JOURNAL OF MARITIME RESEARCH

Vol XIX. No. II (2022) pp 1–7

ISSN: 1697-4840, www.jmr.unican.es

Evolution of the profile of alleged offending vessels producers of illegal discharges in spanish waters

Andrés Ortega Piris[1,*], Emma Díaz Ruíz de Navamuel[1], Alberto Muñoz Amor[1], Carlos Pérez Labajos[1]

ARTICLE INFO

Article history:
Received 4 Oct 2021;
in revised from 29 July 2022;
accepted 31 July 2022.

Keywords:
illegal discharges, AOV, GINI indices.

ABSTRACT

In 2015, the first study was published on the construction of the profile of what came to be called the "Alleged Offending Vessel" (AOV), in order to verify the characteristics of the vessel that allegedly pollutes the most intentionally and furtively, taking into account aspects such as the type of vessel, its flag and the navigation area. The study was carried out with data on traffic and detected cases of illicit discharges during the five-year period 2008-2012 that took place in Spanish SAR territorial waters. The results of this work were conclusive: "the AOV profile corresponded to a passenger ship, sailing through the Mediterranean Sea and which was registered in an open registry."

In the present work, which covers the following five-year period 2013-2017, the study is repeated for the same areas. This study consists of two parts. First, a comparative analysis is made between the data from the first five years and that of the second five, and then, using the GINI indices of inequality and the associated Lorenz curves as a tool, the profile of the polluting vessel will be determined again and it will be verified whether this is the same or if it has changed over time. Additionally, the study will serve to evaluate the consequences of the use of the different methods of detection of cases of deliberate marine pollution from vessels, specifically aerial and satellite surveillance. The results obtained will provide an accurate picture of the effectiveness of the system and the evolution of the AOV profile.

Research works currently continues collecting data for the 2018-2021 period, in order to follow the evolution of the behavior and profile of the alleged offending vessels.

1. Introduction.

Since 2007, the Spanish authorities have used three specially equipped aircraft to combat marine pollution (Alpers, Holt and Zeng, 2017), capable of detecting any type of illicit discharge and also of gathering and processing the information necessary for the Spanish maritime administration to be able to proceed to identify and sanction the perpetrator.

Currently, decarbonisation and sustainability feature as general objectives within the Strategic Framework of the Spanish National Rescue and Safety Plan. This is why the Spanish maritime service has committed to continuing with the great effort in aerial and satellite surveillance of marine pollution carried out in recent years and to study its adaptation to the new challenge of marine litter. The current Spanish system of prevention, rescue and fight against pollution is a system committed to sustainable development, which is continuously adapting in order to face the new challenges stemming from the advances in technology, from constantly evolving legal requirements, from new commitments acquired in the EU and with neighboring countries and those that are ever more in demand from a society that is more and more concerned about the cleanliness of the seas and coasts. The ultimate goal of these new challenges is a cleaner marine environment, for which effective monitoring of the marine environment (Fingas and Brown, 2018) and spill identification (Dahlmann and Kienhuis, 2015) is essential.

The first time a study was made on the performance of the system, it took in the period 2008-2012 (Martín Alonso, Ortega

[1]University of Cantabria, Ocean and Coastal Planning and Management R&D Group.

*Corresponding author: Andrés Ortega Piris. E-mail address: andres.ortega@unican.es. C/Gamazo 1, 39004 Santander, Spain.

Piris and Pérez Labajos, 2015). This study established and defined the term “Alleged Offending Vessel” (AOV) as *that vessel that has been identified, through the Spanish aerial detection system, as a potential polluter by means of illicit discharges of hydrocarbons, to which the Spanish maritime administration may subsequently initiate sanctioning proceedings charging them for the said discharge.* In the same study, the term “illicit discharge” was defined as *that which is made in contravention of the International Convention for the Prevention of Pollution by vessels of the IMO, known as MARPOL* (IMO, 2017)(Uddin and Karim, 2018)

The aim of the 2012 study was twofold: on the one hand, to undertake an assessment of the efficiency of the detection system and, on the other hand, to establish the profile or stereotype of the AOV, in order to be able to contribute to the development of national prevention policies, national action policies and to serve as a tool for mapping resources in the most efficient way possible (Purwendah, Mangku and Periani, 2019).

As a result of this work, taking into account the spatial (navigation area), functional (class of vessel) and administrative (vessel’s flag status) aspects, it was determined that:... the profile of the alleged offending ship (AOV) corresponded to a passenger vessel, sailing through the Mediterranean Sea and that is registered in an open registry (...) and that the effectiveness of the aerial surveillance system was verifiable from its start-up, as well as constituting an effective deterrent.

