RAMONES
Radioactivity Monitoring in Ocean Ecosystems

Deliverable

Document ID: D5.5 Forecasting and Risk Assessment for awareness policy support no1

4/2023

RAMONES funded by European Union under Horizon 2020 FET Proactive programme via grant agreement No.101017808

Document Info

Project Information			
Acronym	RAMONES		
Name	Radioactivity Monitoring in Ocean Ecosystems		
Start Date	1 Jan 2021	End Date	31 Dec 2024
Program	H2020-EU.1.2.2. - FET Proactive		
Call ID	H2020-FETPROACT-2020-2	Topic	FETPROACT-EIC-08-2020 - Environmental Intelligence
Grant No	101017808	Instrument	RIA
Document Information			
Document Id	D5.5		
Document Title	D5.5 Forecasting and Risk Assessment for awareness policy support no1		
Due Date	31-Mar-2023	Delivery Date	13-04-2023
Lead Beneficiary	UDUR(7)		
Beneficiaries (part.)	UDUR(7), NKUA(1), ENS(4), UCA(8)		
Editor(s)	Konstantinos Nikolopoulos (UDUR)		
Authors (s)	Konstantinos Nikolopoulos (UDUR), Theodoros Mertzimekis (NKUA), Lydia Maigne (UCA), Pavlos Krasakis (NTUA)		
Contributor (s)	Eleni Petra Paraskevi Nomikou, Effie Zafirakopoulou, Stavroula Kazana, Konstantina Bejelou (NKUA), Antonio Pascoal, Pedro Batista, Luis Sebastiao (IST-ID), Konstantin Kebkal (EVOL), Javier Escartin (ENS), Konstantinos Karantzalos, Valsamis Ntouskos, (NTUA), Angelos Mallios (PLOA).		
Reviewer(s)	NKUA		
Workpackages	WP5 - Citizen Awareness, Dissemination and Communication Activities		
Version	V1.0	Stage	Submission
Distribution	Public		
Keywords	Pathfinder, EIC, FET, Radioactivity, Environmental Intelligence, Underwater Research	Type	R

Document Change Record

Version	Date	Change Description	Editor	Change Location (page/section)
1.0	09/11/2022	Presentation made in GoodIT22	UDUR	
	11/04/2023	Document delivered to main authors	UDUR	
	12/04/2023	Document delivered to all authors	UDUR	
	13/04/2023	Feedback implemented and document/deliverable submitted to funder	UDUR	

Disclaimer

RAMONES is a European Innovation Council (EIC) FET Proactive project in the Environmental Intelligence Scope B, related to radically novel approaches to resilient, reliable and environmentally responsible in-situ monitoring. It is funded by the European Union under the Horizon 2020 FET proactive programme, via grant agreement No. 101017808.

RAMONES project's main objective is to close the current marine radioactivity gap in sampling and foster new interdisciplinary research in ocean ecosystems. RAMONES will invest a significant effort to provide tools to enable long-term data acquisition missions, rapid deployments, low cost per information byte, and propose new AI and Robotics-driven and supported methodologies, being ambitious to eventually offer scaled-up solutions to researchers, policy makers and communities. These goals will be achieved by combining state-of-the-art (SoA) methodologies and equipment from various disciplines in a well-balanced synergy. It will also design new and effective methodologies targeting the marine environment, which will provide efficient response to existing natural and man-made hazards, and shape future policies for the global population. RAMONES will additionally contribute to shaping a blueprint on Environmental Intelligence in the EU and worldwide.

The European Union (EU) was established in accordance with the Treaty on the European Union (Maastricht). There are currently 27 member states of the European Union. It is based on the European Communities and the member states' cooperation in the fields of Common Foreign and Security Policy and Justice and Home Affairs. The five main institutions of the European Union are the European Parliament, the Council of Ministers, the European Commission, the Court of Justice, and the Court of Auditors (http://europa.eu.int/).

