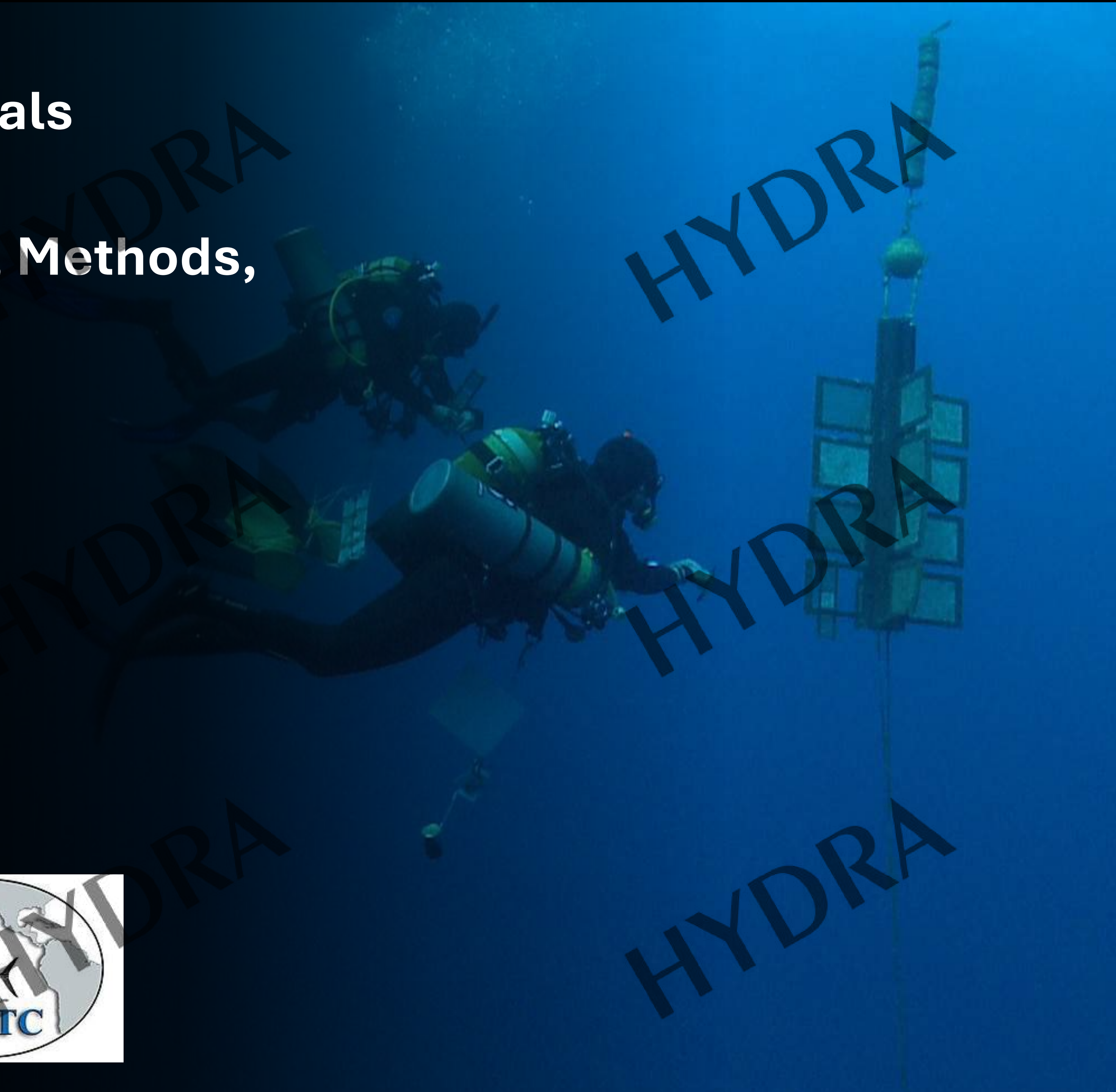
Marine Biodegradable Materials and how to assess them - Basic Definitions, Standards, Methods, Potential and Gaps

Christian Lott
c.lott@hydramarinesciences.com

IATTC Workshop Contribution, June 3rd 2026



HYDRA Marine Sciences

CIAT IATTC

40 years marine biologists

20 years: fate of plastic in the environment

Focus on biodegradable materials and plastic polymers

(mainly marine: Arctic, Mediterranean, tropical SE Asia)

Field station in the MED (Italy)

Lab facilities in Germany

>150 Projects & Expeditions worldwide

HYDRA Marine Sciences

Linking

field expertise with

lab experience

HYDRA

Marine Sciences

We **combine** work

in the lab, at the desk with

working outside, 'in reality’

HYDRA Marine Sciences

We **impart** knowledge at conferences, seminars and workshops, **connect** stakeholders

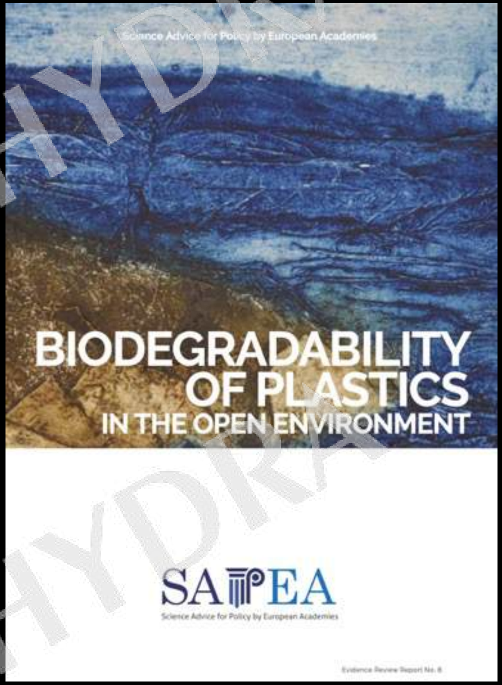
European Bioplastics Conference, Berlin


European Commission, Brussels

We deliver

- *Strategies, evaluations, test procedures*
- *Reports, scientific publications*
- *Presentations/lectures, workshops*
- *Short films, TV documentaries*
- *Network to numerous stakeholders*