After another five-year period (2013-2017), and after numerous studies carried out on pollution in the Mediterranean (Carpenter, 2016) (Amir, 2017) (Alves et al., 2016) (Alves et al., 2015), it was necessary to verify the effect of the dissuasive measures and the discharge detection plan on the behaviour of the total fleet in the area of the Spanish SAR territorial waters. That is, in the same scenario, to repeat the study on the type of AOV and the rates of alleged infractions in order to carry out a comparison between the data from the first five years and that from the second, which will provide a clear picture of the suitability or not of the investment and the methods used.

In the last year of the study, Maritime Rescue carried out surveillance with its airplanes and satellites of over 159 million km^2 of sea, a surface area equivalent to 313 times that of the national territory. Today, the Spanish maritime authorities are firmly on the path towards the use of unmanned aircraft for the surveillance and control of marine pollution.

2. Methodology.

Three will be the number of methodologies applied in the present study. The first consists of a comparative study of the data obtained between the two periods of time analysed, in order to then, following the guidelines of the first study, use the Gini indices as a method of analysis of the concentration or inequality and the associated Lorenz curves (Gastwirt.Jl, 1971), a methodology widely described in (Martín Alonso et al., 2015) since, as has been shown, it is a tool that has been used successfully in the analysis of marine pollution by illegal discharges.

$$PII = \left(\sum_{i=1}^{k-1}(p_i - q_i)\right) \Big/ \left(\sum_{i=1}^{k-1} p_i\right)$$

Gini Coefficient of concentration of alleged offending vessels.

Finally, a more disaggregated analysis will be made for the same variables, by formalising the rates of potential offending vessels, both by type of vessel, by area and by flag.

Table 1 shows the variables to be used in the elaboration of the concentration indices. These are the population variables that might potentially have committed an offense, out of the total traffic, and those of the alleged offending population, which have already been verified as real pollution data. The variable, GT, (gross registered tonnage) will be the proxy variable for the size of the vessels, since this variable weights the magnitude of the infringement, given that normally the amount of illicit discharge carried out by vessels is closely linked to their tonnage: the larger the vessel, the greater the amount of waste. This is why the concentration analysis based on Gini inequality indices and represented in the corresponding Lorenz curves will refer exclusively to this variable.

Table 1: Variables used in the construction of Alleged Offending Vessel: inequality indices.

G^a	Potential Offending Traffic Population Variable $X(t)^b$		Alleged Offending Traffic Population Variable $OX(t)^c$	
	$V(t)$	$GT(t)$	$POV(t)$	$POGT(t)$
1	$V_1(t)$	$GT_1(t)$	$POV_1(t)$	$POGT_1(t)$
...	...	...	...	...
i	$V_i(t)$	$GT_i(t)$	$POV_i(t)$	$POGT_i(t)$
...	...	...	...	...
k	$V_k(t)$	$GT_k(t)$	$POV_k(t)$	$POGT_k(t)$
Total	$\sum_{i=1}^{k} V_i(t)$	$\sum_{i=1}^{k} GT_i(t)$	$\sum_{i=1}^{k} POV_i(t)$	$\sum_{i=1}^{k} POGT_i(t)$

Source: Author.

In Table 1, the first column with the superscript “a” shows the groups of variables. Specifically, there are three used in the study: one for the type of vessel (container ship, oil tanker, bulkcarrier, passenger, general cargo, chemical tanker, Roll on/ Roll-off, reefer and others), another for the areas studied (coastal strip of the Mediterranean Sea, Strait of Gibraltar, Canary Islands and Finisterre) and the last one for the flag groupings (the 15 countries of the European Union, countries of the rest of the OECD, open or convenience registries and countries of the rest of the world) . The next two columns with the superscript “b” correspond to the data of the variables of the total population of potential offending vessels: number of vessels (V) and size (GT), in a given period. Finally, the third group of columns with the superscript “c” corresponds to the same variables, but in this case of the AOV population in the same period.

The expression that determines the average rate of alleged infringements of a population variable X, of fleet i of group G, in a period t, is given by the following equation:

$$PR/X_i(t) = [OX_i(t)/X_i(t)] * 1000 \quad (1)$$

where:

PR /Xi (t) = rate of alleged offenses of the population variable X (nº of vessels and y GT) of fleet i of group G, in the period t, per thousand.

3. Data.

As in the previous work, the data used for the period 2013-2017 are those obtained in the Rescue Coordination Centres (RCC) of the Spanish coast, located in the Strait of Gibraltar (RCC Tarifa), in Cabo de Gata, which is located in the southeastern end of the Iberian Peninsula (RCC Almería), in Cape Finisterre (RCC Finisterre) and in the two that are found in the Canary archipelago, specifically on the island of Tenerife (RCC Tenerife) and on the island of Gran Canaria (RCC Las Palmas). Research works currently continues collecting data for the 2018-2021 period, in order to follow the evolution of the behavior and profile of the alleged offending vessels.

