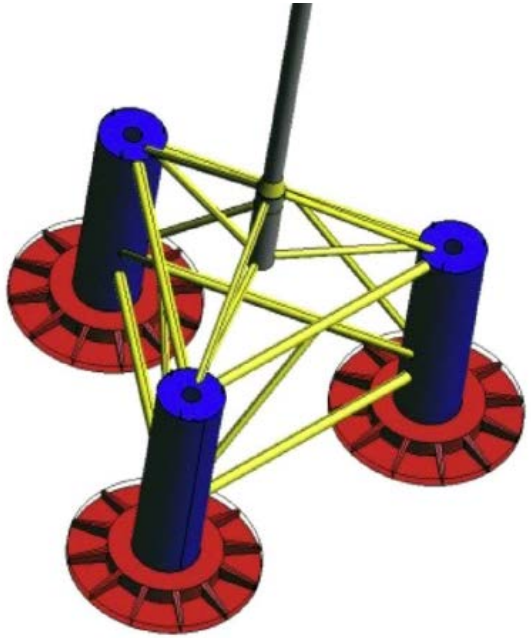
Platform → Marine growth → Transformation of the platform → • Stress • Excursions

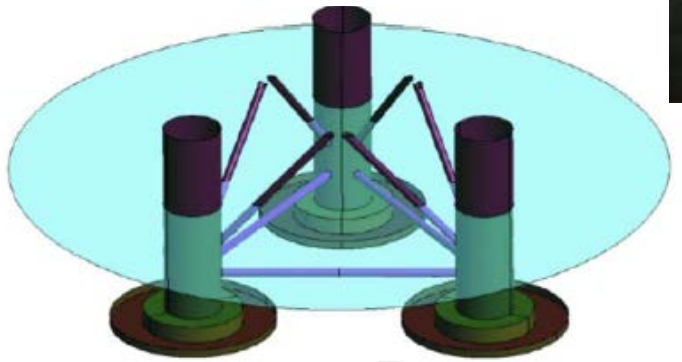


Wave Spectrum Operational Areas

- The variation in biofouling thickness over 15 years of mooring is analyzed.
- In the mooring lines, the following parameters are varied: drag coefficient [CD], weight [We], and diameter [De].
- On the platform, the mass is varied, and the diameter of the pontoons is increased.

IV. APPLICATION CASE. HiPRwind

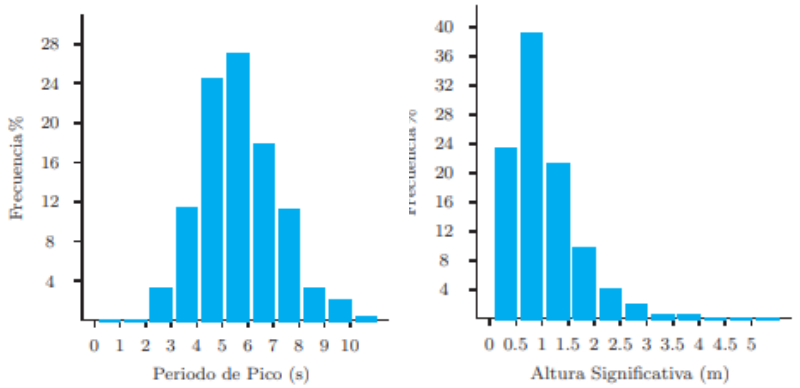




Characteristics	Unit	Value
Depth	m	80.00
Draft	m	15.50
Distance between column centers	m	35.00
Column diameter	m	7.00
Heave plates diameter	m	20.00
Displacement. Δ	t	2390.00
XG	m	0.00
YG	m	0.00
ZG	m	-4.46
GM	m	5.95
XB	m	0.00
YB	m	0.00
ZB	m	-9.02
Roll radius of gyration. R_{xx}	m	22.38
Pitch radius of gyration. R_{yy}	m	22.38
Yaw radius of gyration. R_{zz}	m	22.38

IV. APPLICATION CASE. Operational area

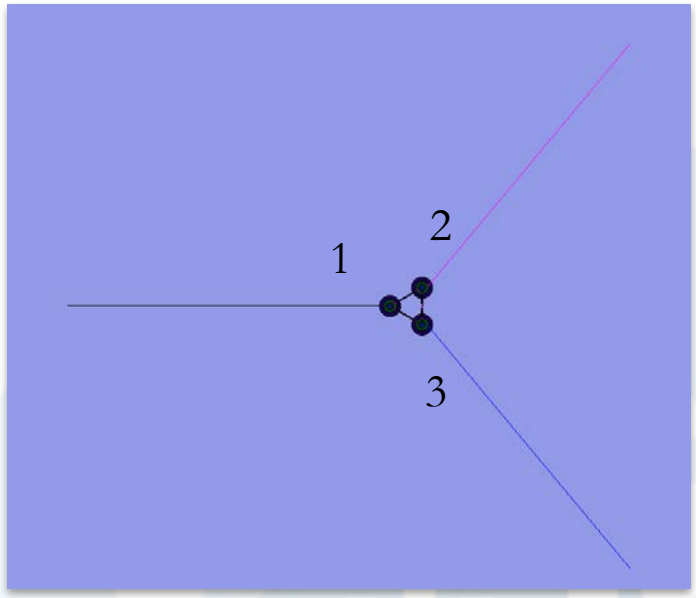
Bouy of Cabo de Palos



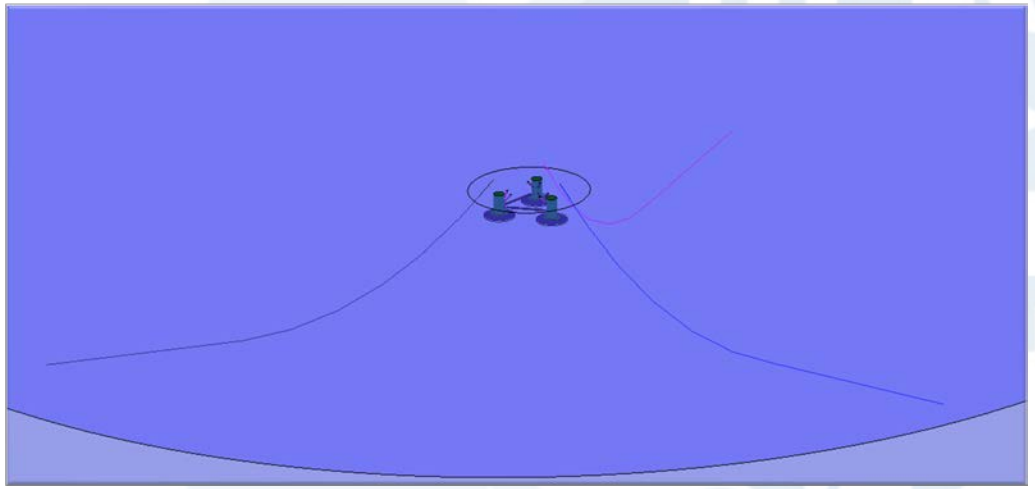
Zone	Mediterranean sea	
Tr [years]	1	100
Hs [m]	4.93	7.59
Tp [s]	8.98	10.69
Heading - spreading	0 - 60	
Type	Jonswap	

