Chronotoxium Risk Priority:

A Toxicological Calculator Measuring Aquatic Biological Harm Per Species.

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Author Note This paper provides an accessible overview and workable algorithm of the emerging concept of chronotoxium and its relevance to modern changing aquatic environmental pollution.

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Chronotoxium: A New Way to Understand Changing Pollution in Our Waters

Keywords: 6PPDq, Wastewater management, Effluent discharge, Road Waste, Microplastics, Chronotoxium, Zeta, Deuterium

Abstract

Chronotoxium Risk Priority (CRP) is a new idea for understanding surface pollutants that *change over time* after they enter oceans, lakes, or rivers. Recent events of surface flooding flushes a great deal of loose pollutants or products with multi-component ingredients into waterways and these collections are creating highly toxic situations in various aquatic biomes. Instead of staying the same, these Persistent Organic Pollutants (POPs) transform as they interact with sunlight, salt, temperature, redox capabilities, and living organisms creating altered biomes. Because of natural currents and sedimentation principles, typical aquatic habitat chemistry is skewed as they evolve, their risks also change and sometimes becoming more dangerous days, weeks, months, or years after they're released. With current weather extremes, these chemicals and process are ever evolving so there needs to be updated understanding and standards that reflect these ongoing changes. This paper explains the importance for updated surface wastewater management principles with new environmental protection, regulations, and processes.

1. What Is Chronotoxium?

Chronotoxium is a pollution calculator that puts a quantitative number of a wide variety of chemical compounds and what that collective effect has on any ocean species and the effects on that species.

Unusual weather patterns and increasing storm volumes now allow many modern contaminants like microplastics, metal particles, industrial chemicals, pharmaceuticals, current sewage treatment, including waste water treatment bypass where removal is not 100%. Other aspects include intense flushing of roadways, rooftops, and general land flooding that moves all of this chemical and physical debris into natural waterways and eventually ocean habitats.

Chronotoxium refers to pollutants that:

- Change over time
- Become more or less harmful as they transform
- React to environmental conditions like sunlight, salt, and temperature
- Effects of redox, cross-contamination, and admixture
- Chronic accumulators & residual buildup

In other words, chronotoxium is pollution that *evolves,* usually because of outmoded, outdated or uncontrolled effluent spills and a lack of discharge controls.

With all of this in mind, an algorithm was created by focusing on 106 chemicals, elements, reactions, and compounds and factored by their individual damage potential as follows:

CRP (Chronotoxium Risk Priority) is a structured, quantitative framework filtered through 11 nodes that evaluates how marine species experience the full *cause-to-effect cascade* of environmental stressors—ranging from stormwater pulses and sewage overflows to hypoxia, redox, chemistry, physiological collapse, various time periods, ecosystem-level regime shifts, and user education.

CRP integrates three components for each of 11 nodes in the Chronotoxium cascade:

1. Exposure Score

How strongly a species encounters a given process (e.g., stratification, POC accumulation, boundary-layer hypoxia).

2. Hazard Score

How harmful that process is to the species' biology (eg. Sensitivity to hypoxia, toxicants, redox, species).

3. CRP Weight

The structural importance of that node within the cascade (e.g., boundary-layer hypoxia and physiological collapse carry higher weights than upstream pulses).

These three values combine into a CRP Composite Score:

$$\textbf{CRP Composite} = \textbf{Exposure} \times \textbf{Hazard} \times \textbf{Weight}$$

Summing all node scores produces a species-level CRP total, which is then assigned to a risk tier:

- **Tier 3 - Critical Risk: CRP ≥ 700** Severe vulnerability; cascade-terminal failure; ecosystem-level leverage.
- **Tier 2 - High Risk: CRP 500 - 699** Strong vulnerability; multiple cascade nodes activated; major ecological or economic impact.
- **Tier 1 - Moderate Risk: CRP 300 - 499** Meaningful vulnerability; partial cascade activation; localized or conditional impacts.
- **Tier 0 – Low Risk: CRP < 300** Minimal cascade activation; low systemic leverage.

