

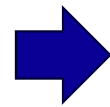
# NATIONAL PROPOSITIONS FOR POST-ACCIDENTAL MANAGEMENT IN CASE OF NUCLEAR RELEASES IN THE MARINE ENVIRONMENT

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# INTRODUCTION

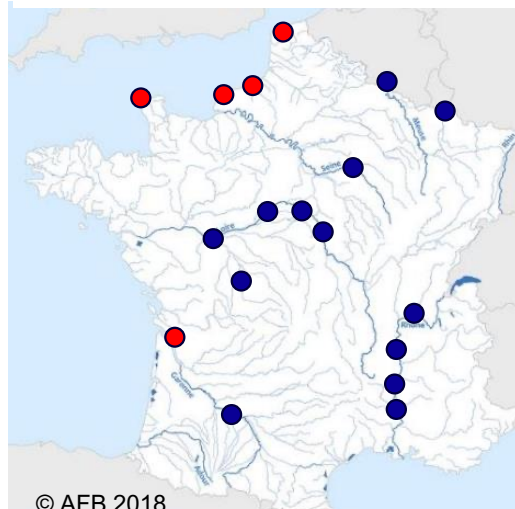
**CODIRPA** is a french steering committee created by the Prime Minister. It gathers experts, scientists, state bodies, local authorities, nuclear operators and civil society representatives, in charge to **provide recommendations for the management of post-accidental phase of nuclear or radiological accident.**



Objectives, principles and key points for the post-accidental management of contaminated terrestrial areas.

What if the contamination occurs on sea ?

18 nuclear plant sites in France



- Are these recommendations applicable and relevant in the event of contamination of the marine environment ?
- What are the specific challenges in protecting the population ?
- What actions will be useful for economic recovery and support for population and stakeholders ?
- What kind of monitoring should be done ?

# MAIN OBJECTIVE OF THE PRESENT PLAN : POST-ACCIDENT ZONING

**One zone = one main action to protect the population**

— **Exclusion zone:** no population if external dose during the year following the accident is  $> 20\text{mSv}$

*“I don't live here”*

— **No consumption zone:** prohibition of the consumption of fresh locally produced foodstuffs

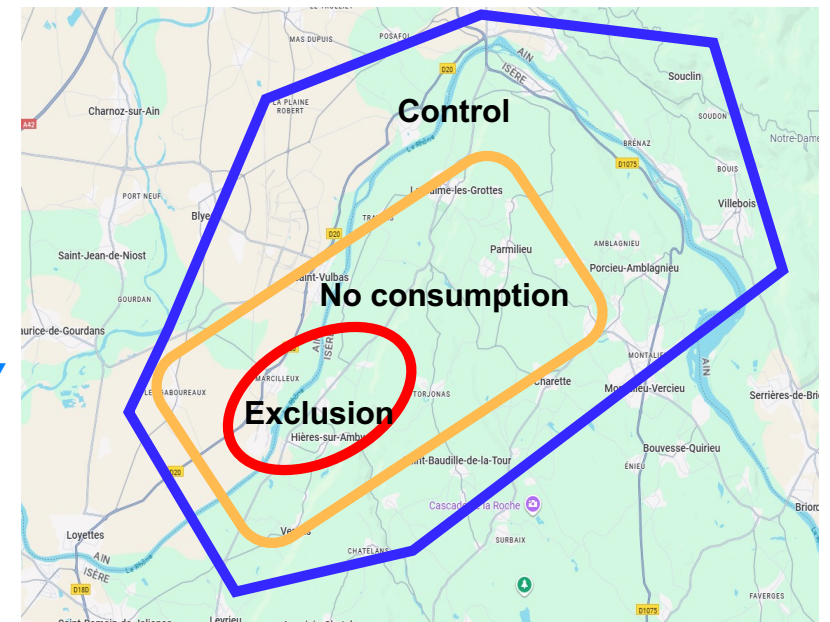
*“I don't eat the products of my garden, hunting, fishing or gathering”*

— **Pre-market control area with dietary recommendations:**

*“I can't sell my production without control, and I must diversify the origin of my diet”*

It may be decided to prohibit access to areas where radioactive substances may be higher: forests, public gardens...

Zoning will evolve with the monitoring of radioactivity levels (decay, decontamination...)



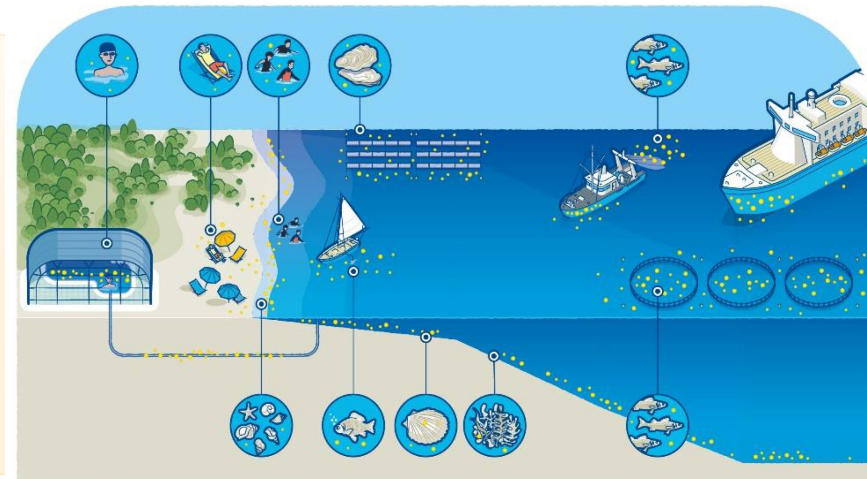
**Is this zoning necessary and adaptable to the marine environment ?**

# THE MARINE WORKING GROUP OF THE CODIRPA

- **52 participants** issued from state bodies, nuclear operators, scientific institutes, fish and shellfish farming committees, associations, external experts (DSA Norway).
- **Methods:** WG meetings and sub-group meetings + **2 citizen panels near coastal nuclear plant sites.**
- **Points discussed:** radionuclides behavior in the ocean, lessons from Fukushima, role of state and local authorities on uses and controls of the ocean, capacities of marine monitoring, fisheries and shellfish farming managements, regulation of maritime traffic...



