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STUDY OF OCCUPATIONAL EXPOSURE TO ULTRAVIOLET SOLAR RADIATION ON FISHING VESSELS

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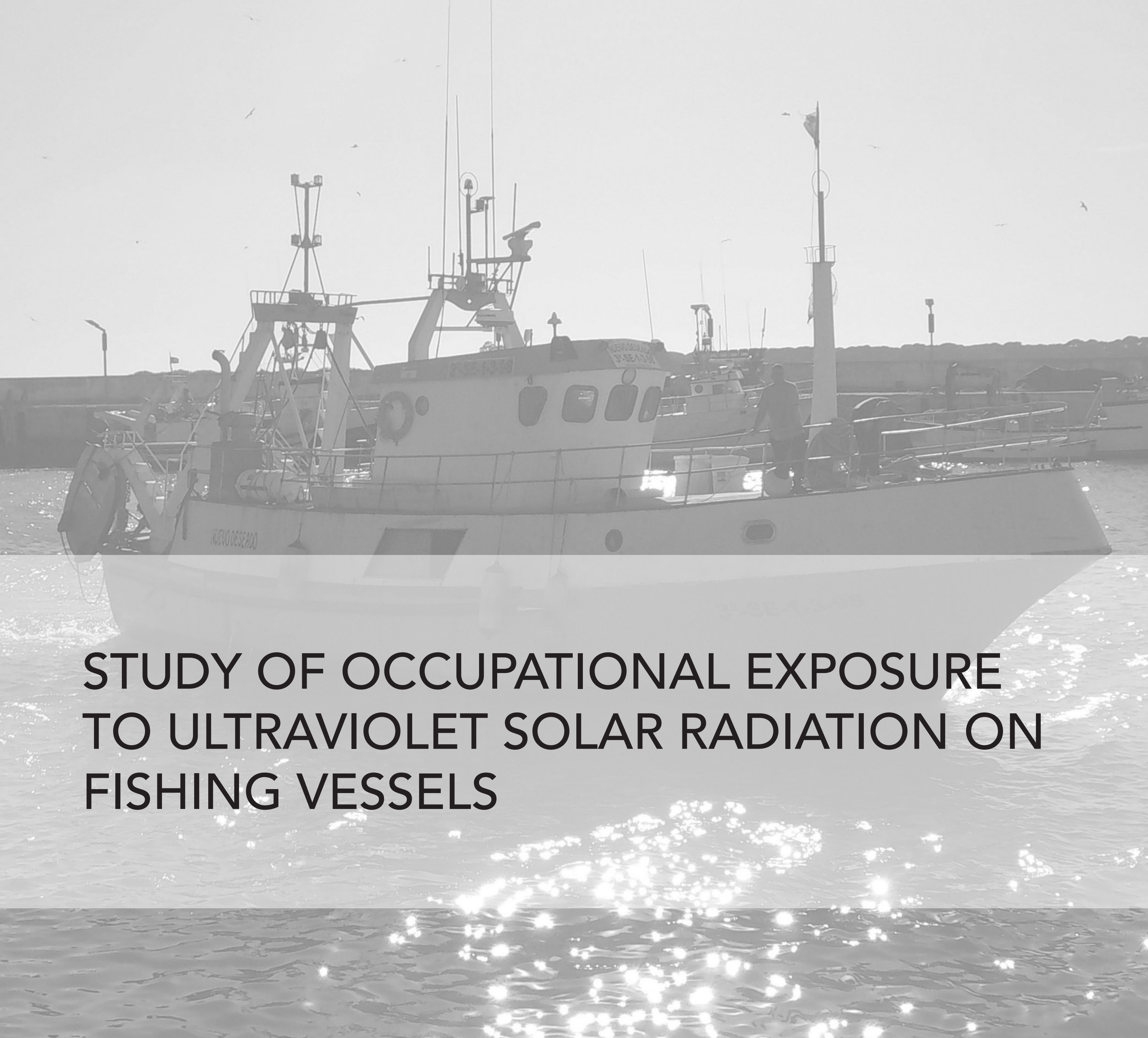

STUDY OF OCCUPATIONAL EXPOSURE TO ULTRAVIOLET SOLAR RADIATION ON FISHING VESSELS

Title:
Study of occupational exposure to ultraviolet solar radiation on fishing vessels.

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INTRODUCTION

1. INTRODUCTION

Ultraviolet (UV) radiation has been classified by the European Risk Observatory of the European Agency for Safety and Health at Work (EASH) as an emerging risk for exposed workers, given that UV exposure is cumulative, and the longer workers are exposed during and outside working hours, the greater the risk of injury. The EASH study, published in 2009 [*EASH, 2009*], highlights the high incidence of negative health effects caused by UV radiation among professionals who work outdoors and spend a large part of their workday exposed to solar radiation. It estimates that some 14.5 million working people in the European Union are exposed to the sun for at least 75% of their workday, 90% of them men.

In turn, in its report *Solar Ultraviolet Radiation. Global Burden of Disease from Solar Ultraviolet Radiation* [*Lucas, R. et al.*, 2006], the World Health Organization (WHO) found an association between exposure and an increased occurrence of nine pathologies (melanoma, basal and squamous cell carcinoma, solar keratitis, cortical cataract, pterygium, corneal and conjunctival carcinoma and reactivation of herpes labialis).

The risk of exposure to UV radiation from the sun at work is especially important in the fishing industry, as a high percentage of the crew spends much of their workday outdoors for many months of the year throughout their working life, which in some cases begins at an early age and lasts until retirement. For this reason, they can be considered one of the most at-risk groups due to cumulative sun exposure.

All of this is compounded by the failure to take preventive and protective measures due to the lack of awareness of exposure to solar UV radiation. Therefore, this risk is so important that it has to be considered and assessed in the work environment of the fishing sector.

It should be noted that assessing this risk is very complex, first due to the numerous variables to be considered and the constant variations in both environmental factors (intensity of solar radiation, season of the year, solar reflection and scattering, angle of incidence, time of day, cloudiness and other climatic factors such as ambient temperature) [*IARC, 2012*], [*ICNIRP, 2010*] and individual factors (exposure time, part of the body exposed, skin type, movements of the exposed worker, etc.) [*Modenese A. et al.*, *2018*] that have to be considered. On the other hand, although Law 31/1995, of 8 November 1995, on Occupational Risk Prevention (LORP), requires this type of occupational health risk be taken into account, there are no explicit regulations containing occupational exposure limits for solar UV radiation for comparison's sake, but instead only recommendations contained in international guidelines like those of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [*ICNIRP, 2010*].

It is imperative to highlight the proposal of the European Strategy for Safety and Health at Work 2021-2027 [COM, 2021. 323 final] to make every effort to lower occupational mortality to the extent possible, in line with the European Commission's commitment to study measures on exposure to ultraviolet radiation (which increases the risk of melanoma, the most serious form of skin cancer) [COM, 2021. 44 final].

Consequently, and faced with the challenge of improving the prevention of work-related diseases, the National Institute for Safety and Health at Work, in compliance with the functions entrusted to it by the LORP (such as promoting and supporting the improvement of safety and health conditions at work), has performed this study in order to describe seamen's overall exposure to UV radiation.

BACKGROUND

2. BACKGROUND

To achieve the objective of the study, a literature review on exposure to solar UV radiation in the fishing sector was conducted in order to assemble all the information available in the scientific literature.

The search focused on investigating and comparing the different methodologies used in order to choose the one best suited to the objective of this study, taking into account the identification and description of general factors that could influence exposure (factors which affect the intensity of solar UV radiation, the UV index, skin type, maximum exposure time, sun protection factor, reference values, etc.).

For this purpose, the MEDLINE (PubMed) and Web of Science databases were consulted, with different search strategies for each of them using the equations shown in Table 1.

Table 1
Search strategy adapted to each of the bibliographic databases and journal collections consulted

Database	Search equations
MEDLINE (Pubmed)	((Fishing Industry [MeSH Terms]) OR (Fisheries [Title/Abstract]) OR (seaman [Title/Abstract]) OR (fisherman [Title/Abstract])) AND ((solar energy [MeSH Terms]) OR (solar energy) OR (sun exposure) OR (solar exposure) OR (solar exposition) OR (solar radiation)) AND ((radiation effects) OR (melanoma) OR (skin cancer) OR (sunburns) OR (ocular cataracts) OR (photo aging) OR (Keratosis, Actinic [MeSH Terms])).
	((“fishes” [All Fields] OR “fished” [All Fields] OR “fishes” [MeSH Terms] OR “fishing” [All Fields]) AND “industry” [MeSH Terms] OR “Fisheries” [Title/Abstract] OR “seaman” [Title/Abstract] OR “fisherman” [Title/Abstract]) AND (“sunlight” [MeSH Terms] OR “solar energy” [MeSH Terms] OR “sunlight” [MeSH Terms] OR “sunlight” [All Fields] OR “solar” [All Fields]) AND (“energy” [All Fields]) OR “solar energy” [All Fields] OR “solar energy” [MeSH Terms] OR “solar” [All Fields]) AND (“energy” [All Fields] OR “sunlight” [MeSH Terms] OR “sunlight” [All Fields] OR “sun” [All Fields]) AND (“exposure” [All Fields] OR “exposures” [All Fields]

MEDLINE (Pubmed)	OR "exposured" [All Fields] OR "exposures" [All Fields] OR "exposuring" [All Fields] OR "solar" [All Fields]) AND ("exposure" [All Fields] OR "exposures" [All Fields] OR "exposured" [All Fields] OR "exposures" [All Fields] OR "exposuring" [All Fields] OR "solar" [All Fields]) AND ("exposition" [All Fields] OR "expositions" [All Fields] OR "solar energy" [MeSH Terms] OR "solar" [All Fields]) AND ("energy" [All Fields] OR "solar energy" [All Fields] OR "solar" [All Fields]) AND ("radiation" [All Fields] OR "solar radiation" [All Fields]) AND ("radiation effects" [MeSH Subheading] OR "radiation" [All Fields]) AND ("effects" [All Fields] OR "radiation effects" [All Fields] OR "radiation effects" [MeSH Terms] OR "radiation" [All Fields]) AND ("effects" [All Fields] OR "melanoma" [MeSH Terms] OR "melanoma" [All Fields] OR "melanomas" [All Fields] OR "melanomas" [All Fields] OR "skin neoplasms" [MeSH Terms] OR "skin" [All Fields]) AND ("neoplasms" [All Fields] OR "skin neoplasms" [All Fields] OR "skin" [All Fields]) AND ("cancer" [All Fields] OR "skin cancer" [All Fields] OR "sunburn" [MeSH Terms] OR "sunburn" [All Fields] OR "sunburns" [All Fields] OR "sunburned" [All Fields] OR "sunburning" [All Fields] OR "ocular" [All Fields] OR "oculars" [All Fields]) AND ("cataract" [MeSH Terms] OR "cataract" [All Fields] OR "cataracts" [All Fields] OR "cataractic" [All Fields] OR "cataractous" [All Fields] OR "photoaged" [All Fields] OR "photoageing" [All Fields] OR "photo aging" [All Fields] OR "keratosis, actinic" [MeSH Terms]) AND (y_5[Filter]) AND (fha[Filter])).
Web Of Science	(TS=(fisheries) OR TS=(fishing industry)) OR TS=(sailor) OR TS=(seaman)) AND (TS=(solar energy)) OR TS=(sun exposure)) OR TS=(radiation exposition)) AND (TS=(skin cancer) OR TS=(sunburns) OR TS=(melanoma) OR TS=(skin neoplasms) OR TS=(ocular cataracts) OR TS=(Photoaging)).

In addition, numerous databases of official agencies and institutions were analysed, including the *Institut National de Recherche et de Sécurité (INRS)*, *Health and Safety Executive (HSE)*, *Institution of Occupational Safety and Health (IOSH)*, European *Agency for Safety and Health at Work (EU-OSHA)* and *International Labour Organization (ILO)*.

Magazines specialised in the sector and in occupational risk prevention were also consulted, such as *International Maritime Health*, *Maritime Medicine*, *Mar* and *Safety and Health at Work*.

The criteria used to choose the documents to be analysed were including all the articles and studies that describe the solar radiation to which workers in the fishing sector were exposed and articles and studies where there was a causal relationship between solar exposure and the negative effects on these workers' health, including terms such as skin cancer, actinic keratosis, burns, cataracts, etc. Likewise, several publications related to other sectors were also included because of their special interest.

When applying the exclusion criteria, articles in languages other than those chosen (English, German and Spanish) and articles whose full text was not available were eliminated. Records where the exposure was not occupational or the population was not adult were also excluded.

With the search criteria described above, 19 references were retrieved in MEDLINE and 13 in Web of Science. After filtering out the duplicates, applying the inclusion and exclusion criteria and carrying out an initial reading of the articles, nine references were chosen for detailed analysis. In addition, the bibliography of the publications chosen was reviewed with the intention of analysing all possible relevant references. By doing so, 13 more were found for a total of 22 publications.

The analysis showed a wide range of methodologies for describing UV radiation exposure, including:

- Qualitative methods, based on specific questionnaires, whose limitations must be taken into account, such as reliance on self-reported data and potential social desirability bias when answering questions, even anonymously.
- Quantitative methods, divided into two types: publications that described exposure via numerical models and those that took either environmental or personal measurements to describe exposure.

The qualitative methods [Worswick S.D. et al., *2008*] [*Reeder A.I., et al., 2013*] aim to assess workers' risks, knowledge and attitudes, as well as to describe occupational safety behaviours regarding solar radiation using specific questionnaires.

Particularly noteworthy is a study [*Zink A. et al., 2018*] conducted in Germany among outdoor workers (farmers, gardeners, mountain guides), with indoor workers (office employees) as a control group, in which a questionnaire on UV radiation exposure and sun protection behaviour was used together with a skin examination by a dermatologist. The results showed different levels of skin cancer risk, as well as different skin cancer risk behaviours for different professions.

Meanwhile, the University of Nottingham (UK) [*Houdmont J. et al., 2016*] conducted a four-phase study. The first phase examined scientific knowledge on skin cancer epidemiology, knowledge, attitudes and sun safety behaviours in the construction sector. In the second phase, these factors were profiled via a survey of 1,154 professionals. The results showed that two-thirds of the respondents thought they were not at risk for skin cancer or did not know if they were at risk, and nearly three-quarters reported that they had never received any training in sun safety. In the next phase, an informative DVD was produced to increase awareness of the risks of exposure to solar radiation and to promote healthy attitudes and behaviours. In the last phase of the project, a follow-up questionnaire was filled out to assess the effectiveness of the previous phase (with a positive change found in certain behaviours), while the opinions of crews and shipowners on the barriers and factors that facilitate sun protection were surveyed using other qualitative techniques, such as focus groups. The conclusion of this study was that there are two key barriers to adopting safe behaviours: positive perceptions of tans being healthy and attractive, and the nuisance of applying/ using sunscreen.

As part of this same methodology, another article [*De Troya-Martín M. et al., 2009*] was also examined; it showed the validation process of a questionnaire used to assess habits, attitudes and understanding of exposure to sunlight.

Regarding the quantitative methodologies, studies based only on numerical models were analysed, such as the one conducted in Queensland (Australia), which calculated the likelihood of a group of farmers engaging in outdoor activities and the distribution of solar radiation striking on the human face; the results were then compared with environmental levels of UV-B radiation for that region [*Aitey D. K. et al., 1997*]. We also analysed a study [*Milon A. et al., 2014*] conducted to assess occupational UV-radiation exposure considering break periods to describe exposure patterns and anatomical distribution and estimate carcinoma risk through an existing epidemiological model.

We also examined studies that combined estimates based on qualitative methodologies using questionnaires and quantitative methodologies using numerical models, taking into account that they may underestimate exposure due to subjectivity in the interpretation of the results.

One such study [*Boniol M. et al., 2015*] assessed occupational UV exposure in a population sample in France by conducting a random survey of a sample of 889 people that estimated UV radiation dose (expressed in "standard erythema dose", or SED[1] , units) based on time and location of exposure and comparing it with UV radiation records from weather satellites. The highest doses observed were in the gardening sector (1.19 SED), construction workers (1.13 SED), farm workers (0.95 SED) and cultural / art / social science workers (0.92 SED), and the significant factors associated with high occupational UV exposure were sex ($P<0.0001$), phototype[2] ($P= 0.0003$) and eating lunch outdoors ($P<0.0001$).

Another study considered [*Peters C. E. et al., 2016*] was conducted in Vancouver (Canada) with the goal of measuring personal solar UV radiation exposure among a sample of outdoor workers (81% from the construction industry and the remaining workers from the horticultural industry) and examining whether personal, occupational or meteorological factors had any influence on exposure levels. During the summer of 2013, measurements were taken for one week using calibrated electronic UV radiation dosimeters to determine UV irradiance with erythemal potential on the skin. These measurements were supplemented with questionnaires collecting additional worker data on skin cancer risk factors, family history of skin cancer and type of work, as well as weather data for the sampling days. It concluded that exposure to ambient UV radiation depended on many factors, including latitude, altitude, season, time of day, surface reflection and climatic conditions, which had a clear impact on exposure levels in the study, with sunnier days showing higher levels of exposure. Among the personal factors identified, the most influence was from the frequency and time of exposure (intensity), the work performed (construction workers showing a significantly higher dose than horticulture workers) and the availability and use of shade, as well as other sun protection behaviours. Given all this, marginal models were constructed to describe the worker, the job and weather factors related to UV radiation exposure levels measured in the standard erythema dose (SED).

[1] Standard erythema dose (SED): Term equivalent to an erythemal radiant exposure of 100 J/m^2. (1 SED = 100 J/m^2 per day [*ICNIRP, 2010*], [*ISO 17166:1999 CIE*]).

[2] Phototype: Each person's ability to adapt to the sun from birth, that is, the set of characteristics that determine whether their skin tans or not, and how and to what degree it does. The lower this capacity, the less the effects of solar radiation on the skin will be counteracted. Fitzpatrick scale [Fitzpatrick T.B., 1988].

Another combination of both techniques was also used in the Netherlands [*Keurentjes, A. J. et al., 2021*] to investigate the effectiveness of sunscreen use in construction industry professionals. To do so, two test groups and two control groups were recruited in four different locations, who were tracked for more than 12 weeks by providing sunscreen dispensers (SPF + 50) at construction sites and electronically monitoring sunscreen consumption. The effect of this intervention was assessed based on data on self-reported sunscreen use via questionnaires collected at the baseline and after the 12-week follow-up. In addition, personal UV sensors were used to assess the outdoor UV radiation dose, and all this was complemented by a skin check of the sun-exposed parts at the end of the study. The conclusion of this study showed that the risk of non-melanoma skin cancer can be reduced by taking appropriate measures to reduce exposure to ultraviolet radiation, providing evidence that regular sunscreen use was effective in lowering this risk.