There are eleven nodes that the CRP applies which creates a score for each node and is then computed as follows:

<u>Algorithmic computation</u>

$\text{Composite}_{\text{node}} = \{ W_{\text{node}} \cdot E_{\text{node}} \cdot H_{\text{node}} \cdot \zeta MP \text{if}\ _{\text{node}} \in \{P,O,R,H\}\ W_{\text{node}} \cdot E_{\text{node}} \cdot H_{\text{node}}$

<u>Cascade c/w modifiers:</u>

$(F \cdot \Delta D + S + X) \rightarrow M \rightarrow P \cdot \zeta \rightarrow O \cdot \zeta \rightarrow R \cdot \zeta \rightarrow H \cdot \zeta \rightarrow C \rightarrow W \rightarrow \Omega$. Where $\boldsymbol{\zeta} = \boldsymbol{\zeta}_{(MP)}$.

Tier Computation

$CRP = \Sigma_{(F\rightarrow\Omega)}\ (W\cdot E\cdot H\cdot \zeta_{(MP)}\text{\textasciicircum}(P,O,R,H)) \rightarrow Tier$

Symbolic Visual Form

🟦 F + 🟧 S + 🟪 X → 🟩 M → 🟫 P → 🔵 O → 🔴 R → 🟣 H → 🔶 C → 🔻 W → ● Ω

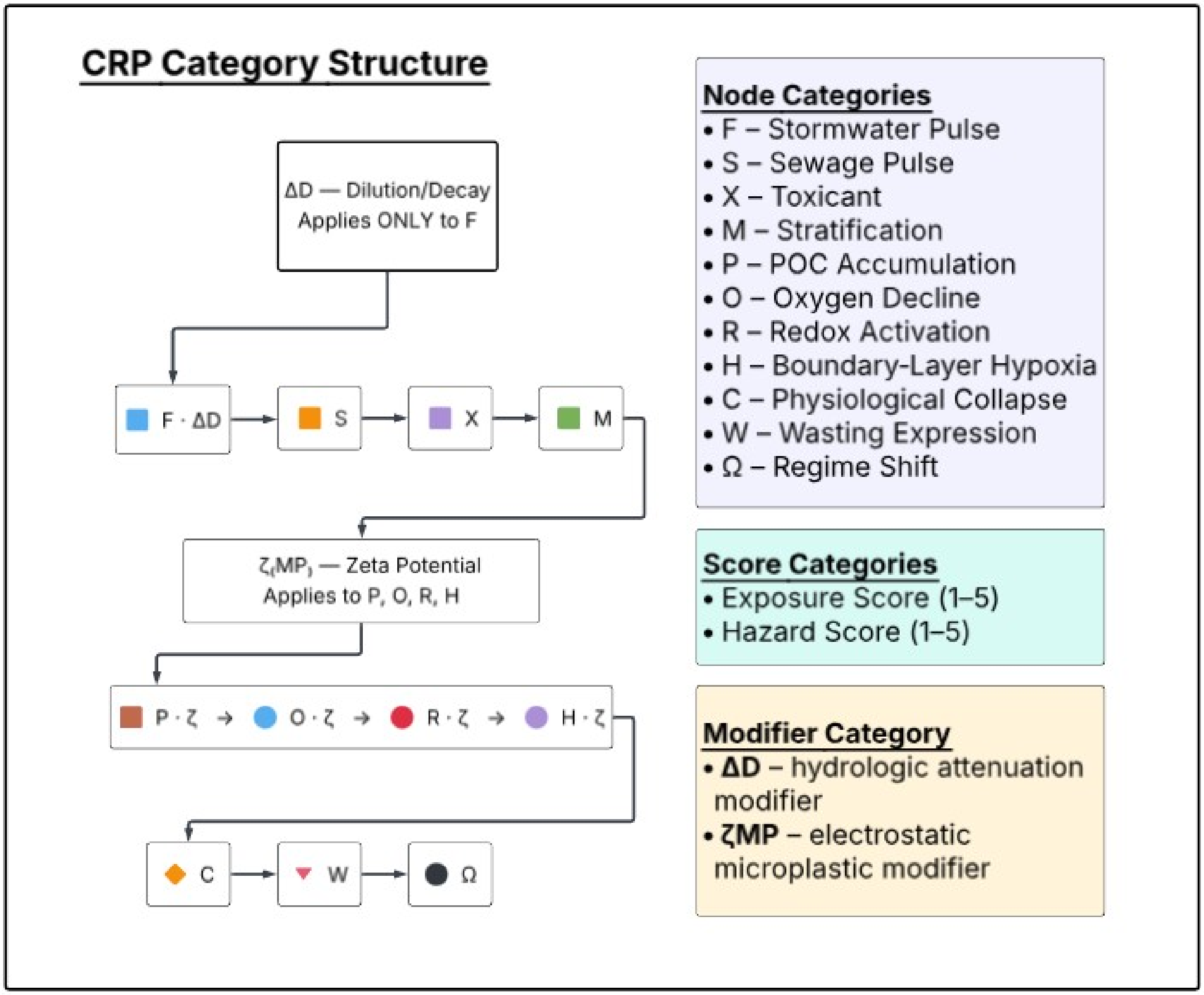

Figure 1: Chronotoxium Risk Priority (CRP) algorithm used to create a damage-value score based on pollution in ocean aquatic environments. (Concept & graphic created by the author)

2. Why Time Matters

These pollutants don't have a single "toxicity level." Instead, they move through stages:

1. **Early Stage** Fresh particles enter the water and begin reacting with light or oxygen.
2. **Transformation Stage** Sunlight, waves, and saltwater break them down through abrasion increasing surface area or change their chemistry or ionicity.
3. **Peak Danger Stage** They reach their most harmful form — often when they dissolve, release metals, or produce reactive chemicals.
4. **Long-Term Stage** What remains settles into sediments, where it can cause slow, ongoing harm for years due to leakage or detrital persistence.

