Challenges of Incorporating Ecosystem Level Endpoints into Radiation Protection Programs

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Mismatch between Protection Goals and Effects Data

Protection Goals

- Ecosystem Services
  - Structure
  - Function
- Populations of Valued taxa

Effects Data

- Predominantly focused on organism-level
- Typically explores single stressor
- Mostly single species
- Largely laboratory-based studies

Focal Endpoints

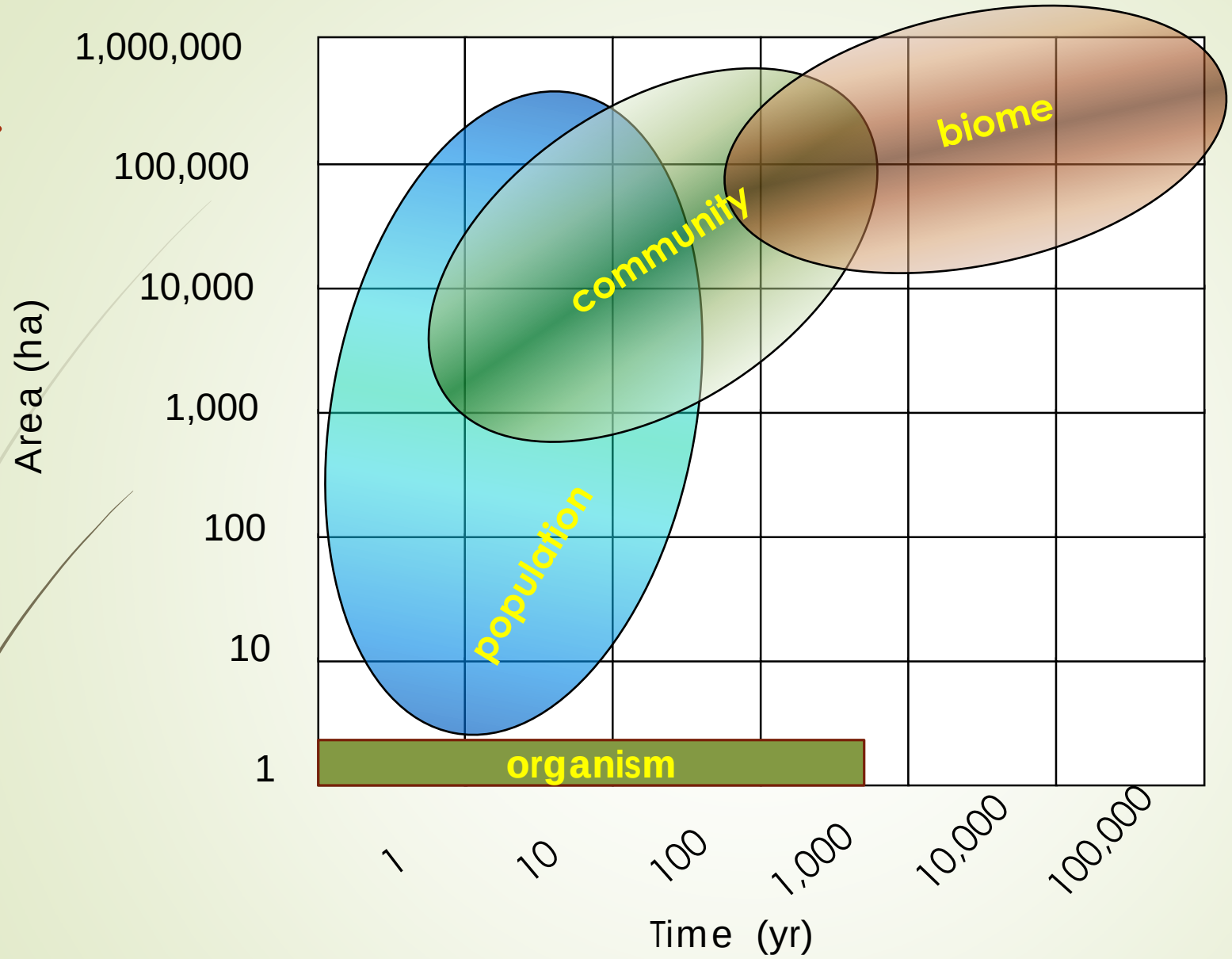
- **Organism-based**
  - Provide high quality data that are relatively easy to corroborate through repeated experiments
  - Have the least relevance to the different regulatory entities – endpoints at population and higher levels of ecological organization
- **Population-based**
  - Quality data acquisition more difficult and costly than organism-based efforts
  - Higher relevance to stated protection goals
- **Ecosystem-based**
  - Generally, one-off studies due to the uniqueness of any ecosystem
  - Highest relevance to protection goals, including consideration of ecosystem services