Following the order established for the database for the 2008-2012 period, the data has been structured in the same way, by type and subtype of vessel, according to its characteristics (length, beam, gross tonnage, load capacity or dead weight, age and registration), type of flag, according to the origin and destination ports, with navigation data (course and speed) and RCC monitoring.

The data on the volume of traffic by type of vessel, area and flag represented in Table 2 show the population that will be considered as the total number of potential AOVs, both in number of vessels (V) and in tonnage (GT). In the third column, the value of the variation of the data between the two periods studied is shown as a percentage.

At the same time, data on real cases of detection of pollution sources have been obtained, providing us with information on the AOVs detected in the area of Spanish territorial waters. The database created for these vessels incorporates, in addition to the same data as the traffic data, the list to which it belongs (according to the criteria of the Paris Memorandum), the means used to detect the discharge (by satellite or from an aerial medium) and finally, the method of selection of the AOV used (backtracking technique or infraganti detection).

Table 3 shows that data of the number of AOV detected in the first and second periods of the study, by type of vessel, area and flag.

4. Results.

Once the traffic and AOV data bases were processed, the next step was to address the calculation of the AOV inequality indices for the period 2013-2017 by number of vessels (V) and their size (GT) for the groupings of types of vessel, area and flag, by means of the application of the methodology described above and their representation in the corresponding associated Lorenz curves. The final indices are listed by year and grouping in Table 4.

[a] Alleged Offending Vessel inequality indices for the total traffic in Spanish SAR waters

Table 2: Comparison of data on traffic and GT by type of vessel, area and flag.

	TRAFFIC (V)			TONNAGE (GT, in thousands of tons.)		
	2008-2012	2013-2017	%	2008-2012	2013-2017	%
CONTAINER	150,977	106,338	-29.6	6,249	5,824	-6.8
TANKER	121,020	95,530	-21.1	4,735	3,978	-16.0
BULKCARRIER	97,131	75,784	-22.0	2,826	2,327	-17.7
PASSENGER/FERRY	178,942	137,474	-23.2	2,053	1,938	-5.6
GENERAL CARGO	188,167	157,991	-16.0	1,246	1,499	20.3
CHEMICAL	56,317	44,008	-21.9	599	472	-21.2
ROLL ON/ROLL OFF	22,095	23,905	8.2	448	1,034	130.8
REEFER	17,960	7,704	-57.1	159	77	-51.6
OTHERS	50,944	18,304	-64.1	1,059	71	-93.3
MEDITERRANEAN	174,808	115,729	-33.8	4,512	3,540	-21.5
STRAIT	467,364	341,819	-26.9	8,893	7,529	-15.3
CANARY ISLANDS	42,091	30,824	-26.8	1,349	1,114	-17.4
FINISTERRE	199,290	178,666	-10.3	4,620	5,037	9.0
EU15	224,159	172,547	-23.0	5,233	4,247	-18.8
ROECD	33,993	24,833	-26.9	929	733	-21.1
OR	417,276	359,670	-13.8	9,091	9,327	2.6
RW	208,125	109,988	-47.2	4,121	2,913	-29.3
TOTAL	**883,553**	**667,038**	**-24.5**	**19,374**	**17,220**	**-11.1**

Source: Author.

Table 3: Comparison of AOV data by vessel type, area and flag.

	AOV			AOV GT (in thousands of tones)		
	2008-2012	2013-2017	%	2008-2012	2013-2017	%
CONTAINER	48	18	-62.5	1,865	919	-50.7
TANKER	27	9	-66.7	842	603	-28.4
BULKCARRIER	53	18	-66.0	1,413	518	-63.3
PASSENGER/FERRY	100	56	-44.0	5,461	3,606	-33.9
GENERAL CARGO	80	11	-86.2	792	56	-92.9
CHEMICAL	111	122	9.9	1,528	1,423	-6.9
ROLL ON/ROLL OFF	33	6	-81.8	893	118	-86.7
REEFER	16	2	-87.5	151	11	-92.8
OTHERS	23	10	-56.5	32	15	-52.5
MEDITERRANEAN	345	209	-39.4	9,379	6,134	-34.6
STRAIT	22	8	-63.6	430	266	-38.2
CANARY ISLANDS	55	16	-70.9	1,452	464	-68.0
FINISTERRE	69	19	-72.5	1,577	406	-74.3
EU15	101	71	-29.7	3,040	2,289	-24.7
ROCDE	24	5	-79.2	267	21	-92.0
RA	219	167	-23.7	6,836	4,850	-29.0
RM	147	9	-93.9	2,836	110	-96.1
TOTAL	491	252	-48.7	12,977	7,269	-44.0

Source: Author.