In Alberta, Canada [*Rydz E. et al., 2020*], measurements were collected from individuals who work outdoors in the summer of 2019. Electronic dosimeters calibrated at different positions were used for five days on 179 professionals, and data on the job, sun protection behaviours, personal risk factors and demographic characteristics were collected by means of a questionnaire, while the weather data for each sampling day was also recorded. The average daily dose, measured in SED, was calculated and compared with the limits recommended in international guidelines. The result was that more than half of the workers were exposed to levels exceeding the recommended exposure limits, so exposure to high levels of solar UV radiation was common for workers in the area.

Lastly, we analysed studies that used only quantitative methodologies through measurements to describe exposure using individual or environmental dosimetry.

Among the environmental measurements, a study conducted by the Instituto Tecnológico de Costa Rica [*Sierra M. A. 2016*] was reviewed in detail; its objective was to describe the exposure of the farmers in the area, specifically quantifying the level of radiation by determining SED. To do so, a radiometer was used to measure the incident irradiance on a horizontal surface, a methodology that is difficult to apply to sea professionals given the special conditions of their workplace.

Focusing the analysis on published studies where individual dosimetry was used, a study [*Grandahl K, et al., 2017*] conducted in Denmark stands out. It considered the technical and practical feasibility of measuring individual solar ultraviolet exposure in professions that require spending a lot of time outdoors using personal UV-B dosimeters based on a gallium aluminium nitride photodiode detector. The results after measuring more than 350 workers from different professions showed that the use of this type of dosimeter was indeed technically and practically feasible for measuring solar UV radiation exposure at work.

During the summer of 2013, also in Vancouver, Canada, another study [*Peters C. E. et al., 2020*] was conducted using personal electronic dosimeter monitoring data to determining when peak UV radiation exposure occurred in outdoor workers, while also collecting ambient UV radiation data from the nearest weather station for parallel analysis. The conclusion was that providing information on the periods of highest solar UV radiation could help identify key times to reduce exposure by implementing a series of preventive measures.

Within the framework of the Genesis - UV Project, several publications were analysed [*Wittlich M. et al., 2016*] [*Wittlich M et al., 2020*] whose aim was to collect long-term individual UV radiation measurements in people who work outdoors in different European countries. To measure solar UV radiation exposure, an electronic dosimeter was placed on the worker's left arm to take measurements autonomously and then transfer the overall data to an Internet server owned by the IFA - DGUV(*Institute for Occupational Safety and Health of the German Social Accident Insurance*), where all the data was collected for subsequent analysis. This project has studied almost 100 different occupations and drawn up profiles of occupations and tasks that show different groups' exposure to solar radiation. Another study that has also used the methodology of the Genesis - UV project [*Kovačić J. et al. 2020*] focused on estimating annual occupational exposure to UV radiation based on five consecutive months of dosimetric measurements in Croatian construction professionals and assessing its relationship with environmental data collected during the same period.

Regarding the use of electronic dosimeters, the study concluded that although the feasibility of using these dosimeters to measure exposure to solar UV radiation was demonstrated, because of their technical features and the way the data were collected, these measurement methods were not applicable to seamen, given the special circumstances in which the measurements have to be taken.

Next, a series of studies using personal dosimeters were analysed, although their operating principle was based on using a biofilm of spores whose exposure to solar UV radiation resulted in DNA damage, which was then related to the level of solar UV radiation capable of producing skin erythema[3].

In southern Switzerland [*Antoine M. et al., 2007*], this methodology was used to assess short-term effective exposure among construction workers in a mountainous region. The effective exposure was researched by short-term dosimetry, with individual measurements taken during 20 working periods using Spore film dosimeters (97 dosimeters) on five body locations (neck, left and right shoulder, lower back and forehead) considering three altitudes (500, 1,500 and 2,500 m). There was high variability among the doses measured among workers and different anatomical locations, emphasising the role of local exposure conditions and individual factors. The study concluded that the effective exposure of construction professionals in the area was high and exceeded the recommended occupational limits.

This same technique was used in several studies in Spain, specifically in the construction industry in Valencia, [*Serrano M. A. et al., 2013*] and the open-pit mining sector [*Florez C. (INS), 2014*].

There are very few publications on the subject in the maritime fishing sector. Among them, a thorough analysis was performed of a study conducted by the DGUV, prior to the Genesis project mentioned above, entitled "The determination of UV radiation exposure for seafarers" [*Meyer G. et al., 2014*], which took measurements on four international transport routes with high UV exposure using both personal and environmental dosimeters. In addition to creating an occupational exposure matrix, this study also analysed and compared the technical features of different dosimeters that could be used for taking measurements. However, due to the type of tasks, exposure time, vessel conditions and other factors, the results and conclusions are considered difficult to extrapolate to the working conditions on board the most common fishing vessels along Spain's coasts (inshore and coastal fishing).

3 Erythema: reddening of the skin. It is an inflammatory response triggered by the actinic effect of solar radiation or artificial optical radiation.

A study conducted in the Mediterranean region of Northern Italy was also reviewed [*Modenese A. et al., 2019*], in which individual UV exposure was specifically assessed with electronic dosimeters by taking measurements for two days on a group of seven workers on three different types of vessels: mussel fishing, snail and cuttlefish fishing and trawling. The dosimeters were placed in different places (back, chest and neck). The results of the measurements of the fishermen showed high levels of UV exposure in northern Italy, particularly in fishing activities carried out on boats with insufficient shade-providing structures.

This literature review confirmed that there were no national studies that objectively and individually analysed the sun exposure patterns and doses received by workers in the fishing sector. For this reason, a detailed study including different fishing modes in different locations along the entire coastal territory of the Iberian Peninsula and the Canary Islands was deemed necessary.

OBJECTIVES

3. OBJECTIVES

3.1. Overall Objective

The overarching objective of the study is to describe the exposure to solar UV radiation to which workers in the fishing sector are subjected. For this purpose, the solar UV radiation to which workers are exposed during their workday shall be estimated by means of individual dosimetry (personal dosimeters) and environmental dosimetry (radiometers and spectroradiometers) in the workplace. To assess the effective short-term exposure of workers in the fishing sector, the particularities of each job will be considered and the possible influence of individual and local factors on this exposure will be described.

The results will be compared with the exposure limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

3.2. Specific objectives

The specific objectives are as follows:

- To describe the main factors on which the risk of exposure to solar UV radiation in the sector depends (season of the year, latitude, fishing mode, type of work performed in relation to exposure time, etc.).
- To compare actual individual exposure measurements with the erythemal UV radiation doses above which health damage occurs.
- To conduct a survey of sun exposure habits and attitudes towards sun protection using an anonymous questionnaire.
- To compile a series of preventive and protective measures applicable to the sector.
- To develop an action proposal regarding seamen's exposure to solar UV radiation.

METHODOLOGY

4. METHODOLOGY

The methodology used to achieve the proposed objectives includes different phases, which are as follows:

- measuring exposure,
- retrospective study of the effects of solar radiation on sea professionals and collection of information on the crew's sun protection habits.
- study of sun protection habits among the crew.

4.1. Measuring exposure

Solar UV radiation can be measured in the form of irradiance (incident power on a surface, W/m^2) or radiant exposure, also called dose (incident radiant energy on a surface, J/m^2). These radiometric quantities are related to each other through exposure time, as explained below.

In addition, both irradiance and radiant exposure should be spectrally weighted to take into account only the biologically effective wavelength range that produces erythema. The action spectrum considered in this study is the one proposed by the International Commission on Illumination (CIE) [CIE, 1998].

UV radiation's interaction with human skin is considered a chemical interaction. According to the *Law of Reciprocity* or the *Bunson-Roscoe Law*, high-level exposure for a short period of time has the same effect as low-level exposure over a long period of time. Therefore, radiant exposure, the irradiance product (W/m^2) and exposure time are important when considering erythema.

Radiant exposure is weighted according to the effect that is being studied. Thus, for measurements of erythemal effects, the results of the dosimeters are expressed as the effective dose to produce erythema in J/m^2. This effective dose to produce erythema is called the minimum erythemal dose (MED), defined as the erythemal radiant exposure that produces a barely perceptible erythema on an individual's previously unexposed skin after 24 hours of exposure. This measure is subjective in its determination of skin redness and depends on many variables, including individual skin pigmentation and exposure site. When MED is used in populations with different skin types, the skin type has to be defined, so its use is limited. The skin of people with phototype II is generally taken as a reference, which corresponds to an effective dose of 250 J/m^2 [*Perez A. et al., 2014*], based on Fitzpatrick's phototypes [*Fitzpatrick T.*

B., 1988]. Since this MED refers to phototype II, in order to standardise it to the different phototypes, the term standard erythemal dose (SED) was established, which is equivalent to an erythemal radiant exposure of 100 J/m^2. (1 SED = 100 J/m^2 per day [*ICNIRP, 2010*], [*ISO 17166:1999 CIE*]). The SED is independent of skin type; therefore, in our study, we use J/m^2 units, taking into account the equivalence with SED to interpret the results. This standardises the erythemal dose to which each crew member was exposed and the sensors placed on the ships to establish a standard of erythemal incident radiation dose regardless of skin phototype.

The ICNIRP recommends a maximum exposure of 30 J/m^2 effective UV dose over an eight-hour period using the American Conference of Industrial Hygienist (ACGIH) action spectrum [ICNIRP, 2004], which takes into account both skin (erythema) and eye (photokeratitis) effects. Therefore, an equivalence has to be established between the ICNIRP criterion and the ICD criterion [*ICD, 1998*] which only considers effects on the skin. This equivalence is established within a range of 100 to 130 J/m^2 [*ICNIRP, 2010*]. Therefore, the maximum daily limit is 130 J/m^2, and this the value is used to compare the measurements taken in the present study.

Table 2

Equivalence between ICNIRP and CIE criteria

ICNIRP Criteria	CIE Criteria
30 J/m^2 **Applicable to skin and eyes [ICNRIP, 2004]**	**100-130 J/m^2** **Applicable to skin [CIE,1998]**

4.1.1. Personal and fixed dosimeters

Using biological UV dosimeters was considered an appropriate way to estimate individual UV radiation exposure, based on the limitations observed with the use of calibrated electronic devices to estimate erythemal dose and their use in conditions of high humidity and contact with water. For this purpose, the technology used was based on a biofilm of spores, whose cellular DNA is damaged by exposure to solar UV radiation. This amount of damaged DNA is subsequently quantifiable and correlates with the amount of the effective dose for the production of skin erythema. Based on the above, *Viospor Blue line type II* (Biosense Systems, Bornheim, Germany) UV dosimeters were chosen.

These devices, which simulate human skin's erythemal response (dose) according to the CIE reference spectrum, are mounted on 32-mm diameter casings which do not hinder the crew's

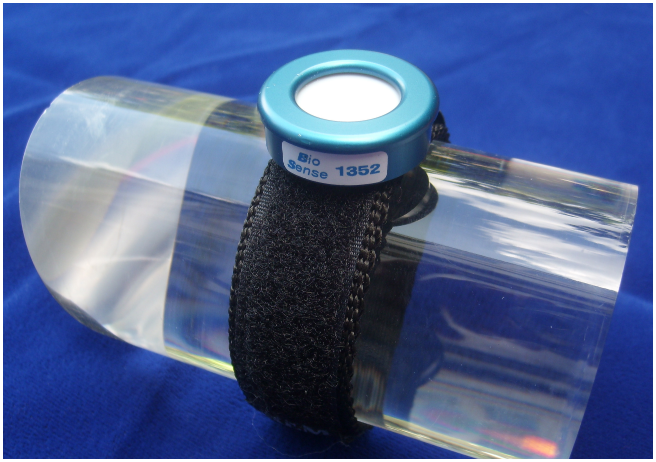

Figure 1. *VioSpor(R) Blueline Type II UV dosimeter. Photo owned by Dr Hans Holtschmidt, BioSense Labor für Biologische Sensorik.*

work. Furthermore, they are water-resistant, their response is extremely close to that of human skin (290 to 380 nm) and they operate in a temperature range between -20°C and +50°C. The results are expressed in the effective dose needed to produce erythema (J/m^2) or minimum erythemal dose (MED).

The working range of the dosimeters is 50 - 2250 J/m^2, which is considered appropriate for achieving the project's objectives.

The measurement area (Figure 1) is exposed to UV radiation while the dosimeter is in use.

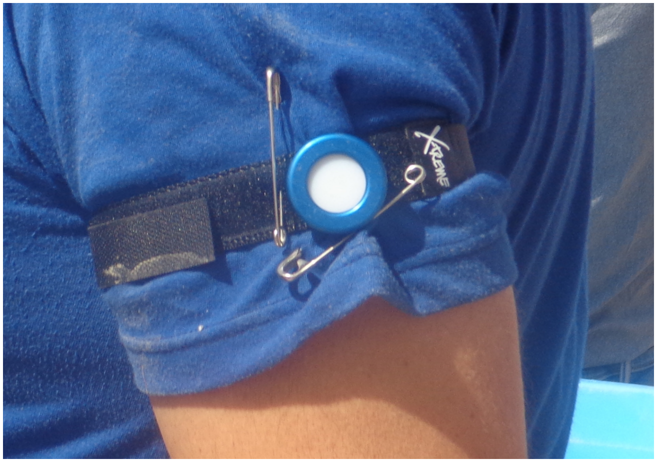

Figure 2. *Dosimeter on arm.*

Figure 3. *Dosimeter on wrist.*

The personal dosimeters were placed on the worker's arm or wrist using a Velcro bracelet at the beginning of the workday and removed at the end of the workday (Figures 2 and 3).

Figure 4. *Reference dosimeter.*

Figure 5. *Reference dosimeter.*

Each personal dosimeter remained on the worker for the entire workday for three consecutive days (between July and September 2019, depending on the area), thus assessing the total dose received during that three-day period.

Simultaneously, extra reference dosimeters were used to monitor total daily radiation; they were placed on a horizontal surface on the vessel that was directly exposed to solar radiation in areas free of any obstacles that could create shadows as a consequence of the sun's orientation throughout the measurement period (Figures 4 and 5).

4.1.2. Study population

The target population was determined by the previous selection of trawlers and small gear vessels. These two modes were chosen because they have greater potential solar exposure based on the time they enter and leave the port and the work performed during the fishing operations. In the trawl mode, different samples were taken for the positions of skipper and deckhand. This distinction was not made with the small gear mode, since the tasks carried out by both are very similar, and in some cases the vessels have only one crew member who performs all the tasks.

This selection was carried out in four areas in the national fishing grounds (Cantabrian-Northwest, Mediterranean, Gulf of Cadiz and Canary Islands) in conjunction with the National Federation of Fishermen's Guilds (FNCP); the technical occupational risk prevention organisations of Galicia (ISSGA), Valencia (INVASSAT) and the Canary Islands (ICASEL); and the Merchant Marine of the Ministry of Public Works.

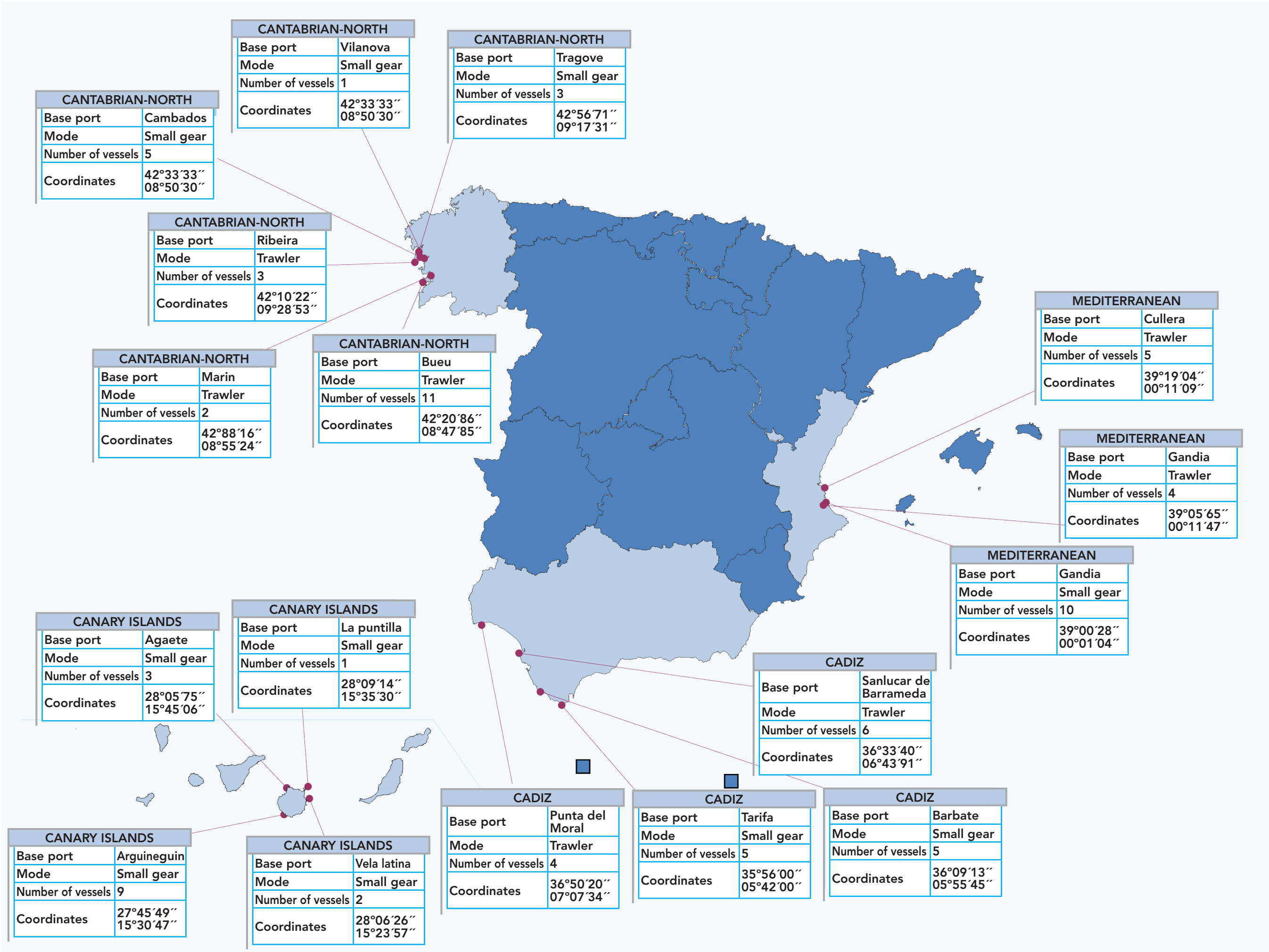

Figure 6. *Vessel location map.*

For the Mediterranean area, 9 trawlers and 10 small gear vessels were selected; in the Cantabrian-Northwest area, 5 trawlers and 20 small gear vessels (9 of them speedboats) were selected; in the Canary Islands area, 15 vessels were selected (9 in the southern area and 6 in the northern area), given that only the small gear mode is used there; and in the Gulf of Cadiz, 11 trawlers and 9 small gear vessels (five of them of the auxiliary almadraba type) were selected. Figure 6 shows the locations of the selected vessels.