https://www.hydramarinesciences.com/

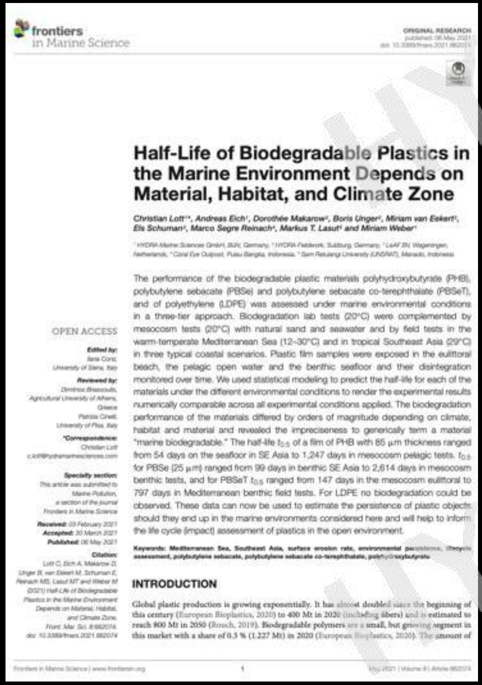

Science Advice for Policy by European Academies

BIODEGRADABILITY OF PLASTICS IN THE OPEN ENVIRONMENT

SAPEA

Science Advice for Policy by European Academies

Evidence Review Report No. 8


frontiers in Marine Science

ORIGINAL RESEARCH

Half-Life of Biodegradable Plastics in the Marine Environment Depends on Material, Habitat, and Climate Zone

Christian Lott, Andreas Eich, Dorothée Makarow, Boris Unger, Miriam van Eekert, Els Schuman, Marco Segre Reinach, Markus T. Lasut and Miriam Weber

OPEN ACCESS

INTRODUCTION


PeToPLA

A meta-study on the persistence and toxicity of PLA, and the formation of microplastics in various environments

Technical Summary Report

prepared by

HYDRA Marine Sciences

Christian Lott, Kristina Stemmer-Rau, Miriam Weber
HYDRA Marine Sciences, Bühl, Germany
info@hydramarinesciences.com

sponsored by

HOLLAND BIOPLASTICS

Corbion NatureWorks futerro

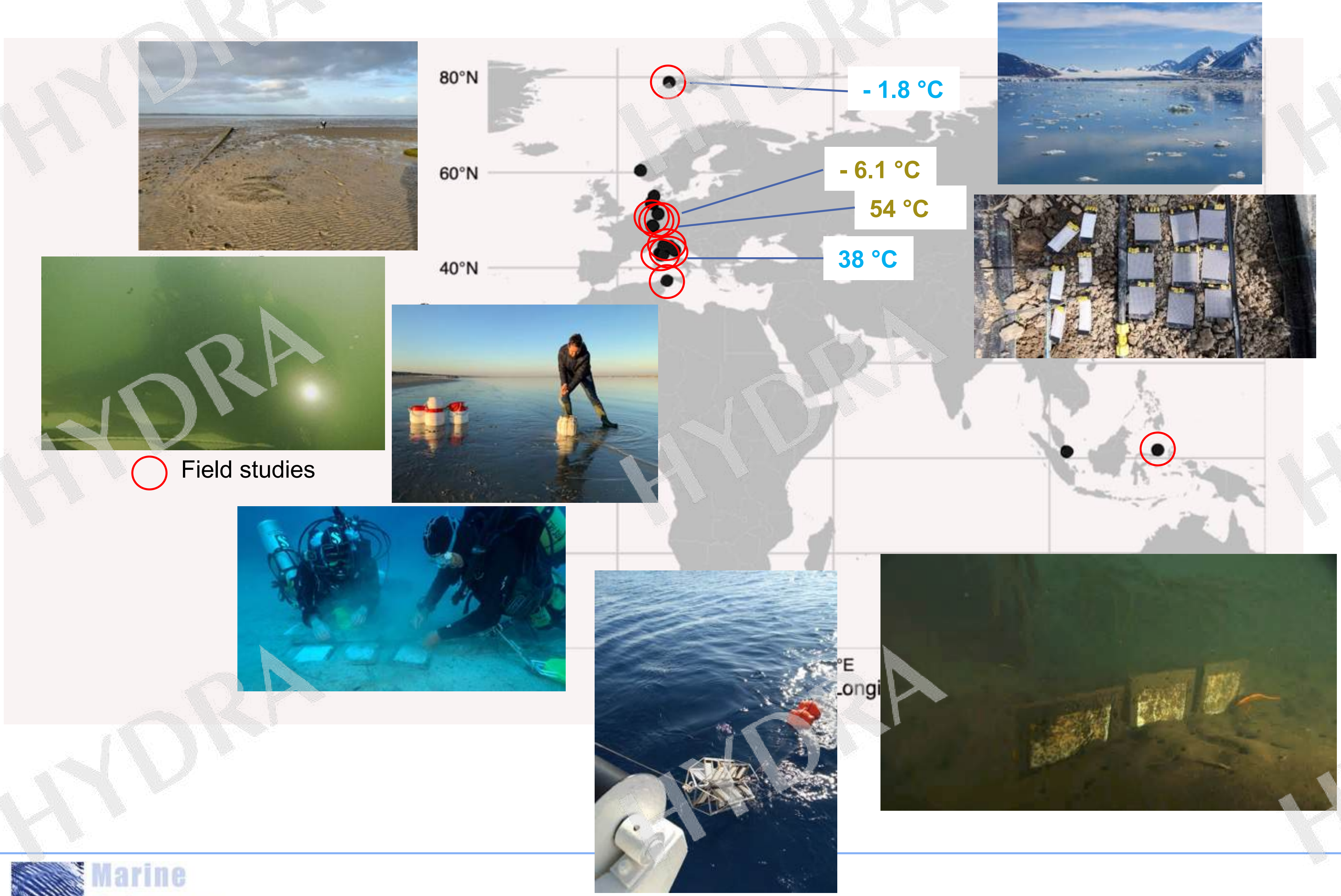
Declaration on potential conflict of interest
The sponsors had no influence on the outcome of the meta-study and did not interfere with the interpretation of the scientific evidence.