List of acronyms

Acronym	Description
AI	Artificial Intelligence
cps	Counts per second
DB	Database
DL	Deep Learning
EaR	Exposure at Risk
EIC	European Innovation Council
EU	European Union
FSS	Forecasting Support Systems
F2SS	Forecasting & Foresight Support System
GIS	Geographical Information System
GO	Governmental Organization
JA	Judgmental Adjustment
Maastricht	Treaty on the European Union
MAE	Mean Absolute Error
MdAE	Median Absolute Error
NGO	Non-Governmental Organization
pF2SS	Prototype Forecasting & Foresight Support System
POIS2ON	**P**rototype RAM**O**NES **I**nformation **S**ystem for **S**ocioec**ON**omic stakeholders
RelMAE	Relative Mean Absolute Error
RelMdAE	Relative Median Absolute Error
RMIS	**R**isk **M**anagement **I**nformation **S**ystem
SF	Statistical Forecasts
SME	Small and Medium Enterprise
SoA	State of the Art
SRF	Strategic Response Frameworks
VaR	Value At Risk
WP	Work Package

Table of Contents

Table of Figures

Abstract

RAMONES is an ambitious, high-risk FET H2020 project which aims to achieve high-resolution temporal and spatial underwater AI-driven radioactivity measurements, in situ and in near-real-time, forming a game changer in deep-water environmental monitoring. RAMONES proposes a new generation of submarine radiation-sensing instruments, assisted by State of the Art robotic and artificial intelligence solutions towards understanding radiation related risks near and far from coastal areas, while providing data for the international community towards shaping new policies and governance guidelines for environmental sustainability, economic growth, and human health.

One of the main goals also of RAMONES is to **inform** key **socio-political and socio-economic stakeholders** at regular intervals at medium frequencies (daily, weekly) of **evolving risks** in sea-areas of interest. To that end, the deliverable 5.5. of Work Package 5, first of four deliverables focusing on **building** and communicating **Risk Indices** via the **RMIS** (Risk Management Information System), a **subsystem of the POIS2ON** (presented in D5.1 & D5.2 with more to follow in D5.3 & D5.4), a subsystem focusing on Risk Assessment for awareness and policy support (with input from POIS2ON). We provide in this first deliverable for RMIS **the Business Logic** and the **main Risk Indices** to be constructed during the RAMONES project.

As per T5.2 intent to Raising Awareness and Supporting policymaking we describe in D5.5 how we create a data-driven risk monitor at medium frequency (daily & weekly) informing on the probability and likelihood of reaching maximum annual dosages of radioactivity in areas of interest; we aim via providing this information at raising awareness to interested stakeholders and support enhanced resilience for environmental sustainability, and communities' social, financial and health safety.

Keywords

RAMONES; POIS2ON; Radioactivity; Risk Information System; Forecasting; Risk; Probability distributions.

1. Introduction

1.1 Context

This document belongs to Work Package 5 (WP5, *Citizen Awareness, Communication and Dissemination Activities*), and in particular to Task T5.2 Raising Awareness / Supporting policymaking [M25-M48] - Lead: UDUR with Participants: NKUA, UCA, ENS within which RAMONES [Me22] creates a data-driven risk monitor at medium frequency (daily & weekly) **informing on eminent reach of annual limits (within much shorter periods of time than a yea**r), and aiming at raising awareness to interested stakeholders and eventually support enhanced resilience for environmental sustainability, and communities' social, financial and health safety

In this deliverable we describe the capabilities and business logic of the **RMIS** (Risk Management Information System), a subsystem of POIS2ON (Prototype RAMONES Information System for SocioecONomic stakeholders). RMIS aims to **inform** key **socio-political and socio-economic stakeholders** at regular intervals at medium frequencies (daily, weekly) of **evolving risks** in sea-areas of interest. We do present our proposition of how risk indices and a system to monitor them should look like in D5.5, but also to that end we aim also during the next 21 months to get in discussion and consultation with IAEA and ENS, for the later phases of T5.2 as part of the linked deliverables D5.6, D5.7, & D5.8 due in months 33, 39, & 45, respectively.