Table 4: Alleged Offending Vessel concentration indices by vessel type, area and vessel's flags.

Year	PII[a] by Vessel type		PII[a] by Area		PII[a] by vessel's flag	
	V[b]	GT[c]	V[b]	GT[c]	V[b]	GT[c]
2013	-0.357758	-0.406859	-0.870592	-0.741653	-0.113558	-0.102623
2014	-0.533240	-0.421455	-0.99887	-0.800960	-0.144472	-0.214095
2015	-0.434723	-0.489965	-0.75383	-0.724697	-0.087589	-0.148512
2016	-0.600125	-0.731064	-0.99614	-0.864590	-0.144818	-0.167284
2017	-0.700169	-0.413274	-0.75795	-0.781977	-0.141557	-0.130382

Source: Author.

[b] Alleged Offending Vessel inequality indices by number of ships sailing in Spanish SAR waters

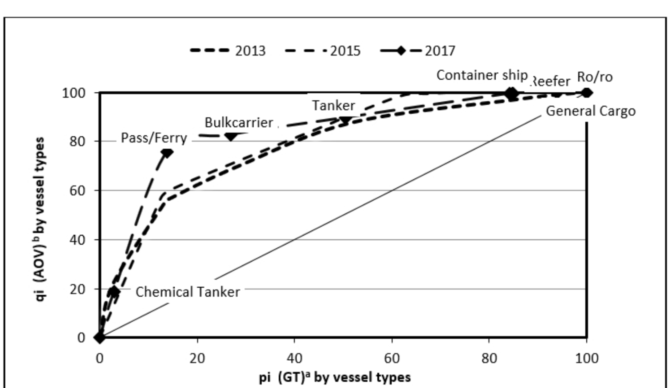
[b] Alleged Offending Vessel inequality indices by GT of the ships sailing in Spanish SAR waters

Finally, the calculation was made of the average rates of AOV, again by the different types of vessels as a function of their size (Table 5), area (Table 6) and flag (Table 7). In order to provide a clearer picture of the trends taking place in these last years, the variation in the rates between the periods 2008/2012 and 2013/2017 have been included in these three tables.

4.1. By type of vessel.

The values for the concentration indices as a function of the size of the different types of vessels and their GT remain almost constant throughout the period analysed, with a value of around 0.4, as from the year 2014 onwards around 75% of the GT of the AOV detected is concentrated in 14% of the GT of the total population analysed, this concentration being centred on chemical tankers and passenger/ferry vessels. It is noteworthy that 22% of the AOV which make up 3% of the population are chemical tankers (Fig.1). Bear in mind that the chemical tanker group includes product tankers and that the Passenger/ferry group includes both large cruise ships and regular line ferries.

Figure 1: Lorenz curves for Alleged Offending Vessels by vessel type. (a) % accumulated of GT; (b) % accumulated de GT of AOV.



Source: Authors.

In contrast, oil tankers, container ships, reefers general cargo and Ro-Ro vessels and others account for less than 10% of the AOV while they make up 50% of the population studied.

The highest rates of AOV for the period 2013-2017 are registered by chemical tankers (3.02‰) and passenger vessels (1.86 ‰), all other types being below 0.22%, this value corresponding to bulkcarrier type vessels (Table 5).

Table 5: Rates of AOV by vessel types and GT.

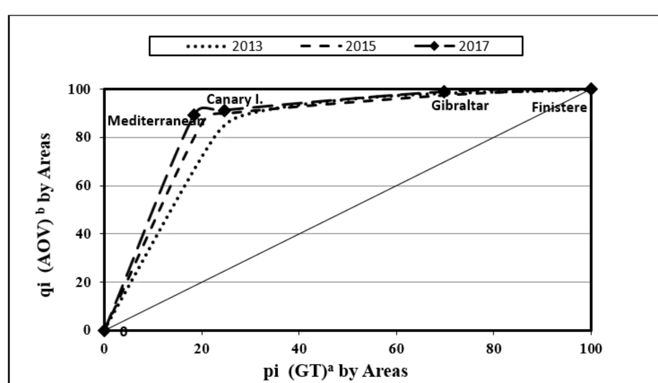
Vessel types	Rates of AOV by vessel types and GT 2013/2017 and Variation in periods 2008/2012 – 2013/2017							
	2013	2014	2015	2016	2017	Total 2013/2017	Total 2008/2012	Variation
Container	0.1323	0.2409	0.2517	0.0026	0.1598	0.1578	0.2985	-0.1407
Tanker	0.3622	0.1982	0.0000	0.0292	0.1637	0.1515	0.1778	-0.0263
Bulkcarrier	0.4480	0.0237	0.2362	0.1123	0.2848	0.2225	0.5000	-0.2775
Passenger/ferry	1.4795	1.7198	1.3854	1.8766	2.8644	1.8606	2.6596	-0.7990
General cargo	0.1119	0.0095	0.0216	0.0266	0.0207	0.0374	0.6356	-0.5982
Chemical	3.7062	3.9704	0.8066	2.9410	3.5455	3.0173	2.5477	0.4696
Roll on/Roll off	0.0793	0.0000	0.0509	0.4383	0.0000	0.1146	1.9954	-1.8808
Reefer	0.0000	0.5770	0.0000	0.0000	0.1064	0.1474	0.9530	-0.8056
Other	0.7180	0.0000	0.3019	0.0097	0.1235	0.2119	0.0301	0.1817
Average	**0.4753**	**0.4225**	**0.3056**	**0.3595**	**0.5483**	0.4222	0.6699	-0.2477