This time-based behavior is what makes Chronotoxium (CRP) different from traditional pollutant measuring platforms or calculations, because it takes into account a "*disturbance level"* of authenticity and how those accumulative effects of those disturbances can alter the safe toxicity levels of chemicals that are released.

3. What Makes Chronotoxium Harmful?

With the right set of circumstances Chronotoxic pollutants can combine, dilute, counteract, neutralize, infill, electrochemical potential and offset, redox, and any variant currently known which can:

- Produce harmful molecules that damage cells
- Break into smaller pieces that are easier for animals to consume or absorb
- Release metals, or chemicals that were not dangerous in their original form
- Interfere with marine life, from plankton to fish to seabed ecosystems
- Manipulate oxygen, pH, conductivity, and food content

Because they change, they can create skepticism by only measuring pollution at one moment in time. The CRP algorithm measures that same chemical in a wide variety of states, volume, longevity, potential serendipitous modifications and disturbance factors.

4. How Chronotoxium Moves Through the Ocean

Chronotoxium pollutants behave differently depending on where they are:

Open water

- Sunlight speeds up chemical reactions
- Particles clump together or break apart
- They interact with natural organic matter

Deeper layers

- Less light but more mixing from waves and currents
- Combined pollutants may shift into new forms

On the seafloor

- Low-oxygen zones change their chemistry again
- Microbes and biofilms grow on them
- Mass influxes of fresh water or waste water blooms can smother
- They can stay for decades due to changing specific gravity

Storms or human activity can stir them back up, restarting the harm once again, and refouling the water column.