Sampling was carried out with a total of 200 dosimeters distributed among 79 vessels and 119 workers. The distribution of the sampling by area is as follows: 48 measurements in the Mediterranean area (Table 3), 58 in the Cantabrian-Northwest area (Table 4), 36 in the Canary Islands area (Table 5) and 58 in the Gulf of Cadiz (Table 6). This leads to a total of 87 samples for trawlers and 112 for small gear vessels, plus a blank used to check the measurements.

Tables 3 to 6 list the ports, the participating vessels and the dosimeters used in the study.

Table 3
Vessels and dosimeters. Mediterranean Area

Mediterranean Area						
Port	**Vessels**		**Dosimeters**			
			Personal		**Fixed**	
	Trawler	**Small gear**	**Trawler**	**Small gear**	**Trawler**	**Small gear**
Gandía	4	10	10	10		9
Cullera	5		10		9	
Total	9	10	20	10	9	9
	19		30		18	
			48			

Table 4
Vessels and dosimeters. Cantabrian - Northwest Area

<table>
<tr><th colspan="7">Cantabrian - Northwest Area</th></tr>
<tr><th rowspan="3">Port</th><th colspan="2">Vessels</th><th colspan="4">Dosimeters</th></tr>
<tr><th rowspan="2">Trawler</th><th rowspan="2">Small gear</th><th colspan="2">Personal</th><th colspan="2">Fixed</th></tr>
<tr><th>Trawler</th><th>Small gear</th><th>Trawler</th><th>Small gear</th></tr>
<tr><td>Ribeira</td><td>3</td><td></td><td>9</td><td></td><td>9</td><td></td></tr>
<tr><td>Tragove (Cambados)</td><td></td><td>6</td><td></td><td>6</td><td></td><td></td></tr>
<tr><td>Santo Tomé</td><td></td><td>2</td><td></td><td>2</td><td></td><td></td></tr>
<tr><td>Vilanova</td><td></td><td>1</td><td></td><td>1</td><td></td><td>3</td></tr>
<tr><td>Marín</td><td>2</td><td></td><td>5</td><td></td><td>6</td><td></td></tr>
<tr><td>Bueu</td><td></td><td>10</td><td></td><td>10</td><td></td><td>6</td></tr>
<tr><td>Beluso</td><td></td><td>1</td><td></td><td>1</td><td></td><td></td></tr>
<tr><td rowspan="3">Total</td><td>5</td><td>20</td><td>14</td><td>20</td><td>15</td><td>9</td></tr>
<tr><td colspan="2" rowspan="2">25</td><td colspan="2">34</td><td colspan="2">24</td></tr>
<tr><td colspan="4">58</td></tr>
</table>

Table 5
Vessels and dosimeters. Canary Islands Area (Small gear only)

Canary Islands Area (Small gear only)			
Port	**Vessels**	**Dosimeters**	
		Personal	**Fixed**
Arguineguin	9	9	9
Agaete	3	3	6
La Puntilla	1	1	
Vela Latina	2	2	5
Total	15	15	20
		35	
1 blank dosimeter was retained (Total 36 dosimeters)			

Table 6
Vessels and dosimeters. Gulf of Cadiz area

<table>
<tr><th colspan="7">Gulf of Cadiz area</th></tr>
<tr><th rowspan="3">Port</th><th colspan="2">Vessels</th><th colspan="4">Dosimeters</th></tr>
<tr><th rowspan="2">Trawler</th><th rowspan="2">Small gear</th><th colspan="2">Personal</th><th colspan="2">Fixed</th></tr>
<tr><th>Trawler</th><th>Small gear</th><th>Trawler</th><th>Small gear</th></tr>
<tr><td>Punta del Moral</td><td>4</td><td></td><td>8</td><td></td><td>3</td><td></td></tr>
<tr><td>Sanlúcar de Barrameda</td><td>7</td><td></td><td>12</td><td></td><td>6</td><td></td></tr>
<tr><td>Barbate</td><td></td><td>5</td><td></td><td>10</td><td></td><td>3</td></tr>
<tr><td>Tarifa</td><td></td><td>4</td><td></td><td>10</td><td></td><td>6</td></tr>
<tr><td rowspan="3">Total</td><td>11</td><td>9</td><td>20</td><td>20</td><td>9</td><td>9</td></tr>
<tr><td colspan="2" rowspan="2">20</td><td colspan="2">40</td><td colspan="2">18</td></tr>
<tr><td colspan="4">58</td></tr>
</table>

4.1.3. Radiometric and spectroradiometric measurements

In the area of Barbate (Gulf of Cadiz), in addition to measurements with personal and fixed dosimeters, two types of environmental measurements were carried out in conjunction with researchers from the Dermatological Photobiology Laboratory of the Centre for Medical and Health Research of the University of Malaga. First of all, an intercalibration of environmental measurements of erythemal irradiance and the subsequent calculation of the cumulative solar radiation dose with respect to those measured by the biological dosimeters was carried out to verify that the measurements made with the dosimeters used correspond to the real dose received by the crew members. Secondly, solar radiation measurements were made at the spectral level using a Macam SR2271 double monochromator spectroradiometer (Irradian Co. UK). This equipment was connected to an Ulbrich sphere with fibre optics and allowed solar spectral measurements to be made between the UV range and all visible radiation (290-750 nm). The spectroradiometer was placed horizontally on the highest part of the vessel next to a biological dosimeter. Each spectrum was taken at 30-minute intervals and, if cloud cover was observed at that time, the spectra were performed immediately afterwards, once the sky cleared, in order to obtain real data on both potential incidence with clear skies and real incidence with partial cloud cover. From the spectral measurements, absolute irradiance levels (W/m^2) were taken for the different UVB, UVA and visible (blue, green, red) spectral bands, and weighted measurements of the absolute UV irradiance (290-400 nm) were taken by multiplying the absolute irradiance values at 1-nm intervals by the relative effective values for that wavelength for potentially producing erythema, based on the erythemal action spectrum contained in ISO 17166:2019 [*ISO 17166:1999 CIE*].

Based on the erythemal irradiance calculation data, the doses received at 15-minute intervals were calculated for both cloudy and clear skies, and the cumulative doses for phototypes I, II, III and IV were calculated, as well as the number of cumulative standard doses of erythemal radiation. The amount of erythemal irradiance is further expressed in terms of the UV index, which was obtained by multiplying the value of erythemal irradiance expressed in W/m^2 x 40, following the WHO UV index guideline [*WHO, 2003*].

All this information is complemented by using a flat sensor for total UV radiation, thus obtaining the total UV irradiance (UVA + UVB) in order to have radiometric monitoring on the same day and during the same hours.

4.2. Retrospective study of the effects of solar radiation on sea professionals. (Analysis of CEPROSS, PANOTRATSS and SANIMAR databases)

In order to analyse the possible effects of exposure to solar ultraviolet radiation [*Muñoz - Cobo B. et al., 2021*], [*INSST, 2014*] in greater depth, we enlisted the collaboration of the Social Marine Institute (ISM) to study pathologies that could be caused or influenced by exposure to solar UV radiation, as contained in the ISM's own SANIMAR database.

This database contains the health records of workers under the special seafarers regime, the medical records for any type of doctor's visit in the event of illness or accident and the record of pre-embarkation check-ups (abbreviated RMEM in Spanish), managed by the ISM's central services and provincial directorates.

Specifically, the data analysed come from the RMEM for the period from 1 January 2010 to 1 January 2020. Table 7 provides the details of the data requested.

Table 7
Data analysed from the SANIMAR database

Module	RMEM
Period	Between 1 January 2010 and 1 January 2020.
Crew members	By sex and age. By job (skipper or deckhand). By years on the job.
Vessel	Type of activity (inshore fishing, trawling and small gear).

To complement the data contained in the study, we analysed the information collected in the system for reporting occupational diseases (CEPROSS) and the information system for non-traumatic pathologies caused or aggravated by work (PANOTRATSS) for the period 2009-2018, by the fishing CNAE, which may be related to exposure to solar UV radiation.

4.3. Study of sun protection habits among the crew.

The day before the sampling, a brief talk was given to tell the crew the objective of the project, to give them the instructions needed so they could do their jobs as usual while avoiding covering the sensor with any object or fabric, and to provide them with an anonymous questionnaire on sun protection habits to fill in.

Based on the studies compiled in the literature review, the questionnaire was designed to get information on the attitudes, knowledge, work practices and sun protection practices of the crew participating in the study. The questionnaire consisted of the following sections:

- Section I collected demographic data to identify the participant by age, sex, nationality, educational level and job.

- Section II collected information on individual factors that may influence the risk of skin cancer, such as eye colour, hair colour and skin phototype.
- In section III, the professional's behaviour in relation to the sun was analysed by collecting information on the average number of hours of daily sun exposure, years on the job and sun protection habits both during the workday and in their free time.
- Finally, section IV gathered information on the worker's knowledge of the damage caused by solar UV radiation.

RESULTS

5. RESULTS

5.1. Measuring exposure.

The results shown below were analysed on the basis of J/m^2 units.

As noted in section 4.1, it is important to point out that the detection range of the dosimeters is between 50 and 2250 J/m^2, so measurements above or below this range were discarded when performing the data analysis.

Secondly, we should note that in order to compare with the limit recommended by ICNIRP, the data had to be weighted for an 8-hour period given that many of the activities on ships begin before dawn, when there is no exposure to UV rays. Therefore, only the hours of potential solar radiation have been considered, calculating the average dose per hour in that effective period and transferring it to an 8-hour period for comparison's sake, with the limitation that the intensity of solar radiation is not constant throughout the sun's daily cycle.

5.1.1. Personal dosimeters.

The results from the personal dosimeters for a total of 115 crew members in terms of mean, median and 95% confidence intervals are shown in Table 8.

Table 8
Results of total personal measurements

	UV radiation exposure (J/m^2)			
	Mean	Median	IC 95%	ICNIRP Recommended (CIE, 1998)
Personal dosimeters	495	491	440-550	100 - 130

Based on the results, we can state that half of the workers are subjected to exposure almost five times higher than the limit recommended by the ICNIRP.

5.1.1.1. Data analysis by fishing mode

The results from the analysis of the personal dosimeters according to the fishing mode are shown in Table 9 and are expressed in terms of mean, median and estimates by 95% confidence intervals, which yielded 62 valid measurements for small gear fishing vessels and 53 valid measurements for trawlers.

Table 9
Results by fishing mode

Fishing mode	UV radiation exposure (J/m²)		
	Mean	Median	95% CI
Trawler	264	224	214 – 314
Small gear vessel	693	692	635 – 751
Non-parametric test to compare means: $p<0.001$			
Non-parametric test to compare medians: $p<0.001$			

When analysing the fishing mode variable and the level of statistical significance, we found significant differences between the different modes sampled.

According to the values found, there is a major difference between the exposure to which the crew of the two modes is subjected; specifically, although the recommended limit is exceeded in both modes, the crew of small gear vessels have three times as much exposure as the crew on trawlers (Figure 9).

This result is basically related to the characteristics of the vessels, since trawlers are larger and have covered areas (Figure 7), while small gear vessels (Figure 8), in the best of cases, only have a manual awning or a small bridge to shelter under while reaching the fishing area.

Figure 7. *Trawlers.*

The work schedule also plays a role, since fishing operations and the task of sorting the catches generally take place during times of higher solar radiation on small gear vessels.

Another factor to consider, which will be analysed later, is related to the differences between the exposure of deckhands and skippers according to the measurements made in the trawler mode.

Figure 8. *Small gear vessels.*

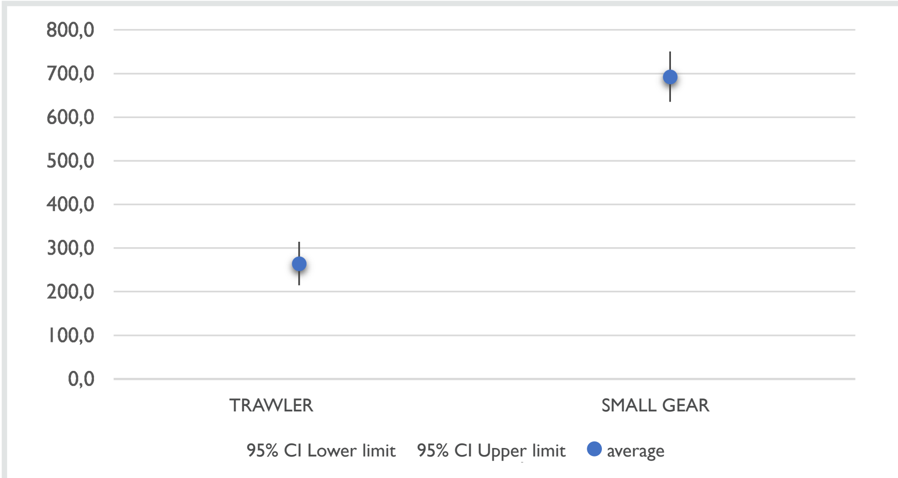

Figure 9. *Variability of exposure levels by fishing mode.*

5.1.1.2. Analysis by sampled areas in the national fishing grounds

The data for the Mediterranean area were statistically processed on the basis of 30 measurements, one of which was rejected because it was below the detection[4] range of the dosimeters.

For the Cantabrian-Northwest area, an analysis was carried out based on 34 observations, one of which was rejected because it was above the detection range of the dosimeters.

In the Canary Islands, 15 observations were made, two of which were rejected because they were above the detection range of the dosimeters.

The analysis of the Gulf of Cadiz was based on 40 observations, all of which were valid.

Table 10 shows the results, which are graphically represented in Figure 10.

[4] The detection range of the dosimeters is between 50 and 2250 J/m^2, so any measurements above or below this range were discarded during the data analysis.

Table 10
Results by areas in the national fishing grounds

National fishing grounds	UV radiation exposure (J/m²)		
	Mean	Median	95% CI
Mediterranean	320	266	243 – 396
Cantabrian-Northwest	538	572	418 – 658
Canary Islands	730	673	563 – 897
Gulf of Cadiz	511	522	426 – 595
Non-parametric test to compare means: $p=0.001$			
Non-parametric test to compare medians: $p<0.001$			

By analysing the fishery grounds variable and the level of statistical significance, we can state that there are significant differences among the different areas sampled. According to the values found, the limit recommended by the ICNIRP is exceeded in all the areas sampled, with the Mediterranean area particularly standing out with exposure that is practically half of the other areas.

One possible justification of this is that all small gear vessels in the Mediterranean area have a manual awning whose purpose is to protect the catch while it is being sorted, but which also indirectly provides the professionals with protection as they handle and sort these catches. This analysis can be observed in greater detail when compared by different fishing modes and areas sampled.

5.1.1.3. Analysis of data by fishing mode and area sampled in the national fishing grounds

The results of the analysis of the personal dosimeters according to the fishing modes and the area sampled are shown in Table 11.

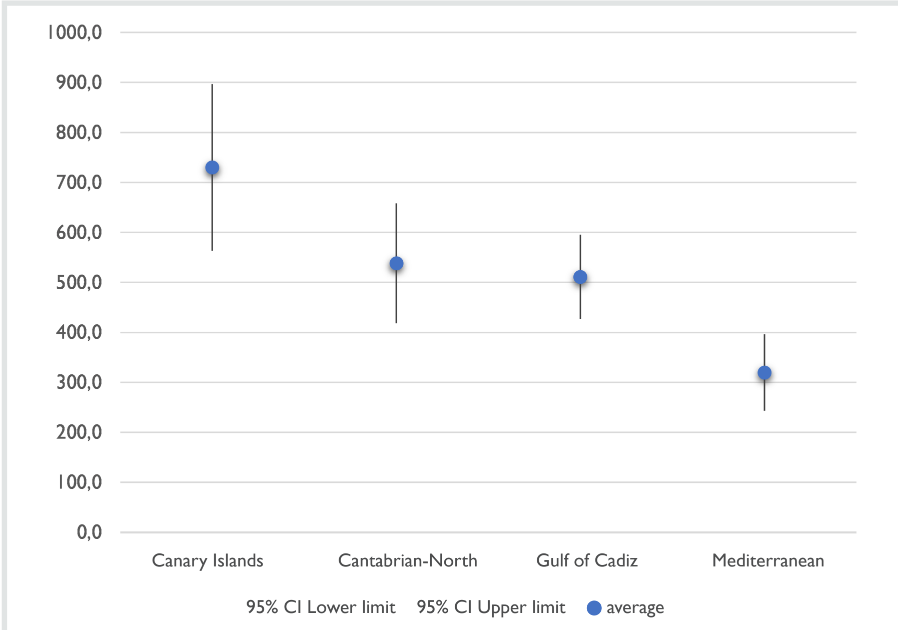

Figure 10. *Variability of exposure levels by area in the national fishing grounds.*

The exposure is much higher in small gear vessels in each of the areas than in trawlers.

For the trawler mode, there are no major differences between vessels in the different areas (Figures 11 and 12). These are coastal trawlers that operate less than 60 nautical miles from the coast and generally return to port every day to unload their catches. This type of vessel has an average of five crew members.

The trawlers in the Cantabrian are usually the largest, between 24 and 28 metres long. They make an average of 4 hauls per workday, have a large fixed deck but do not have an awning to sort the catches on the deck. Andalusian trawlers range in

Table 11
Results by mode and areas in the national fishing grounds

National fishing grounds		UV radiation exposure (J/m²)		
		Mean	Median	95% CI
Mediterranean	Trawlers	230	231	190 – 270
	Small gear vessels	490	501	311 – 670
Cantabrian-Northwest	Trawlers	196	176	133 – 258
	Small gear vessels	791	745	698 – 882
Canary Islands	Small gear vessels	730	673	563 – 897
Gulf of Cadiz	Trawlers	345	266	227 – 463
	Small gear vessels	677	707	607 – 746

length from 17 to 24 metres and make an average of 3 to 4 hauls per workday. Within the Andalusia area, several differences were found among the vessels sampled from the different ports; for example, in Ayamonte, they have a larger fixed deck than in Sanlúcar de Barrameda. With respect to schedules, the average for the different areas is between 3:00 am and 7:00 pm, with no major differences regarding the workday and departure and arrival at port. It is worth mentioning that vessels arrive earlier to port (around 4 pm) in the Mediterranean area. Therefore, the trawlers' exposure is very similar among all areas, although it is slightly higher in Andalusia, which may be due to the fact that it has a larger fixed deck size and some vessels do not use awnings when sorting the catches.