1.2 Structure of the document

From this point, the current document is organized according to the following structure and contents:

Section 2. Basic Usage Scenarios of RMIS

Section 3. Risk Indices and functionality of RMIS

Section 4. Conclusion and the Future

1.3 Objectives and approach

The objectives of the RAMONES D5.5 deliverable is to first propose the **Risk Indices** to be implemented with **RMIS,** and also describe the basic functionality of the RMIS subsystem of POIS2ON (see D5.1 & D5.2), a subsystem that aims to inform when eminent reach of annual limits of dangerous radionuclides (within much shorter periods of time than a year).

2. Basic usage Scenarios

RMIS is a subsystem of POIS2ON and as such and following the elaboration in deliverables D5.1 & D5.2, our basic usage scenarios involve socioeconomic stakeholders depict an area of interest in the sea, where natural activity takes place (like an underwater Volcano) or anthropogenic activity takes place (like an underwater Drilling for Oil) and respective risks are realised and thus need to be measured, estimated, and forecasted. The area of interest is depicted in the sea in a map, by either indicating a polygon of (latitude, longitude) for each corner of the polygon. Then the RAMONES deployment team will break the area of interest into a number *of 3D polygonal objects* into thousands of datapoints of (latitude, longitude, depth from surface) on which measurements will be made for the element(s) of interest (e.g., Rn-222), for the period of time of interest, at high frequencies per datapoints. Interpolations can be made for in between the areas of interests in order to have indicative estimations of exposure there. Fore these areas, Risk Indices and a Risk monitor needs to be built (thus this deliverable and the subsequent ones D5.6-8).

3. Risk Indices and functionality of RMIS

3.1 Architecture of the prototype RMIS subsystem

The subsystem is depicted in **figure 1** as the **RED-circled** subsystems within POIS2ON.

