An Indicator of Boarded Staff Good Practices About Waste Management

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Abstract. In this manuscript, is complemented a study that carried out an analysis of the waste management system of the Portuguese Navy ships (earlier presented in [14]). This study, restricted to the pollution contemplated in Annexes I, IV and V of Marpol 73/78 [3] (namely hydrocarbons, sewage and all types of garbage), analyzed the methods and types of storage and disposal of ship waste to verify the existing equipment, operating conditions and on-board waste management plans. The evaluation of knowledge and cooperation of the military people on board and their contribution to the sustainability and environmental protection was also investigated. With such purpose, a questionnaire was created and implemented for the garrison of some NRP warships, after legal authorization. In [14] we were able to use Exploratory Factor Analysis (EFA) to identify important queries to identify the latent variables that take into account waste management skills. In the present manuscript it is proposes an indicator of good practices about environmental issues between embarked staff. Analysis of variance techniques were used to relate the proposed indicator with some explanatory variables.

Keywords: Waste management · Navy and environment · Pollution of ships · Literacy · Questionnaire · Statistical analysis · ANOVA

1 Introduction

Since the Navy has a very close relationship with the marine environment, it is a continuous concern to reduce the environmental impact of ships in their missions. Under the keywords of environmental protection and sustainability, know how waste treatment is handled on Portuguese Navy ships is an important issue. Implementing a waste management system (WMS) correctly on board helps to minimize the ecological footprint, which must comply with national and international regulations that cover the entire process from collection, separation and treatment types to discharges or storage of produced waste. Given that the Portuguese Navy has some aged ships in its fleet, the current study is to find out under what conditions the WMS is implemented, when possible. This study takes interest on the garrison's status in terms of training and environmental awareness. It

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is important to note that ships are the main focus of this study, we have visited several ships and other ground support units and collected data in interview mode and applying questionnaires.

This work started from [8], where the author resumed the specific regulations about the topic. In addition, in the same monograph, we implemented a questionnaire to assess knowledge, attitudes and practice (KAP) in waste management during boarding time for NRP ships. Using an incomplete sample of the embarked staff, a preliminary statistical analysis was performed on [10,11] to be used as a support for the current work. In this manuscript, we continued the statistical approach proposed in [9,14,15].

This article consists of an introduction, results and concluding remarks sections, a Sect. 2 where we present some motivations and references to the legal regulation of waste management in the marine environment. Section 3 has some details about the methodology. Empirical application can be found in Sect. 4.

2 Preliminaries

In accordance with the principles of sustainable development, the most important legal tool for dealing with marine environmental issues with regard to the management of ship-generated waste and cargo residues in EU ports is an important element to be studied. Receiving waste and cargo residues from ports is especially important for organization. In [2] the author describes the existing environmental tax system, the basis for calculating such taxes, several ports in Europe, namely Rotterdam, Antwerp, Klaipeda, Szczecin.

Another issue related with waste management is the life cycle of ships with age restrictions related to their operations. When the ship is no longer economically profitable, it is recycled or thrown away. Abandoned ships contain many hazardous materials, so special care must be taken to handle waste in accordance with national and internationally available rules. In this connection, dismantling and ship clothing, ship recycling facilities for recycling machinery and infrastructure must be well designed to comply with all regulations so as not to generate contaminated waste that is harmful to humans and the environment. The authors of [12] promoted a study to design an environmentally friendly ship recycling workshop, a pilot project that predicted the rise of old used merchant ships.

In [2], the authors placed particular emphasis on the legal provisions of international law that define how waste and exhaust gases are treated on ships (MARPOL Appendices 5 and 6). Due to the standardization and automation of the handling of shipping, shipping orders and documents are issued in accordance with classification societies in certain countries. In Fig. 1 we can find a generic scheme of a WMS installed in a ship.