For the small gear mode, the situation is more variable, depending on the type of gear used, the type of vessel and work schedules. The limit

Figure 11. *Trawlers - Cantabrian.*

Figure 12. *Arrastre - Trawlers - Gulf of Cadiz.*

recommended by the ICNIRP is exceeded in all areas, with the highest exposure in the Cantabrian-Northwest area, followed by the Gulf of Cadiz, the Canary Islands and finally the Mediterranean.

In the Cantabrian-Northwest area, measurements were taken on small speedboat-type shipboard shellfishing vessels (between 4.5 and 6 metres in length) that fish very close to the coast and offer no protection against solar UV radiation. They usually have one or two crew members, with working hours between 6:30 am and 2:30 pm. Their activity consists of extracting bivalves with the help of a rake-like tool called a *raño*, using manual traction. When using this type of gear, exposure is constant throughout the day.

In this same area, measurements were included on vessels that fish for octopus using pots and two other vessels that use nets to fish for mullet and pouting. These are larger vessels (between 7 and 13 metres in length), with a small

Figure 13. *Small gear vessels with cabin.*

Figure 14. *Small gear vessels - speedboats.*

wheelhouse and working hours between 6:00 am and 4:00 pm.

Figures 13 and 14 show the selected vessels in the Cantabrian area.

In the Mediterranean, the selected vessels work in trammel net fishing, and they all have a bridge and a manual awning (Figures 15 and 16). Their working hours are between 5:30 am and 4:00 pm. They head out to sea at around 5:00 a.m. to collect the catches from the net, return to port at around 10:00 a.m. and sort the catches under a manual awning on the boat itself. At around 12:00 noon they go back out to sea to cast the net and leave it in the sea until the following morning. They return to port at around 4:00 p.m., the end of their workday. The use of a manual awning - which, as stated above, is used to prevent the sun from spoiling the fish as the catches are being

Figure 15. *Small gear vessels - Mediterranean.*

Figure 16. *Small gear vessels - Mediterranean.*

sorted, as well as to protect the crew from solar UV radiation - has been identified as the reason the exposure measured in this area is much lower than in the other areas.

In the Gulf of Cadiz area, measurements were taken on vessels that fish for bluefin tuna. A notable difference was found between the vessels in the area of Barbate working in almadraba fhising and those used in the area of Tarifa for artisan fishing with live bait and line (Figures 17 and 18).

The artisan fishing vessels are between 12 and 17 metres in length and have an average of 5 crew members. They fish when the tide is low, since this is when there is the greatest movement of the bait on which the tuna feed. Thus, depending on the tide, they sometimes fish in the morning and sometimes in the afternoon, so sun exposure varies accordingly. On the date when the sampling was carried out, the working hours were generally in the afternoon, between 3 pm and 11 pm, with the addition of the morning baiting hours between 6:30 am and 3 pm.

Figure 17. *mall gear vessels with cabin.*

Figure 18. *Small gear vessels - almadraba.*

In the case of almadraba fishing, the technique is totally different. In the spring, the 3-kilometre-long set of nets is laid out not far from the coast. Only the tuna weighing more than 200 kilos are let through the hole in the mesh to ensure that they have spawned at least a dozen times to avoid endangering the species. Sampling was carried out during what is called the *levantá*, when the tuna are being encircled, at which time the divers dive into the water, select the catches and kill them with a rifle called a *lupara* so the animal suffers as little as possible. In this case, the seamen's exposure is constant; the selected vessels where the crew were located were auxiliary vessels towed along with no protection against solar radiation, with a working schedule between 6:30 am and 3:00 pm. The tasks they performed included hauling the nets to attract the tuna to the surface and helping to bring the catches to the boat. For all of the above reasons, the exposure measured in this area ranks second among the measurements made for each of the areas.

Figure 19. *Small gear vessels with cabin.*

Figure 20. *Small gear vessels - speedboats.*

Finally, for the Canary Islands, the samples taken differed between the northern and southern areas due to a totally different climatology, characterised mainly by the presence of clouds in the northern area.

Regarding the selected vessels, there were no significant differences among them in the southern area (Figure 19). All of them have a bridge, and their working hours are from 4:00 am to 2:30 pm, except for the hook-and-line vessels that return to port at around 7:00 pm, depending on the amount of fish caught. The length of these vessels is between 10 and 15 m for hook-and-line vessels, with an average of 3 - 4 crew members, and between 6 and 9 m for pot and trammel net fishing, with an average of 1 or 2 crew members. Tuna hook-and-line vessels stand out, as the results show that they pose a higher risk of exposure to solar UV radiation because the deckhands remain on deck

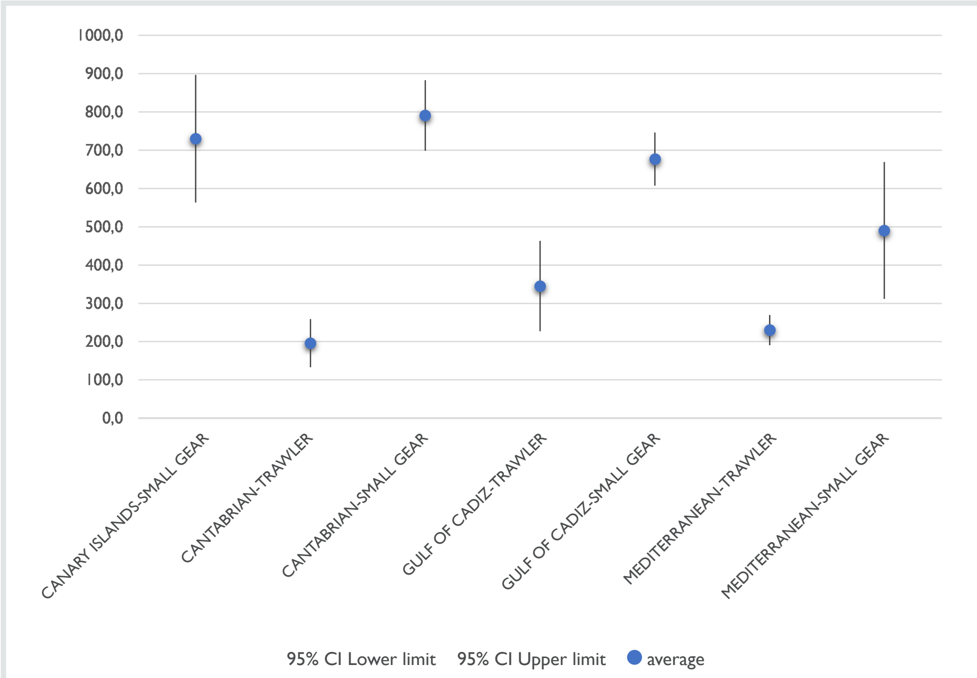

Figure 21. *Variability of exposure levels according to fishing mode and area in the national fishing grounds.*

for a long time to catch the tuna one by one. The tasks they perform consist of attracting the tuna to the capture area with pressurised water jets on the surface of the water and live bait that is released, making what is commonly called "*bulla*" to attract and confuse the tuna, which are finally caught with large hooks one at a time.

In the northern area, the vessels sampled (Figure 20) are smaller, like speedboats (8-9 meters in length), use the pot and trap modes and lack a bridge; their schedule is between 6:00 am and 1:30 pm. These vessels use small pots that are usually set at shallow depths, so the time spent at sea is much briefer than in the southern area.

Table 12
Small gear mode. Measurement results by area, vessel type and technique used

Area	Boat (vessels)	Technique	Average (J/m²)
Mediterranean	With bridge (10)	Trammel nets	490
Cantabrian	Speedboat (9)	Shipboard shellfishing	782
	With bridge (9)	Pot	793
	With bridge (2)	Trammel nets	932
Canary Islands	With bridge (1)	Trammel nets	752
	With bridge (5)	Hook-and-line	1073
	With bridge (3)	Pot	562
	Without bridge (6)	Pot	654
Gulf of Cadiz	Without bridge (3)	Almadraba	682
	With bridge (2)	Almadraba	606
	With bridge (4)	Hook-and-line	694

The results obtained according to the modality and the fishing area are represented graphically in Figure 21.

By way of summary, Table 12 shows the types of vessels and gear used for the small gear mode, with the results of the measurements made for each of the areas.

Once again, the influence of the conditions described above stands out, namely:

- The use of the manual awning in the Mediterranean, which causes the average exposure to be much lower than in the other areas.
- The time of exposure and the angle of incidence of the sun, which makes the intensity

of exposure much greater depending on the time of day. For example, in the Cantabrian area, the lowest exposure recorded is for speedboat-type vessels; thus, although these vessels offer workers the least protection, their work schedule means that exposure is not concentrated in the hours when the sunlight is the most intense. In the Canary Islands area, the highest exposure was recorded for southern vessels with a bridge that fish for tuna with a hook-and-line and return to port at around 7 pm, while the lowest exposure was recorded for speedboat-type vessels with a bridge which do pot fishing, which return to port around 1 pm.

5.1.1.4. Data analysis by job

The results of the analysis of the personal dosimeters according to job are shown in Table 13 and graphically illustrated in Figure 22. This analysis was only performed for the trawling mode, where sampling was differentiated between the skipper and deckhands to analyse whether there are significant differences between the jobs sampled.

The results show that, as expected, there are significant differences between the two jobs

Table 13
Results by job

Job	UV radiation exposure (J/m²)		
	Mean	Median	95% CI
Skipper	202	178	158 – 245
Deckhand	316	250	235 – 398
Non-parametric test to compare means: p=0.03			
Non-parametric test to compare medians: p=0.2			

sampled. In all of them, the mean and median values exceed the limit recommended by the ICNIRP, and there is a clear difference between the measurements for the job of skipper, whose values are around the limit, and the job of deckhands, who receive twice as much exposure as the recommended level.

The tasks they perform are clearly different: the skipper steers the vessel and directs the fishing operations, while the deckhands spend more time on deck performing different tasks such as hauling, trawling and handling the gear, as well as handling, sorting and storing the catch. The results are in accordance with expectations, as the skipper spends more time protected from solar UV radiation on the bridge directing operations and steering the ship, while the deckhands always have twice as much exposure as the skipper due to their assigned tasks.

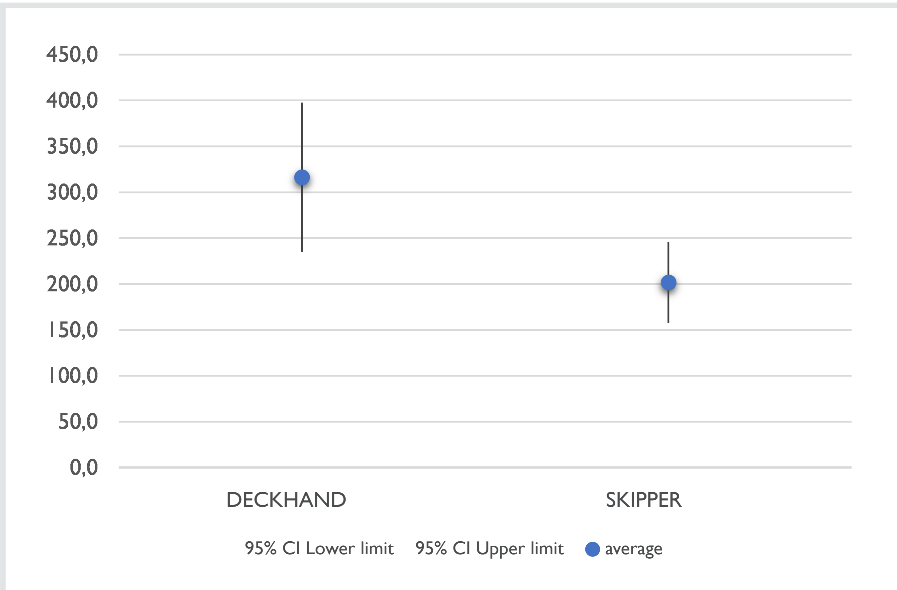

Figure 22. *Variability of exposure levels according to job.*

The following is a breakdown of the information for the different jobs among the areas sampled.

Table 14
Results by job and area in the national fishing grounds

National fishing grounds		UV radiation exposure (J/m^2)		
		Mean	Median	95% CI
Mediterranean	Skipper	192	194	126 – 257
	Deckhand	258	252	206 – 310
Cantabrian-Northwest	Skipper	155	126	71 – 239
	Deckhand	227	233	124 - 329
Gulf of Cadiz	Skipper	237	218	145 – 330
	Deckhand	453	416	236 – 669

Figure 23 confirms that the deckhands' exposure exceeds that of the skippers' in all areas. There are no major differences between the Mediterranean and Cantabrian areas, since the trawling mode has practically the same characteristics in all areas, as mentioned above. The differences are greater, in the Gulf of Cadiz, with the deckhands' exposure being twice as high as the skippers'. As mentioned above, this is because these vessels have a larger deck and catches are sometimes sorted without the protection of an awning, which leads to greater variability in the results obtained.

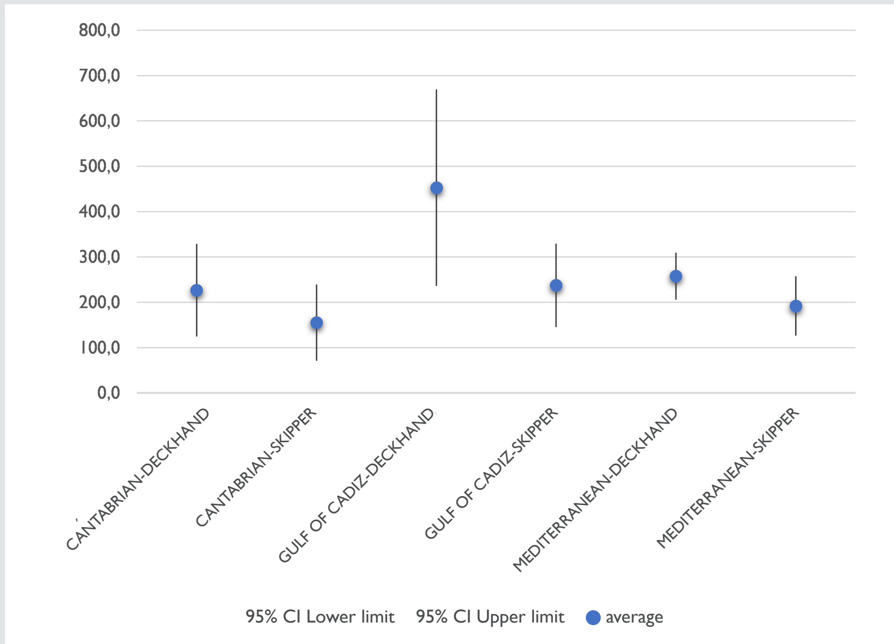

Figure 23. *Variability of exposure levels according to job and area in the national fishing grounds.*

5.1.1.5. Comparison of measurements recorded with personal dosimeters, group prevalence and the reference criterion recommended by the ICNIRP

The deviation from the reference criterion of 130 J/m^2 recommended by the ICNIRP was calculated for each category of independent variables (fishing ground, fishing mode and job) using 95% confidence interval estimates.

Overall, exposure exceeds the ICNIRP recommended value by 310 to 420 J/m^2.

Excess exposure compared to the reference criterion was corroborated in all fishing grounds

Table 15
Comparative results of independent variables by confidence intervals

		Mean difference with respect to the reference criterion	95% CI Lower limit	95% CI Upper limit
Fishing grounds	Mediterranean	189	113	266
	Cantabrian-Northwest	408	288	528
	Canary Islands	600	433	766
	Gulf of Cadiz	380	296	465
Mode	Trawlers	134	84	184
	Small gear vessels	562	504	620
Job	Skipper	71	27	115
	Deckhand	186	105	267
Total	Total	365	310	420

and is particularly noteworthy for the Canary Islands area, where only the small gear mode is recorded.

Excess exposure compared to the reference criterion was also corroborated with regard to the modes, although the small gear mode stands out for greater disparities, given that the exposure exceeds the recommended value by 505 to 621 J/m^2.

Additionally, for each category of the independent variables (fishing ground, fishing mode and job), the group prevalence is compared according to whether or not they exceed the reference criterion.

As shown in Table 16, when analysing the fishing ground variable, the distribution of the percentages exceeding the limit of 130 J/m^2 is homogeneous in

Table 16
Comparative results of independent variables by confidence intervals

		Does not exceed the reference criterion of 130 J/m² (%)	Exceeds the reference criterion of 130 J/m² (%)	Statistical significance (p)
Fishing grounds	Mediterranean	13,8	86,2	0,38
	Cantabrian-Northwest	15,2	84,8	
	Canary Islands		100,0	
	Gulf of Cadiz	7,5	92,5	
Mode	Trawlers	20,8	79,2	0,001
	Small gear vessels	1,6	98,4	
Job	Skipper	33,3	66,7	0,04
	Deckhand	10,3	89,7	
Total	Total	10,4	89,6	

relation to the different locations (Mediterranean, Cantabrian-Northwest, Canary Islands and Gulf of Cadiz), with no significant differences among them. On the other hand, significant differences were found according to fishing mode, with a higher proportion exceeding the 130 J/m^2 limit in small gear vessels compared to trawlers. The same was found when analysing the job, where the proportion exceeding the limit of 130 J/m^2 is higher in deckhands than in skippers.

5.1.2. Fixed dosimeters

As explained in section 4.1, extra reference dosimeters were placed on some vessels to monitor the ambient UV radiation at the worksite. A total of 80 reference measurements were made.

The result of this comparison shows that, as expected, the daily exposure to which the crew is subjected is much lower than the maximum potential exposure received on the vessels.