The key findings presented here reflect the scientific opinion of HYDRA Marine Sciences' authors based on the available literature and do not constitute an advocacy in favor or against certain materials.


visit of politicians

Latest Biodegradation Study: 177 single experiments

Wide geographical range: from freezing point of seawater to a hot tropical beach



Svalbard, High Arctic

Bergen, NOR

North Sea, GER

Lakes, rivers, soils, GER

Lake, ITA

Coastal Med, ITA

Deep-Sea Med, ITA

Marine beach, SIN

Marine coastal, IDN

Happy to support your transition to biodegradable FADs

- select suitable biodegradable plastic materials, where meaningful
- check claims, properties declared, esp. regarding “bioplastics”

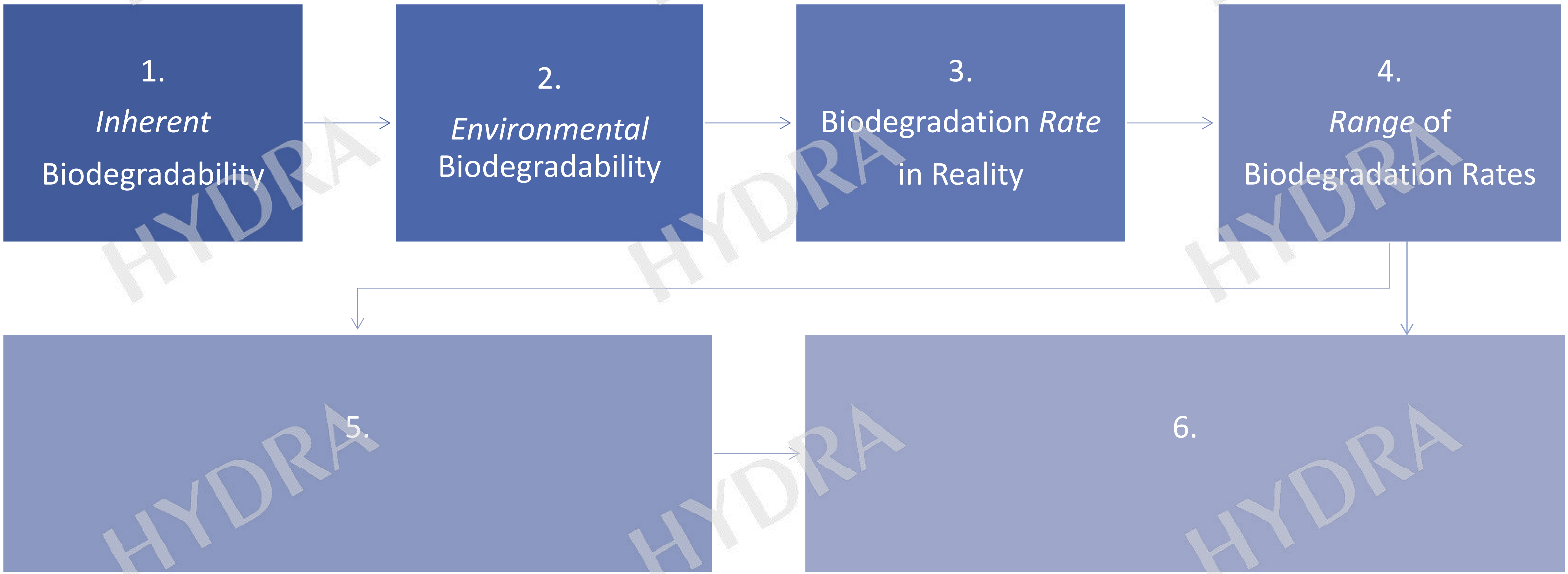
- ensure complete, safe biodegradation
    - by product evaluation
    - by standard and non-standard testing (lab, field, mesocosm)
        - biodegradability
        - biodegradation rate
        - ecotoxicity

- support certification, user evaluation, transparency
- revise a specific FAD-compatible material catalogue

Our multi-tier assessment

- Is the material biodegradable?
- How long does it take to biodegrade?
- What life-times reduce accumulation?
- What are the impacts?
- Which impacts are reversable and how long does it take?

Application of the multi-tier testing scheme:



Some definitions

What do we mean?

Biodegradation:

*Plastic biodegradation is the **microbial conversion** of its **organic constituents***

*to **carbon dioxide, new microbial biomass** and **mineral salts** in the presence of oxygen,*

*or to **carbon dioxide and/or methane, new microbial biomass** and **mineral salts** in the absence of oxygen.*

SAPEA 2020 Biodegradability of plastic in the open environment.

What do we mean?

Biodegradation is a process,
i.e. the biological action of the habitat towards a specific material

Biodegradation Rate is the amount of biodegraded material per time

What do we mean?

Biodegradability is the potential to be biodegraded (i.e. on molecular level attacked by microbial enzymes).

***Environmental* Biodegradability** is a system property. It is the accessibility of the material to microbial action in the receiving environment.