The Portuguese navy has been trying to become more and more green in recent years. The Navy's Admiral Chief of Staff has defined the security and health policy for the Navy's work and environment, where there are environmental guidelines on land and ships to which all military, military and civilian work and contribute for good waste management and environmental protection. In [4] the author gives a good description of this effort. This work has completed these studies in order to

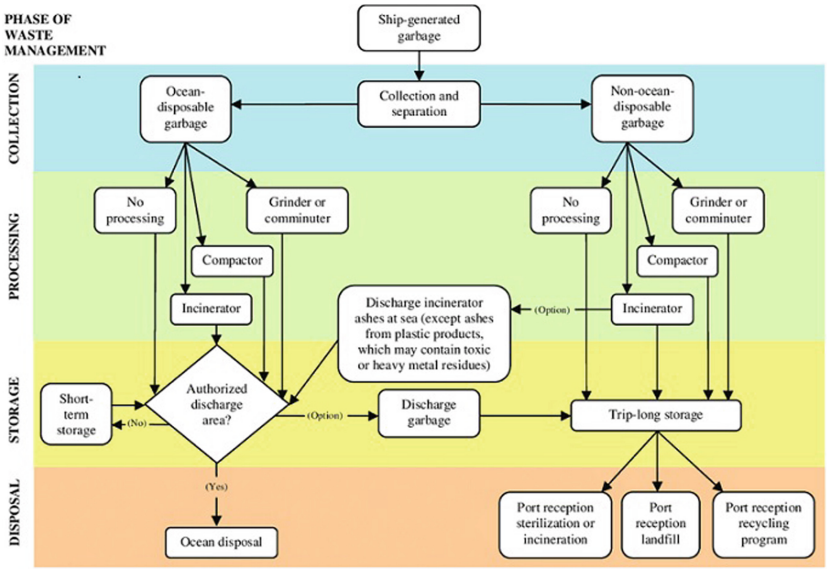


Fig. 1. Scheme of a Waste Management System. Source: [1].

carry out a waste management analysis of Portuguese naval ships and restricts the study to the residues mentioned in Annexes I, IV and V of Marpol 73/78. For this analysis, a questionnaire with relevant questions about knowledge, practice and attitudes was completed and implemented on the crew of the NRP ships to gather the information necessary about the waste management.

3 Methodology

3.1 Analysis of Variance

Experimental design is primarily due to *Sir* Fisher in designing a methodology for agricultural experiments. The main purpose of these methods is to

- assess how a set of qualitative explanatory variables, factors, affect the answer variable,
- discern the most important factors,
- select the best combination of factors to optimize the response,
- fit a model that can make predictions and/or adjust controllable factors to maintain the response variable in the proposed objective.

Noise factors (uncontrollable) that condition the response variable will not be considered. The different values of a factor are called levels. A combination of levels of different factors is denominated treatment. If there is only one factor, each level is a treatment. This work considers only two distinct cases: one-factor and two-factor experimental design [5,6].

Multivariate analysis of ANOVA (MANOVA) is an extension of univariate analysis of ANOVA. In ANOVA, we examined the statistical difference between the continuous dependent variable and the independent grouping variable. MANOVA expands this analysis with several consecutive dependent variables in mind and groups them into weighted linear combinations or complex variables. MANOVA compares whether the newly created combination is different from other groups or levels of independent variables. In this way, MANOVA primarily tests whether the independent grouping variables at the same time constitute statistically significant fluctuations in the dependent variable.

Experimental Design One Factor. The purpose of these techniques boils down to comparing k treatments ($k \geq 2$). Suppose there are k groups of individuals chosen at random. Each group is subject to treatment, i, $i = 1, \ldots, k$. Each group does not necessarily have the same group of individuals. Consider n_i the number of individuals in group i. If in each group the number of individuals is equal, the design is denominated as balanced. When two independent ($k = 2$) random samples are available, t-tests can be established to compare means, when there are $k > 2$ independent samples there is no way to establish this test to proceed with their analysis. It is necessary to resort to a completely different technique known as analysis of variance. The data of k samples are generally presented as y_{ij}, the response of individual j in sample i.