- **List of activities to take into account for the economic impact:** recreational and professional fishing, aquaculture, beach activities....
- **List of internal and external exposures modes for the population:** ingestion of seawater or fishery products, sea spray, boating, beach...
- **Definition of a « test case scenario »** of an accidental radionuclides release at sea: dispersion, transfer to biota and radiation doses to the population.

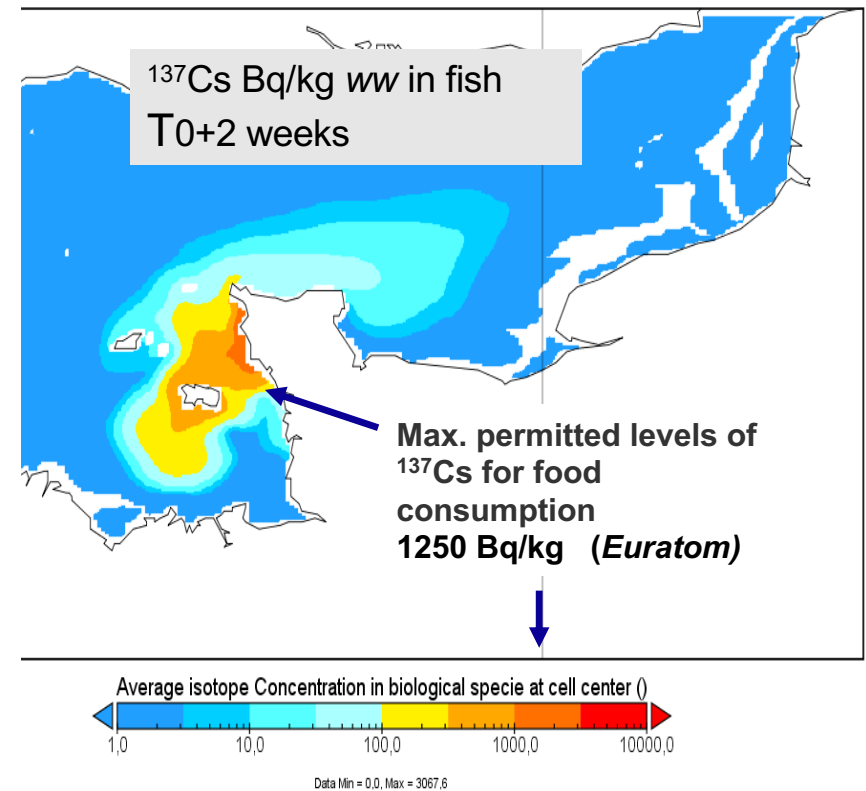
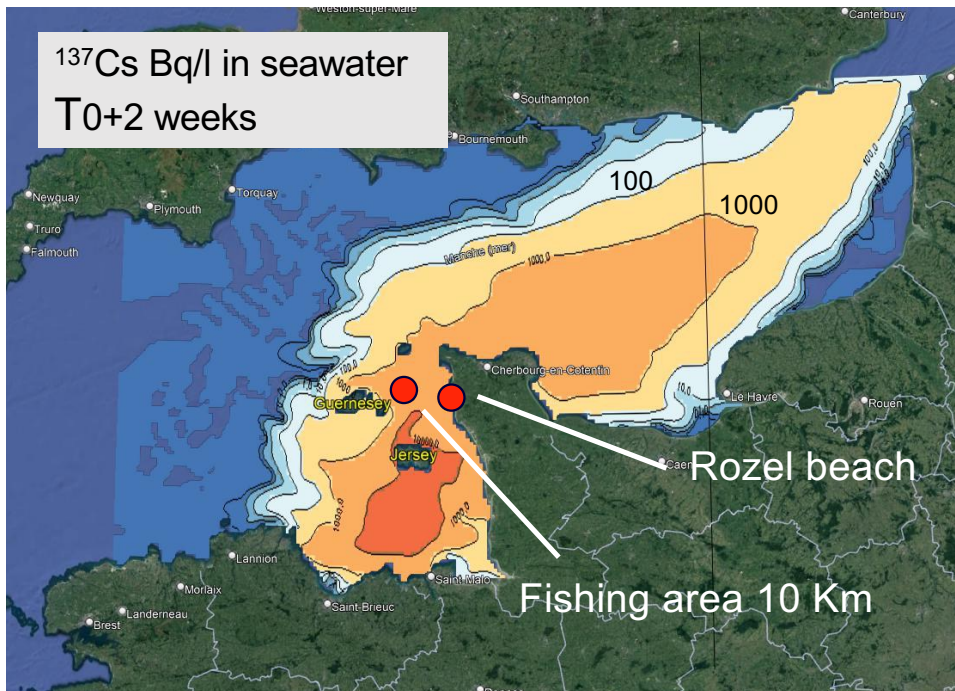