Source: Authors.

4.2. By area.

The Gini indices remain within the range of 0.74 to 0.86 for all of the years of the period 2013-2017 as a function of the area and the GT of the AOV, 85% of the AOV being concentrated in approximately 20% of the traffic analysed, which corresponds to the traffic that sails through the Mediterranean (Fig.2).

Figure 2: Lorenz curves for Alleged Offending Vessels by areas. (a) % accumulated of GT; (b) % accumulated of GT of AOV.



Source: Authors.

As for the total rates of AOV as a function of their GT and navigation area, the highest rate is to be found in the Mediterranean area with a value of 1.73 for every 1000 vessels monitored, although a spike can be observed in 2017 which makes this value rise to 2.6, the zone with the lowest rate, in contrast, being the Strait of Gibraltar, with a value of 0.03‰ (Table 6).

Table 6: Rates of AOV by areas and GT 2013/2017 and Variation in periods 2008/2012 – 2013/2017.

Areas	Rates of AOV by GT							
	2013	2014	2015	2016	2017	Total 2013/2017	Total 2008/2012	Variation
Mediterranean	1.6848	1.5245	1.3094	1.5941	2.6545	1.7328	2.0786	-0.3459
Strait of Gibraltar	0.0315	0.0000	0.0510	0.0000	0.0928	0.0353	0.0484	-0.0130
Canary Islands	0.6408	0.8410	0.2213	0.1711	0.1784	0.4166	1.0758	-0.6592
Finisterre	0.1204	0.0849	0.0263	0.1544	0.0195	0.0805	0.3414	-0.2609
Average	0.4753	0.4225	0.3056	0.3595	0.5484	0.4222	0.5460	-0.1239

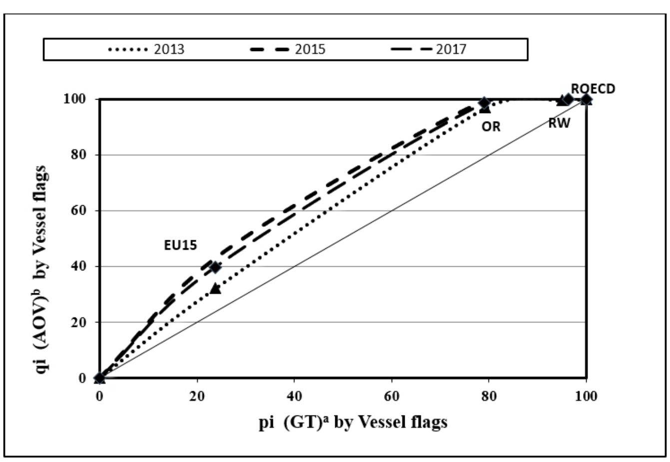
Source: Authors.

4.3. *By flag.*

The results for the concentration indices of the AOV as a function of their flag and GT range between 0.1 and 0.2, very low values reflecting a low concentration of AOV in all flags and a maximum inequality.

The same occurs with the AOV results in relation to their number, the lowest index found being 0.08 in 2015 and the highest being 0.14 in 2014, 2016 and 2017 (Table 4).

Figure 3: Lorenz curves for Alleged Offending Vessels by flags. (a) % accumulated of GT; (b) % accumulated of GT de AOV.



Source: Authors.

Over the five years of the period studied, the concentration of AOV is polarised in vessels with EU15 and OR flags, constantly and maintaining the values, so much so that 78% of the vessels studied belong to this group of flags, accounting between them for 98% of the AOV.