Different classes of biodegradable polyester provide a toolset for material development

e.g. Polybutylene Succinate: PBS; similar: PBAT, PBSeT, etc.;
PHAs, PCL, PLA,

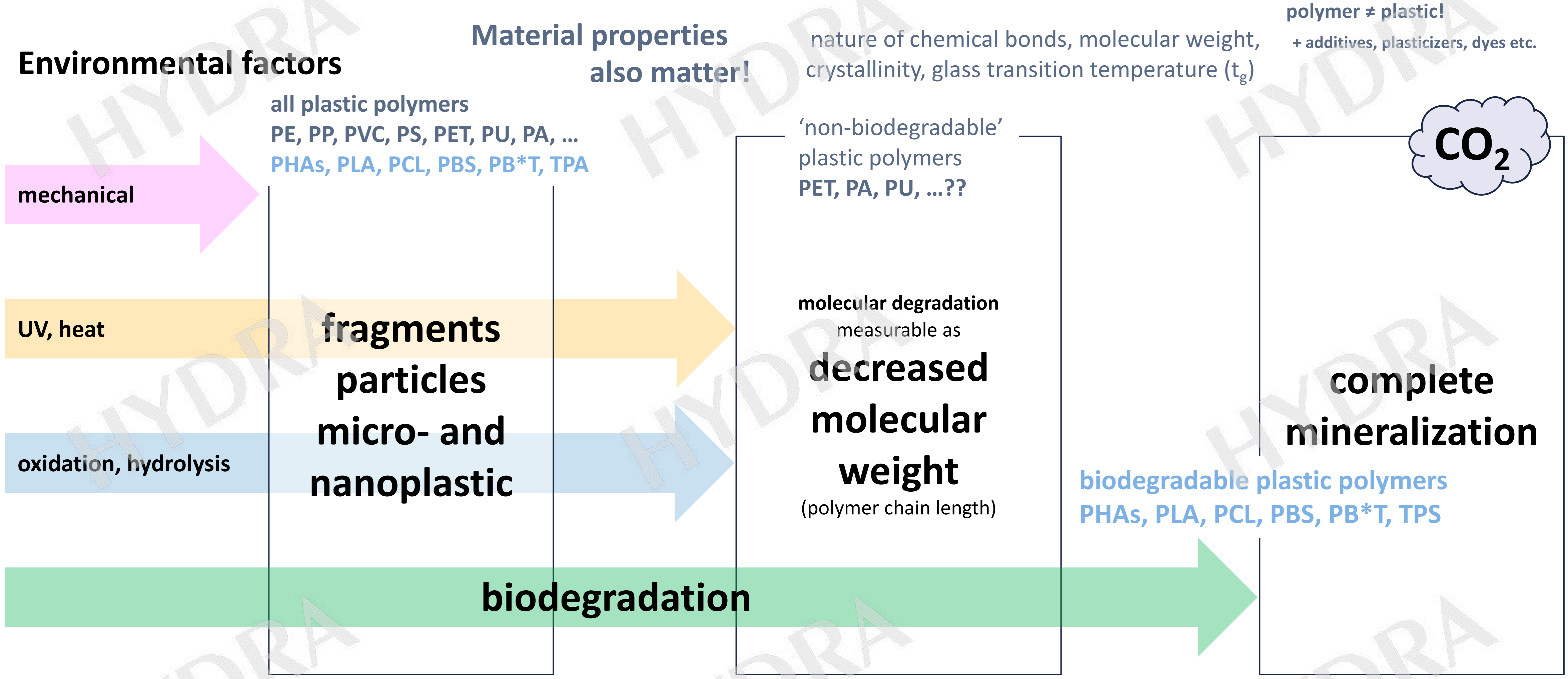
Polymers ≠ Plastics

Plastics:
Base polymers usually blended and functionalized with additives (UV protection, colorants, fillers)

Biodegradable polyesters

- Contain hydrolysable ester bonds
- Break down via biological processes (microbes can feed on them)
- Fundamentally different from conventional plastics such as PE, PP, PS, PVC, PA, PU

Environmental degradation of plastic polymers



Marine behaviour of biodegradable polyesters

Technical biodegradable polymers are heavier than seawater → sink to seafloor

Higher interaction with seabed microbes (→ higher biodegradation activity)

Degradation depends on environment
(physical: UV, heat, mechanical stress),
chemical (oxidation, hydrolysis), biological (abundance and activity of microbes)

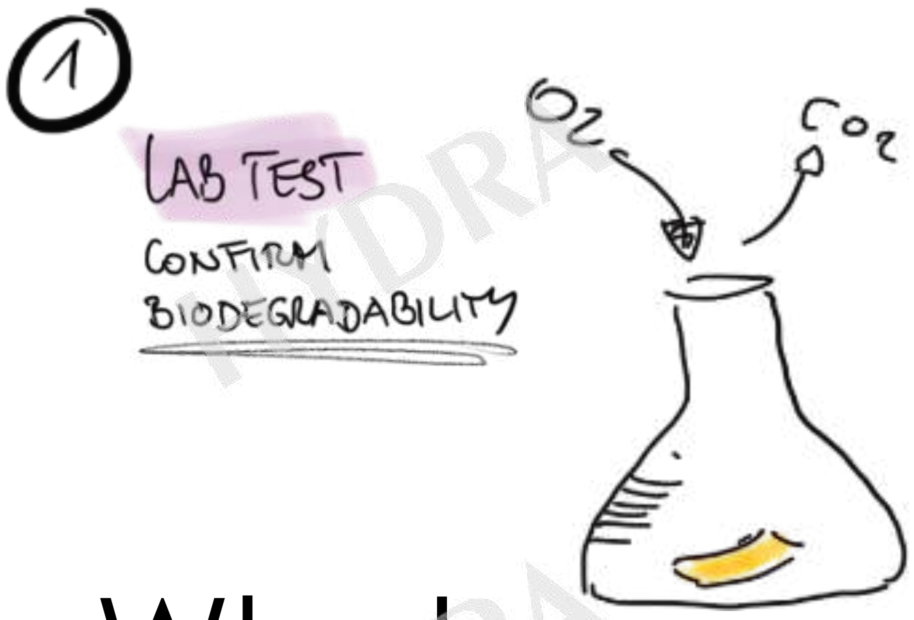
(bio-)degradation mostly a surface process:
→ Thicker materials degrade slower, exception PLA

Limits: dry conditions, very cold conditions

1. Proof of Biodegradability in a closed-system

Measuring end products CO_2
under controlled conditions

What do we apply?