Theoretical Model. Formal inference to compare means of different treatments implies the definition of probabilistic models [7,13]. It is assumed that the relative data on the $i - th$ treatment have a normal distribution of mean μ_i and variance σ^2. If Y_{ij} is a random variable (rv) associated to the observed value y_{ij} the theoretical model can be represented by (1)

$$Y_{ij} = \mu_i + \epsilon_{ij}, \ (\ j = 1, \ldots, n_i, \ i = 1, \ldots, k), \tag{1}$$

with ϵ_{ij} rv's independents and Gaussian

$$\epsilon_{ij} \cap N(0, \sigma^2). \tag{2}$$

The model can be rewritten as (3)

$$Y_{ij} = \mu + \alpha_i + \epsilon_{ij}, \ (i = 1, \ldots, k, \ j = 1, \ldots, n_i). \tag{3}$$

We are able to obtain confidence intervals at $(1 - \alpha) \times 100\%$ for each μ_i. Since $\widehat{\mu}_i = \overline{y}_i$ and from (1) and (2) we can conclude

$$\overline{y}_i \ \cap N(\mu_i, \sigma^2) \tag{4}$$

following

$$\frac{\overline{y}_i - \mu_i}{\sigma/\sqrt{n_i}} \cap N(0, 1) \tag{5}$$

or, if σ is unknown,

$$\frac{\overline{y}_i - \mu_i}{S/\sqrt{n_i}} \cap t_{[N-k]}. \tag{6}$$

The confidence intervals (CI) considering a confidence level $(1-\alpha)\times 100\%$ for each μ_i are given by (7)

$$\overline{y}_i - t_{[N-k;1-\alpha/2]}\frac{s}{\sqrt{n_i}} \leq \mu_i \leq \overline{y}_i + t_{[N-k;1-\alpha/2]}\frac{s}{\sqrt{n_i}}. \tag{7}$$

To investigate whether the treatments have identical means or not can be tested the hypothesis (8) using as statistical test the formula (6)

$$H_0 : \mu_1 = \cdots = \mu_k \text{ versus } H_1 : \text{ some } \mu_i \text{ are not equal.} \tag{8}$$

A rejection of H_0 means that there is experiential evidence that treatments differ from each other. In terms of the effect of treatment α_i, the above hypothesis can be described as

$$H_0 : \alpha_1 = \cdots = \alpha_k \ = 0 \text{ versus } H_1 : \text{ some } \alpha_i \text{ are not null.} \tag{9}$$

To perform the test defined by (9) it is necessary to calculate the total variability of $\widehat{\mu}_i = \overline{y}_i$ around $\widehat{\mu} = \overline{y}$ given by the sum of squares of treatment deviations (16)

$$SS_{TREAT} = \sum_{i=1}^{k} n_i \left(\overline{y}_i - \overline{y}\right)^2. \tag{10}$$

A large SS_{TREAT} suggests that the treatments are distinct. It is necessary to take its average value, dividing by the degrees of freedom (11)

$$MS_{TREAT} = \frac{\sum_{i=1}^{k} n_i \left(\overline{y}_i - \overline{y}\right)^2}{k-1} \tag{11}$$

and compare with the variability of each observation within the sample, i.e., with the mean sum of squared errors defined as (12)

$$MSE = s^2 = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(y_{ij} - \overline{y}_i\right)^2}{N-k} = \frac{SSE}{N-k}. \tag{12}$$

The F test statistic associated to test hypothesis (9) is given by (14)

$$F = \frac{\text{average sum of squares due to treatments}}{\text{mean sum of squares of residuals}} \tag{13}$$

$$= \frac{MS_{TREAT}}{MSE} \cap F(k-1, n-k). \tag{14}$$

The critical region of test (9), for significance level α is given by (15)

$$F_{|H_0} > F_{(k-1,n-k,1-\alpha)}. \tag{15}$$

The total variability SST (16) is measured by the squared mean of the deviations of each observation from the overall mean

$$SST = \sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(y_{ij} - \overline{y}\right)^2 \tag{16}$$

and can be decomposed by the sum of two terms: the inter-group variability given by SS_{TREAT} and a variability within each group SSE, given by (17)

$$SST = SS_{TREAT} + SSE. \tag{17}$$

This relationship is generally presented in tabular form, the ANOVA table.