IV. APPLICATION CASE. Mooring characteristics

Parameter	Value
Nº mooring lines	3
Length	300 m
Section	1.32 x 10^{-2} m^2
Equivalent Young modulus	5.72 x 10^{10} Pa
Linear weight in water	1453 N/m

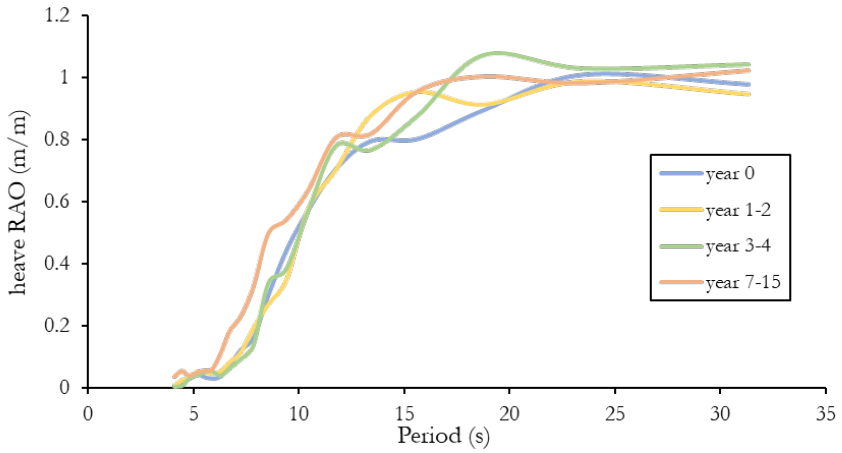


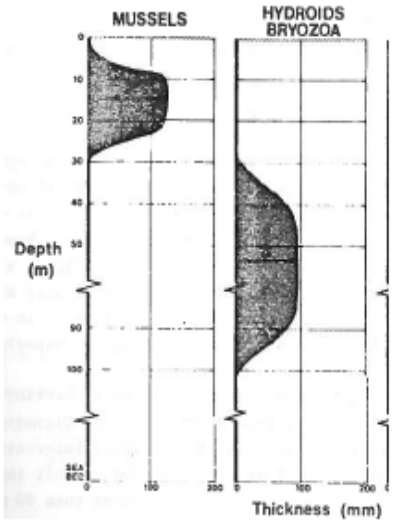
	Fairlead point [m]	Anchor point [m]
Line 1	[-325.73; 0.00; -80.00]	[-23.73; 0.00; 10.00]
Line 2	[206.79; -248.00; -80.00]	[15.24; -18.17; 10.00]
Line 3	[206.79; 248.00; -80.00]	[15.21; 18.17; 10.00]



IV. APPLICATION CASE. Biofouling characteristics

Depth [m]	Thickness [mm]	Roughness [mm]	Density [Kg/m^3]
2< D > -40	100	20	1330
D<-40	50		



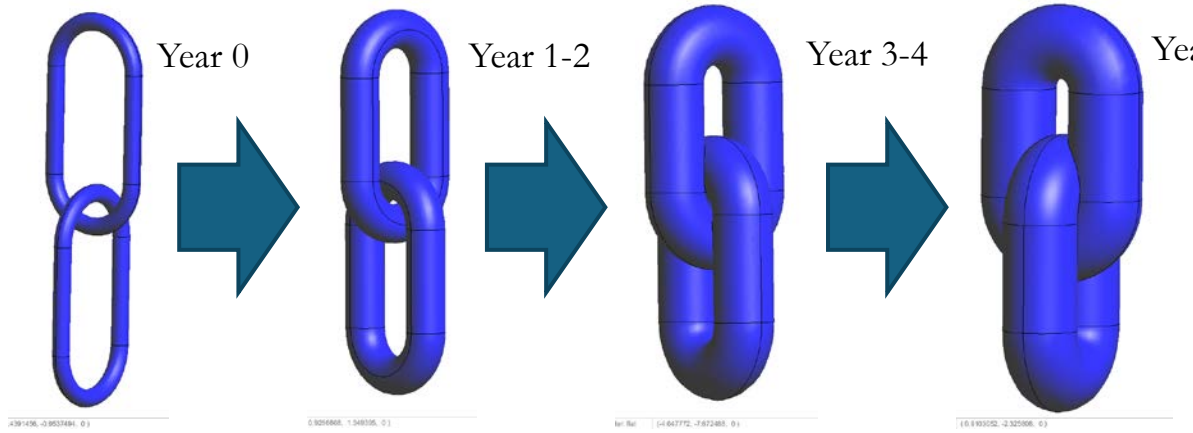


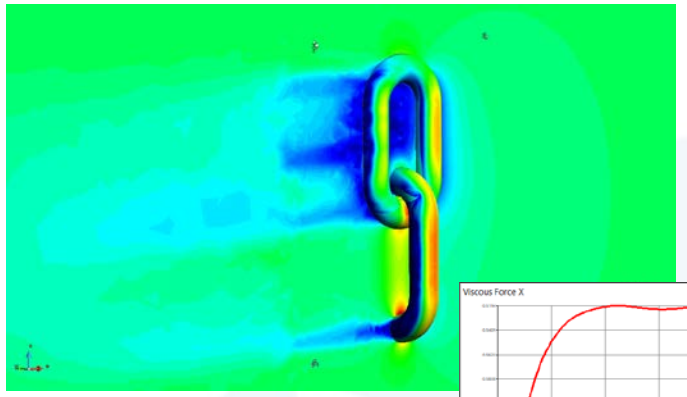
Indicative thickness of fouling [mm]

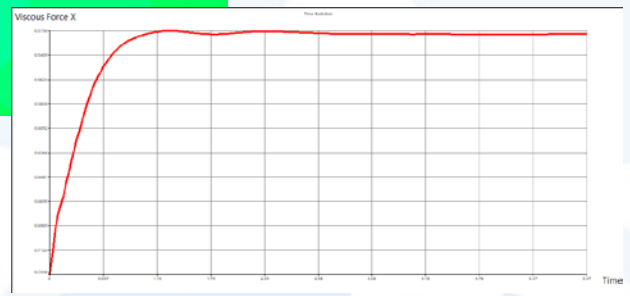
	Depth [m]	Years 1-2	3-4	7-8	12-15
Mussels	0-30	80	150	200	200
Hydoids Bryozoa	30-100	30	90	110	110

		Years	0	1-2	3-4	7-15	
Mooring	0-30 [m]	Sectional area	1.32	6.60	14.51	22.04	[x10^{-2} m^2]
		We	1453	2141	3173	4157	[N/m]
	30-80 [m]	Sectional area	1.32	2.82	4.15	4.90	[x10^{-2} m^2]
		We	1453	1649	1821	1920	[N/m]
Columns		Sectional area	39.02	40.82	42.42	43.58	[m^2]
		Biofouling mass	0	↑ 4.5	↑ 8.3	↑ 10.8	%