# A FICTITIOUS RELEASE SCENARIO

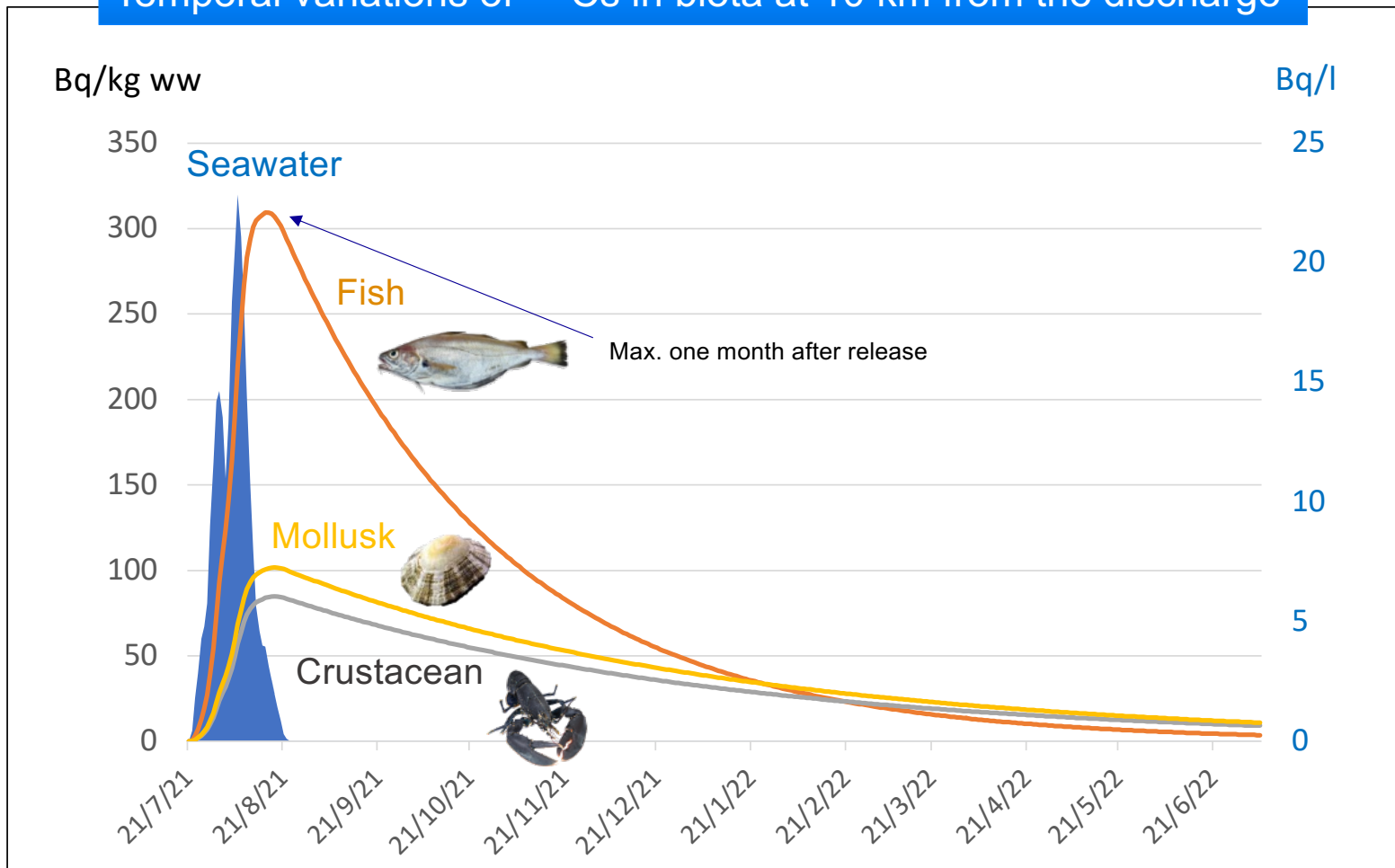
2.6 PBq of  $^{137}\text{Cs}$  directly released on the sea from a coastal NPP

Dispersion and direct transfer to marine organisms modeled with STERNE (one year)

Two locations for the dose evaluation: one beach near the release and one fishing area 10 km away



## Temporal variations of $^{137}\text{Cs}$ in biota at 10 km from the discharge



## EXTERNAL AND INTERNAL DOSES TO THE POPULATION

- **3 exposure scenarios: seaside resident, fisherman** (consuming his production) and **tourist** (15 days when contamination is maximum)
- **External exposure:** irradiation, water immersion
- **Internal exposure:** ingestion of water, sand, marine food and inhalation of sea spray
- Radionuclide:  $^{137}\text{Cs}$  (secular equilibrium with  $^{137}\text{Ba}$ ) only!!

|                                       | Resident - adult | Resident child < 5 y | Tourist | Fisherman |
|---------------------------------------|------------------|----------------------|---------|-----------|
| <b>Mean effective dose (mSv/year)</b> | 1.3              | 1.5                  | 2.5     | 0.1       |

**Dose dominated by: Exposure on the beach for local residents and tourists**

**Ingestion of seafood for fisherman**



→ It is very unlikely to reach activity levels inducing +20 mSv

# RECOMMENDATIONS FOR TRANSPOSITION OF LAND ZONING

## Exclusion zone:

This area will probably not exist in case of liquid release, but monitoring should be done on beach, aquaculture and shellfish farming areas.



## No consumption zone:

- **Prohibition of shellfish harvesting and recreational fishing** in all areas where the marketing of seafood products is subject to control before marketing.
- Outside these areas, **diversified diet** occasionally including local foodstuffs **will be recommended**.
- Devices for measuring the contamination of these products must be made accessible to the population.



## Citizen panels



- Train people to carry out these measurements.
- Provide the population with the educational necessary to understand these results.



# RECOMMENDATIONS FOR TRANSPOSITION OF LAND ZONING - 2

Pre-market control zone: → management by sector or fishing technique.

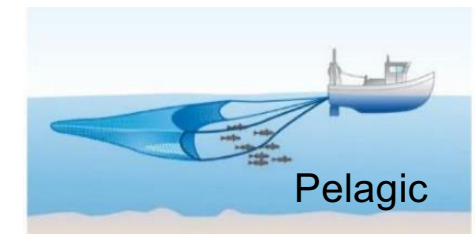
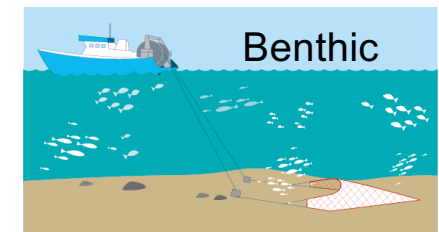
Static activities: shellfish farming, sea farming, seaweed and salt harvesting...