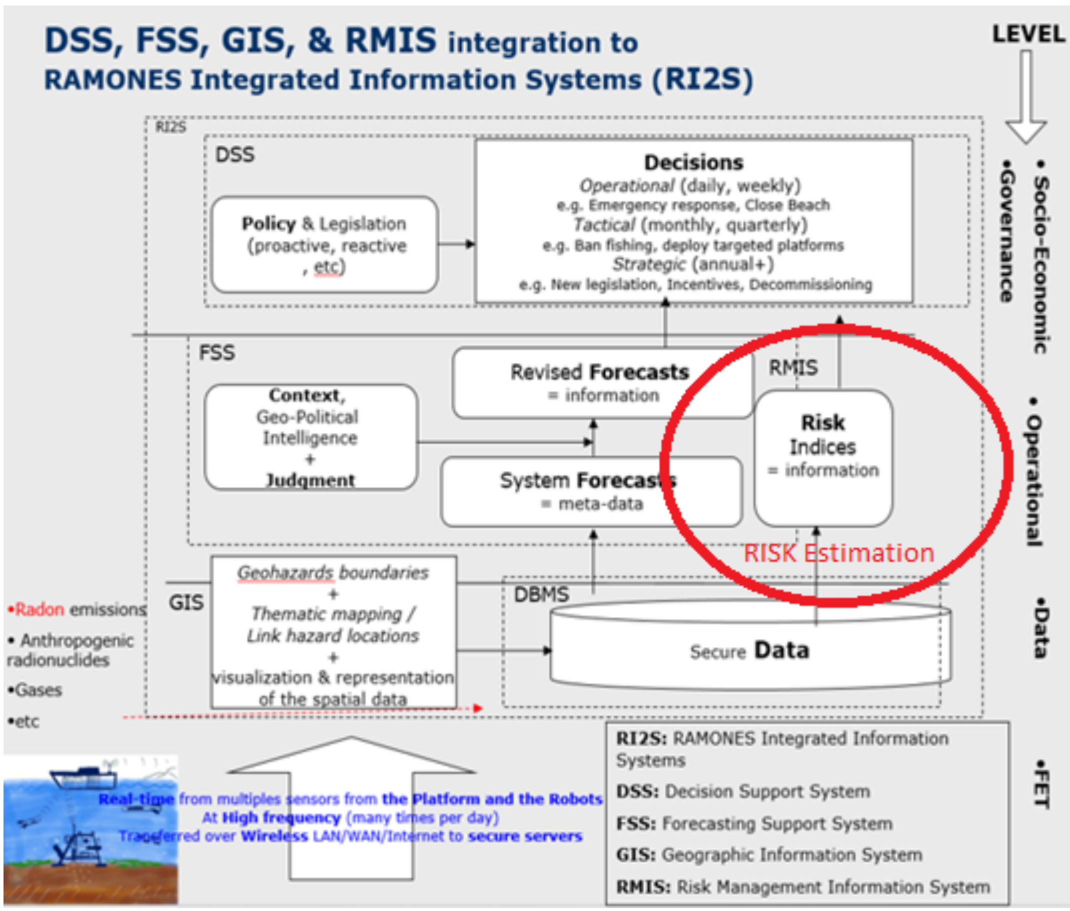

Figure 1 - RMIS Subsystem within POIS2ON Prototype RAMONES Information System

The overall architecture of POIS2ON is described in D5.1 followed by D5.2, and within this **RMIS** is a key **subsystem**. The logic of modular system and respective subsystems is derived from several similar successful implementations of FSS and F2SS as in [Ni03].

RMIS receives as input measurement data from the distributed database, as these are concentrated in POIS2ON, and also forecasts of these as calculated in the **FSS** subsystem of POIS2ON.

Thus, also Forecasting errors can be estimated at the respective frequency of POIS2ON observation – for now set at hourly, daily, and weekly as:

$$\text{Forecasting Error}_t = \text{Actual Measurements}_t - \text{Forecasted Measurement}_{t\text{-}1 \text{ for } t}$$

This can be performed for all measurement and with all forecasting methods and best forecasts (in terms of forecasting accuracy over a period of time) will thereafter been use for risk estimations.

Forecasting accuracy over a period of time can be measured through the Mean Absolute Error and Median Absolute Errors and the relative forms of them over the forecasts of the Naïve method, so

- MAE
- MdAE
- RelMAE
- RelMdAE

With preference in the latter as it excludes outliers – nevertheless in this specific case outliers might be of extreme importance, and thus all four measures need to be considered and probably an average rank in between them to be used.

At the current stage two separate apps are running, one taking care of the main interface of POIS2ON, and one taking care all the forecasting capabilities of POIS2ON. From month 33 onwards, a third one, the RMIS subsystem, will be added and taking care all the risk indices capabilities. This distributed business logic ensures the scalability and smooth maintenance of the information system, as well as the potential reuse of some subsystems in future information systems.

3.2 The Business Logic of the RMIS subsystem and the Risk Indices

RMIS is a subsystem of POIS2ON and as such and following the elaboration in deliverables D5.1 & D5.2, our basic usage scenarios involve socioeconomic stakeholders depict an area of interest in the sea where natural activity takes place (like an underwater Volcano) or anthropogenic activity takes place (like an underwater Drilling for Oil) and respective risks are realised and thus need to be measured, estimated and forecasted. The area of interest is depicted in the sea in a map, by either indicating a polygon of (latitude, longitude) for each corner of the polygon.

Then the RAMONES deployment team will break the area of interest into a number *of 3D polygonal objects* into thousands of datapoints of (latitude, longitude, depth from surface) on which measurements will be made for the element(s) of interest (e.g. Rn-222), for the period of time of interest, at high frequencies per datapoints.

These measurements will then be converted into hourly measurements (and bi-daily, daily, weekly) via using the maximum, median or average (there will be an option in the system of what to be used) measurement per area of interest for the time block of interest as depicted in figure 2.

Targeted measurements in all likelihood include the following radioisotopes:

- Cs-137
- K-40
- Rn-222
- Ra-226
- Pb-214
- Pb-210
- Bi-214
- Tl-208m
- Pu-239/240

And we will be constructing time series of those at the prescribed aforementioned frequencies.