IV. APPLICATION CASE. Viscous forces on mooring line

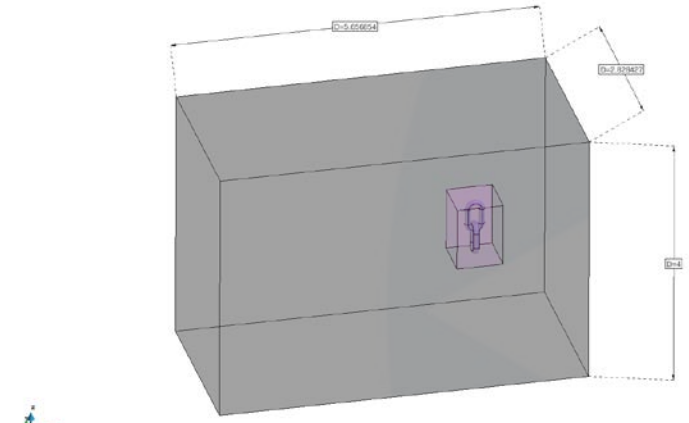


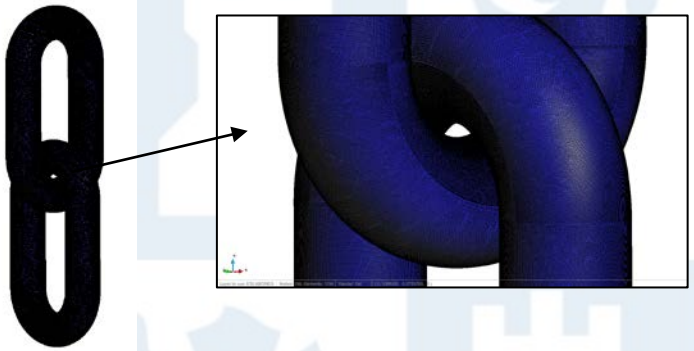




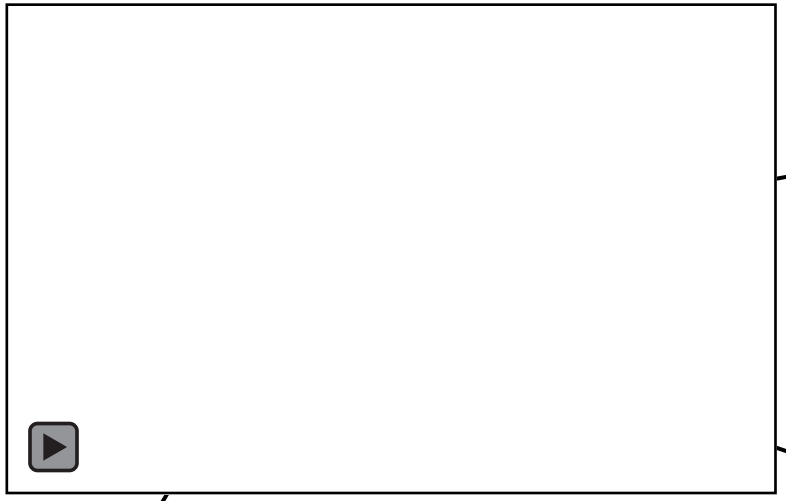
	Year 0	Year 1-2	Year 3-4	Year 7-15
Drag coefficient [CD]	0.43	0.78	1.18	1.73

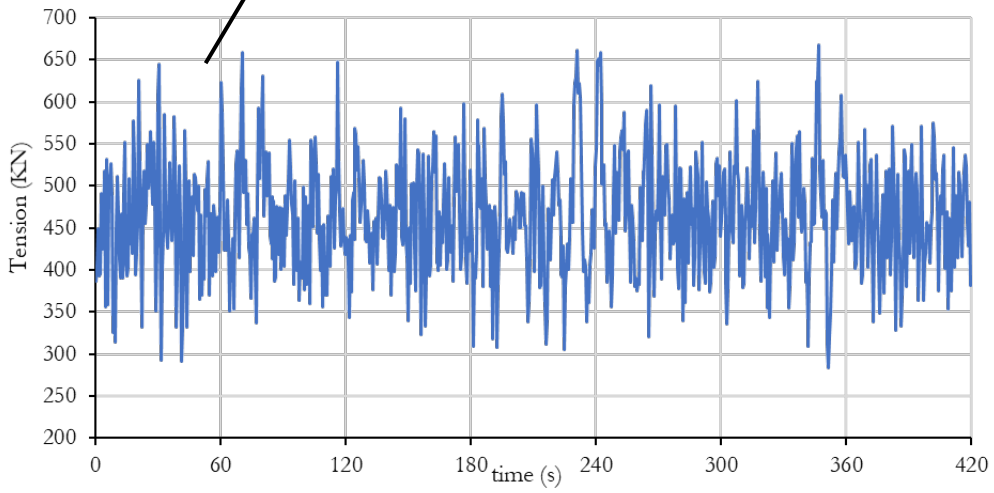
	Value	Units[m]
Computational Domain	5.6 x 4 x 2.8	m
Elements number [10^6]	12.3	-
Turbulence Model	$k-\omega$	-
Time step	..001	s