The management of these products can be done as for other health risks in these activities (bacteria...) by **blocking the production and releasing after radiological controls.**



## Fishing activities

- Management based on **enhanced environmental monitoring guided by modelling results prior to fishing operations** → areas open or close.
- The type of fishing that may be permitted (benthic, pelagic, tuna...) can be defined as for **current management for quota compliance.**
- The organization and implementation of radiological controls of products upon landing must not delay their marketing.



# NEEDS AND PERSPECTIVES

Ecological Modelling 516 (2026) 111540

## Numerical models able to :

Provide **activities by species** and not only by group →

Ecotrophic modelling of cesium-137 dispersion and bioaccumulation in the Gulf of Lion following hypothetical nuclear accident scenarios

Thomas Seyer<sup>a,\*</sup>, Vincent Faure<sup>b</sup>, Sabine Charmasson<sup>a</sup>, Hugo Durand<sup>a</sup>, Daniela Bănaru<sup>c</sup>

Provide **activities in sediments** and their possible transport in the medium term (1-3 years)

## Analytical tools:

Numerous **measuring devices adaptable** to various sites (port, beach...) and various products (fish, mollusk...)

**Effective communication tools:** colored flags for beach access, user guide for nautical activities....



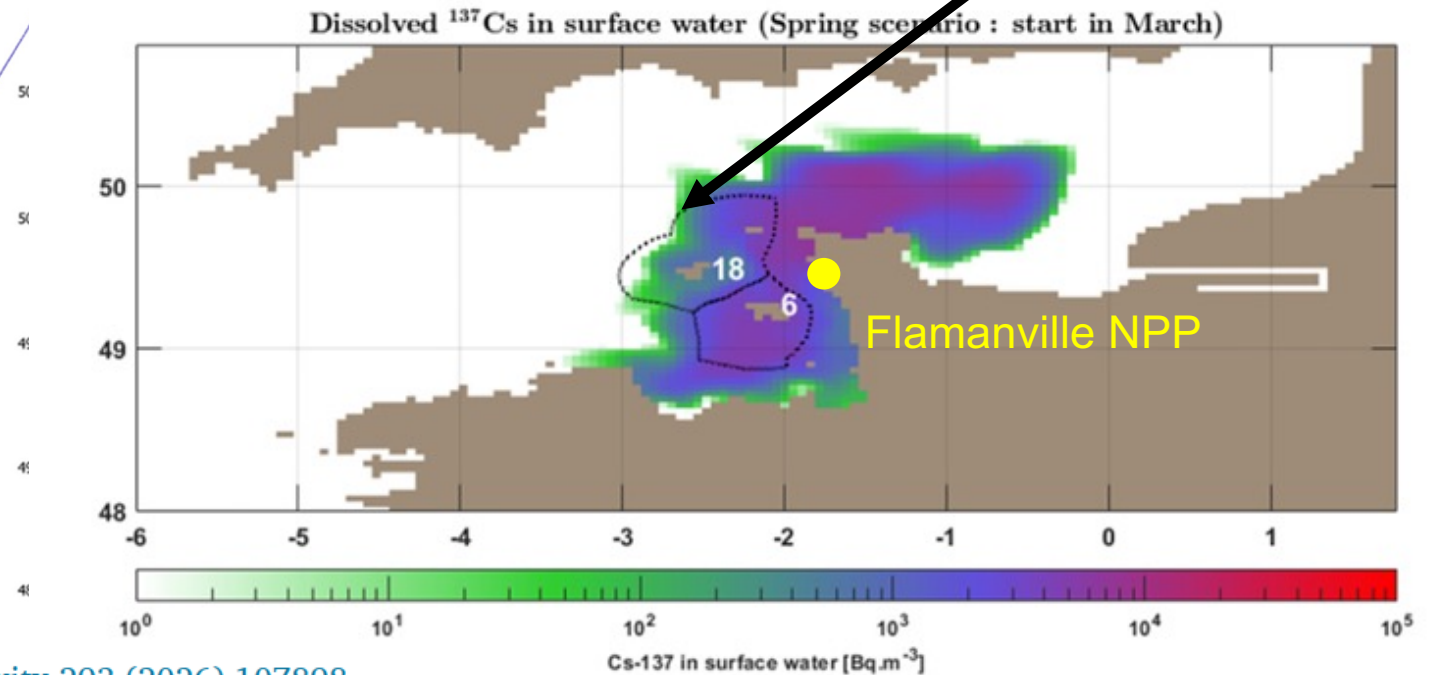
## Communication:

Results accessible on a national scale but also on an appropriate **local scale** (touristic sites, beaches, cities) and accompanied by clear and appropriate recommendations.



## H. Durand-PhD: An interdisciplinary approach to post-accident management of the marine environment subject to radioactive contamination

Addition of marine boundaries



Journal of Environmental Radioactivity 293 (2026) 107898

From modelling to management: improving decision-making through contextualized marine radiological impact assessments after a nuclear accident

Hugo Durand<sup>a,\*</sup>, Karine Beaugelin-Seiller<sup>b</sup>, Céline Duffa<sup>a</sup>, Sophie Gambardella<sup>c</sup>, Olivier Radakovitch<sup>a</sup>

# FRENCH LEGAL FRAMEWORK FOR NUCLEAR ACCIDENT PREPAREDNESS AND RESPONSE

## Nuclear law

### On-site

On-site emergency plans to control an accident situation.

### Off-site

Emergency management system and off-site emergency plans.

### International cooperation

- Notification and exchange of information
- Assistance
- Bilateral agreements

## Law of the sea

General obligation regarding prevention, control, and mitigation of marine pollution.  
Bilateral agreements.