Respirometry:

Test material

+

natural seawater & sediment containing microorganisms

→ Measure the natural respiration as the microbes feed on the test material

measure CO_2 evolution in a closed system:

proving biodegradability as such in an optimized system

e.g. seawater with sediment
under warm conditions (25 °C)
(ISO 19679)

Marine Sciences
HYDRA

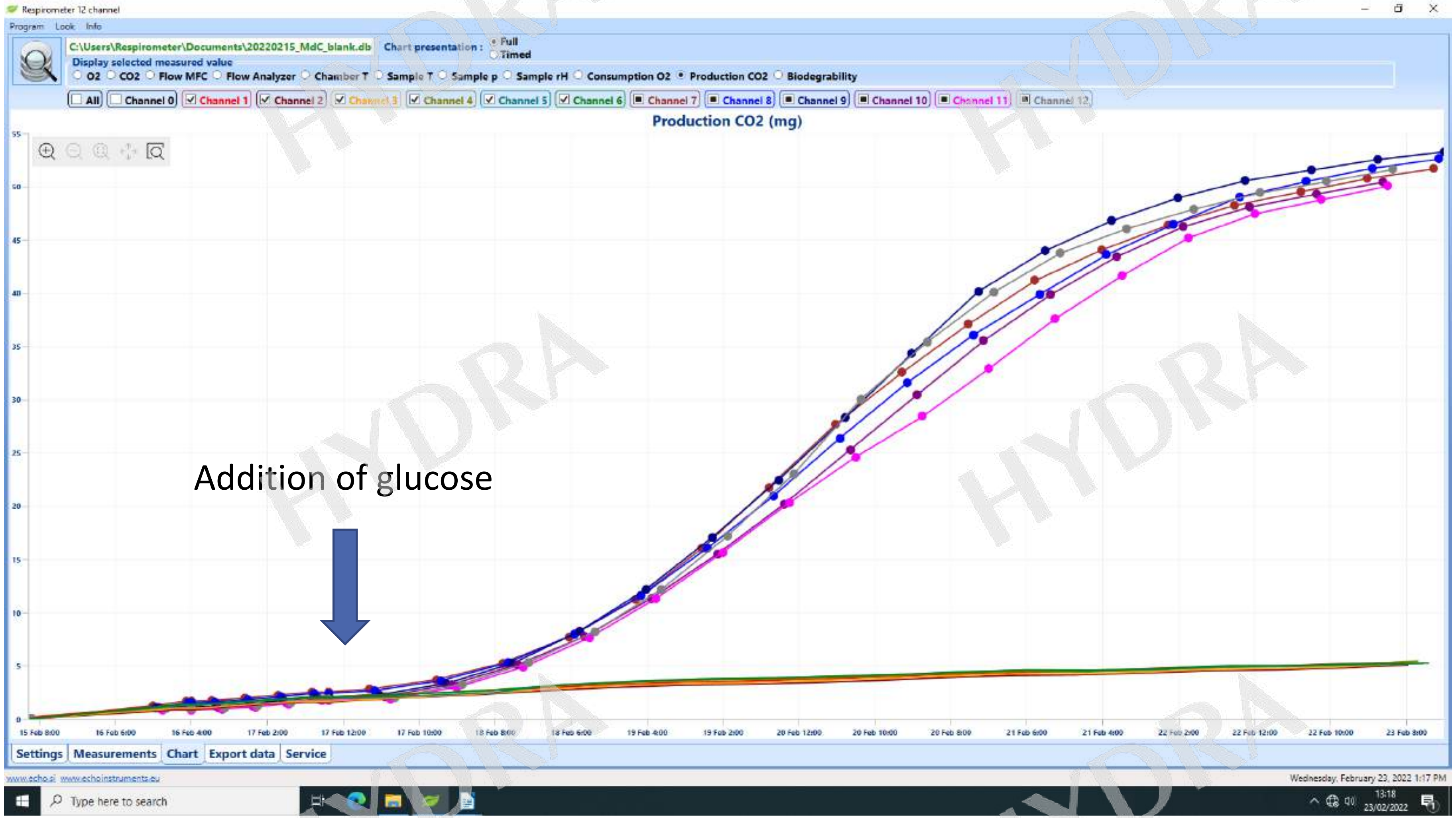
Closed system
for
capturing CO_2:

following
polymer **C**arbon

into

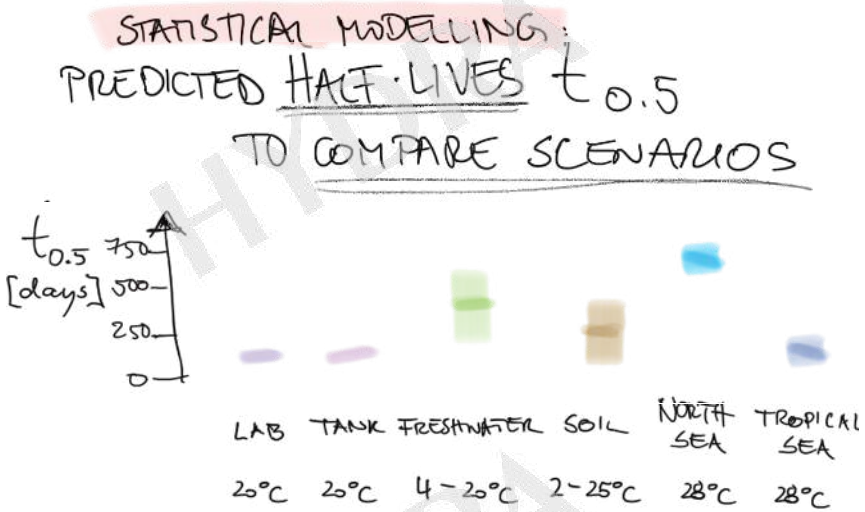
$\mathbf{C}O_2$

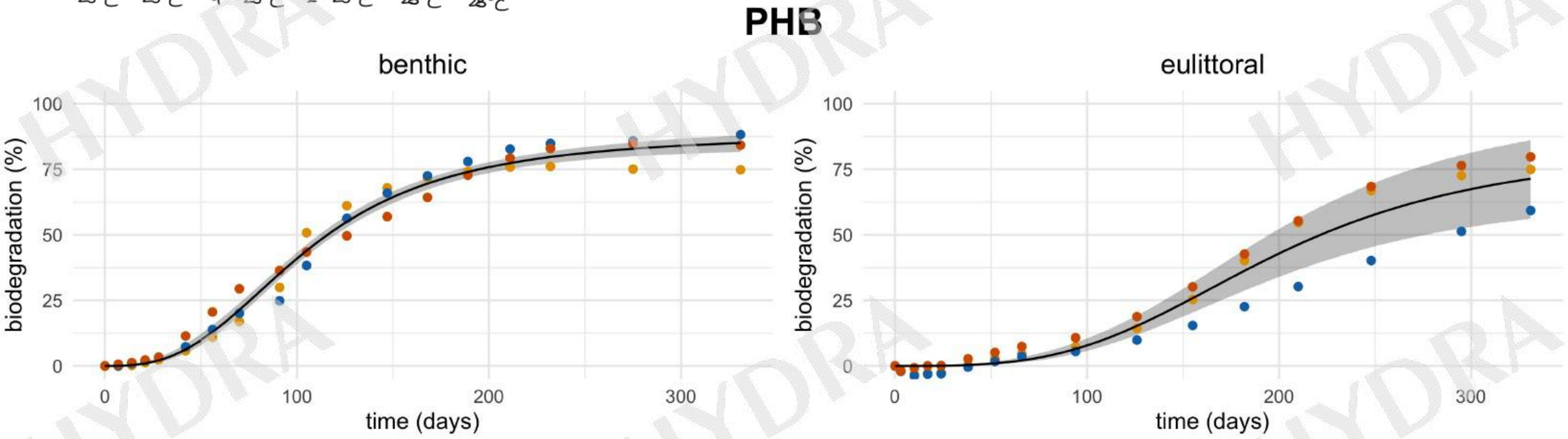
Example: CO2 evolution from the ready degradable substance glucose



Statistical data treatment

e.g. kinetics, confidence intervals, half-life modelling (see later)





20 °C

Lott et al., 2020, PLOSone

①

What do we get?

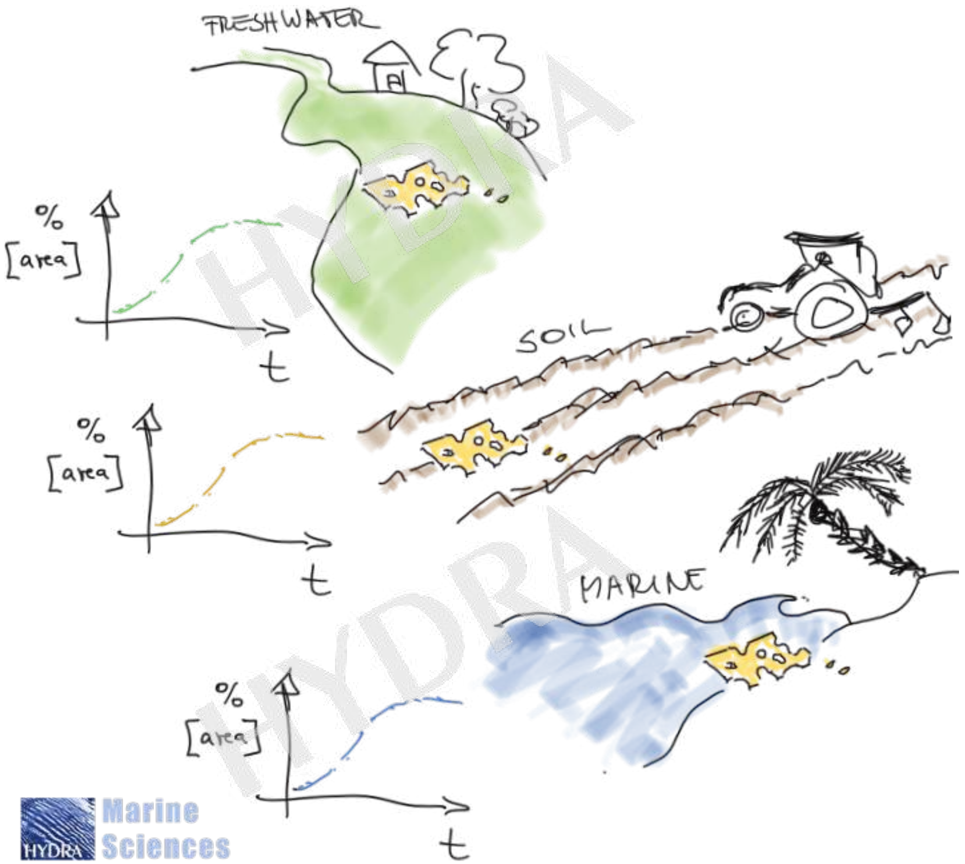
- **Proof of biodegradability**
- **Knowledge on biodegradation kinetics**
- **Extent of biodegradation per time**
- **Standards: pass/fail criteria,**
  e.g. 90 % biodegradation in x days
- Attention: microbes need (some of the) acquired carbon for growth, e.g. for biomass production (~10 % biomass)