The reference dosimeter was placed in a stationary position throughout the day in order to monitor the overall radiation to which the workers are exposed; however, the crew is not continuously exposed to UV radiation, given that during their work they

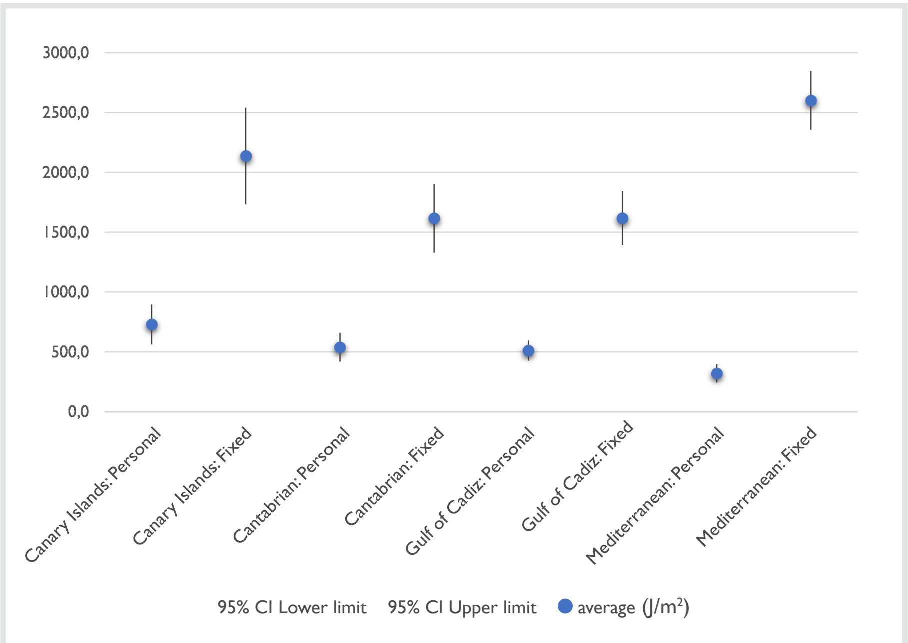

Figure 24. *Comparison of the average exposure between personal dosimeters and fixed dosimeters for each of the sampled areas.*

perform different tasks, and some of them are not performed on deck, so their exposure is not continuous. However, this environmental exposure is a necessary fact to take into account in order to ascertain the maximum potential exposure in the worksite and thus highlight the need to acquire solar radiation protection habits.

When comparing the average exposure collected in the personal dosimeters and the fixed reference dosimeters (Figure 24), we can clearly see the difference between the measurements collected.

As with the personal dosimeters, the measurements collected by the fixed dosimeters were analysed, with the results presented as a function of the mean, the median and estimates by 95% confidence intervals.

5.1.2.1. Analysis by sampled areas in the national fishing grounds

The results of the analysis of the fixed reference dosimeters for each of the areas are shown in Table 17. The statistical processing of the data was based on 18 measurements for the Mediterranean area, 24 for the Cantabrian-Northwest area, 20 for the Canary Islands area and 18 for the Gulf of Cadiz area, with only one measurement in the Cantabrian-Northwest area rejected because it was above the detection range of the dosimeters.

Table 17
Results by areas in the national fishing grounds

National fishing grounds	UV radiation exposure (J/m^2)		
	Mean	Median	95% CI
Mediterranean	2601	2713	2356-2847
Cantabrian-Northwest	1624	1784	1329-1906
Canary Islands	2137	2260	1733-2543
Gulf of Cadiz	1618	1558	1393-1843
Non-parametric test to compare means: $p<0.001$			
Non-parametric test to compare medians: $p<0.001$			

By analysing the fishery grounds variable and the level of statistical significance, we can state that there are significant differences among the different areas sampled. According to the values obtained (see Figure 25), the Mediterranean is in first place, followed by the Canary Islands and the Cantabrian-Northwest, with the Gulf of Cadiz in last place. These data demonstrate the effectiveness of the awning available to the boats in the Mediterranean area as a measure of protection against UV radiation, as the workers there received approximately half the dose of workers in the other areas, even though the levels of ambient radiation collected there rank first in terms of exposure levels.

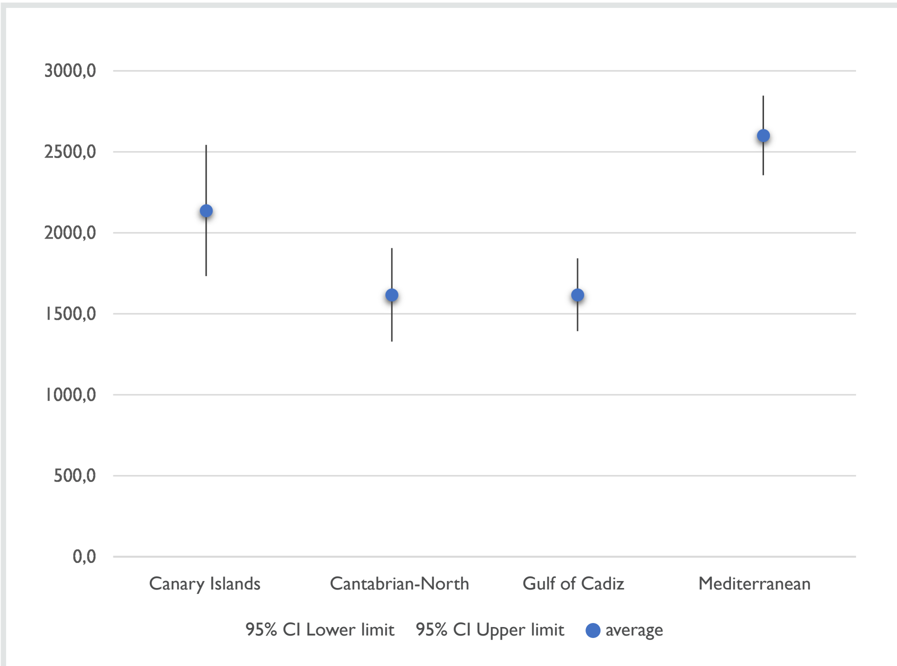

Figure 25. *Variability of environmental exposure levels by area in the national fishing grounds.*

5.1.2.2. Data analysis by fishing mode

Table 18 below shows the UV dosimetry measurements in J/m^2 taken on a total of 80 vessels, divided into 47 valid measurements for small gear vessels and 32 valid measurements for trawlers (one of which was rejected because it was above the detection range of the dosimeters).

As seen in Table 18, when analysing the fishing mode variable and the level of statistical significance, we find that there are significant differences between the different modes sampled. Although the difference is not as clear as in the personal dosimeter measurements, it is again evident that the maximum potential dose to which the crew are exposed in the small gear mode is higher than in the trawler mode (see Figure 26). This may be due to the schedule for small gear fishing, as it tends to be concentrated in the hours when the sunlight is the most intense.

Table 18
Results by fishing mode

Fishing mode	UV radiation exposure (J/m^2)		
	Mean	Median	95% CI
Trawlers	1785	1642	1465 – 2105
Small gear vessels	2101	2081	1917 – 2286
Non-parametric test to compare means: $p=0.05$			
Non-parametric test to compare medians: $p=0.05$			

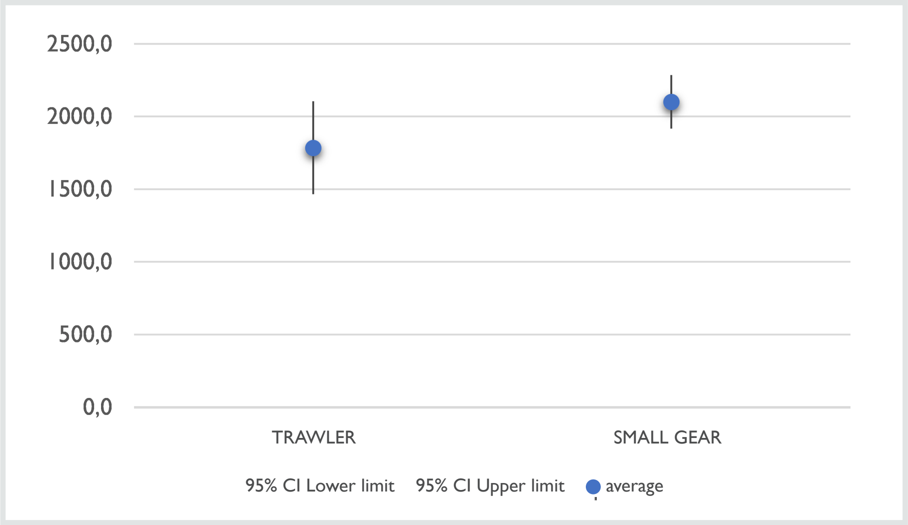

Figure 26. *Variability of environmental exposure levels according to fishing mode.*

5.1.3. Radiometric and spectroradiometric measurements

As stated in the methodology section, in the Barbate area (Gulf of Cadiz), in addition to measurements with personal and fixed dosimeters, two types of environmental measurements were taken using a double monochromator spectroradiometer (Figure 27).

Figure 27. *Location of the spectroradiometer and reference dosimeter.*

Figure 28 shows the incident solar radiation spectra over the measurement period for 19 September 2019 during working hours from 9 am to 1:30 pm.

A gradual increase in both UV and visible spectral irradiance can be observed throughout the analysis period. Several curves corresponding to 11:53 am are also represented due to the presence of clouds, which caused a decrease in total solar radiation; however, we find that the presence of those clouds does not cause a drastic drop in UV irradiance, which is a reminder of the need to use sun protection even on cloudy days.

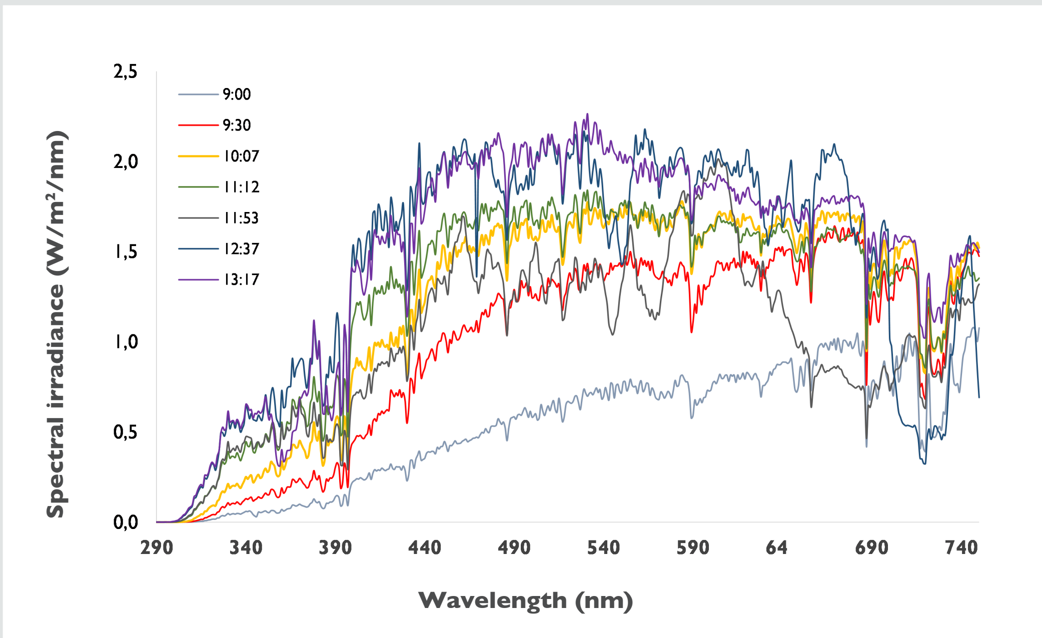

Figure 28. *Absolute spectral irradiance in the 290-750 nm interval for solar measurements at different times during the working period on 19-09-2019.*

Table 19 shows the absolute irradiance for the different measurements taken with data from the analysis of the spectra performed.

The erythemal irradiance measured with the spectroradiometer was 1309.68 J/m². The fixed reference dosimeter located near the spectroradiome-

Table 19
Absolute irradiance

	Absolute irradiance (W/m²)								
	Time of day								
	9:02:50	9:29:03	10:07:46	11:01:23	11:28:02	12:17:56	12:37:13	13:17:08	Total dose (J/m²)
UVB (290-320 nm)	0,1	0,2	0,5	1,4	1,7	2,2	2,5	2,7	21,6
UVA (320-400 nm)	6,2	14,5	27,1	43,8	50,2	50,0	57,6	50,9	620,1
UV (290-400 nm)	6,3	14,6	27,6	45,0	51,7	51,9	59,8	53,3	639,1
BLUE (400-500 nm)	41,4	93,3	132,8	162,7	180,7	128,8	183,8	182,1	2251,0
GREEN (500-600 nm)	70,6	136,7	166,9	187,6	194,6	104,0	195,6	202,6	2345,9
RED (600-700 nm)	85,9	145,5	162,8	155,0	166,0	87,1	181,8	175,5	2295,8
VISIBLE (380-750 nm)	238,5	439,0	535,0	580,3	613,3	363,1	613,3	642,6	7915,0
Erythemal irradiance (290-400nm)	0,006	0,014	0,032	0,076	0,101	0,132	0,153	0,166	1309,7
UV INDEX (erythemal irradiance x40)	0,2	0,6	1,3	3,0	4,0	5,3	6,1	6,6	

ter yielded a value of 1584 J/m^2, so we can conclude that the use of fixed dosimeters to monitor ambient UV radiation in the workplace is totally acceptable, as the dose measurements made by the spectroradiometer are at intervals of 20-30 minutes. Therefore, if the measurement in any sampling period is taken during cloud cover, the intensity of the following minutes is considered the measurement of that time, so they are underestimated by a few percentage points. In the case of the fixed dosimeter, the measurements were continuous, hence the difference of about 370 J/m^2 erythemal.

To conclude the measurement, Figure 29 shows the measurement of total UV radiation via total UV irradiance (UVA + UVB) measured with a flat sensor from 9 am, the time of the first measurement, until 1:30 pm, with intervals of between 15 and 30 minutes.

If a clear day is taken for a given date, Figure 30 shows the expected daily solar UV index cycle with maximum UV index values of 7 around solar noon, which corresponds to 2:15 pm for the latitude of the town of Barbate.

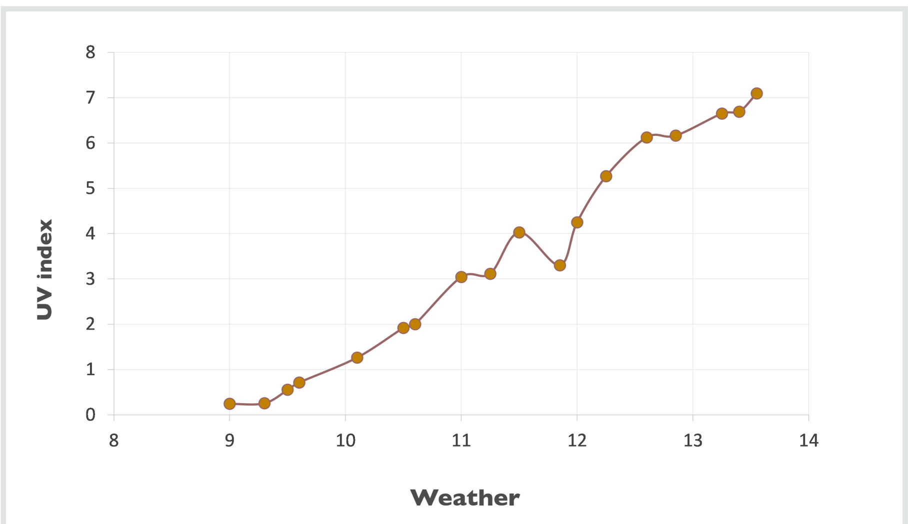

Figure 29. *UV index measured in Barbate.*

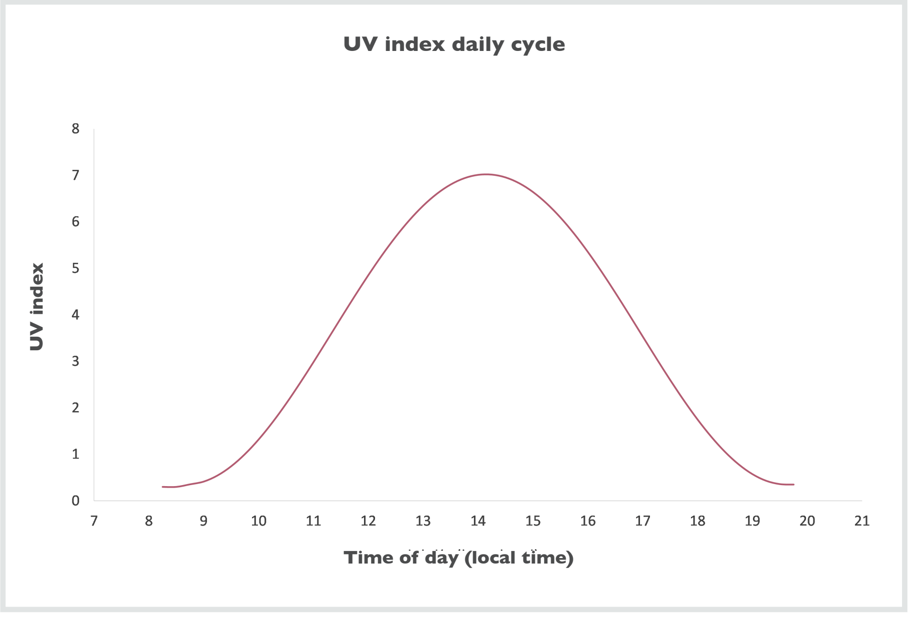

Figure 30. *Daily cycle of solar UV Index expected in Barbate.*

Table 20 shows the results of:

- erythemal irradiance obtained at 15-minute intervals under a clear sky,
- erythemal doses at 15-minute intervals,
- the cumulative doses both in erythematic J/m^2 and in SED and MED for the different phototypes.

We see that with clear skies, a worker during the period from 9 am to 2:15 pm (local solar noon) would receive up to a total of 18 cumulative SEDs since the beginning of the period with erythemal irradiance.