As can be seen in Table 7, the values of the AOV rates show a reduction for all types of vessels, very slight in the case of vessels with an EU15 flag, significant in those with OR and ROECD flags and very pronounced in vessels with an RW flag.

Table 7: Rates of AOV by flags and GT 2013/2017 and Variation in periods 2008/2012 – 2013/2017.

Flags	Rates of AOV by GT							
	2013	2014	2015	2016	2017	Total 2013/2017	Total 2008/2012	Variation
EU15	0.6422	0.2504	0.5416	0.3688	0.9169	0.5388	0.5810	-0.0422
ROECD	0.0454	0.0319	0.0000	0.0399	0.0235	0.0290	0.2870	-0.2580
OR	0.1126	0.6644	0.3101	0.4820	0.5824	0.5200	0.7519	-0.2319
RW	0.0790	0.0195	0.0132	0.0383	0.0420	0.0377	0.6880	-0.6503
Average	0.4753	0.4225	0.3056	0.3595	0.5483	0.4222	0.6699	-0.2477

Source: Authors.

5. Discussion.

With the data from the last period studied, 2013-2017, we can ascertain which type of vessel, which area and which flag concentrated the most AOV and we can thus undertake a study comparing the data with those of 2008/2012. The results of this study will allow us to verify whether the means employed to fight illicit pollution in Spain have been, and are, effective and whether the behaviour of certain vessels has changed or not.

5.1. *By vessel type.*

A first reading of the absolute data (Table 2) shows the decrease in traffic and GT for all types of vessels, clearly as a consequence of the global economic crisis suffered at that time and its subsequent recovery period. This trend has not been reflected in the data for Ro/Ro vessels, as they have increased significantly both in number and tonnage.

The decrease in the number of reefer vessels (-57%) and container ships (-30%) is particularly striking, but even more so is that of those vessels included in the group "others" which takes in dredgers, fishing boats, tugboats, rescue vessels and warships, etc., which fell by 64%.

A curious case is that of general cargo ships: these have decreased by 16% in number, while their GT has increased by 20%, which seems to indicate that the number of lower tonnage vessels has been reduced while the larger ones remain active.

Regarding the AOV data represented in Table 3, it can be concluded that the GT of the detections of alleged offending vessels has decreased significantly from the period 2008-2012 to the period 2013-2017, by an average of around 44%. This variation ranges from approximately a 90% decrease in general cargo, Ro/Ro and reefer vessels to 7% in chemical tankers. In this last case, even though its traffic and tonnage have decreased by around 21%, cases of AOV involving this type of vessel increased by 10%, from 111 in the first period to 122 in the second. This, taken together with the data on the decrease in GT, leads to the conclusion that the vessels of this type that have been detected as potential offenders were the chemical tankers of lower tonnage.

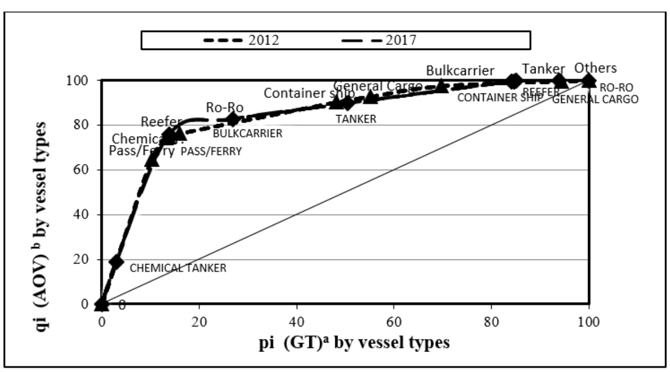
The values of the inequality indices based on the size of the different types of vessel and their GT remain practically constant throughout the 2013-2017 period with a value of around 0.4 (Table 4), showing that from the year 2014 onwards, around

75% of the GT of detected AOVs are concentrated in 14% of the GT of the total population analysed, this concentration corresponding to chemical tankers and passenger/ferry vessels (Fig. 1).

Fig. 4 shows a comparison of the graphs of the last year of each period studied, 2012 and 2017, in which for the 2012 curve the labels can be read in lower case and for 2017 in upper case.

Looking at the curves, it can be seen that they practically overlap, which indicates that the concentration indices are very similar in both years, but when comparing the data, it can be seen that within the aforementioned 75% of the GT of the AOVs, the distribution has varied, as in the period 2008-2012 65% corresponded to passenger vessels and in this last period the percentage of these vessels has fallen to 19%, the remaining 57% corresponding to chemical tankers; that is, the weights of these two types of vessel has been inverted. From all of this, it can be deduced that the type of vessel that concentrates the most cases of AOV is the chemical tanker.

Figure 4: Lorenz curves for Alleged Offending Vessel by vessel type: comparative 2012-2017.