5. Effects on marine life

Chronotoxium can harm living organisms in several ways:

- **Cells:** oxidative stress, DNA damage
- **Animals:** weakened immune systems, behavioral changes, altered reproduction
- **Ecosystems:** altered food webs, oxygen loss in sediments & coral stress due to coatings

Because the pollutant changes over time possibly due to an undetermined interaction, or redox, then the type of harm also changes. An example is when recorded volumes of δD freshwater floods into benthic regions where typical ocean water settings are replaced with fresh water, which allows chemicals to react differently in fresh water as opposed to salient. The types of storms experienced today could be allowing massive water changes in benthic regions creating very low alkalinity, destroying carbonate and bicarbonate habitats, and radically reducing ionic strength. This would be a rapid acidification event that could take place in days and not a slow one like atmospheric CO_2-driven ocean acidification. This combined with how chemicals and metals react in fresh water as opposed to salient could exacerbate stress on benthic creatures. A good marker is that 6PPDq does not seem to be as potent in ocean settings as it is in fresh water and the chemistry of seawater strongly suggests reduced bioavailability and lower acute toxicity, although not confirmed as no research could be found detailing that.

6. How to Measure Chronotoxium Levels

The main focus is on chemicals that can be released from roadway storm sewers and wastewater bypasses or emergency releases of unprocessed sewage. After researching nearly every chemical and biological condition available that could have adverse effects on aquatic systems based on abundance, availability and severity, I created a database with all these variables and findings into a structured list. I then queried AI and asked it to create a workable algorithm in order provide quantitative framework that evaluate how marine species experience the full *cause-to-effect cascade* of environmental stressors; ranging from stormwater pulses and sewage overflows, to hypoxia, redox chemistry, physiological collapse, ecosystem-level regime shifts, as well as anthropogenic potential.

CRP integrates three components for each node in the Chronotoxium cascade:

1. Exposure Score

How strongly a species encounters a given process (e.g., stratification, POC accumulation, boundary-layer hypoxia).

2. Hazard Score

How harmful that process is to the species' biology (e.g., sensitivity to hypoxia, toxicants, redox, species, etc).

3. CRP Weight

The structural importance of that node within the cascade (e.g., boundary-layer hypoxia and physiological collapse carry higher weights than upstream pulses).

These three values combine into a CRP Composite Score:

CRP Composite=Exposure×Hazard×Weight

Summing all node scores produces a species-level CRP total, which is then assigned to a risk tier:

- **Tier 3 — Critical Risk**
- **Tier 2 — High Risk**
- **Tier 1 — Moderate Risk**
- **Tier 0 — Low Risk**

CHRONOTOXIUM ORG-CHART (Cause → Effect)

Color-coded information balloons with directional flow

TOP LEVEL – INPUT DRIVERS

🟦 **Stormwater Pulse (F)**

- Low δD freshwater (Delta D only effects F)
- High flow
- Watershed organics **CAUSE** → contributes to stratification and toxicant transport

🟧 **Sewage Pulse (S)**

- CSO / WWTP bypass
- POC, DOC, pathogens, nutrients **CAUSE** → increases organic load and microbial demand

🟪 **6PPD-q Toxicant Load (X)**

- Tire-derived quinone
- Automotive chemicals and road salts
- Storm-mobilized **CAUSE** → adds direct toxicant stress and synergizes with hypoxia

⬇ **All three feed into the next node**

SECOND LEVEL - PHYSICAL TRANSITION

🟩 **Stratification (M) CAUSE:** Buoyant freshwater + sewage + 6PPD-q lens **EFFECT:**

- Suppressed mixing
- Benthic isolation
- δD layering

⬇

THIRD LEVEL - ORGANIC ACCUMULATION

🟫 **POC Accumulation (P) CAUSE:** Convergence zones + sewage solids **EFFECT:**

- High microbial respiration
- Increased sedimentation

⬇

FOURTH LEVEL - BIOGEOCHEMICAL ENGINE

🔵 **Oxygen Altering (O) CAUSE:** Microbial respiration of POC **EFFECT:** Hypoxia → anoxia