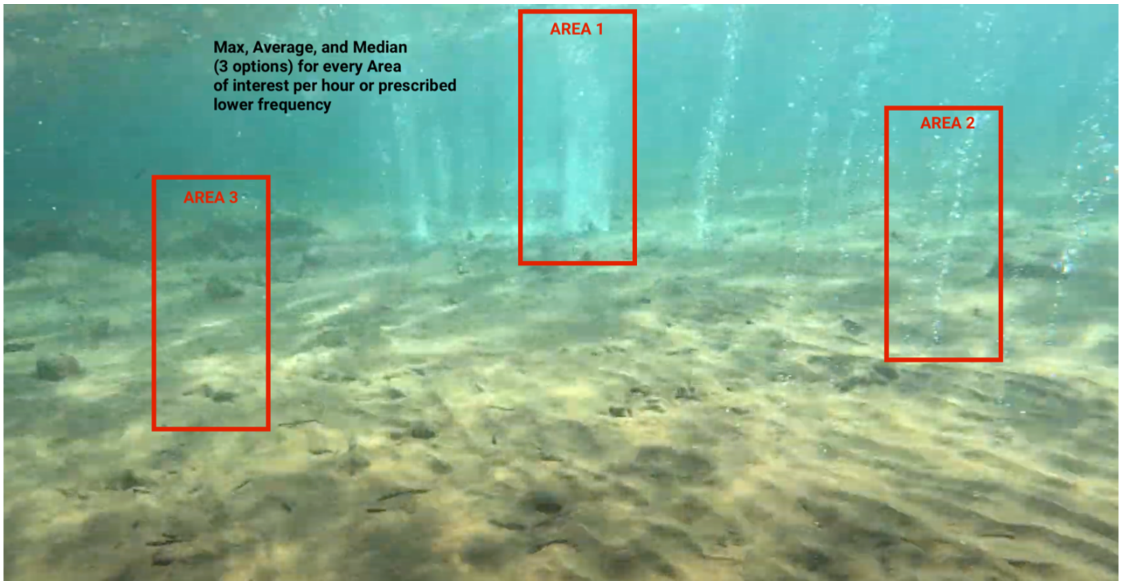

Figure 2 - Measurements for POIS2ON and RMIS in Areas of interest (Background Image: Wirestock on Freepik)

Cumulative versus Instantaneous measurements

We will be constructing timeseries both for the cumulative and the instantaneous measurements. The γ- or α-ray measurements by the dedicated RAMONES instruments will provide both full spectra (histograms) and counting rates (counts per second, cps). Instantaneous measurements are more relevant to cps, which will provide the level of activity in the area under investigation. The cps can be organized in time series in a straightforward way.

From spectra, photopeaks corresponding to specific isotopes can be measured to provide cumulative counts per photopeak. Such information can be used further to deduce doses (e.g. in μSv) or dose rates (in μSv/hr). Time series for this type of measurements can be constructed for either instantaneous or cumulative modes.

Measured counts/spectra Versus Exposed Activity versus Absorbed Dose

Measured counts (from measurements in scaler mode) or measured spectra (from measurements in pulse height mode) can be used to extract the mean energy emitted (in keV). The “exposed” signal corresponds the activity of particular isotopes per volume (in Bq/m^3). The absorbed dose will be calculated through dedicated simulations, and it will be given as a dose rate (in μGy/h) received by a microorganism. This dose rate depends on the activity in the medium as well as the size of the microorganism. Different size of microorganisms (from 2 to 100 μm in diameter) will be considered positioned on the seabed in the vicinity of the vent exit, and at different distances from the vent on the seabed (e.g. from 0 to 200 cm, placed every 20 cm). Similarly, different depths in the water column can considered.

We will have three time series per isotope – one being the actually measured, and two more for the actually 'absorbed' by a living microorganism - with parameters, *distance,* and *level of absorption* that can be set in the RMIS system – with ability to be expanded in the future this feature.

Forecasts and Forecast Errors

These hourly/bi-daily/daily/weekly series can then be forecasted via POIS2ON (see D5.2) and estimates of how soon annual limits might be reached/exceeded can be made [Ni21]. These estimates can be done based on:

a) the POIS2ON forecasts,
b) the respective forecasts errors as in 3.1,
c) the original measurements

So, there are three options of which distributions to be used. In all three cases – the **EaR (Exposure At Risk)** will be calculated in a similar fashion like the VaR (Value At Risk) [Li16] where from the distribution we estimate the probability to be exposed at a certain quantity of an element at a certain level of confidence.