2. Assessment of biodegradation *rate* in reality

Measuring disintegration in one or several field tests

② FIELD TESTS

CONFIRM BIODEGRADATION & RATES UNDER NATURAL CONDITIONS

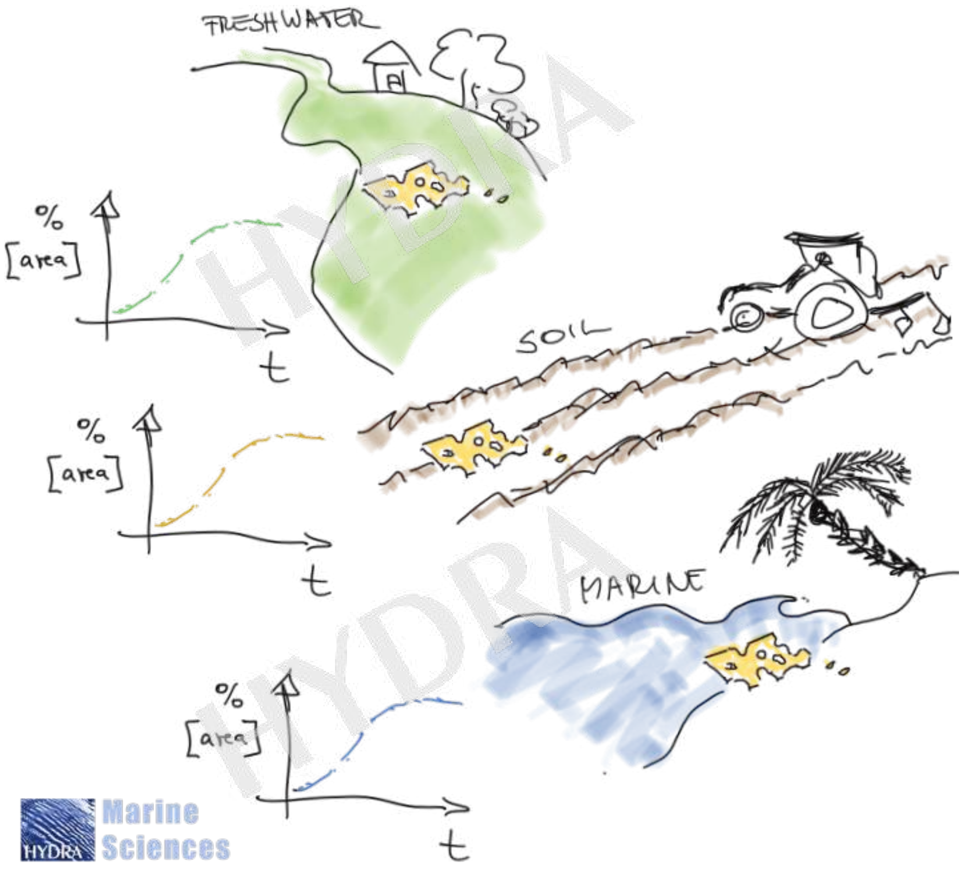


Challenge

How to measure biodegradation in an open system where we cannot capture CO_2?