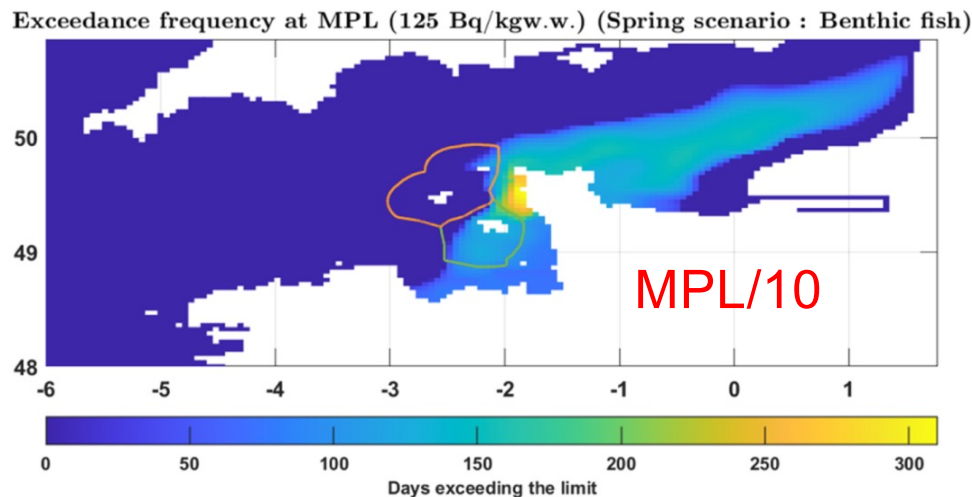
## Soft law

- International Atomic Energy Agency
- International Commission on Radiological Protection
- Other relevant organizations

International cooperation mechanisms are primarily designed for the emergency phase. But there are no legal obstacles that would prevent their extended implementation to the post-accident phase (information exchange, assistance, or measures to reduce and control marine pollution).

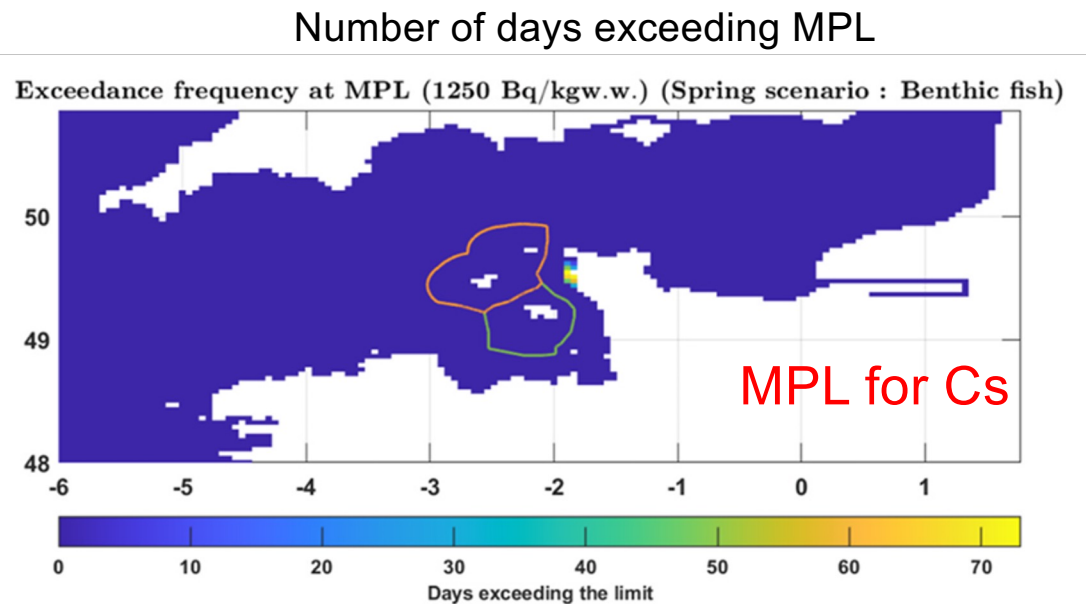
# NEW INDICATORS FOR RADIOECOLOGICAL OR ECONOMICAL CONSEQUENCES

## Exceedance of dose rates



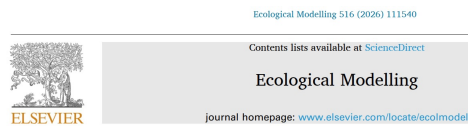
## Consequences for the fishing industry:

Maximum Permitted Levels (European regulatory values used for the marketing of foodstuffs and animal feed)





# GOLEM: a complete ecosim, ecopath, ECOSPACE and ecotracer model based on the gulf of Lion ecosystem



Ecotrophic modelling of cesium-137 dispersion and bioaccumulation in the Gulf of Lion following hypothetical nuclear accident scenario

Thomas Seyer<sup>a,\*</sup>, Vincent Faure<sup>b</sup>, Sabine Charmasson<sup>a</sup>, Hugo Durand<sup>a</sup>, D.

- Represent 99% of the total Gulf biomass
- 66 living groups + 2 detritus group
- Scenarios of long or short release of  $^{137}\text{Cs}$  at various seasons