Methods to measure ecological endpoints at different hierarchical levels of organization.

level of ecological organization	abundance	density	distribution pattern	structural features	theoretical constructs	association	diversity	temporal pattern	trophic association	functional diversity	nutrient cycling	productivity	stability	Grand Total
population	289	208	130	100	11	--	--	--	--	--	--	--	--	738
community	5	135	--	--	4	159	257	92	54	20	--	--	--	726
ecosystem	--	--	--	12	1	--	--	--	--	--	92	80	11	196
all	3	12	4	2	--	3	--	--	2	1	--	16	--	43
Grand Total	297	355	134	114	16	162	257	92	56	21	92	96	11	1703

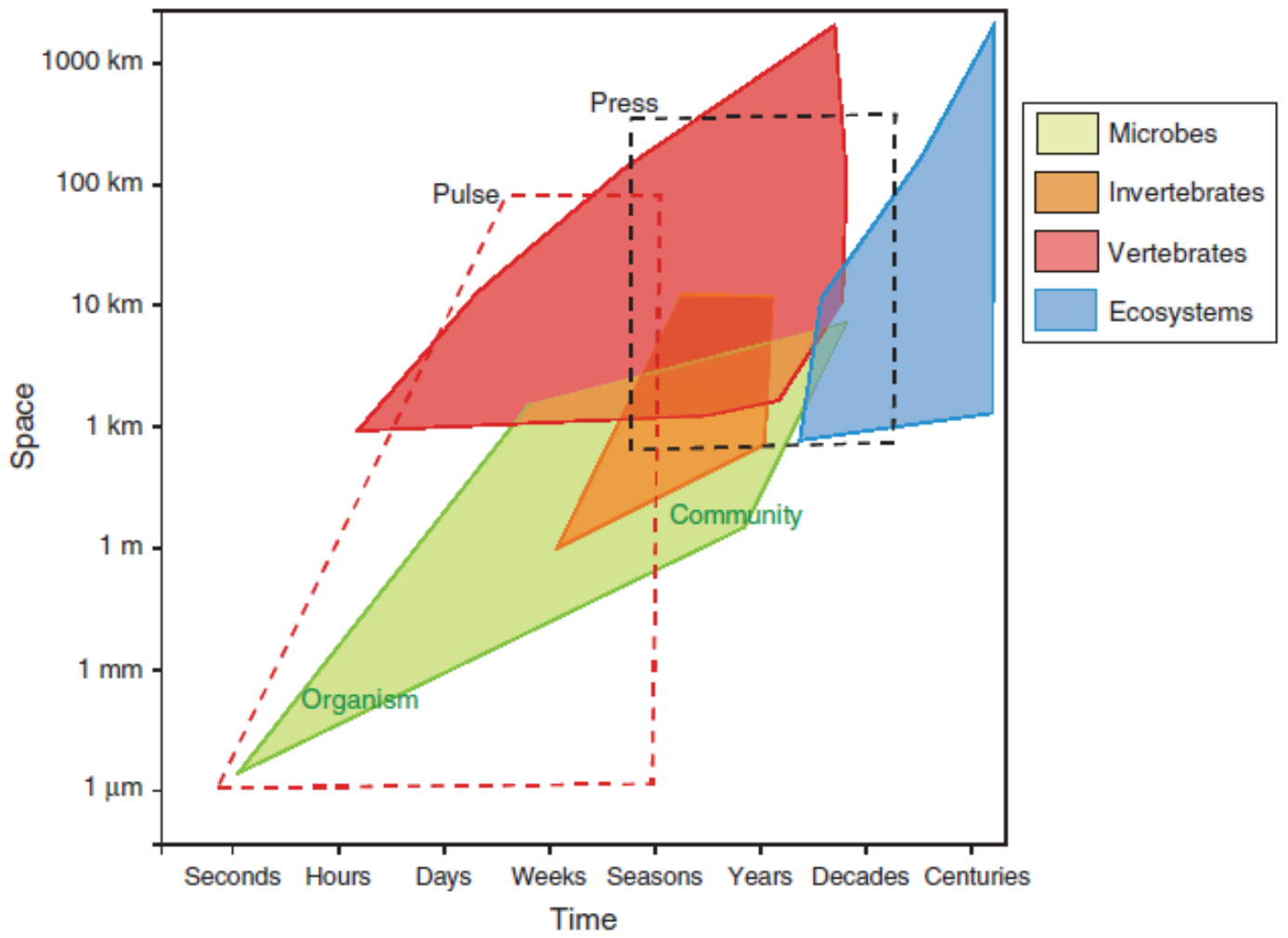
Methods to measure ecological endpoints for different ecological types.