Source: Authors.

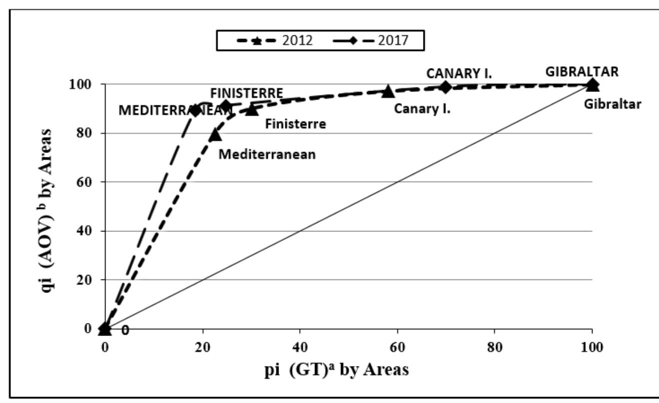
As for the AOV rates, these have generally been reduced from the year 2013 for all types of vessels, except for chemical tankers whose rate has increased, going from 2.5 to 3 AOV for every 1,000 vessels of total traffic, verifying the concentration indices data for this period. In the case of passenger/ferry vessels, a decrease from 2.6 to 1.8 AOV can be observed for every 1,000 vessels of total traffic. These two types of vessel are the ones with the highest rates in the two periods studied (Table 5).

5.2. *By area.*

In relation to the traffic data, it can be observed that in the period 2013-2017 there has been a significant decrease which has been similar in the areas of the Mediterranean, Strait and the Canary Islands, around 30% in number and 18% in tonnage, while traffic through Finisterre to and from northern Europe has only decreased by 10%, although in tonnage, in this particular case, there has been a slight increase of 9% (Table 2).

In Table 3 it can be seen how the decrease in the GT of AOV detections has been significant in the 2013/2017 period in all areas. This general decrease has been more pronounced in the areas of Finisterre and the Canary Islands, around 70%, and almost half of that, just over 36%, in the areas of the Strait of Gibraltar and the Mediterranean. These data point to the effectiveness of the systems of surveillance and control of marine pollution of the Spanish authorities, which have been improved with the recent installation of new equipment in the area of the Canary Islands and Finisterre. Overall, it can be considered that the work of monitoring and detecting sources of pollution and the subsequent identification of the vessels involved is proving to be highly effective and that the custom of many vessels of discharging part of their hydrocarbon and oil waste into the sea is no longer a common practice in all areas.

Figure 5: Lorenz curves for Alleged Offending Vessel by Regions: comparative 2012-2017.



Source: Authors.

In the Lorenz curves of Fig.5 corresponding to the years 2012 and 2017, it can be observed that the degree of inequality is very low and that practically all of the curves overlap, which indicates that the concentration indices are very similar for both years. However, on comparing the data, it can be seen that the concentration of AOV in the area of the Mediterranean is even higher in 2017 than in 2012, this concentration in the Mediterranean rising from 79% of the AOV to 89%, representing 20% of the total GT analysed.

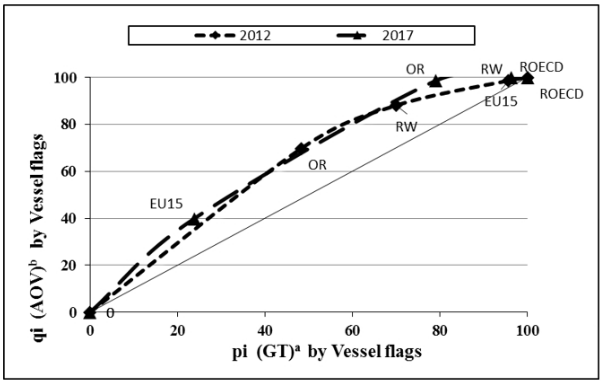
5.3. *By flag.*

In the context of the decrease in traffic outlined above, on analysing the data as a function of the vessels' flags, the most notable outcome is that the group of vessels that did not have an EU or OECD flag or a registration of convenience, that is to say, those called "rest of the world" are the ones with the greatest decrease, with 47% compared to the previous period. Vessels with EU15 and ROECD flags had a similar decrease of around 25% and the smallest decrease of only 14% corresponded to vessels with flags of convenience. Curiously, however, this decrease in the number of vessels has not been reflected in the GT, since in this case this value increased by 2.6% while in the other groups of flags the decrease in GT was proportional to the decrease in units (Table 2).

The numbers of the detected AOVs are very significant, revealing a decrease in GT of more than 90% in vessels with

ROECD and RW flags, and only around 26% for the EU15 and ORs, which indicates that the vessels that continue to pollute the seas the most are the same as ten years ago, although it is also true that they do this in smaller quantities.