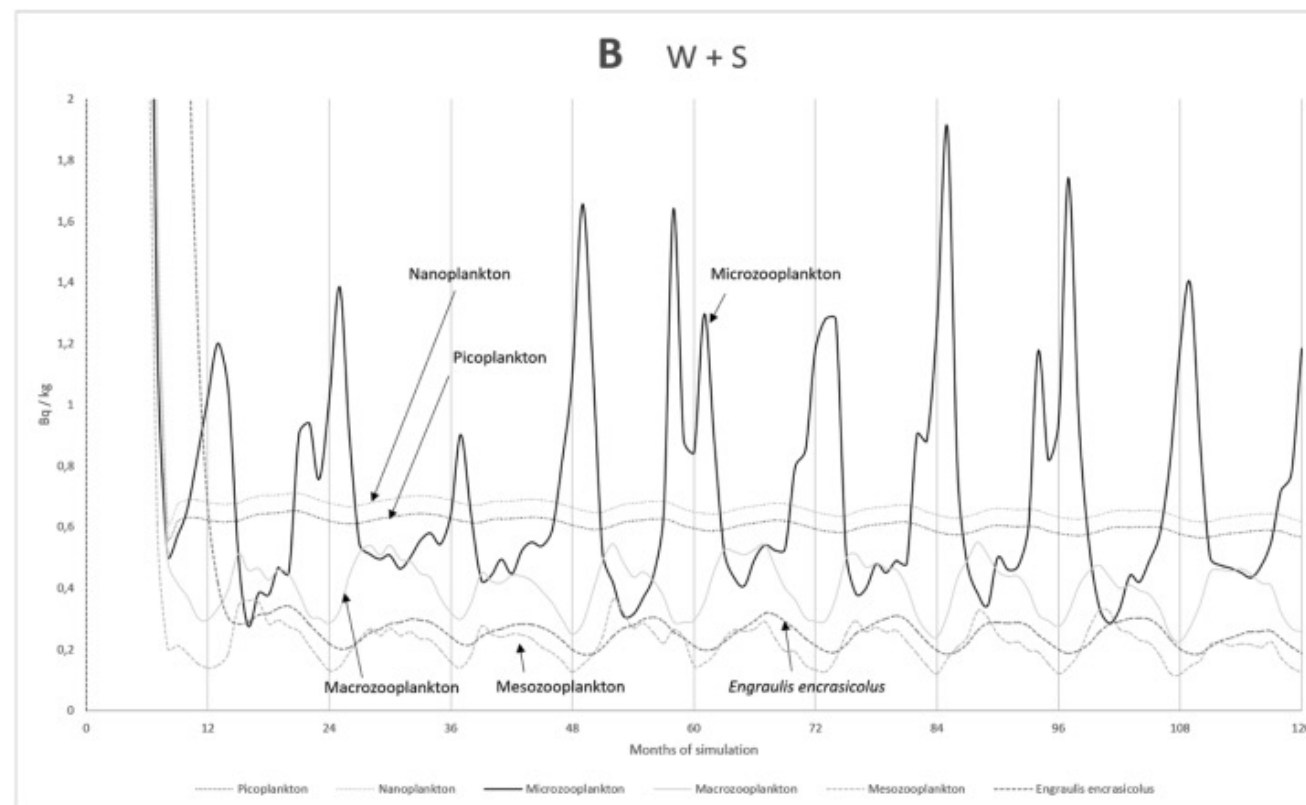
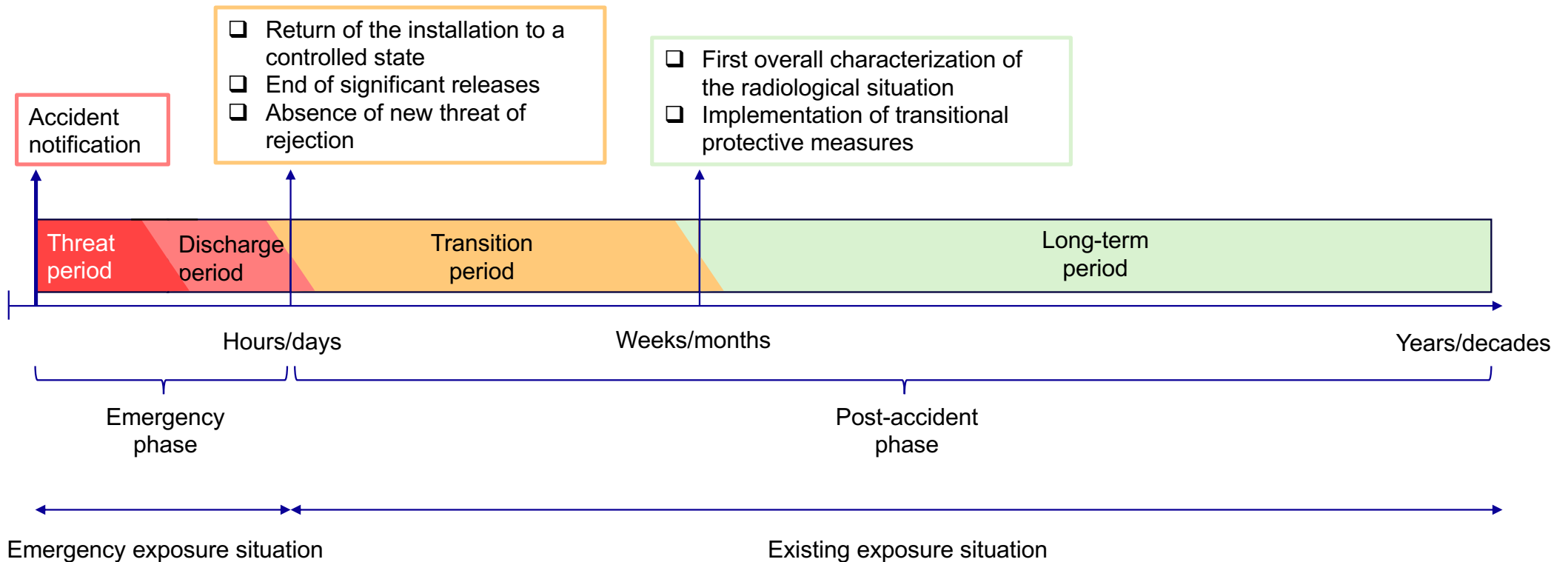


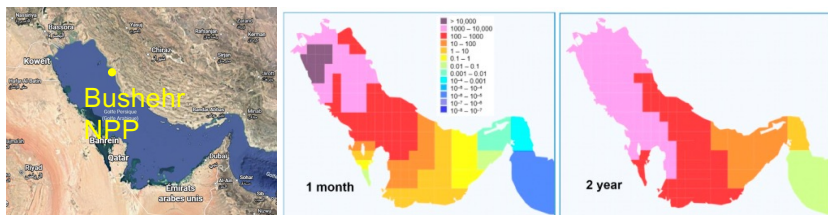
Fig. 10. Spatial average concentrations of cesium-137 (Bq / kg) during scenario W + S in A: benthic and pelagic sets of groups; B: some pelagic groups. Vertical graduation corresponds to December of each year.