ecosystem type	abundance	association	density	diversity	functional diversity	productivity	temporal pattern	trophic association	structural features	theoretical constructs	distribution pattern	nutrient cycling	stability	Grand Total
Marine	36	10	27	18	1	1	10	9	20	3	--	--	--	135
Freshwater	86	54	122	68	7	43	28	18	35	--	9	67	1	538
Estuarine	16	3	10	19	4	3	5	--	--	--	--	--	--	60
Terrestrial	127	90	166	125	6	34	47	16	30	4	116	12	--	773
All	32	5	30	27	3	15	2	13	29	9	9	13	10	197
Grand Total	297	162	355	257	21	96	92	56	114	16	134	92	11	1703



Adapted from Kapustka L. 2008. *Integrated Environ. Assess Management 4:290-298*

Kapustka L. 2008. Limitations of the current practices used to perform ecological risk assessment. *Integrated Environ. Assess Management 4:290-298*



Dafforn et al. 2016. *Marine Fresh Water Res* 67:393-413.

Constructing an Agreed, Detailed Conceptual Model

- Essential for a successful assessment
- Ideally captures the breadth of important stakeholder values
- Relates these stakeholder values to assessment endpoints

Rule 1 of Conceptual Model Development: Emphasize the most important elements

Ecosystem Services Focus

- Explicitly considers the delivery of goods and services that people care about (e.g., biodiversity, productivity, stable wildlife populations)
- Implicitly considers multiple stressors across the spectra of biological, chemical, and physical parameters
- Ecosystem services endpoints can be used in the existing ecological risk framework
- May be especially important for ionizing radiation settings in areas with
  - little demonstrable adverse effects to plants or wildlife
  - sites subject to exclusion of humans as a safeguard for human health (and thus constituting a loss in terms of many ecosystem services, particularly provisioning services).

Guidance on Assessment Endpoints

US EPA Documents

- A technical background document that explains ecosystem services and describes how to use them as endpoints for ecological risk assessments
- Generic Ecological Assessment Endpoints for Ecological Risk Assessment: Second Edition with Generic Ecosystem Services Endpoints Added." – explains how they can be used to complement the conventional assessment endpoints.

Documents available at https://www.epa.gov/osa/ecosystem-services-ecological-risk-assessment-endpoints-guidelines

Opportunities based on New Approaches to Characterize Ecological Community Composition and Ecological Function

- Traditional Taxonomy-based Surveys
- DNA, RNA Sequencing
- Interpreting Data
  - Diversity (Richness – community structure)
  - Function (mRNA)
  - Adverse Outcome Pathways
  - Bayesian(Belief) Networks

Community Composition – Traditional Morphology-based Surveys

- Snapshot of species presence and abundance – strictly time-dependent (complicated interpretation due to phenology or seasonal considerations)
- Focused on restricted groups of organisms (e.g., plants, invertebrates, or microbes)
- Time-consuming to extract, sort, catalog, and identify specimens
- Highly dependent on taxonomic skill (non-additive – i.e., it taxonomic expertise difficult to share from one study to the next)