4 Empirical Application

4.1 The Data

We have focused the study to ships. Under such aim, several visits to ships were performed, the questionnaires were applied and some data collection was done in interview mode. After the adequate approval, data collection was conducted through a questionnaire for the crew of each licensed vessel (see Fig. 2). The questionnaire is divided into two parts. The first part contains socio-demographic variables and personal data (detailed in Table 1).

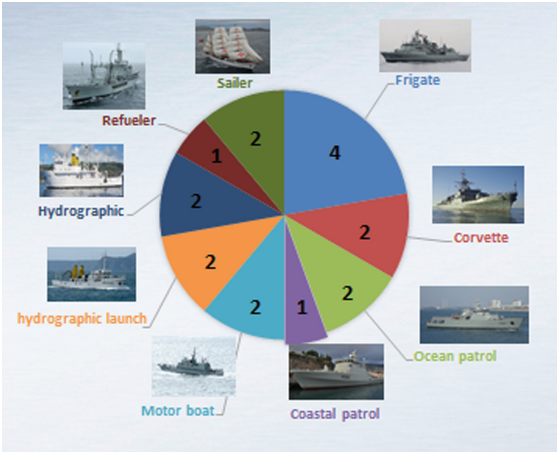


Fig. 2. Selected ships (after authorization by the Surface Fleet Commander from Portuguese Navy).

The second part of questionnaire is composed with questions that allow to evaluate KAP about waste management (detailed in Table 2).

The major number of questions from second part use of Likert scale with four levels from 1 to 4 (1 - Totally Disagree, 2 - Partially Disagree, 3 - Partially agree, 4 - Totally Agree; also some questions have a “yes” or “No” answer. Question related to identifying the factors that contribute to poor waste management has an open answer.

Table 1. Questionnaire questions. Questions about the socio-demographic information of each participant.

- $Q1_1$ - "'*Gender.*"'
- $Q1_2$ -"'*Age.*"'
- $Q1_3$ - "'*Grade.*"'
- $Q1_4$ - "'*Have you ever attended an environmental training course?*"'
- $Q1_{41}$ "'*If you answered "Yes" in the previous question, it was in Navy.*"'
- $Q1_5$ "'*Do you recycle at home?*"'

4.2 Sample Characterization

The collection of data was done taking into consideration that we are interested to know how waste treatment is carried out on Portuguese Navy ships, if there exists a waste treatment plan adapted to the characteristics and needs of each ship and which are the conditions, how is condition of the equipment on board for processing waste and if the garrisons are aware of the importance of minimizing the environmental impact of ships. Were performed fifteen interviews to on board Waste management Officers to understand the application of a WMS; there were 241 participants from garrisons that responded the questionnaires; the chief of the port support service and the head of financial management and supply section were also interviewed (Fig. 3). In this manuscript we have focused our attention in questionnaires data set.

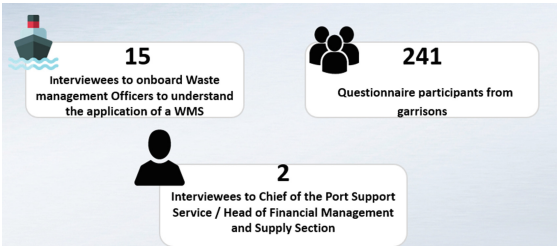


Fig. 3. Collection data.

The questionnaire answers are described as follows. In Fig. 4, the distributions of gender and age are summarized. The sample is composed by 64% of men and 36% of women. People at almost 46% are under 30, and between 38% between 30 and 40. The oldest participant is 51 years old. Information about the environmental issues training and recycling at the home can be found in Fig. 3. Approximately one third of the participants (36%) performed environmental education training. About 68% of participants recycle at home.

Table 2. Questionnaire questions. Questions about the knowledge, Attitude and Practice of each participant about waste management.