# BREAKDOWN OF THE PHASES OF NUCLEAR ACCIDENT MANAGEMENT

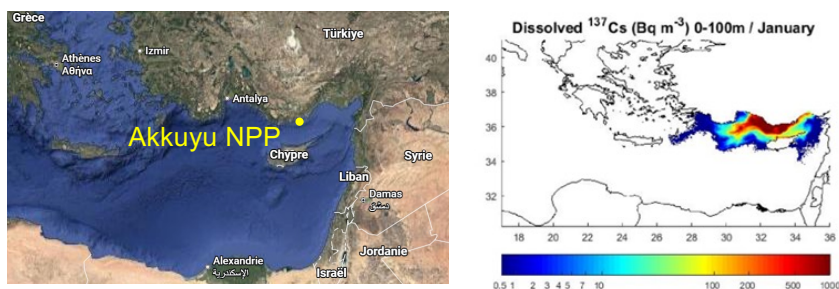
French designation



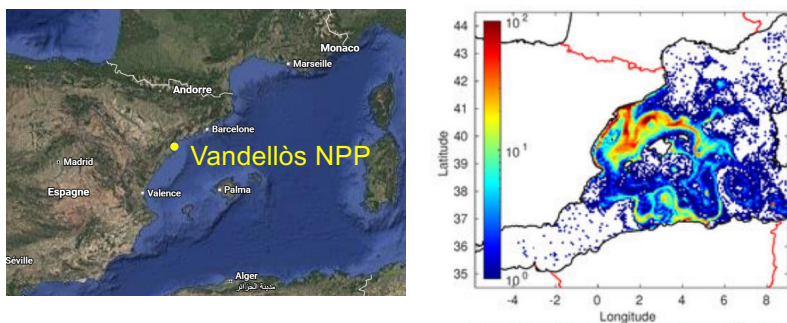
# APPLICATION CASES : DISPERSION



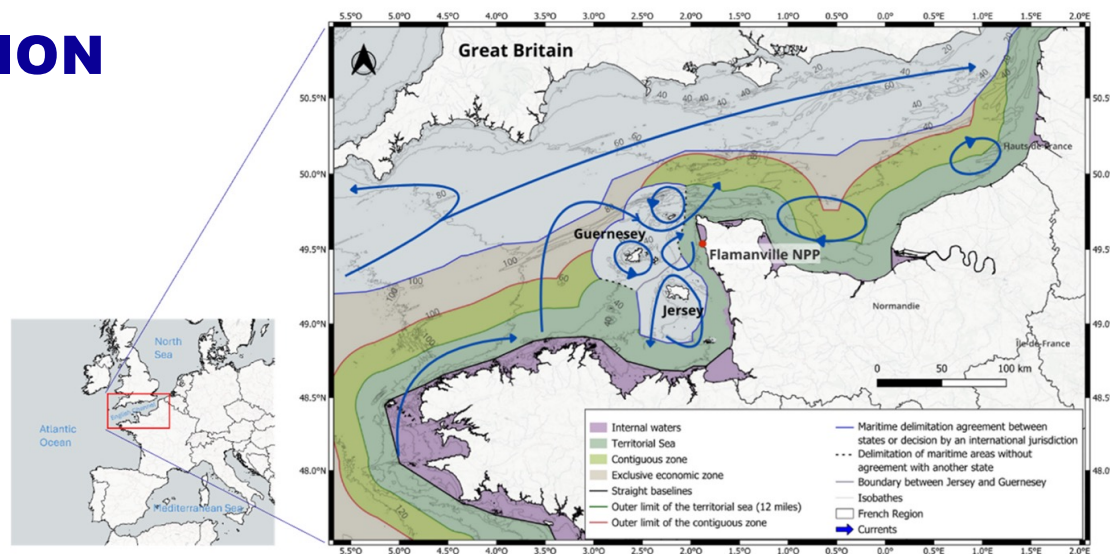
Maderich et al., 2023. <https://doi.org/10.3390/jmse11020331>