Table 20
Erythemal irradiance, erythemal doses and cumulative doses

Hour	UV index	Effective irradiance W/m²	Effective dose J/m2	Cumulative dose	Cumulative SED	MED Phot I	MED Phot II	MED Phot III	MED Phot IV
8:15	0,3	0,01	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8:30	0,3	0,01	6,8	6,8	0,1	0,0	0,0	0,0	0,0
8:45	0,4	0,01	6,8	13,5	0,1	0,1	0,1	0,0	0,0
9:00	0,4	0,01	8,0	21,5	0,2	0,1	0,1	0,1	0,0
9:15	0,5	0,01	9,3	30,8	0,3	0,2	0,1	0,1	0,1
9:30	0,7	0,02	12,3	43,1	0,4	0,2	0,2	0,1	0,1
9:45	1,0	0,03	16,7	59,8	0,6	0,3	0,2	0,2	0,1
10:00	1,3	0,03	22,6	82,4	0,8	0,4	0,3	0,2	0,2
10:15	1,7	0,04	29,7	112,2	1,1	0,6	0,4	0,3	0,2
10:30	2,1	0,05	37,9	150,1	1,5	0,8	0,6	0,4	0,3
10:45	2,5	0,06	47,0	197,1	2,0	1,0	0,8	0,6	0,4
11.00	3,0	0,07	56,8	253,9	2,5	1,3	1,0	0,7	0,6
11:15	3,5	0,09	67,2	321,1	3,2	1,6	1,3	0,9	0,7
11:30	3,9	0,10	77,8	398,9	4,0	2,0	1,6	1,1	0,9
11:45	4,4	0,11	88,5	487,3	4,9	2,4	1,9	1,4	1,1
12:00	4,9	0,12	99,0	586,4	5,9	2,9	2,3	1,7	1,3
12:15	5,3	0,13	109,2	695,6	7,0	3,5	2,8	2,0	1,5
12:30	5,7	0,14	118,9	814,5	8,1	4,1	3,3	2,3	1,8
12:45	6,0	0,15	127,9	942,4	9,4	4,7	3,8	2,7	2,1
13:00	6,3	0,16	135,9	1078,3	10,8	5,4	4,3	3,1	2,4
13:15	6,6	0,17	142,8	1221,1	12,2	6,1	4,9	3,5	2,7
13:30	6,8	0,17	148,6	1369,7	13,7	6,8	5,5	3,9	3,0
13:45	6,9	0,17	153,1	1522,8	15,2	7,6	6,1	4,4	3,4
14:00	7,0	0,18	156,1	1678,9	16,8	8,4	6,7	4,8	3,7
14:15	7,0	0,18	157,7	1836,6	18,4	9,2	7,3	5,2	4,1

Taking into account the WHO recommendations on sun protection based on the UV index (Figure 31), we see that workers should protect themselves from the sun from 11 am until the end of their workday.

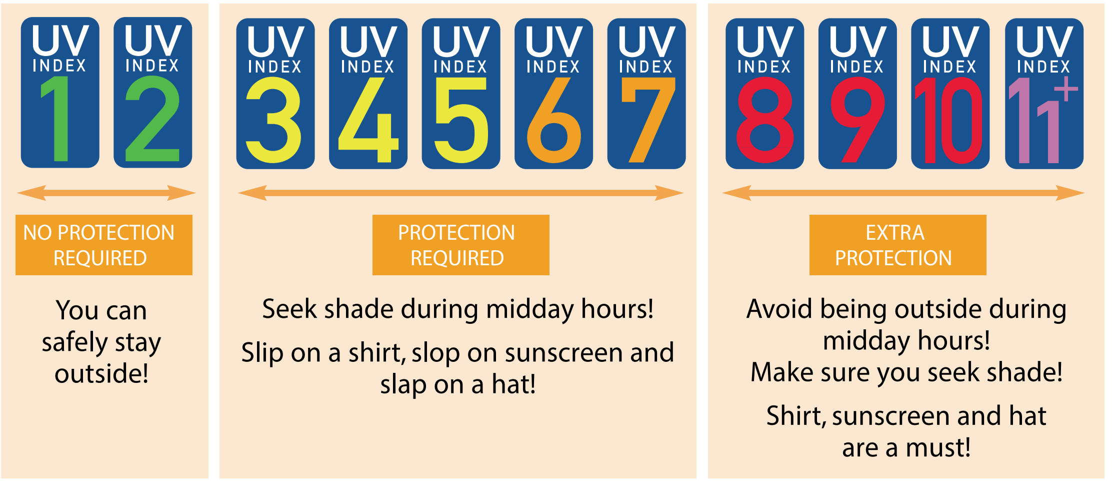

Figure 31. *Recommended sun protection system.*

5.2. Retrospective study of the effects of solar radiation on sea professionals. (Analysis of CEPROSS, PANOTRATSS and SANIMAR databases)

5.2.1. SANIMAR Database

The following is an anonymised analysis of data extracted from the ISM's SANIMAR database.

As a result of the search, the ISM sent a total of 42 cases of dermatological processes distributed in the entities shown in Table 21.

5.2.1.1. Distribution of pathologies according to age and years on the job

When analysing the age and years on the job of the affected people, we found that the different dermatological processes were homogeneously

Table 21
Analysis of dermatological processes. SANIMAR

Dermatological processes	No. of cases	%
Melanoma	5	11,9
Epithelial carcinoma	10	23,8
Actinic keratosis	18	42,9
Sunburn	5	11,9
Other skin lesions	4	9,5
Total	42	100,0

distributed into the groups of lesions found, with no statistically significant differences among them (Table 22). This may seem somewhat strange if we take into account that in the existing literature and routine clinical practice, the prevalence or history of skin cancer is clearly related to age and sun exposure and is much more frequent in older people (both tumours and premalignant lesions (actinic keratoses)). The explanation for these results is that all the cases reported by the ISM were in people between the ages of 41 and 71, with the median age being 55.

5.2.1.2. Distribution of pathologies according to job

When analysing the jobs (Tables 23 and 24), we see that epithelial carcinoma was the most frequent among coastal skippers with dermal lesions, while actinic keratosis was among fishing boat skippers and deckhands (p=0.009).

Up to 27% of the lesions found among the coastal skippers were melanoma.

Table 22
Analysis of dermatological processes by age and years on the job. SANIMAR

Dermatological processes		N	Mean	Standard deviation	CI (mean at 95%)	
					Lower limit	Upper limit
AGE P>0.05	Melanoma	5	56,20	6,496	48,13	64,27
	Epithelial carcinoma	10	54,10	1,595	52,96	55,24
	Actinic keratosis	18	57,22	10,021	52,24	62,21
	Sunburn	5	51,80	8,643	41,07	62,53
	Other skin lesions	4	50,75	7,089	39,47	62,03
	Total	42	55,10	7,926	52,63	57,57
Years on the job p>0.05	Melanoma	5	29,60	13,221	13,18	46,02
	Epithelial carcinoma	10	22,00	14,024	11,97	32,03
	Actinic keratosis	18	22,06	10,837	16,49	27,63
	Sunburn	5	19,40	16,456	-1,03	39,83
	Other skin lesions	4	23,75	4,193	17,08	30,42
	Total	42	22,80	12,034	19,01	26,60

Table 23
Analysis of cases of dermatological processes by job. SANIMAR

		Job			Total
		Coastal skipper	Fishing boat skipper	Deckhand	
Type of lesion	Melanoma	3	2	0	5
	Epithelial carcinoma	5	2	3	10
	Actinic keratosis	2	9	7	18
	Sunburn	1	0	4	5
	Other skin lesions	0	4	0	4
	Total	11	17	14	42

Table 24
Analysis of % of dermatological processes by job. SANIMAR

		Job			Total
		Coastal skipper	Fishing boat skipper	Deckhand	
Type of lesion	Melanoma	27,3%	11,8%		11,9%
	Epithelial carcinoma	45,5%	11,8%	21,4%	23,8%
	Actinic keratosis	18,2%	52,9%	50,0%	42,9%
	Sunburn	9,1%		28,6%	11,9%
	Other skin lesions		23,5%		9,5%
	Total	100%	100%	100%	100%

5.2.1.3. Distribution of pathologies according to activity

Among the affected crew in the trawling mode, the most frequent dermal lesion is epithelial carcinoma, while among professionals on small gear vessels (gillnet fishing and shipboard shellfishing) it is actinic keratosis ($p < 0.0001$). Tables 25 and 26 show the results of this analysis.

Up to 28% of the lesions found among trawler crews were melanoma.

Table 25
Analysis of cases of dermatologic processes by mode. SANIMAR

		Mode					
		Trawlers	Gillnet fishing	Pot / Trapper	Hook-and-line / hook and purse net	Shellfishing Float fishing	Total
Type of lesion	Melanoma	4	0	0	1	0	5
	Epithelial carcinoma	7	0	3	0	0	10
	Actinic keratosis	0	9	1	0	8	18
	Sunburn	3	2	0	0	0	5
	Other skin lesions	0	0	2	0	2	4
	Total	14	11	6	1	10	42

Table 26
Analysis of % of dermatological processes by mode. SANIMAR

		Mode					
		Trawlers	Gillnet fishing	Pot / Trapper	Hook-and-line / hook and purse net	Shellfishing Float fishing	Total
Type of injury (%)	Melanoma	28,6			100		11,9
	Epithelial carcinoma	50		50			23,8
	Actinic keratosis		81,8	16,7		80	42,9
	Sunburn	21,4	18,2				11,9
	Other skin lesions			33,3		20	9,5
	Total	100	100	100	100	100	100

5.2.2. CEPROSS and PANOTRATSS database

As a result of the analysis carried out on the CEPROSS and PANOTRATSS microdata by fishing CNAE (Table 27) corresponding to the period 2009-2018, few cases were found in relation to the analysis specifications.

In the case of CEPROSS, there were only two reported diseases that may be associated with exposure to solar ultraviolet radiation,

Table 27
Data analysed in CEPROSS

	CEPROSS
Period	Between 1 January 2009 and 1 January 2018.
CNAE	Fishing
Reported diseases	448
Number of reported diseases associated with the specifications	2

categorised as skin diseases caused by exogenous photosensitisers.

With regard to this data, it is important to highlight the fact that the official record of occupational diseases largely underestimates the true impact of work-caused diseases for different reasons, as recognised by the "Estudio epidemiológico de las enfermedades profesionales en España" [*García M. et al., 2017*] prepared by the Ministry of Health for the period 1990-2014. Therefore, it follows that the statistics on occupational diseases are not an information system for the prevention of occupational hazards but a record of those occupational injuries that have been compensated.

Table 28 lists the diseases reported for that period.

Table 28
Occupational diseases reported to CEPROSS 2009-2018: CNAE - FISHING

Occupational diseases	Frequency	Percentage
Formic acid, acetic acid, oxalic acid	1	0,2
Amines	1	0,2
Hearing loss	69	15,4
Chronic synovial bursitis	4	0,9
Anterior thigh fascia bursitis	1	0,2
Elbow hygroma	4	0,9
Shoulder: chronic tendon pathology rotator tendons	18	4,0
Elbow and forearm: epicondylitis and epitrochleitis	115	25,7
Wrist and hand: tendinitis	36	8,0
Epitrochleo-lecranial canal syndrome	4	0,9
Carpal tunnel syndrome	115	25,7
Guyon's canal syndrome	2	0,4
Meniscus injuries	1	0,2

Illnesses caused by atmospheric compression or decompression	36	8,0
Zoonosis	3	0,7
Malaria, amoebiasis, trypanosomiasis, dengue fever, leishmania	9	2,0
Mycosis, Legionella and helminthiasis	4	0,9
Other by inhalation: rhinoconjunctivitis from heavy substances	1	0,2
Other by inhalation: asthma from heavy substances	4	0,9
Other by inhalation: extrinsic allergic alveolitis from heavy substances	1	0,2
Other by inhalation: diffuse interstitial fibrosis from heavy substances	1	0,2
Other by inhalation: asthma from light substances	1	0,2
Skin: light substances	2	0,4
Skin: heavy substances	10	2,2
Skin: exogenous photosensitisers	2	0,4
Skin: infectious	3	0,7
Total	448	100,0

In PANOTRATSS, there are only 15 reported diseases possibly associated with exposure to solar UV radiation, five categorised as diseases of the eye and its surroundng regions and ten categorised as diseases of the skin and subcutaneous tissue (Table 29).

Table 30 shows the reported pathologies, including a description of the 15 pathologies related to the specifications.

Table 29
Data analysed in PANOTRATSS

	PANOTRATSS
Period	Between 1 January 2011 and 1 January 2018.
CNAE	Fishing
Number of reported TA due to non-traumatic pathologies	157
Number of reported pathologies possibly associated with specifications	15

Table 30
Title ICD pathologies reported to PANOTRATSS 2011-2018: FISHING

Reported pathologies	Frequency	Percentage	Percentage valid
Certain infectious and parasitic diseases	1	0,6	0,7
Mental and behavioural disorders	4	2,5	2,6
Diseases of the nervous system	7	4,5	4,6
Diseases of the eye and its surrounding region	5	3,2	3,3
Diseases of the ear and mastoid process	28	17,8	18,5
Diseases of the circulatory system	9	5,7	6,0
Diseases of the respiratory system	1	0,6	0,7
Diseases of the digestive system	9	5,7	6,0
Diseases of the skin and subcutaneous tissue	10	6,4	6,6
Diseases of the musculoskeletal system and connective tissue	63	40,1	41,7
Trauma, poisoning and certain other consequences with external causes	13	8,3	8,6
External causes of morbidity and mortality	1	0,6	0,7
Total	151	96,2	100,0
No record	6	3,8	
Total	157	100,0	

Table 31
Pathologies reported to PANOTRATSS 2011-2018: FISHING. Description of the ICD code of the 15 pathologies potentially related to the specifications of the data request

	Title CIE	CIE 10
1	Diseases of the skin and subcutaneous tissue	Cutaneous abscess, boil and carbuncle of the limb
2	Diseases of the skin and subcutaneous tissue	Local skin and subcutaneous tissue infection, unspecified
3	Diseases of the skin and subcutaneous tissue	Contact dermatitis from irritants, due to other agents
4	Diseases of the skin and subcutaneous tissue	Contact dermatitis from irritants, due to other agents
5	Diseases of the eye and its surrounding region	Other superficial keratitis without conjunctivitis
6	Diseases of the eye and its surrounding region	Blepharoconjunctivitis
7	Diseases of the eye and its surrounding region	Blepharoconjunctivitis
8	Diseases of the skin and subcutaneous tissue	Granulomatous skin and subcutaneous tissue disorder, unspecified
9	Diseases of the skin and subcutaneous tissue	Granulomatous skin and subcutaneous tissue disorder, unspecified
10	Diseases of the eye and its surrounding region	Mucopurulent conjunctivitis
11	Diseases of the skin and subcutaneous tissue	Hives
12	Diseases of the skin and subcutaneous tissue	Cellulitis of the trunk
13	Diseases of the skin and subcutaneous tissue	Cellulitis at other sites
14	Diseases of the skin and subcutaneous tissue	Local skin and subcutaneous tissue infection, unspecified
15	Diseases of the eye and its surrounding region	Keratitis, unspecified

5.3. Study of sun protection habits among the crew

The information collected in 139 questionnaires (119 from participating professionals and 20 from crew members who filled out the questionnaire even though they did not wear a dosimeter) distributed throughout the four selected areas in the national coastline was analysed. The completed questionnaires were distributed as follows: 34 in the Cantabrian-Northwest area, 33 in the Mediterranean area, 17 in the Canary Islands area and 55 in the Gulf of Cadiz area.

Absolute and relative frequencies, as well as mode and mean, were studied in order to perform a descriptive analysis of the population studied.

5.3.1. Section I: Demographic data

The 139 professionals surveyed were all male. Regarding age, the average age was 44, while the participants' most frequent age was 56. Looking at the graph (Figure 32), the area with the highest number of young people is the Cantabrian-Northwest area, where 17% of those surveyed were between the ages of 20 and 30, 83% of whom

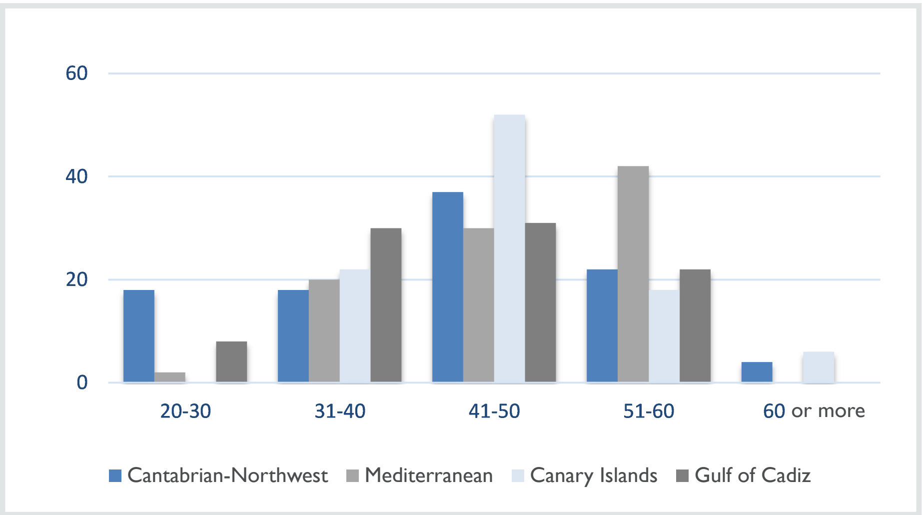

Figure 32. Age of the different areas sampled.

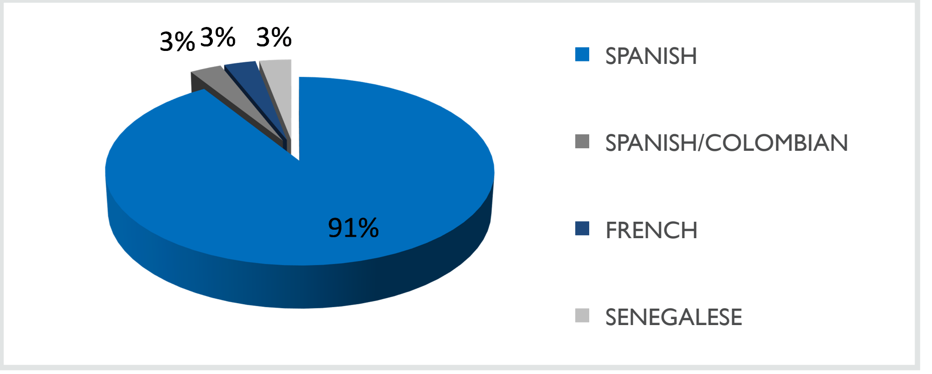

Figure 33. *Nationalities in the different areas sampled.*

fish in the trawling mode. The Mediterranean area has the highest percentage of workers between the ages of 50-60 (45%). The Canary Islands area stands out for having the most workers over the age of 60, and no workers between the ages of 20 and 30.

As for the nationality of the sample, most of the respondents were Spanish (Figure 33), with the Mediterranean and Cantabrian-Northwest areas having the highest number of foreigners.

The analysis of educational levels (Figure 34) shows that most of the surveyed population has only Compulsory Secondary Education (ESO) or less. Broken down by areas, the Mediterranean stands out because most of its workers have more advanced studies, such as vocational training, plus 12% have a bachelor's degree. The Gulf of Cadiz and the Canary Islands with the other areas have a higher percentage of university graduates, 3% and 6% of those surveyed, respectively.