Then respective alarms can be raised and communicated to the respective socioeconomic stakeholders, and Strategic Response Frameworks (SRF) initiated. These estimates of the potential reach of annual limits jointly set by EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO [IA14], as well as the UK Ionising Radiations Regulations 2017 [UK17], in less time than a year is the core of the Risk Indices proposed.

Distributions to be fitted and monitored

Distributions will be fitted automatically via the respective facilities and libraries in R, for the measurements, the forecasts, and the forecast error and with each of those we can estimate the EaR for critical values (i.e. maximum annual dosage, and max weekly dosage assuming constant, linear and exponential growth). These distributions are constructed from prescribed time windows that is the period where the RAMONES instruments will be in-situ. A typical distribution will look like Figure 3 and the respective standard calculation for Var that we will follow in a similar fashion for the EaR.

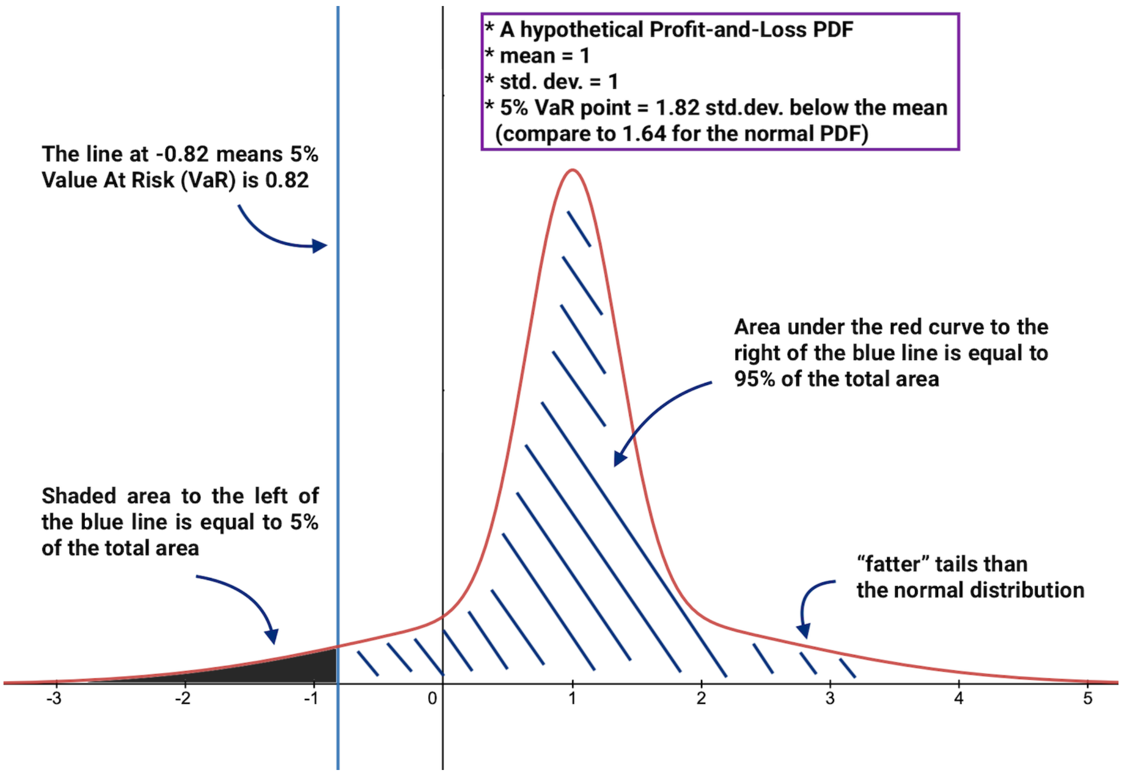

Figure 3 - EaR Distribution along the lines of VaR

Interpolations

Interpolations can be made for in between the areas of interests in order to have indicative estimations of exposure there as in figures 3 and 4, in between measured datapoints (figure 3) or the edges of the respective areas (figure 4). For risk interpolations we should first define the thresholds so as not to overlap; for a microorganism it is admitted that the threshold is 10 μGy/h [Ag06,EU12].