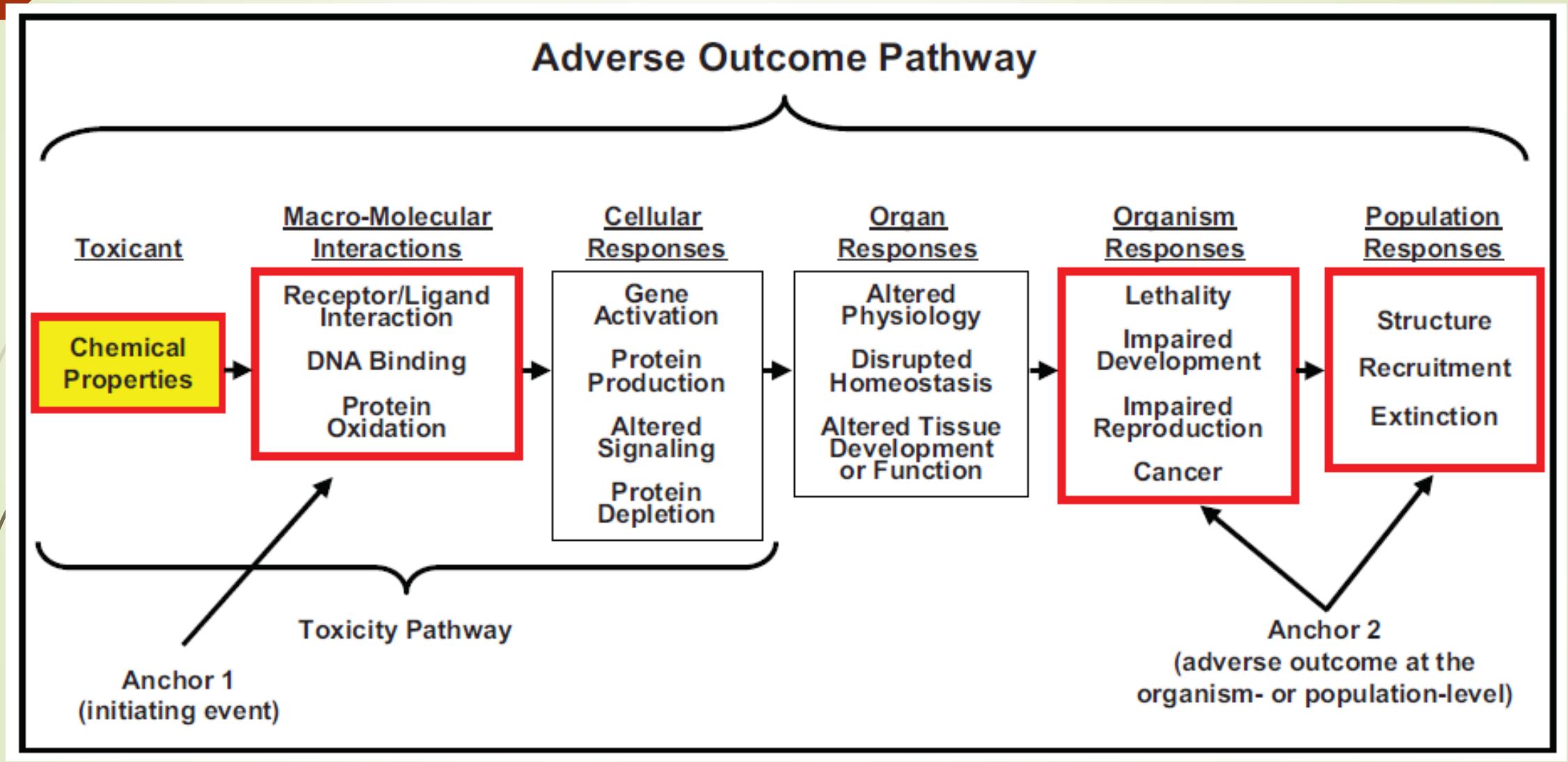
Community Composition Inferred from DNA

- Relies on highly conserved segments of DNA, (e.g., 16s RNA sequence to identify all taxa present)
- DNA libraries progressively expands coverage as data sequences tagged to a particular taxon are added to a database
- Minimizes technician bias – competency largely depends on the robustness of the sequence library
- Rapid analysis of data facilitates larger sampling size compared to traditional taxonomy
- Depending on the library content, the survey is not limited to narrow taxonomic groups including groupings that have yet to be identified
- Similarly a snapshot of community composition, but due to relatively long half-life, the recovered DNA integrates across several weeks, months, even years – leads to a problem referred to as “Zombie DNA” (i.e., residual DNA from organisms that may have died quite some prior to sampling.