By job (Figure 35), there are two categories: deckhand and skipper.

The predominant position among those surveyed is skipper, with 95% of the workers in the Canary Islands area being skippers, since the fishing mode

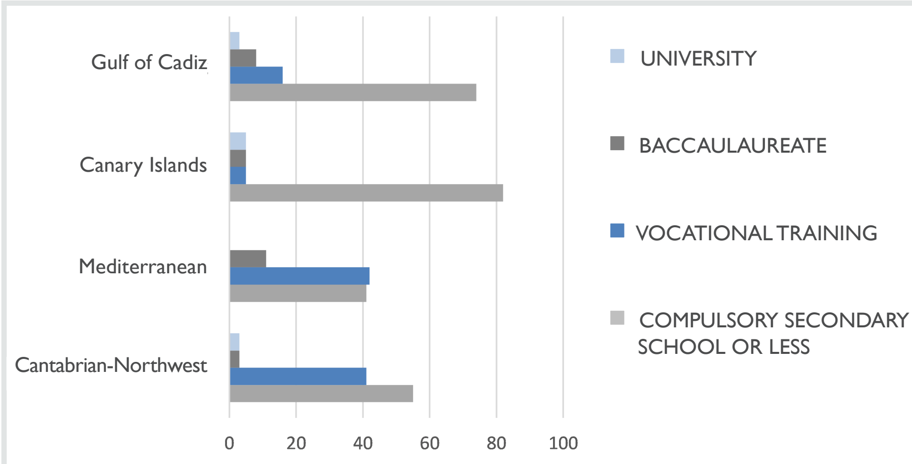

Figure 34. *Educational level by sampled area.*

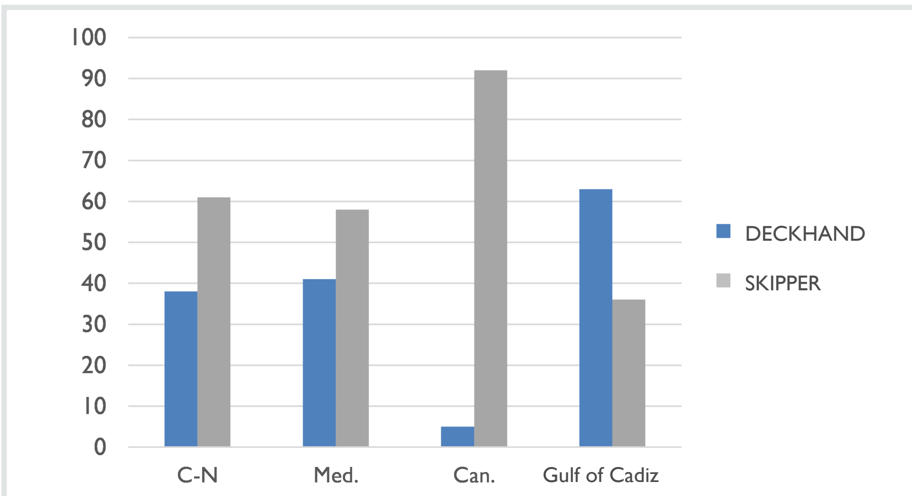

Figure 35. *Job by area sampled.*

selected in that area is small gear vessels, unlike the southern area, where there were more deckhands, who accounted for 63% of the workers. Considering the educational level with the job, none of the categories stand out because they are both made up of people with a certain educational level; that is, university graduates are evenly distributed in both the deckhands and the skipper categories.

5.3.2. Section II: Individual factors

As an individual characteristic, information was collected on the eye and hair colour of the workers surveyed, with 87% having brown or black eyes and 72% having dark hair.

Although the question referring to skin phototype should be determined by a specialist, the respondents were asked to tell us subjectively what skin phototype they believe they have, with an average of phototype III in all areas.

5.3.3. Section III: Worker's sun exposure behaviour and sun protection habits

The workers were asked about the number of hours they are exposed to solar UV radiation during their workday.

Figure 36 shows that overall, for all areas, only 1% responded that they were exposed to the sun

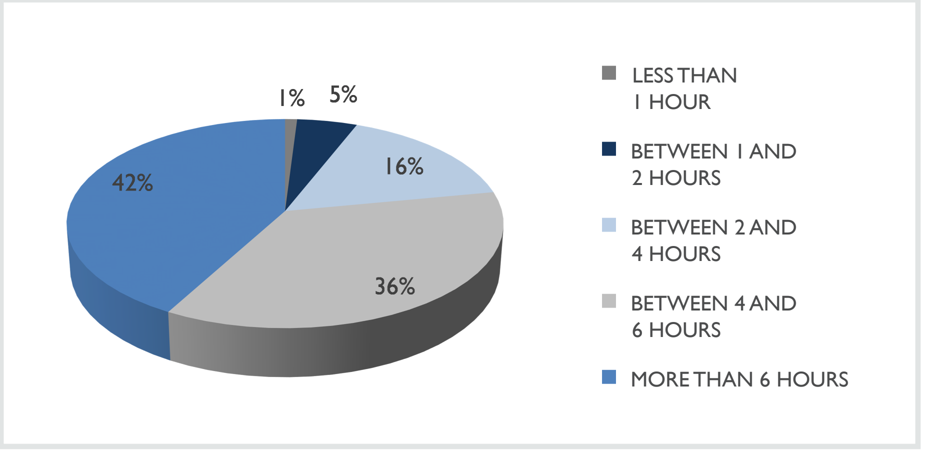

Figure 36. *% of workers per hours exposed to solar UV radiation.*

for less than one hour, while 78% reported being exposed to the sun for more than 4 hours.

However, when the information is broken down by area, certain differences can be found (Figure 37). For example, the only area where workers were exposed for less than one hour is the Gulf of Cadiz, and there were no workers exposed for between 1 and 2 hours either in this area or in the Canary Islands. However, due to the fact that the Canary Islands area only has the small gear mode, a high percentage of workers surveyed stated that they were exposed for more than 6 hours.

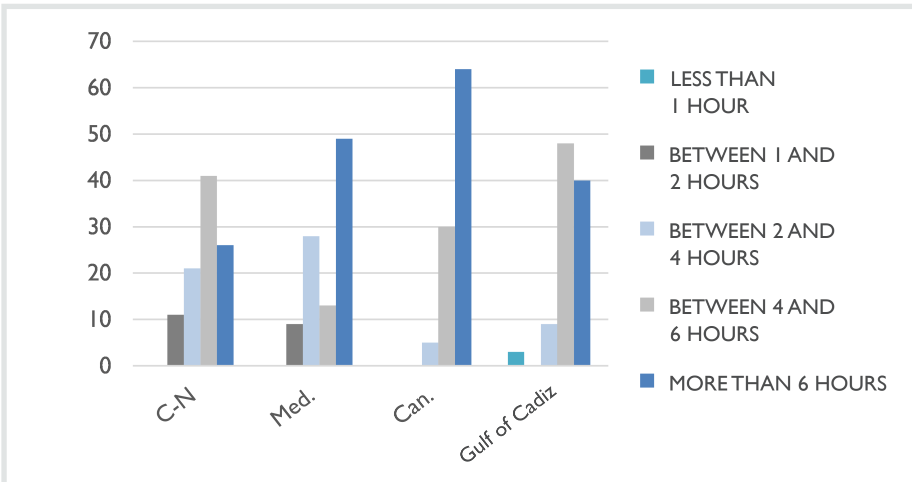

Figure 37. *% of workers by area and hours exposed to solar UV radiation.*

If the responses are extracted distinguishing by mode (Figure 38), we find that the mode influences the number of hours the workers are exposed to the sun. In small gear vessels, no workers surveyed were exposed for fewer than 4 hours, and about half were exposed for more than 6 hours. On the other hand, workers on trawlers clearly spend less time exposed to the sun.

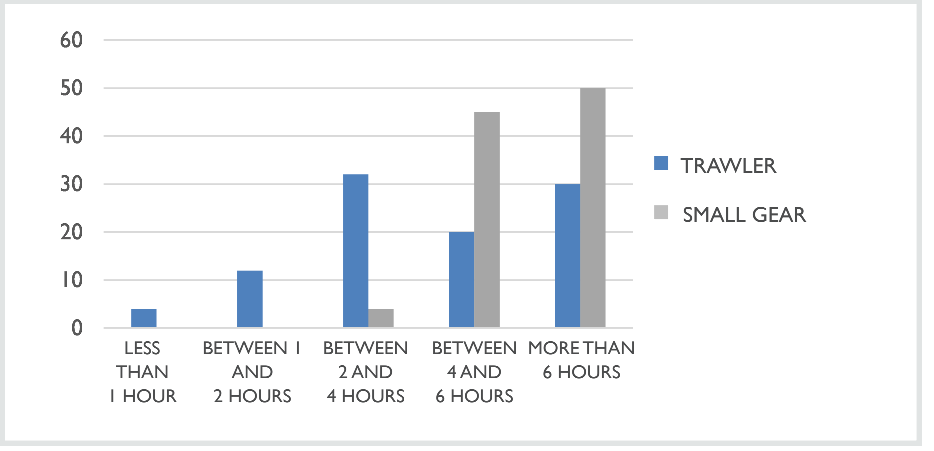

Figure 38. *Comparison of sun exposure in the selected modes.*

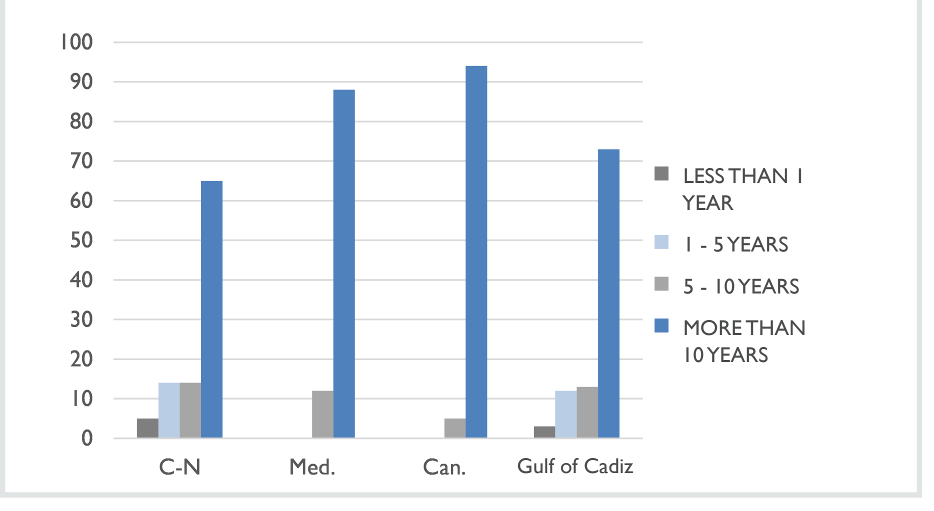

Figure 39. *Employees' years on the job by area.*

Analysing the responses regarding years on the job (Figure 39), it appears that the vast majority of the participants have been working in the sector for more than 10 years. In some of the areas sampled, such as the Mediterranean and the Canary Islands, there was nobody with less than one year of work, or even less than 5 years. This makes sense given the age analysis, which showed that the majority of workers in these areas are over the age of 40.

Regarding protection during the workday (Figure 40) in each area, nearly 70% of the workers surveyed use protection during the workday, with the Canary Islands area standing out, where 88% of the workers use protection.

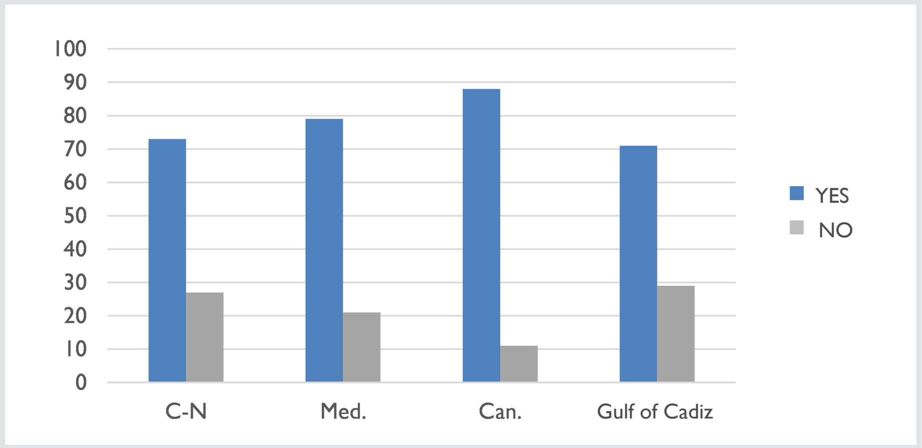

Figure 40. *Workday protection habits.*

The preferred ways to protect against solar rays vary by area (Figures 41 to 44). For example, in the Cantabrian-Northwest area, clothing is preferred, where it is used by nearly 90% of the respondents.

On the other hand, in the Mediterranean and Gulf of Cadiz areas, sunscreen is the most common measure.

For the Canary Islands, the most common means of protection is sunglasses, followed by sunscreen.

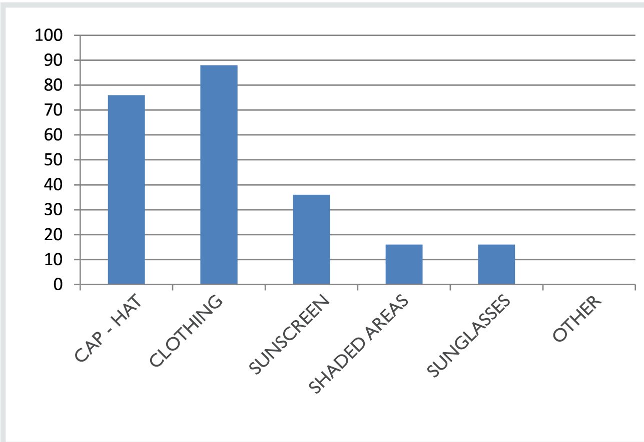

Figure 41. *Protective elements used in the Cantabrian-Northwest area.*

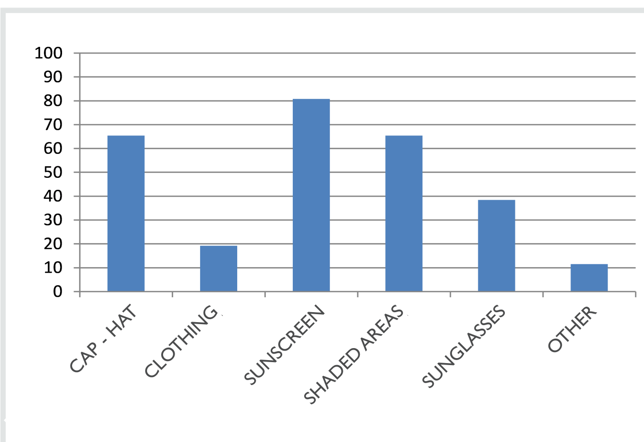

Figure 42. *Protective elements used in the Mediterranean area.*

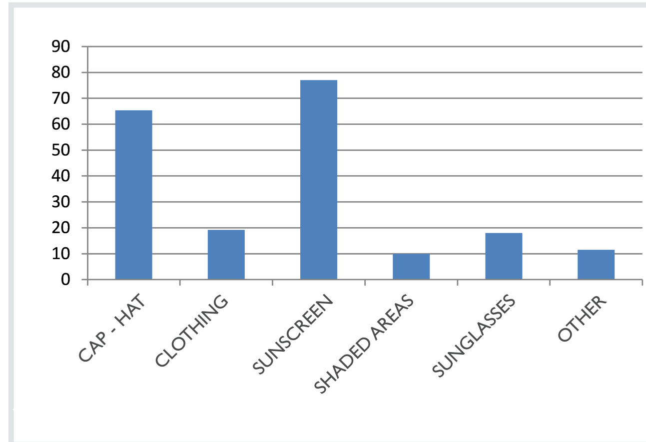

Figure 43. *Protective elements used in the Gulf of Cadiz area.*

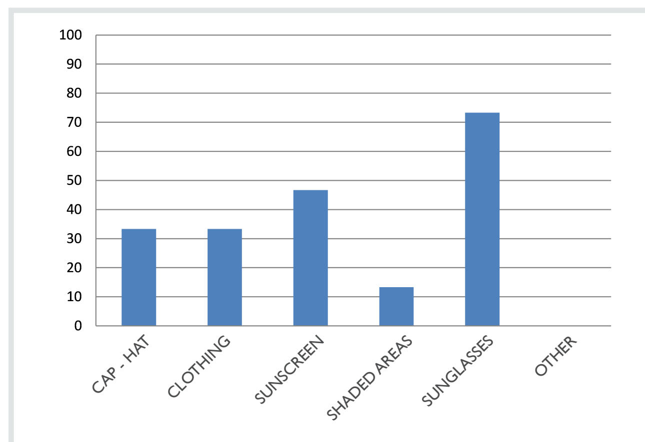

Figure 44. *Protective elements used in the Canary Islands area.*

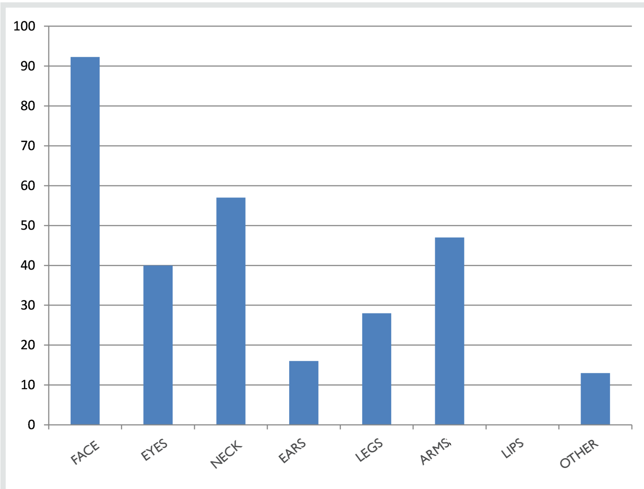

Figure 45. *Most protected body parts. Cantabrian-Northwest.*

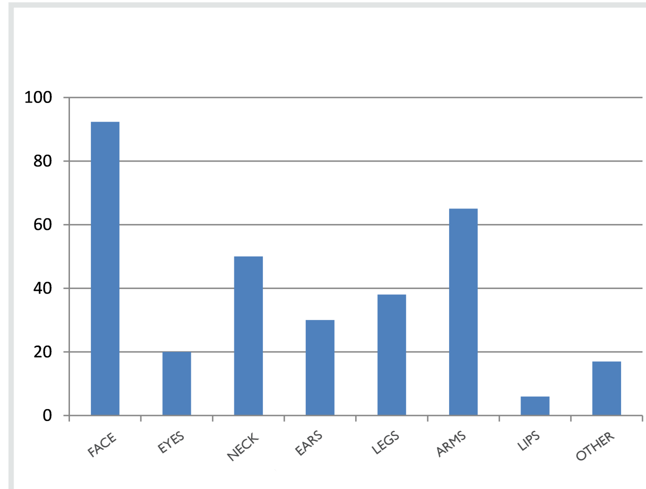

Figure 46. *Most protected parts of the body. Gulf of Cadiz.*

The body parts that are protected the most in all areas are the face, followed by the neck and arms. It is noteworthy that in the Cantabrian-Northwest, there were no responses regarding lip protection (Figure 45).