Further Visualisation

These Risk Indices will also be visualised via the GIS connected to POIS2ON in the form of Heat maps. The series will be reported in Nanosievert per hour and alerts will be raised, given when annual limits are expected to be reached, and the area of interest will be characterised longitudinally by a five-colour code via the Heat map (no risk, normal, low risk, high risk, eminent risk), and informing respective the interested stakeholders.

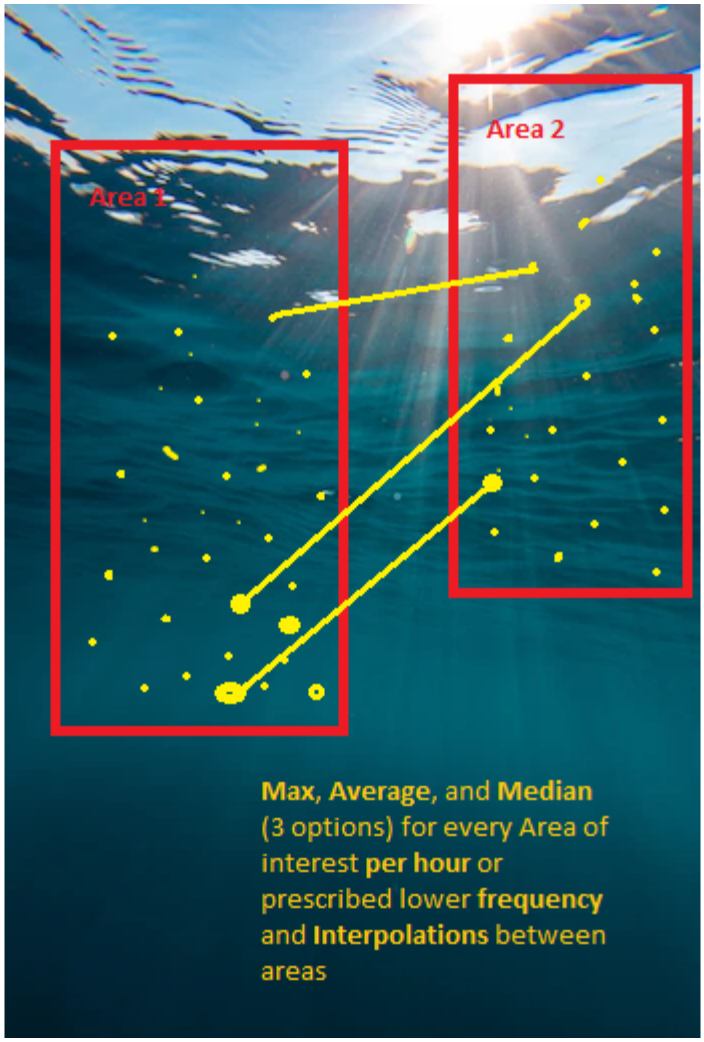

Figure 4 - Risk Interpolations from Point of interest 1 to Point of interest 2 (Background Image: Wirestock on Freepik)