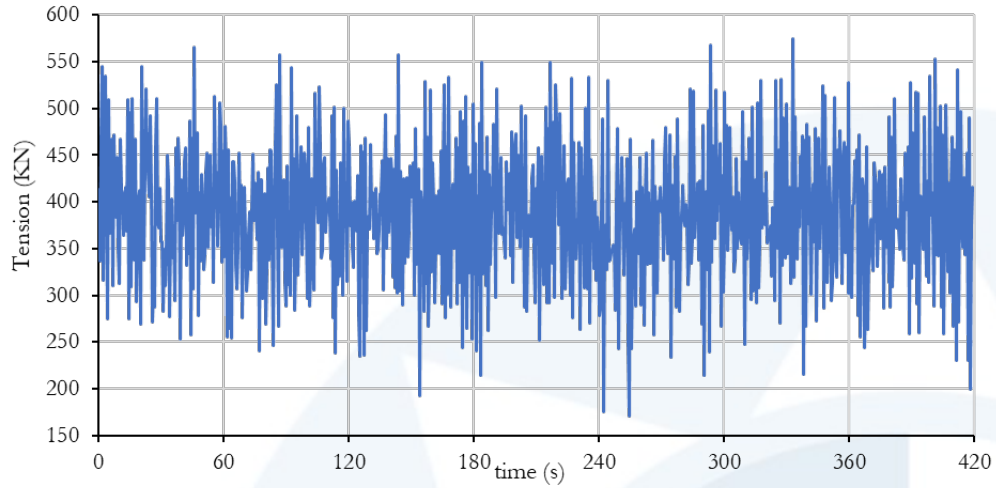


IV. APPLICATION CASE. Tension under operational condition

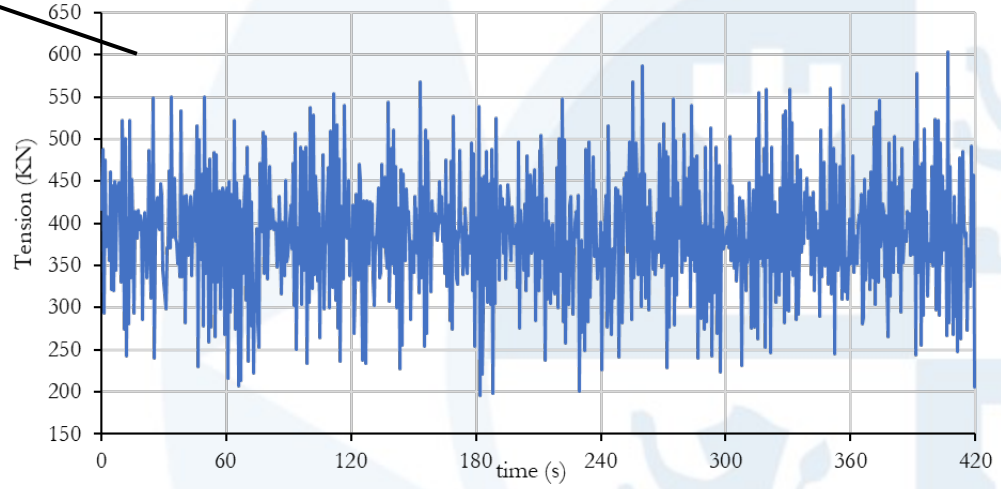




674 KN



578 KN

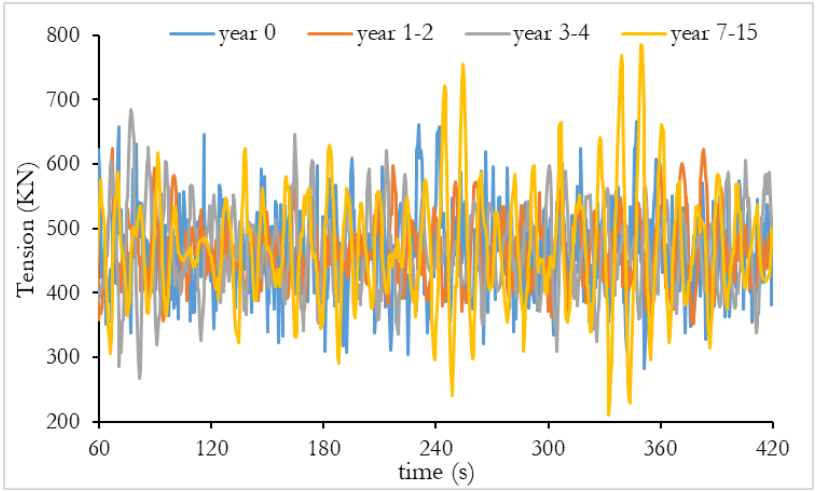


611 KN

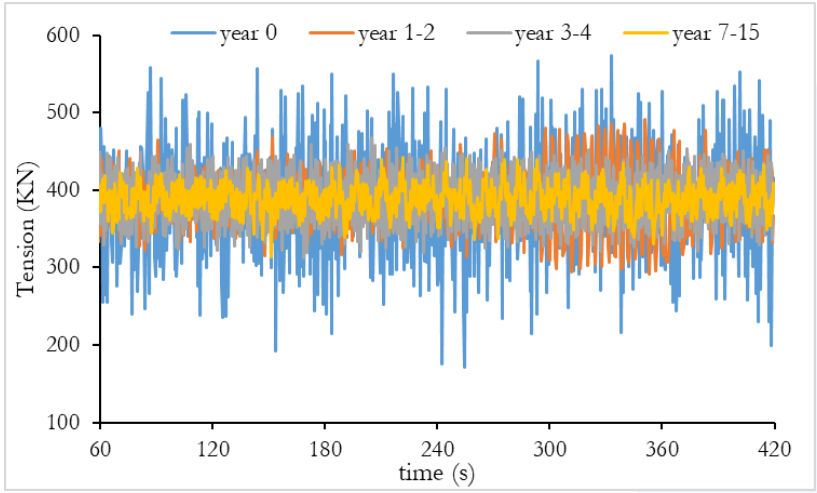
IV. APPLICATION CASE

Stress analysis under operational conditions

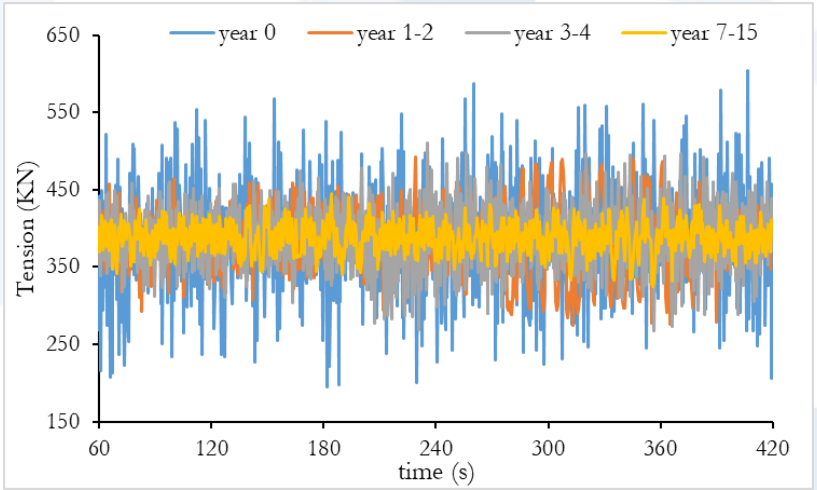
Line 1



Line 2



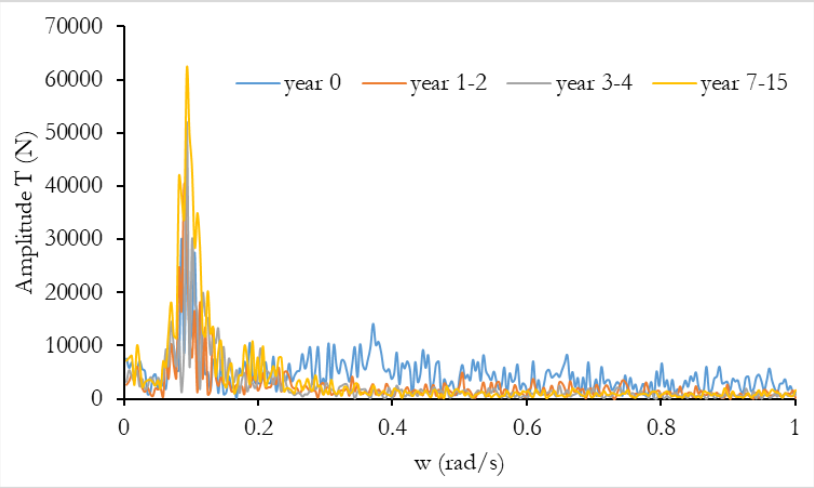
Line 3



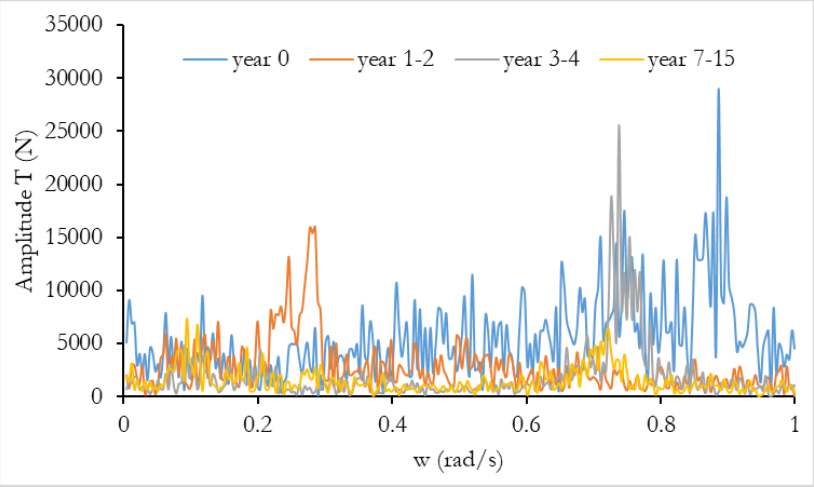
IV. APPLICATION CASE