- $Q2_1$ - *"'The environmental concern on board is always present in my daily life."'*
- $Q2_2$ - *"'I consider good waste management practice on board ships important."'*
- $Q2_3$ - *"'There are regular lectures on board on waste management ."'*
- $Q2_4$ *"'Sometimes I dump small waste into the sea."'*
- $Q2_5$ - *"'I think there is a good waste management policy on board ships."'*
- $Q2_6$ -*"' There are some types of waste that we can discharge into the sea."'*
- $Q2_7$ - *"' The glass can be discharged into the sea, as it ends up in the bottom of the sea, having no interaction with the environment."'*
- $Q2_8$ - *"'Paper and cardboard can be discharged at sea because they easily degrade."'*
- $Q2_9$ *"'Proper packaging of waste contributes to the welfare, hygiene and safety of the trim."'*
- $Q2_{10}$ - *"'Waste storage space is adequate."'*
- $Q2_{11}$ - *"'The conditions of shipboard equipment allow for the treatment of different types of waste."'*
- $Q2_{12}$ - *"'Even if conditions are not adequate, there is an effort and concern from the trim to minimize the environmental impact of the ship."'*
- $Q2_{13}$ - *"'The educational offer of the Navy in the environment preservation is sufficient."'*
- $Q2_{14}$ - *"'The Navy promotes, with its military staff, the preservation of the environment."'*
- $Q2_{15}$ -*"' There has been an increase in people's awareness of environmental preservation ."'*
- $Q2_{16}$ - *"' I know the Navy Environmental Policy and I know where I can consult it."'*
- $Q2_{17}$ - *"'I am aware of national and international regulations for reducing environmental impact."'*
- $Q2_{18}$ - *"'Sometimes on board, environmentally harmful acts are performed due to lack of waste treatment conditions."'*
- $Q2_{19}$ - *"'Feels that their role in minimizing waste generation on board is important for good waste management in the organization."'*
- $Q2_{20}$ - *"'On board are used environmentally friendly consumables."'*
- $Q3$ - *"'Has the waste generated on board ever compromised your well-being?."'*
- $Q4$ - *"'elect from 1 to 2 factors that undermine the proper functioning of onboard waste management."'*
- $Q5$ - *"'As the Navy is a military organization, do you consider your concern about the ecological footprint at sea important?"'*

4.3 Results and Final Remarks

In [9,14], the statistical analysis of the questionnaire was performed. The alpha-Cronbach coefficient was coherent to a good internal consistency. We have measured the homogeneity and internal consistence of questionnaire and respective validation.

A preliminary data analysis using the questionnaire data set and taking into account the non-quantitative nature of the relevant variables, we have computed some measures of association between the distinct questions: the non-parametric Spearmann correlation coefficient and Friedman's non-parametric test for samples [10,14]. Both tests were significant ($p - value < 0.001$) meaning that, in general, questions have not the same distribution Fig. 5.

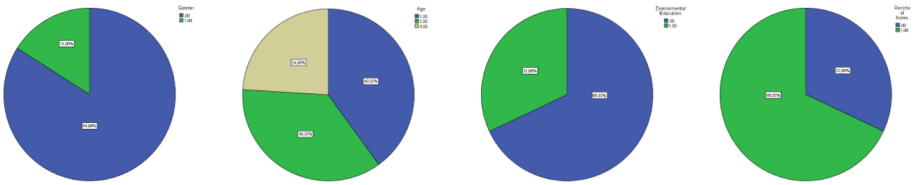


Fig. 4. Sample distribution per gender, per age, pe renvironmental education training attendance, per use of recycling at home. Left: Gender (male/female); Center left: Age; Center right: environmental training (no/yes); Right: Recycling use (no/yes). Source [8].