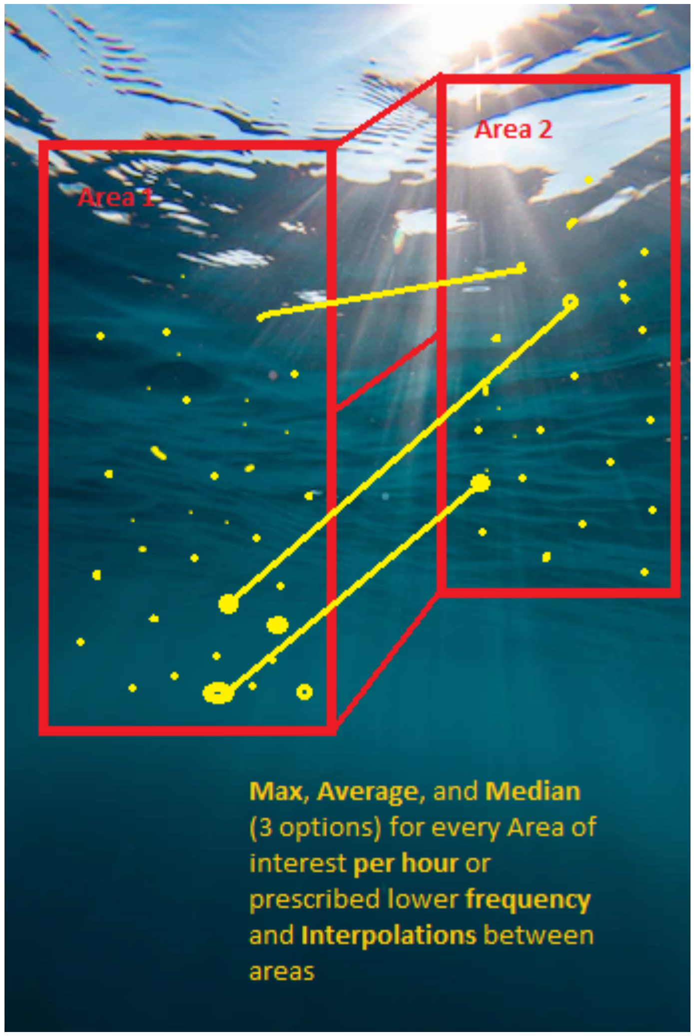

Figure 5 - Risk Interpolations from Area of interest 1 to Area of interest 2 (Background Image: Wirestock on Freepik)

4. Conclusion and the Future

RAMONES aspires to introduce novel monitoring and response channels to inform key socio-political and socio-economics stakeholders at regular intervals at medium (daily, weekly) frequencies. To that end, the deliverable D5.5 of Work Package 5 provides the Risk Indices to be implemented and include in, as well as the business logic for the prototype information subsystem **RMIS** of POIS2ON (see D5.1 & D5.2)**.** In parallel in months 33, 39, and 45 we expect to deliver the working prototype and in time full working version of RMIS for calculating and visualizing the aforementioned Risk indices, that will be added to POIS2ON via RMIS, and the respective deliverables D5.6-D5.8.

References

[Ag06] Agüero A, Alonzo F, Bjork M, Ciffroy P, Copplestone D, Garnier-Laplace J, et al. ERICA DELIVERABLE 5: Derivation of Predicted-No-Effect-Dose-Rate values for ecosystems (and their sub-organisational levels) exposed to radioactive substances. WikiCehAcUk. 2006

[EU12] European Commission Radiation Protection, N ° 177 EU Scientific Seminar 2012 "*Protection of the Environment*"; 2014. November 2012.

[IA14] IAEA "*Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*", 2014, url: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf

[Li16] W. Li (2016), "*Value at Risk (VaR) and its calculations: an overview*", https://web.mst.edu/~huwen/teaching_VaR_Weiqian_Li.pdf

[Me22] T.J. Mertzimekis, P. Nomikou, E. Petra, P. Batista, D. Cabesinhas, A.M. Pascoal, L. Sebastião, J. Escartín, K. Kebkal, K. Karantzalos, A. Mallios, K. Nikolopoulos, and L. Maigne. 2022. "*Radioactivity Monitoring in Ocean Ecosystems (RAMONES)-Environmental Intelligence*". GoodIT2022, Cyprus Larnaca 6-9 Sep 2022

[Ni03] Nikolopoulos, K. and Assimakopoulos, V. (2003). "*Theta Intelligent Forecasting Information System*", *Industrial Management and Data Systems* 103 (9): 711-726

[Ni21] K. Nikolopoulos, "*We need to talk about intermittent demand forecasting*", Eur. J. Oper. Res. 291, 2, 549-559 (2021)

[UK17] UK Statutory Instruments, "The Ionising Radiations Regulations 2017" (2017), url: https://www.legislation.gov.uk/uksi/2017/1075/contents