Stress analysis under operational conditions

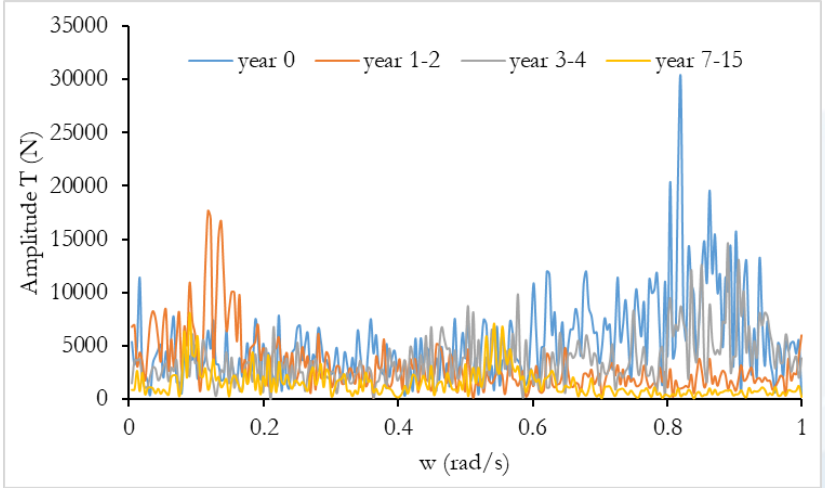
Line 1



Line 2



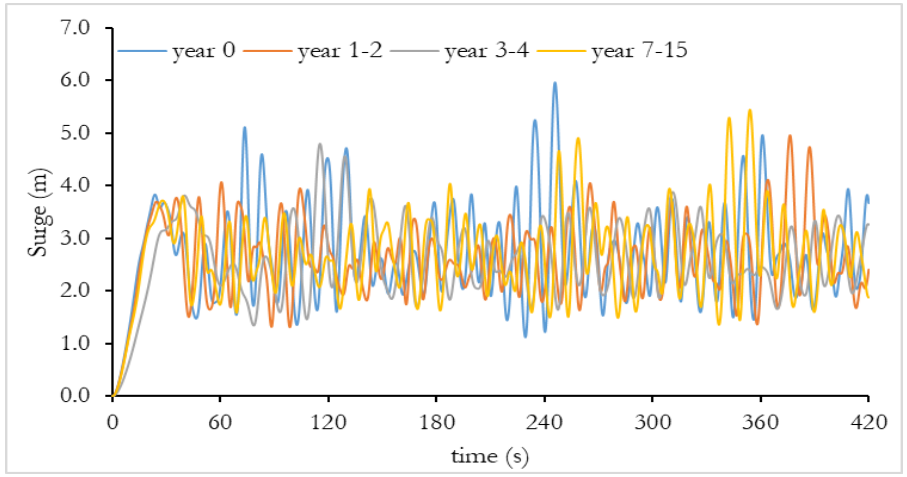
Line 3

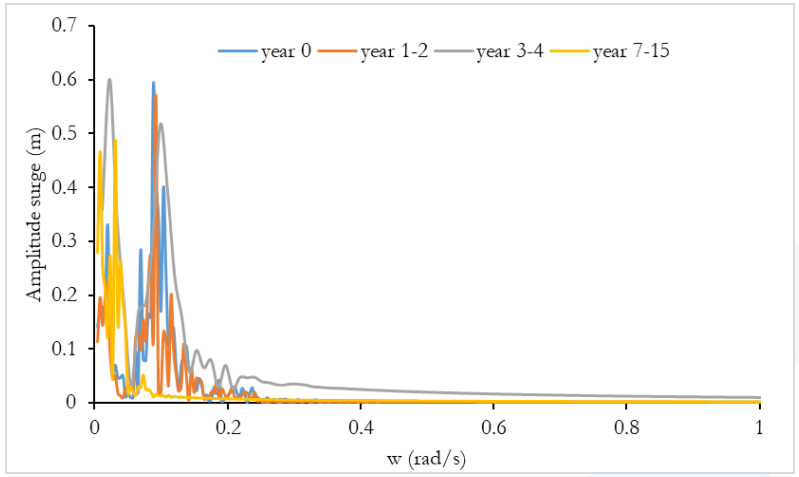


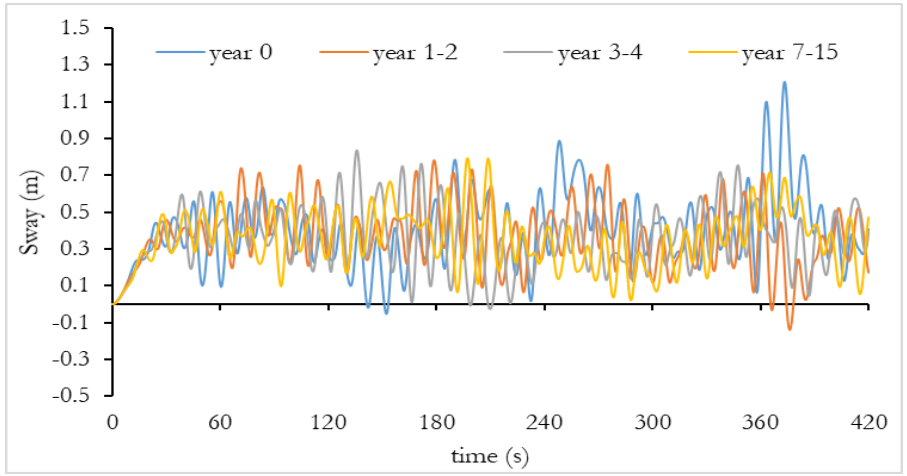
		Years			
	Tension [KN]	**0**	**1-2**	**3-4**	**7-15**
Line 1	Maximum	5.86	6.63	8.72	10.16
	Significant	3.13	3.55	4.66	5.43
Line 2	Maximum	4.87	3.46	2.63	2.57
	Significant	2.60	1.85	1.41	1.38
Line 3	Maximum	5.22	4.78	2.67	2.40
	Significant	2.79	2.55	1.43	1.28