⬇

🔴 **Redox Activation (R) CAUSE:** DO collapse **EFFECT:**

- H_2S
- NH_4^+
- Fe^{2+}

- Mn^{2+}
- CH_4 (δD-shifted)

⬇

__FIFTH LEVEL - ORGANISMAL INTERFACE FAILURE__

🟣 **Boundary-Layer Hypoxia (H) CAUSE:**

- Organic films
- Reduction of species
- 6PPD-q synergy **EFFECT:** Oxygen diffusion failure, direct chemical exposure

⬇

__SIXTH LEVEL – BIOLOGICAL COLLAPSE__

🔶 **Physiological Collapse (C) THE CAUSE:** Hypoxia, toxicants

- Undetermined Redox species **EFFECT:** Mitochondrial failure, immune suppression, tissue hypoxia

⬇

🔻 **Wasting Expression (W) CAUSE:** Irreversible physiological collapse **EFFECT:** Lesions, necorsis, arm loss, mortality

⬇

__FINAL LEVEL - SYSTEM OUTCOME__

● **Regime Shift (Ω) CAUSE:** Population collapse of keystone predators **EFFECT:** Urchin bloods, kelp forest loss, long term ecosystem restructuring

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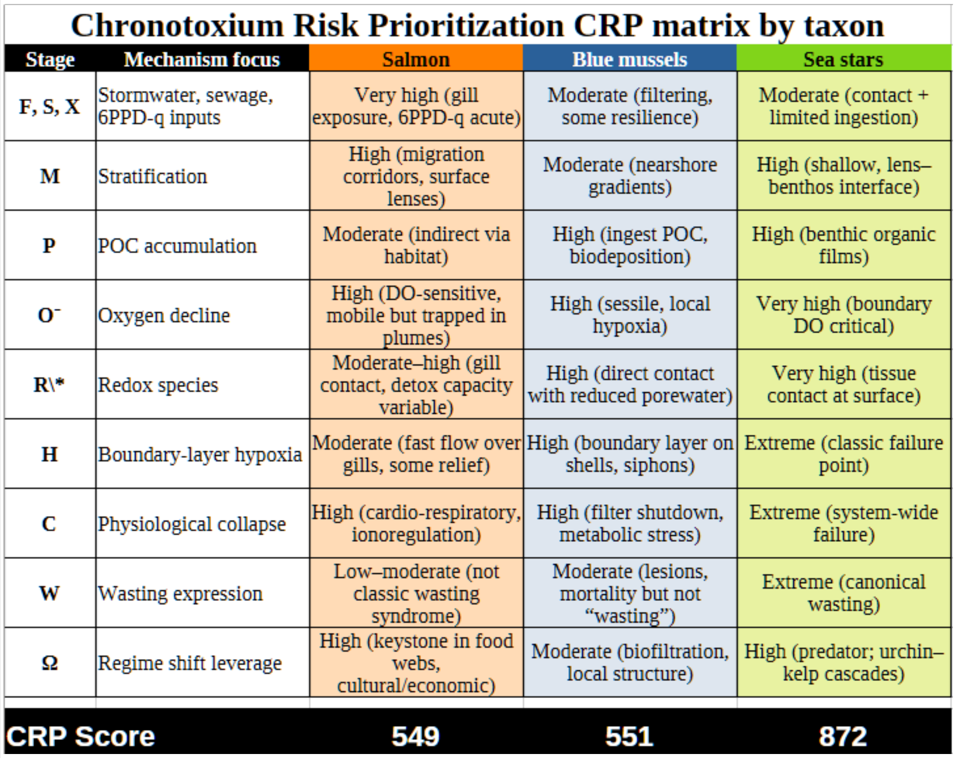
An example was developed using the CRP algorithm on:

- **Salmon -** marine/diadromous vertebrate (fish in benthic regions, not fresh water)

- **Sea stars** - benthic invertebrates (echinoderms)
- **Mussels** - benthic invertebrates (bivalves)

The results are posted in Figure 2 showing CRP scores of 549 for Salmon, 551 for Blue Mussels, and 872 for Sea stars. Additional tests run on Cod fish and results were 475, and lobster was 690.