Figure 6: Lorenz curves for Alleged Offending Vessel by flags: comparative 2012-2017.



Source: Authors.

In Figure 6 which represents the Lorentz curves corresponding to the years 2012 and 2017, it can be clearly seen how the concentration indices hardly change at all in the two study periods, but what has changed are the weights of the different groupings of flags. Hence, in the year 2017, the GT of the vessels with EU15 flags accounted for 40% of the total of the AOV as compared with 10% in the first period and vessels with OR flags made up 58%, as compared to 70% in the first period. These two groups of flags between them account for totals of 80% and 98% in the two five-year periods studied.

Conclusions.

1- In the five-year period studied, there is a decrease of around 24.5% in the traffic and in the GT for all vessel types, except for Ro-Ro vessels.

2- The GT of the AOV has fallen significantly, by an average of around 44%.

3- The inequality indices obtained reveal that in the period 2013-2017:

a) the AOV are concentrated in chemical tanker and passenger/ferry vessels, as was the case for the period 2008-2012.

b) the AOV are concentrated in the Mediterranean area, with higher values still in 2017 than in 2012, the rate rising from 79% of the AOV in 2012 to 89% in 2017.

c) the AOV are concentrated in vessels with flags that belong mainly to the EU15 countries or those with a flag of convenience, the weight of the latter having fallen and the weight of the former having risen with respect to the period 2008-2012.

4. The ”limited profile” of the AOV in Spanish SAR territorial waters corresponds to a chemical tanker, sailing through the Mediterranean Sea with a flag of one of the EU15 countries.

5. The ”wide profile” of the AOV in Spanish SAR territorial waters corresponds to a chemical tanker, or a passenger ship, sailing through the Mediterranean Sea and that is registered in an open registry or with a flag of one of the EU15 countries.

Undoubtedly, this type of study makes it possible to monitor the evolution of active policies for the prevention of pollution by discharge of hydrocarbons applied by Spain within the framework of its obligations as a member of the European Union. In this context, the results obtained clearly indicate that these policies are on the right track, since the levels of deliberate pollution by hydrocarbons from vessels that transit through the waters of Spanish SAR responsibility waters have decreased significantly. Now is the time to focus on the profile of the most polluting vessel and to take the appropriate administrative and sanctioning measures.

References.

Alpers, W., Holt, B. and Zeng, K. (2017) “Oil spill detection by imaging radars: Challenges and pitfalls,” *Remote Sensing of Environment*, 201, pp. 133–147.

Alves, T. M. *et al.* (2015) “Modelling of oil spills in confined maritime basins: The case for early response in the Eastern Mediterranean Sea,” *Environmental Pollution*, 206, pp. 390–399.

Alves, T. M. *et al.* (2016) “Multidisciplinary oil spill modeling to protect coastal communities and the environment of the Eastern Mediterranean Sea,” *Scientific reports*, 6, p. 36882.

Amir, R. (2017) “Oil pollution in the Marine waters of Israel,” in *Oil Pollution in the Mediterranean Sea: Part II*. Springer, pp. 199–228.

Carpenter, A. (2016) “European maritime safety agency activities in the Mediterranean Sea,” in *Oil Pollution in the Mediterranean Sea: Part I*. Springer, pp. 191–213.

Dahlmann, G. and Kienhuis, P. (2015) “Oil spill sampling and the Bonn-oil spill identification network: a common method for oil spill identification,” in *Oil Pollution in the North Sea*. Springer, pp. 237–254.

Fingas, M. and Brown, C. E. (2018) “A review of oil spill remote sensing,” *Sensors*, 18(1), p. 91.

Gastwirt.Jl (1971) “General Definition of Lorentz Curve,” *Econometrica*, 39(6), pp. 1037-. doi: 10.2307/1909675.

IMO (2017) *MARPOL, consolidated edition, Jan. 2017, Incorporating all amend?ants in force on*.

Martín Alonso, J. M., Ortega Piris, A. and Pérez Labajos, C. (2015) “Illegal discharges in Spanish waters. Analysis of the profile of the Alleged Offending Vessel,” *Marine Pollution Bulletin*. doi: 10.1016/j.marpolbul.2015.06.009.

Purwendah, E. K., Mangku, D. G. S. and Periani, A. (2019) “Dispute Settlements of Oil Spills in the Sea Towards Sea Environment Pollution,” in *First International Conference on Progressive Civil Society (ICONPROCS 2019)*. Atlantis Press.

Uddin, M. M. and Karim, M. S. (2018) “Prevention, reduction and control of marine pollution from ships,” *International marine environmental law and policy*, pp. 60–68.