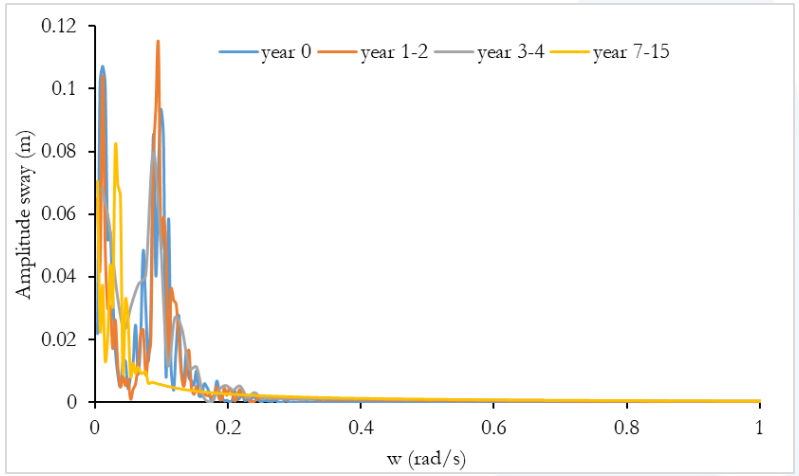
IV. APPLICATION CASE.

Excursions under operational conditions







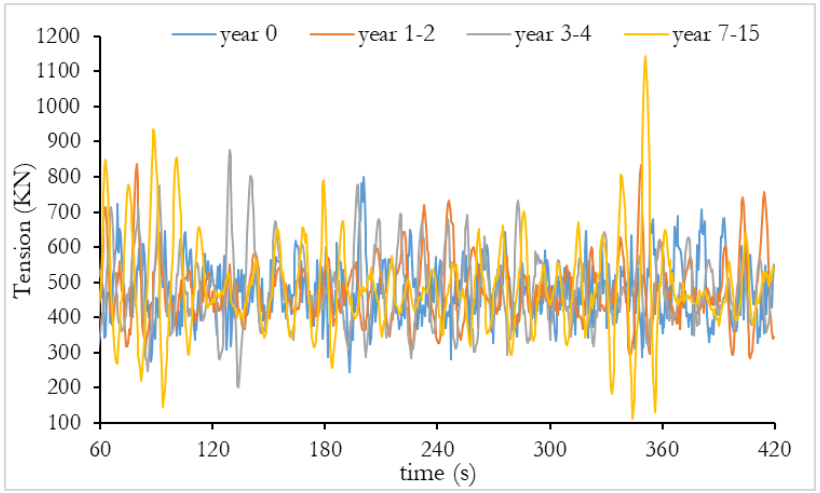


		Surge [m]		Sway [m]	
		Max.	Sig.	Max.	Sig.
Years	0	0.611	0.327	0.270	0.144
	1-2	0.495	0.265	0.282	0.151
	3-4	0.648	0.346	0.193	0.103
	7-15	0.495	0.265	0.257	0.137