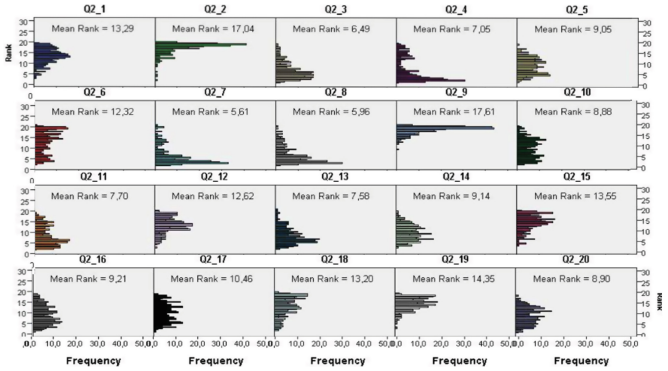


Fig. 5. Sample distribution of ranks $Q2_1 - Q2_{20}$. Source [9].

The paired T-test, McNemar's test for frequencies comparison, Crochan's Q test for binary variables comparison[1] were applied. Also were performed the Friedman test (p-value < 0.001) and kendalls coefficient of concordance test ($p - value < 0.001$). All tests conduced to the same conclusion: the distributions of considered questions are distinct [11].

In [14] were also performed unilateral tests for median considering each question $Q2_1 - Q2_{20}$, the Wilcoxon test and the signal test. We can say that more than 50% of participants have declared that there exists the daily environmental care, consider it an important procedure, also consider that some waste can be left in sea, the waste storage contributes to welfare, security and hygiene of staff. Also consider that the existent equipment to process waste is not enough. The staff declares to know the internal and external rules but claims that there is not a good offer of formation in environmental education. Also we could confirm that environmental awareness is increasing.

[1] When the Crochan's Q test for binary variables is applied, we associate to insuccess the first and second levels of the Likert scale, the third and fourth levels of the Likert scale contribute to success.

The authors of [15] studied the composition of sample per rank and the distribution of the attendance of environmental training per rank. Clearly, it is not uniformely distributed. The authors verified a strongly significant correlation between the training course attendance and the rank.

In [8] we also have applied an exploratory factorial analysis to reduce the dimensionality of the problem. Four factors were selected and was identified a meaning for each: F_1 combines variables that characterize $Awareness$, F_2 combines variables from $Hygiene\ and\ Safety$, F_3 combines variables from $Practice$. This new variables were introduced as independent variables in a ANOVA unidimensional model in [14]. The factor associated with $Hygiene\ and\ Safety$ issues conduced a significant model where the kind of ship is the explanatory variable.

In [15] was built a model with a global F test with a $p - value = 0.073$, using a two dimensional anova where the kind of ship and the first interaction between rank and the kind of ship were significant as covariates to explain the $Awareness$ variable (the dominant factor $F1$ obtained in [9] by EFA).

We also could establish some strong correlations between some questions associated to awareness and some uses of good practices and the age and rank of participants as we can identify in Table 3.

In the present work we have built an indicator of *goodpractices* combining the information of some questions from questionnaire identified as a good practice. Basically we have defined $goodpractices = Q2_3 + Q2_5 + Q2_{10} + Q2_{11} + Q2_{12} + Q2_{18}$ as the indicator under study. The sample distribution of good practices variable is displayed in Fig. 6.

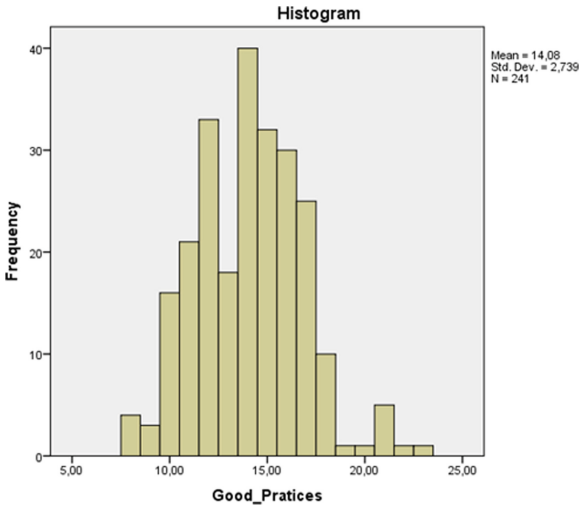


Fig. 6. Distribution of good practices indicator.