In the Gulf of Cadiz and Cantabrian-Northwest areas, the parts protected the most are the face, arms and neck, with only 5% claiming that they protect their lips (Figure 46).

Another question referred to the use of sun protection in their free time, since exposure to solar radiation has cumulative effects. This protection varied greatly from area to area (Figures 47 to 50).

In the Cantabrian-Northwest and Gulf of Cadiz areas, slightly more than half of those surveyed protect themselves from solar radiation in their free time, while in the Mediterranean and Canary Islands areas, more than 70% use protection.

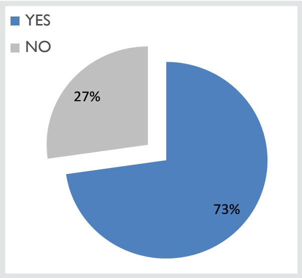

Figure 47. *Cantabrian-Northwest.*

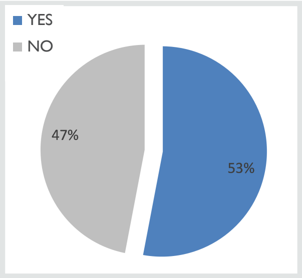

Figure 48. *Mediterranean.*

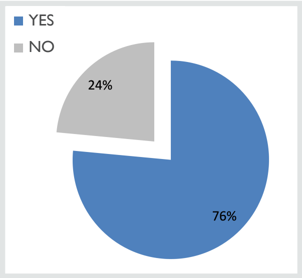

Figure 49. *Canary Islands.*

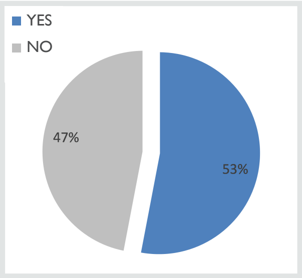

Figure 50. *Golfo de Cádiz.*

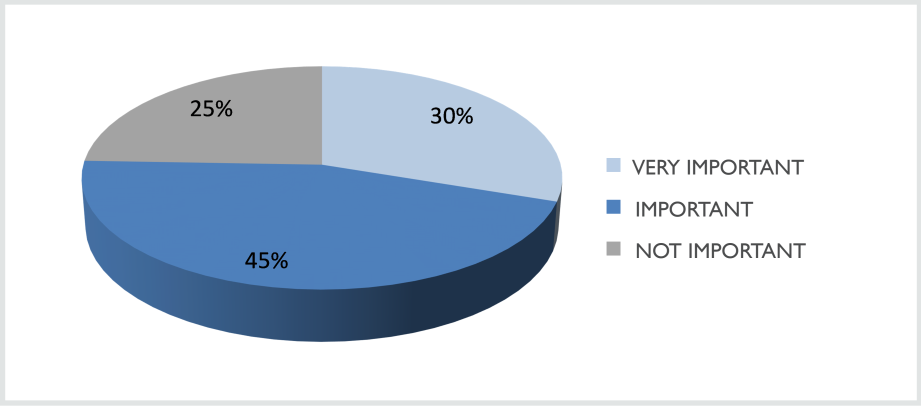

Figure 51. *Importance of sun protection.*

One of the last but very important questions in this section is the workers' degree of awareness of the importance of protection. It is worth noting that only 30% of those surveyed consider protection to be very important (Figure 51).

Breaking down the information by area, those who are most aware of the need for protection against the effects of solar UV radiation are workers in the Canary Islands area (Figure 52).

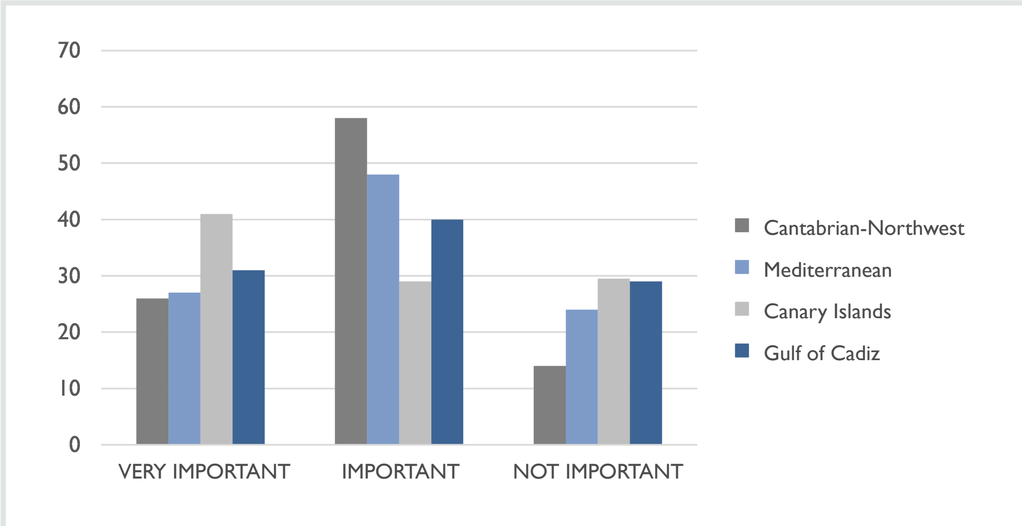

Figure 52. *Importance of protection against solar radiation by sampled areas.*

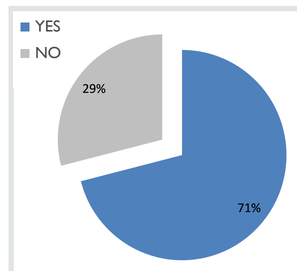

Figure 53. *Information on sunlight damage.*

5.3.4. Section IV: Knowledge of sunlight damage

Within this section, one of the questions asked the workers is whether they are informed about the damage caused by solar UV radiation. The result is that more than 70% have some kind of information about radiation, either by one means or another (Figure 53).

The main channel through which they received information in all areas is the media followed

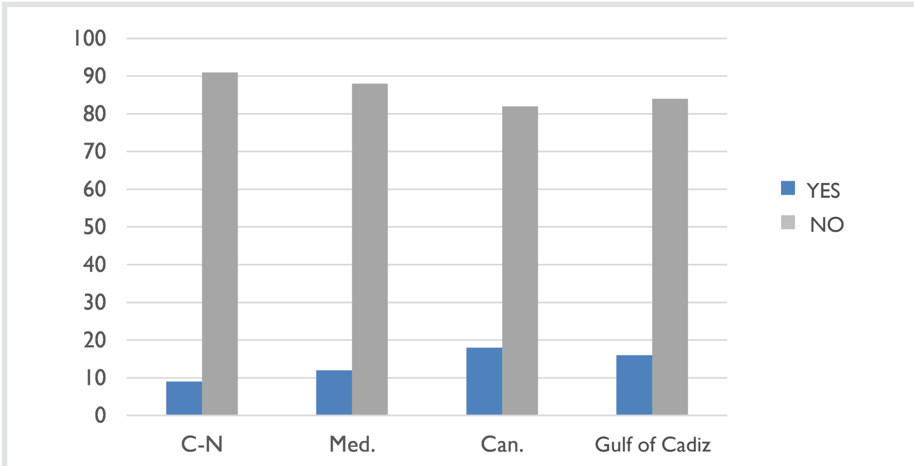

Figure 54. *Knowledge of UVI levels by areas.*

by health monitoring programmes (HP) for the Cantabrian-Northwest area. The Mediterranean area stands out for the fact that no worker stated the Internet as a source of information.

To conclude the questionnaire, they were asked if they were aware of the UVI levels in the area where they were located; 86% answered that they were not aware of these levels. Of those responding affirmatively, the area showing the most knowledge of UVI levels is the Canary Islands, followed closely by the Gulf of Cadiz (Figure 54).

5.3.5. Analysis of the importance attached to solar UV radiation

As a summary of the descriptive information resulting from the questionnaires filled out by the workers participating in the study, the following dependent variable was analysed: 'How important do you consider the risk of exposure to UV radiation in your job? (Important/Not important)', according to the level of exposure detected by the dosimeter they were wearing and the workers' age. The results showed that the workers' awareness level of the risk is independent of age and the amount of radiation detected by the dosimeter (Figure 32).

Table 32
Dependent variable: How important do you consider the risk of exposure to solar UV radiation in your job?

		Awareness level		
		Important (Means)	Not important (Means)	Statistical significance
According to the level of exposure reflected on the dosimeter		405,30	413,79	0,88
According to age		43,7	44,9	0,55
		Important (%)	Not important (%)	Statistical significance
According to educational level	Baccalaureate	25	75	0,44
	Vocational education	17,6	82,4	
	Compulsory secondary school (ESO)	29,4	70,6	
According to job	Deckhand	26,5	73,5	0,80
	Skipper	23,8	76,2	
According to protection	Uses protection	48,3	51,7	0,001
	Does not use protection	16,7	83,3	
According to area	Gulf of Cadiz	32,5	67,5	0,31
	Canary Islands	33,3	66,7	
	Cantabrian	15,2	84,8	
	Mediterranean	21,4	78,6	
Total		24,8	75,2	

We found that perception of risk is independent of the educational level, job and area, and it statistically significant for protection, thus emphasising the fact that the workers who are more aware of the risk of exposure to solar UV radiation protect themselves more.

CONCLUSIONS

6. CONCLUSIONS

High levels of individual exposure to solar UV radiation were detected in the coastal trawler and small gear modes. The median daily exposure for these workers was 491 J/m^2, potentially tripling the recommended benchmarks for uncovered skin exposure. Of the two modes studied, the highest exposures were found for the small gear mode.

In view of this, and given that the study group far exceeded the reference criteria recommended by international guidelines, the risk of exposure to solar UV radiation should be considered for the modes studied. Therefore, the results of this study can provide useful data to be shared with all the stakeholders involved in the sector (shipowners, workers, guilds, etc.) in order to increase their awareness of the risk and increase the use of appropriate preventive and protective measures.

This study provides the first data on personal exposure in real time to solar UV radiation among a prominent occupational group in Spain, namely workers on coastal trawlers and small gear vessels. The findings of this study can serve as the foundation of a proactive approach aimed at implementing good practices and establishing technical, organisational and individual measures to ensure effective protection.

Prevention of adverse skin and eye health effects in outdoor workers exposed to UV sunlight should be based on a variety of preventive actions, including technical and organisational interventions, specific information and worker training, the use of personal protective equipment and adequate health monitoring of the exposed professionals [*EC, 2011*], [*IARC, 2012*], [*Alfonso J. H. et al., 2017*].

The main examples of preventive interventions that can be applied to reduce the risk of exposure to solar UV radiation include:

- Technical / organisational measures. These measures include: providing artificial or natural shade in the workplace; taking breaks in specific indoor areas, or at least in areas protected from UV radiation, especially in the midday hours; and reorganising work activities to avoid (or limit) outdoor work during the midday hours, especially in the periods of the year with the highest UV indices.
- Information and training. Since the risk of developing adverse effects increases with age

and with the cumulative dose of UV radiation received, training and information activities should be implemented as early as possible, such as by including them in maritime vocational training curricula. The content of these prevention initiatives could include aspects like the mechanisms and effects of acute and chronic exposure to solar UV radiation, the possible preventive measures to be taken and the importance of self-examination and health monitoring, as well as periodic dermatological and ophthalmological examinations. Other techniques to improve information can include disseminating preventive materials such as posters, brochures, leaflets, etc.

- Personal protective equipment. The use of sunglasses [*INSST, 2019*], appropriate clothing preferably with high UV-protection factors, wide-brimmed hats and neck protectors is suggested. The use of sunscreen with a high protection factors on all exposed skin areas.
- Health monitoring. Protection and prevention protocols against occupational exposure to solar UV radiation should be included in the mandatory medical check-ups for this sector.

The difficulty of monitoring the risk of exposure to UV radiation in outdoor work, such as the fishing sector, stems from the fact that it is a natural hazard that cannot be eliminated at the source. This is compounded by the complexity of assessing each particular case due to constant variations in the factors that determine the workers' exposure level (angle of incidence of the sun's rays, season of the year, intensity of radiation, existence of reflective surfaces, the worker's movements, exposed areas, skin phototype, etc.), so the intervention should be aimed at implementing an action plan as part of the prevention management system that includes a set of actions aimed at monitoring the risk and preventing the possible harmful effects of the sun's rays, which can trigger skin and eye diseases at a higher rate than in the normal population.

In addition, the implementation of these actions is often hampered by the lack of a culture of prevention and by the characteristics of the sector itself [*Fundamar, 2012*].

For all the above reasons, it is very important and necessary to raise awareness of this occupational hazard (an extremely frequent cause of adverse health effects) in order to protect these workers, taking into account all the stakeholders involved. These include rolling out awareness-raising actions aimed at implementing preventive actions to raise the health level of the population before the disease appears and to reduce occupational risk factors faced by seamen when they are on-board, such as: health campaigns for dissemination, health promotion and prevention, and occupational health and safety awareness plans for the fishing sector, etc. To do this, in addition to the information on sun protection habits in the fishing sector contained in this study, the information should be expanded via a validated questionnaire that would make it possible to guide awareness-raising actions more effectively.

Likewise, as shown in section 4.2. on the analysis of the CEPROSS and PANOTRATSS databases, the competent authorities in this area should be made more aware of occupational diseases derived from sun exposure among.

Equally important is the implementation of preventive policies by the company's management to develop a culture of occupational health and safety by promoting the improvement of working conditions, avoiding unsafe behaviours and creating a healthy work environment.

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ANNEX I

ANNEX I. ANONYMOUS QUESTIONNAIRE FILLED OUT BY THE WORKERS PARTICIPATING IN THE SURVEY

REFERENCE NO: ______________________

1. **SEX**
   - ☐ MALE
   - ☐ FEMALE
2. **AGE** _____
3. **NATIONALITY** ____________________
4. **EDUCATIONAL LEVEL**
   - ☐ COMPULSORY SECONDARY SCHOOL - EQUIVALENT - LESS
   - ☐ BACCAULAUREATE
   - ☐ VOCATIONAL TRAINING
   - ☐ UNIVERSITY
5. **JOB**
   - ☐ SKIPPER
   - ☐ DECKHAND

6. YEARS WORKING IN THE FISHING SECTOR

- ☐ LESS THAN 1 YEAR
- ☐ 1 - 5 YEARS
- ☐ 5 - 10 YEARS
- ☐ MORE THAN 10 YEARS

7. TYPE OF CONTRACT

- ☐ PERMANENT
- ☐ OCCASIONALLY

8. APPROXIMATELY HOW MANY HOURS A DAY ARE YOU EXPOSED TO THE SUN AT WORK?

- ☐ LESS THAN 1 HOUR
- ☐ BETWEEN 1 AND 2 HOURS
- ☐ BETWEEN 2 AND 4 HOURS
- ☐ BETWEEN 4 AND 6 HOURS
- ☐ MORE THAN 6 HOURS

9. SKIN TYPE

- ☐ I and II (LIGHT OR VERY LIGHT)
- ☐ III (MEDIUM)
- ☐ IV - VI (DARK)

10. EYE COLOUR

- ☐ LIGHT BLUE - GRAY - GREEN
- ☐ DARK BROWN OR BLACK

11. HAIR COLOUR

- ☐ BLOND - RED
- ☐ BROWN - BLACK

12. ARE YOU AWARE OF THE HEALTH DAMAGE CAUSED BY SOLAR ULTRAVIOLET RADIATION?

- ☐ YES
- ☐ NO

13. IF YOU ANSWERED "YES" TO THE ABOVE QUESTION, WHAT WAS THE SOURCE OF THAT INFORMATION (You may check more than one box).

- ☐ SAFETY TALKS (guild, shipowner, occupational risk prevention expert, etc.)
- ☐ HEALTH MONITORING PROGRAMME (doctors, nurses, etc.)
- ☐ MEDIA
- ☐ INTERNET
- ☐ OTHER (Specify) ____________________

14. ARE YOU AWARE OF THE SOLAR RADIATION LEVELS IN YOUR AREA?

- ☐ YES
- ☐ NO

15. DURING YOUR WORKDAY, DO YOU USUALLY PROTECT YOURSELF FROM THE SUN?

- ☐ YES
- ☐ NO

16. IF YOU ANSWERED "YES" TO THE ABOVE QUESTION, HOW DO YOU PROTECT YOURSELF?

(You can check more than one box)

☐ SUNSCREEN

☐ CAP - HAT

☐ CLOTHING (LONG SLEEVES - LONG TROUSERS)

☐ STAYING IN SHADED AREAS

☐ SUNGLASSES

☐ OTHER (Specify) ____________________

17. IF YOU USE SUN PROTECTION,WHEN DO YOU USE IT?

(You can check more than one box)

☐ ONCE BEFORE THE WORKDAY

☐ ONCE 30 MINUTES BEFORE SUN EXPOSURE

☐ ONCE WHEN MY SKIN BEGINS TO REDDEN

☐ SEVERAL TIMES THROUGHOUT THE WORKDAY

DO YOU KNOW WHAT "SUN PROTECTION FACTOR" MEANS?

☐ YES. (Specify) ____________________

☐ NO

WHAT PROTECTION FACTOR DO YOU USE?

- ☐ SPF 15
- ☐ SPF 30
- ☐ SPF 50 OR HIGHER

18. IN YOUR FREE TIME, DO YOU PROTECT YOURSELF FROM SOLAR RADIATION?

- ☐ YES
- ☐ NO

19. WHAT PARTS OF THE BODY DO YOU USUALLY PROTECT?

(You can check more than one box)

- ☐ FACE
- ☐ NECK
- ☐ EYES
- ☐ LIPS
- ☐ EARS
- ☐ LEGS
- ☐ ARMS
- ☐ OTHER

20. HOW IMPORTANT IS IT FOR YOU TO PROTECT YOURSELF FROM SOLAR RADIATION?

- ☐ VERY IMPORTANT
- ☐ IMPORTANT
- ☐ NOT IMPORTANT

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