Chronotoxium Risk Prioritization CRP matrix by taxon

Stage	Mechanism focus	Salmon	Blue mussels	Sea stars
F, S, X	Stormwater, sewage, 6PPD-q inputs	Very high (gill exposure, 6PPD-q acute)	Moderate (filtering, some resilience)	Moderate (contact + limited ingestion)
M	Stratification	High (migration corridors, surface lenses)	Moderate (nearshore gradients)	High (shallow, lens–benthos interface)
P	POC accumulation	Moderate (indirect via habitat)	High (ingest POC, biodeposition)	High (benthic organic films)
O^{-}	Oxygen decline	High (DO-sensitive, mobile but trapped in plumes)	High (sessile, local hypoxia)	Very high (boundary DO critical)
R*	Redox species	Moderate–high (gill contact, detox capacity variable)	High (direct contact with reduced porewater)	Very high (tissue contact at surface)
H	Boundary-layer hypoxia	Moderate (fast flow over gills, some relief)	High (boundary layer on shells, siphons)	Extreme (classic failure point)
C	Physiological collapse	High (cardio-respiratory, ionoregulation)	High (filter shutdown, metabolic stress)	Extreme (system-wide failure)
W	Wasting expression	Low–moderate (not classic wasting syndrome)	Moderate (lesions, mortality but not “wasting”)	Extreme (canonical wasting)
Ω	Regime shift leverage	High (keystone in food webs, cultural/economic)	Moderate (biofiltration, local structure)	High (predator; urchin–kelp cascades)
CRP Score		**549**	**551**	**872**

Figure 2: A working example of the Chronotoxium algorithm on 3 separate species.

7. Why Current Regulations Aren’t Enough

Most environmental rules such as the Wastewater Systems Effluent Regulations (WSER) assume that acceptable final discharge of treated water will result in safe dispersion of source chemicals or waste materials. However with changes in climactic weather events these baselines appear to be outdated from the assumptions that current protocols are:

- Stable
- Predictable
- Measured once

WSER sets national minimum standards for treated effluent and systems must meet limits for:

- Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)
- Total Suspended Solids (TSS)
- Un-ionized ammonia
- Chlorine residuals
- Acute lethality (effluent must not be acutely lethal to fish)

These standards define what counts as acceptable effluent discharge. *(Gov of Canada, 2025),* but it appears that there are some areas that are starting to miss the limits due to unforeseen circumstances. As well this does not seem to account for individual user access to storm drains with potential harmful inclusions, or flooding from general storms causing chemical debris from roadway runoff, as well as atmospheric isotopes settling on building and roadways eventually being flushed into aquatic systems instead of being consumed in the soil.

Chronotoxium shows that many of these engineering standards are weakening for many modern contaminants, variants, or dispersion states.

To continue to protect ecosystems, regulations now need to consider:

- How pollutants transform in wildly altering aquatic systems
- When they are most dangerous
- How long they persist
- How environmental conditions speed up or slow down changes
- How alterations in base water actually invite wild changes in aquatic chemistry

This requires new monitoring tools and new standards.

8. Conclusion

Chronotoxium offers a fresh way to understand pollution in a changing world. Instead of treating contaminants as fixed substances or known redox's, it recognizes them as evolving agents shaped by varying quantities, sunlight, salt, temperature, serendipitous chemistry, biology as well as atmospheric anomalies. This perspective helps scientists, policymakers, and the public better understand the real risks facing oceans and waterways and why smarter, time-aware environmental protections are needed, including modifications to current water runoff management, especially from roadways.

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Conflict of Interest

The author declares that there is no known conflict of interest in this study.

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