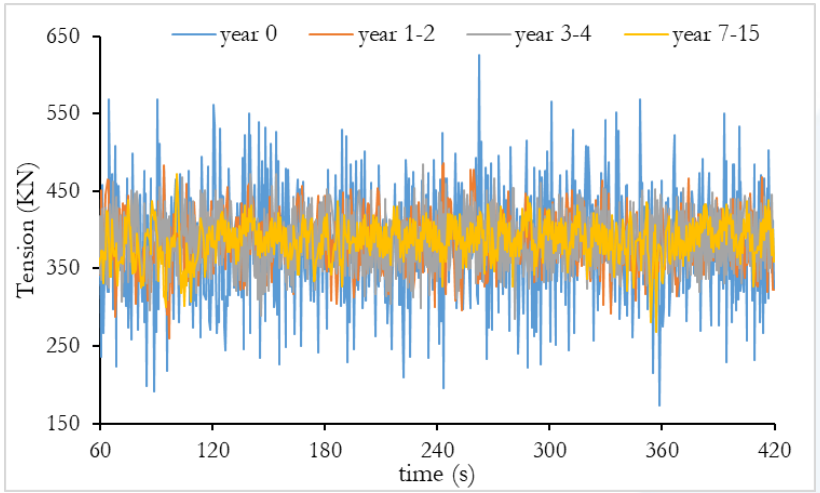
IV. APPLICATION CASE

Stress analysis under survival conditions

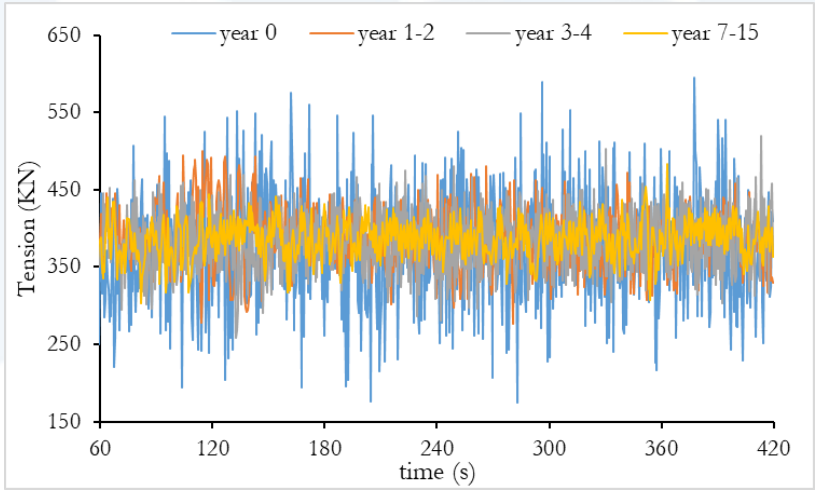
Line 1



Line 2



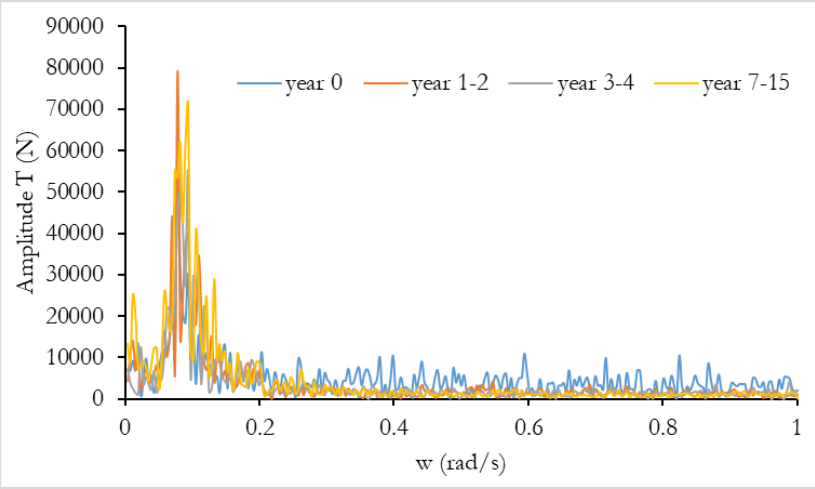
Line 3



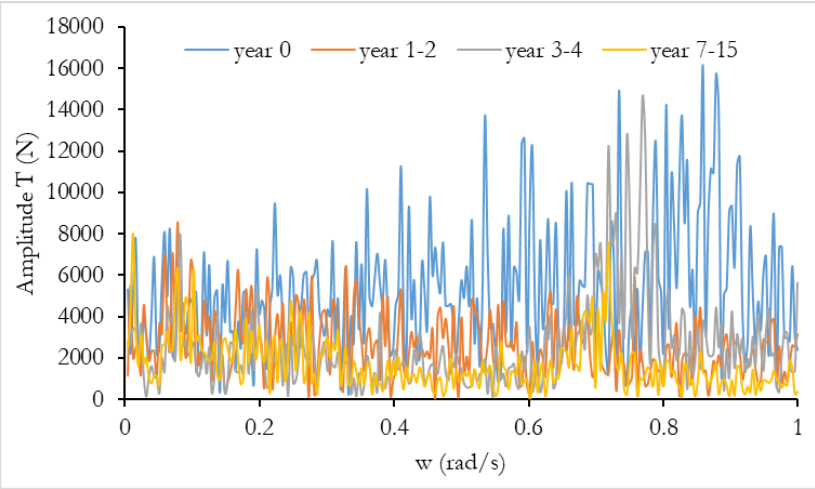
IV. APPLICATION CASE

Stress analysis under survival conditions

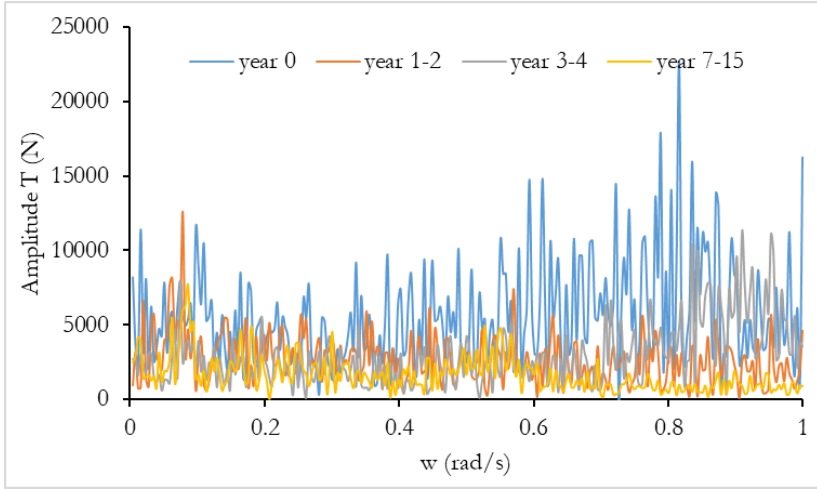
Line 1



Line 2



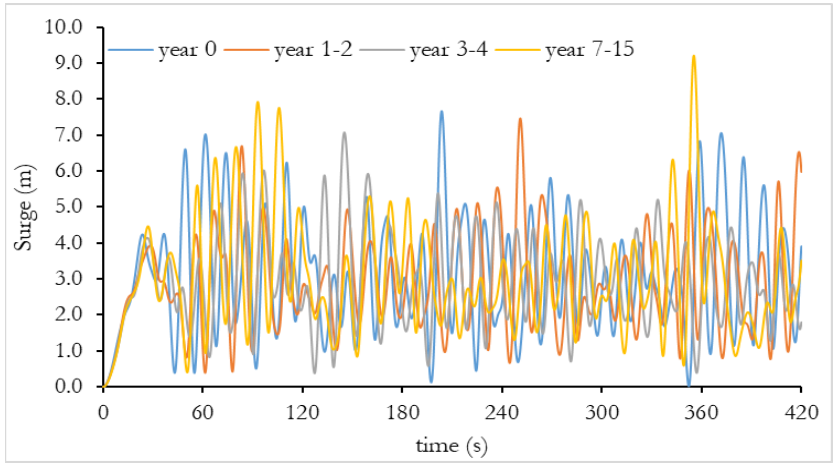
Line 3

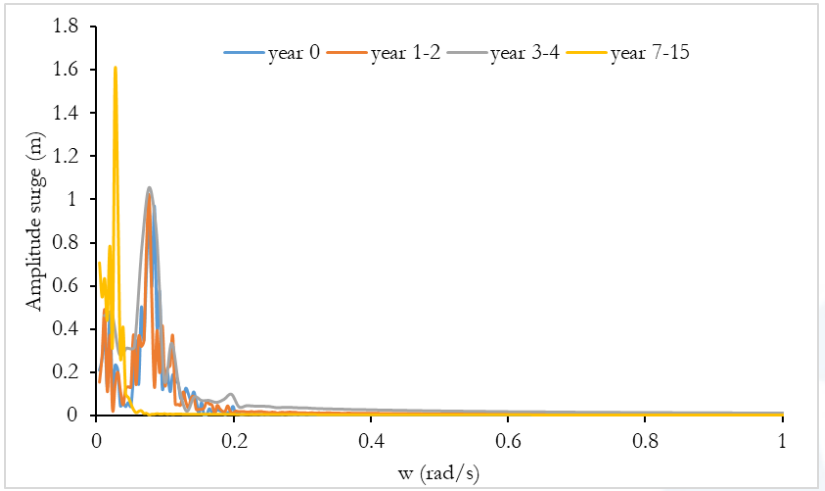


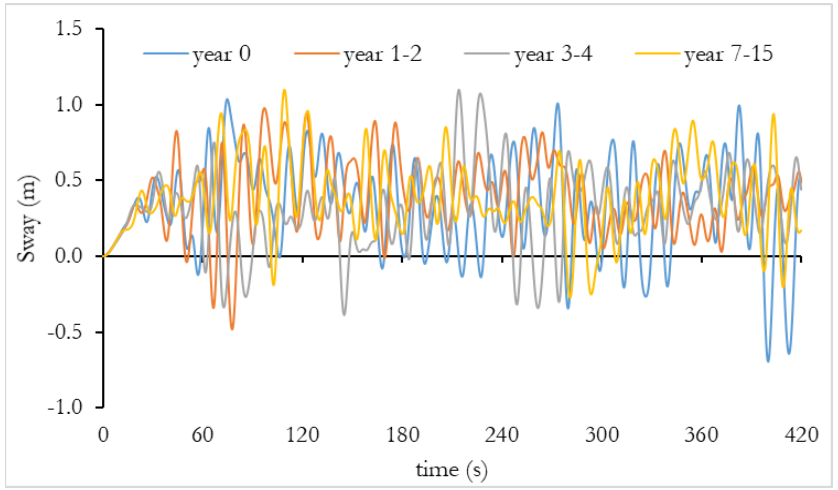
		Years			
	Tension [KN]	**0**	**1-2**	**3-4**	**7-15**
Line 1	Maximum	7.00	8.27	9.57	11.31
	Significant	3.74	4.42	5.12	6.05
Line 2	Maximum	5.06	4.75	3.16	2.90
	Significant	2.71	2.54	1.69	1.55
Line 3	Maximum	4.99	4.70	3.14	2.70
	Significant	2.67	2.51	1.68	1.44

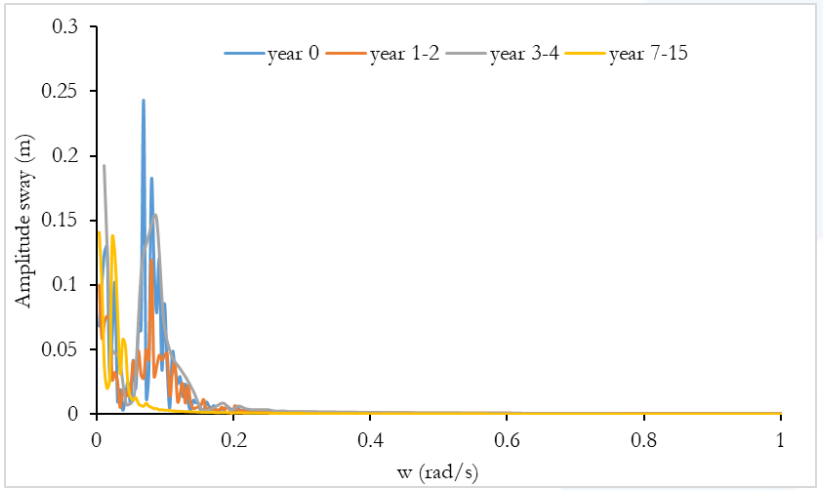
IV. APPLICATION CASE

Excursions under survival conditions







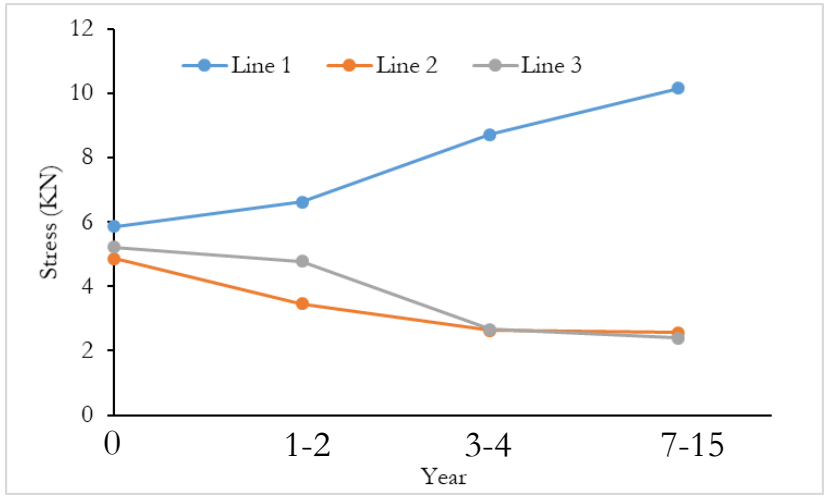


		Surge [m]		Sway [m]	
		Max.	Sig.	Max.	Sig.
Years	0	0.783	0.419	0.364	0.195
	1-2	0.811	0.434	0.301	0.161
	3-4	0.717	0.383	0.243	0.130
	7-15	0.635	0.340	0.246	0.132