Ecological Function Inferred from RNA

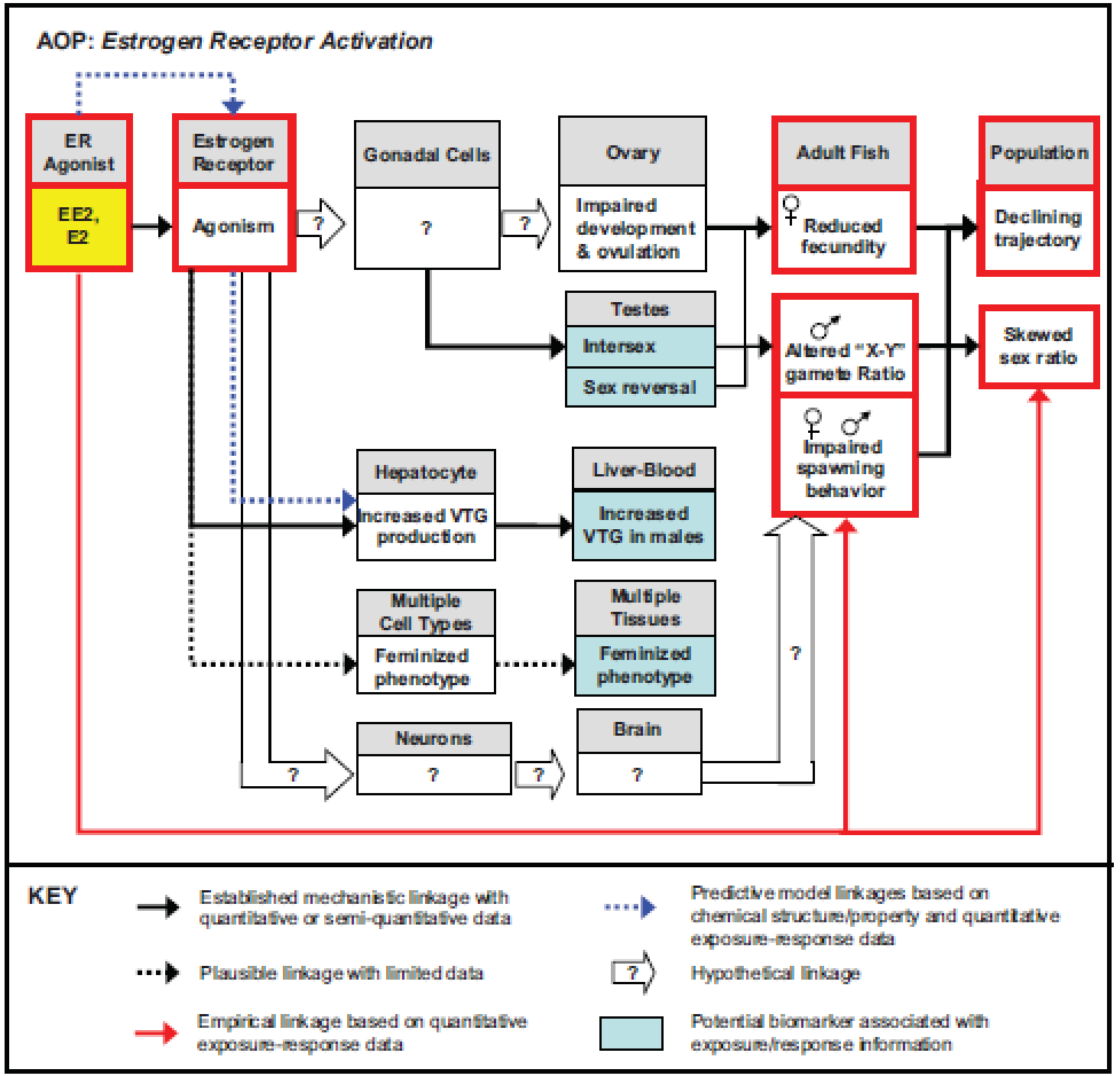
RNA has shorter environmental half-life than DNA

- rRNA considered a better indicator of which organisms are alive and functioning at the time the sample was collected (minimizes the Zombie effect)
- mRNA indicates which genes are being expressed at the time the sample was collected



Ankley et al. 2010. Environ Toxicol Chem 29:730-741.

Can be configured into a Bayesian Network Model to generate probabilistic causal linkages of effects to different stressors



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Summary

- Methods to characterize ecological endpoints (qualitatively and quantitatively) exist.
- Approaches used to measure effects of stressors (particularly chemical stressors) often focused on single-stressors – largely an outgrowth of regulatory requirements.
- Complexity of ecological systems, especially across temporal and spatial scales, should be reflected in conceptual models used in assessing effects multiple of stressors.
- Techniques to characterize nucleic acids in the environment make it possible to describe community composition and ecological functionality (before and after; gradient of stressor within a type)
- Analytical approaches including Adverse Outcome Pathways and Bayesian Network Modelling can be used to assign likelihood of causality linked to multiple stressors (including ionizing radiation)