Tsabarlis et al., 2022. <https://doi.org/10.1016/j.pnucene.2019.103114>



Periáñez and Cortés, 2023. <https://doi.org/10.3390/jmse11091707>

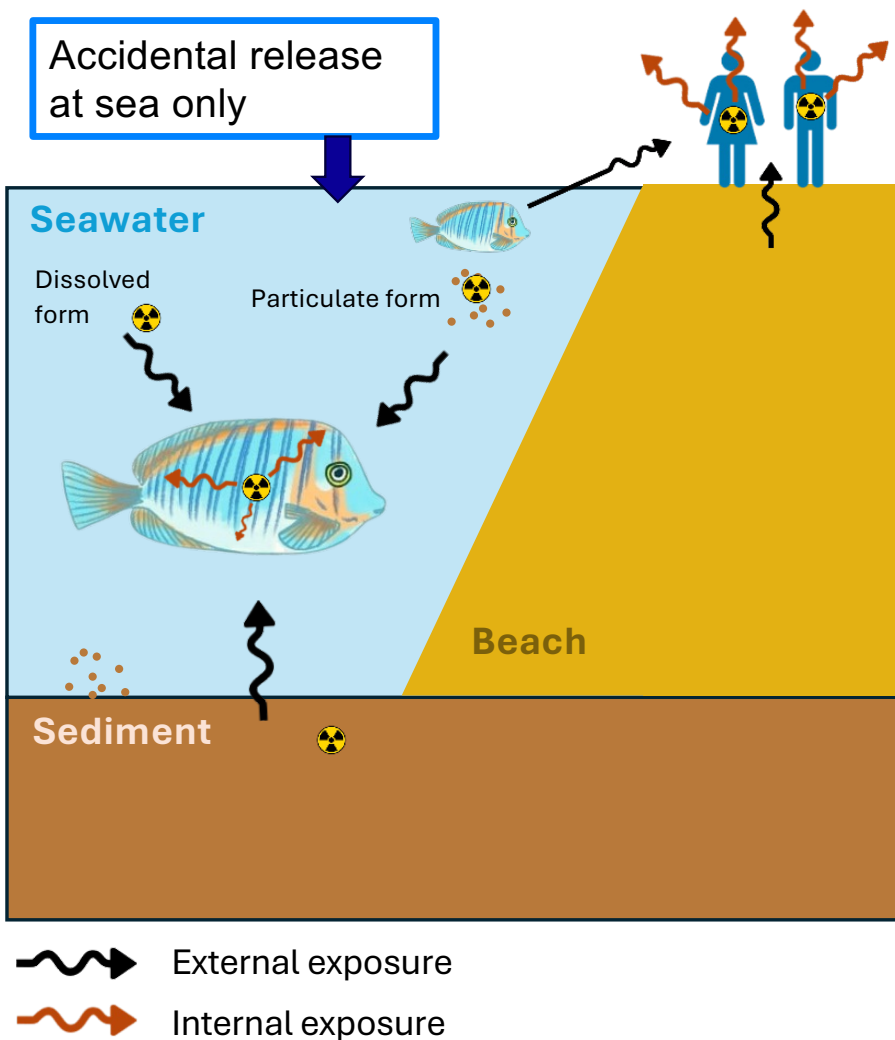


Durand et al., 2026. <https://doi.org/10.1016/j.jenvrad.2026.107898>

## International cooperation ?

Although international cooperation mechanisms are primarily designed for the emergency phase, no legal obstacles have been identified that would prevent their extended implementation in the post-accident phase, whether in terms of information exchange, assistance, or measures to reduce and control marine pollution.

# RADIOLOGICAL IMPACT ASSESSMENT : MODELING APPROACH



## 1 Estimation of radioactive activities

Dispersion model

Transfer model

Activities in :

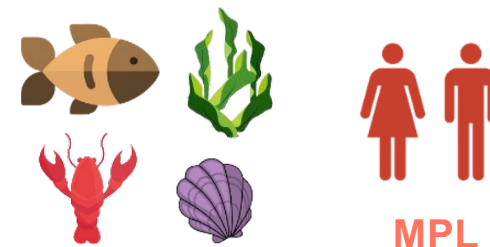
- Seawater
- Suspended particles
- Sediments (including beach)
- Marine organisms
- Humans

## 2 Exposure analysis

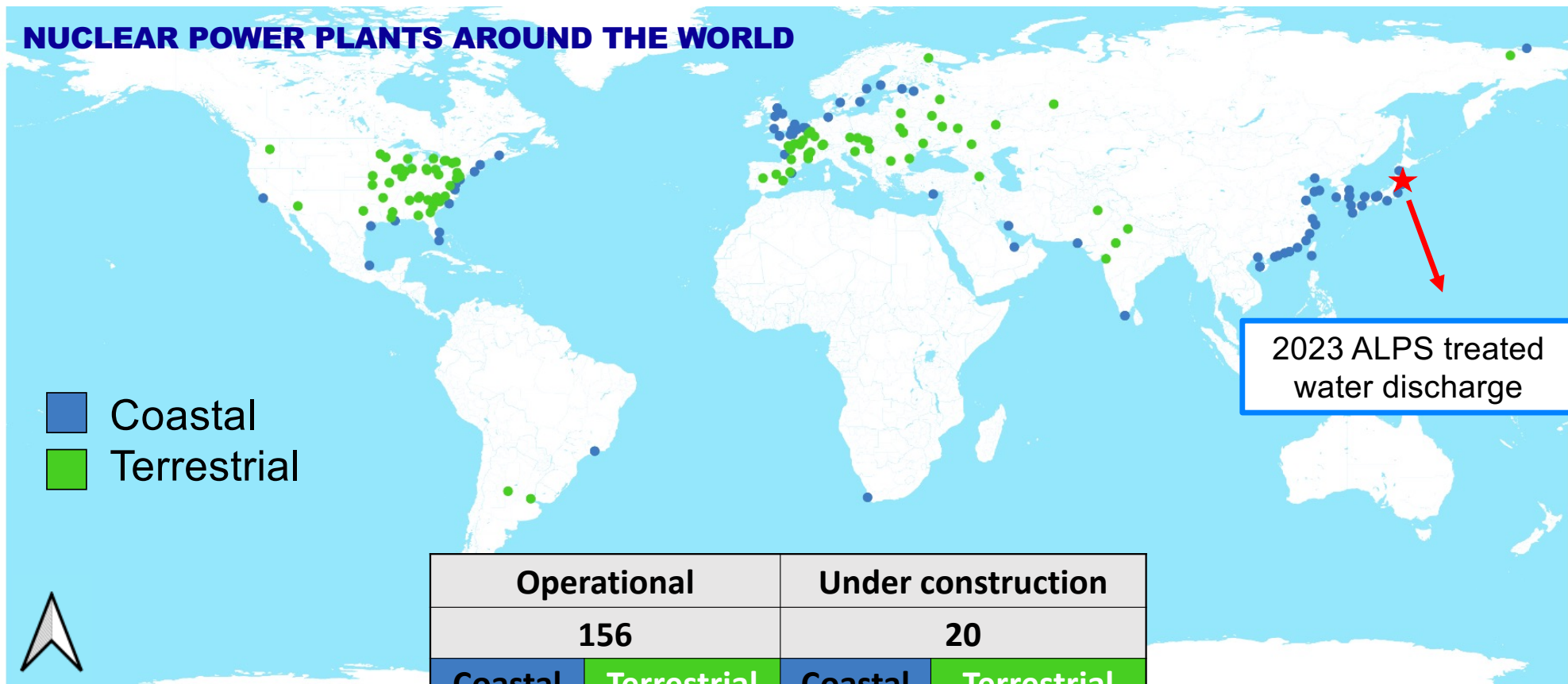
Dosimetric model

Dose rates for marine organisms and humans

## 3 Comparison with radioprotection reference levels



## NUCLEAR POWER PLANTS AROUND THE WORLD



| Operational |             | Under construction |             |
|-------------|-------------|--------------------|-------------|
| 156         |             | 20                 |             |
| Coastal     | Terrestrial | Coastal            | Terrestrial |
| 63          | 93          | 16                 | 4           |