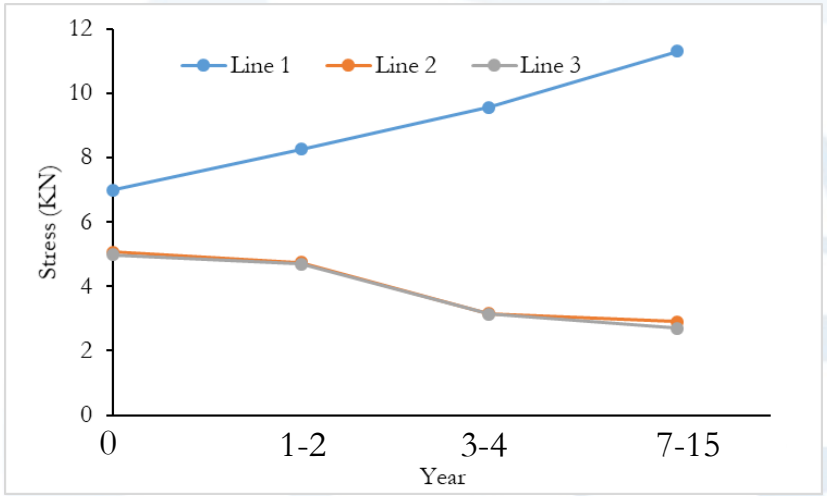
VI. DISCUSSION

		Years	0	1-2	3-4	7-15	
Mooring	0-30 [m]	Sectional area	1.32	↑ 80 %	↑ 91 %	↑ 94 %	[x10^{-2} m^2]
		We	1453	↑ 47 %	↑ 48 %	↑ 31 %	[N/m]
	30-80 [m]	Sectional area	1.32	↑ 53 %	↑ 68 %	↑ 73 %	[x10^{-2} m^2]
		We	1453	↑ 13	↑ 10	↑ 5	%
Columns		Biofouling mass	0	↑ 4.5	↑ 8.3	↑ 10.8	%

Operational condition



Survival condition



VI. CONCLUSIONS

- This study is an **initial analysis**. The **difficulty** of simulating seakeeping variation due to biofouling has been detected. This study only considers wave order efforts and drift forces. It would be necessary to add the effect of the current and second-order waves.
- It is **important** to analyze and characterize the variation of the mooring and platform parameters due to **biofouling**.
- It is observed that the **maximum tension** at the fairlead point increases as biofouling increases.
- In the study of **maximum excursions**, it would be important to introduce the effects of the current and second-order waves.

THANKS FOR YOUR ATTENTION

pablo.romero@upct.es

Questions?