Table 3. Correlation between some awareness and good practices questions with age and rank.

Correlations

		Rank	The environmental concern on board is always present in my daily life.	Do you recycle at home?	I consider good waste management practice on board ships important.	Age
Kendall's tau_b	Rank	1,000	,099	-,124*	-,178**	,118*
			,091	,044	,003	,043
		241	241	241	241	241
	The environmental concern on board is always present in my daily life.	,099	1,000	,138*	,166**	,196**
		,091		,024	,006	,001
		241	241	241	241	241
	Do you recycle at home?	-,124*	,138*	1,000	,081	,117
		,044	,024		,203	,055
		241	241	241	241	241
	I consider good waste management practice on board ships important.	-,178**	,166**	,081	1,000	,004
		,003	,006	,203		,945
		241	241	241	241	241
	Age	,118*	,196**	,117	,004	1,000
		,043	,001	,055	,945	
		241	241	241	241	241
Spearman's rho	Rank	1,000	,110	-,130*	-,189**	,131*
			,090	,043	,003	,043
		241	241	241	241	241
	The environmental concern on board is always present in my daily life.	,110	1,000	,146*	,177**	,216**
		,090		,024	,006	,001
		241	241	241	241	241
	Do you recycle at home?	-,130*	,146*	1,000	,082	,124
		,043	,024		,204	,055
		241	241	241	241	241
	I consider good waste management practice on board ships important.	-,189**	,177**	,082	1,000	,004
		,003	,006	,204		,945
		241	241	241	241	241
	Age	,131*	,216**	,124	,004	1,000
		,043	,001	,055	,945	
		241	241	241	241	241

The good practices indicator seems to be related with the kind of ship when we observe the box-plots of indicator depending on the ship (see Fig. 7).

We used the ANOVA approach to confirm that the kind of ship is a good explanatory variable of the proposed indicator. The Levene test has $p-value = 0.05$, confirming the variances homogeneity. In Table 4, we get a $p-value = 0.09$ for the global F test defined by expression (9). The kind of ship is statistically significant for a significant level of 10%.

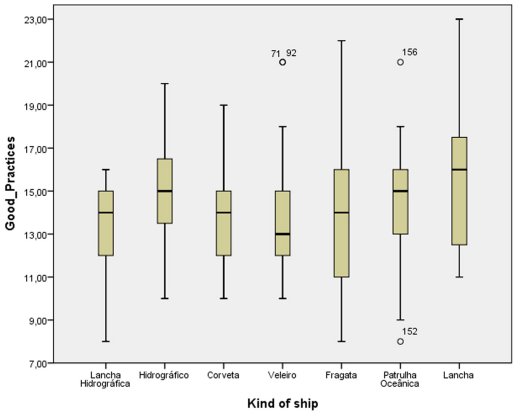


Fig. 7. Distribution of good practices indicator per kind of ship.

Table 4. Analysis of variance. Dependent variable: Indicator of good practices. Explanatory variable: Kind of ship.

ANOVA

Good_Pratices

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	81,505	6	13,584	1,849	,090
Within Groups	1718,835	234	7,345		
Total	1800,340	240			

It means that at least one level of kind of ship has different effects in the indicator than other distinct level, i.e. the difference between the mean estimate per level with the global average is not the same for all levels (see Fig. 8).

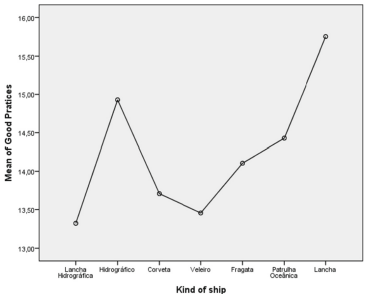


Fig. 8. Effects of the kind of ship in the good practice indicator.

Some ships of Portuguese Navy are previous to the recent environmental concern and a plan of waste management was not a rule, other ships are very small, usually perform short trips, not needing a WMS. The majority of ships have a WMS, but some of them have few space to store the waste or the equipment is not recent. All this details contribute to distinct effects in the good practices indicator.

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