②

FIELD TESTS
CONFIRM BIODEGRADATION & RATES UNDER NATURAL CONDITIONS



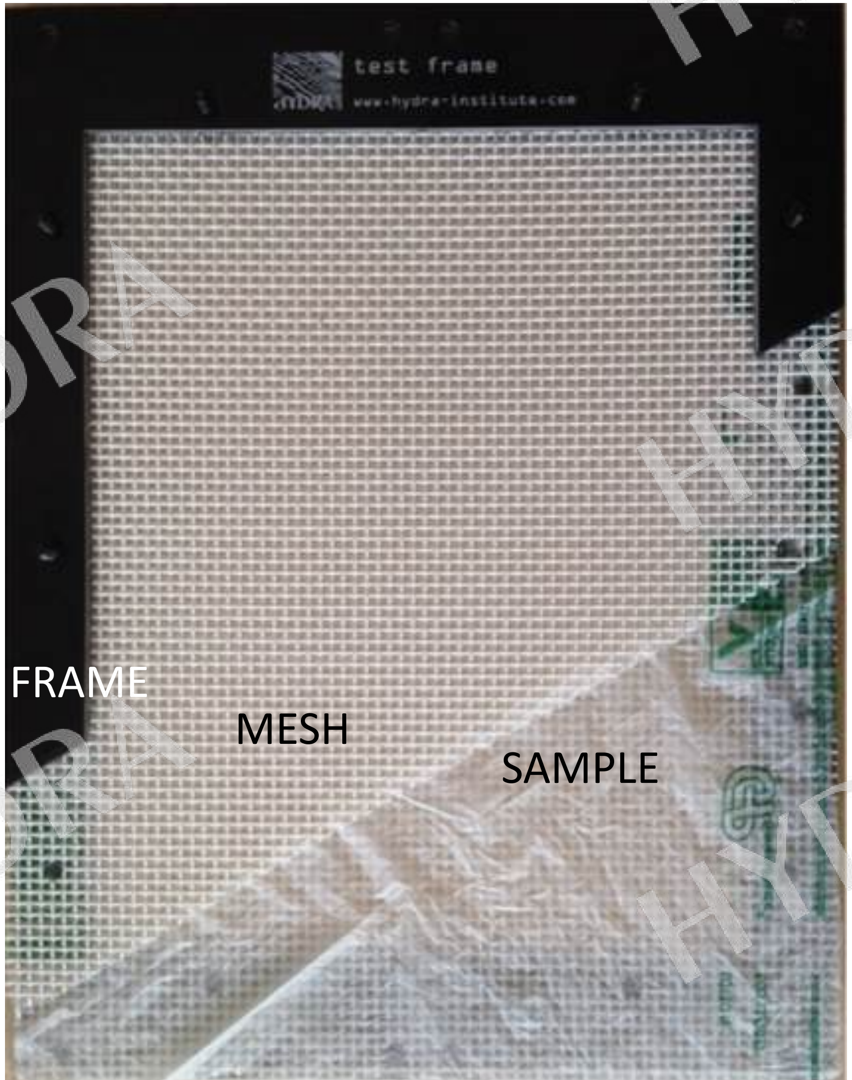
→ Proxy: disintegration, mass loss

with precaution against physical destruction and fragment loss
AND only valid if biodegradability has been proven in lab tests

Disintegration/mass loss as a proxy for biodegradation in an open system

with precaution against physical destruction and fragment loss

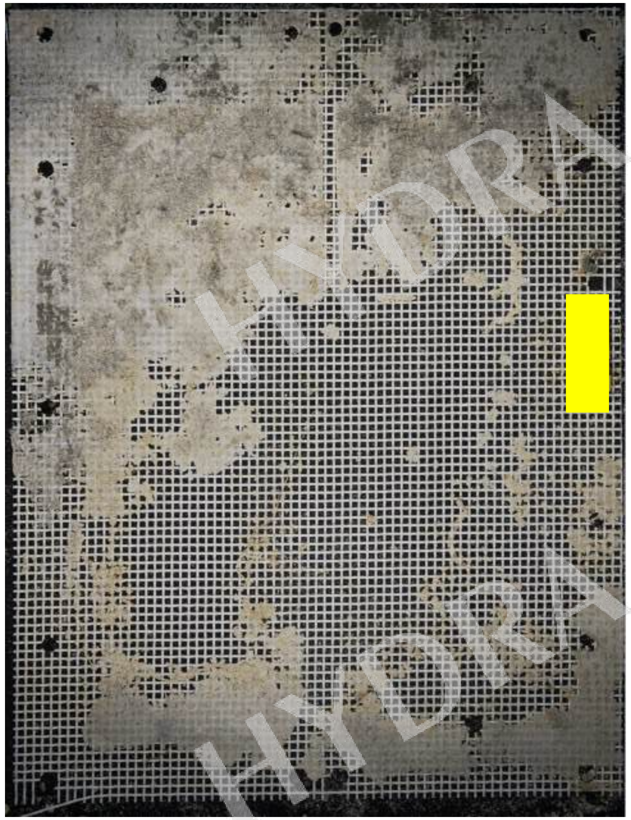
Example of a cut frame to see the sample in between the frame & protective mesh:



Lott et al., 2020, PLOSone

Precaution against physical destruction and fragment loss

for plastic film: HYDRA® Test Frame



... and also e.g. for straws

for 3D objects: HYDRA® Test Cage

After exposure removing the frame and mesh, we detect material loss (as area loss)

Closed frame with sample

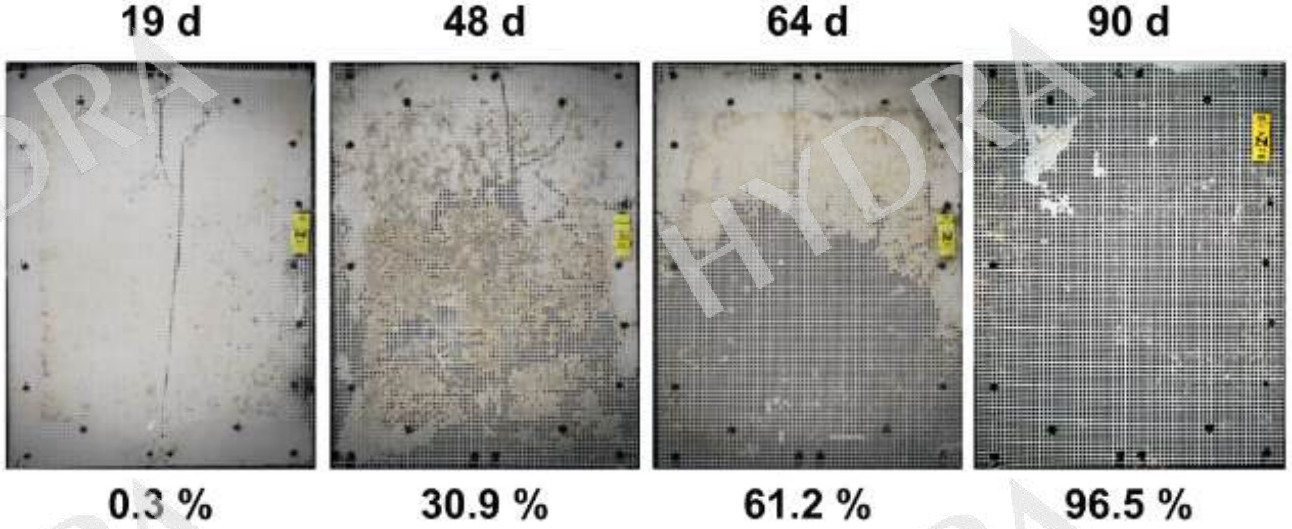
Frame and mesh removed

to document the sample

Material loss is quantifiable as disintegration and is our proxy for biodegradation*.

* given biodegradability is proven

Time series



Lott et al., 2020, Front. Mar. Sci

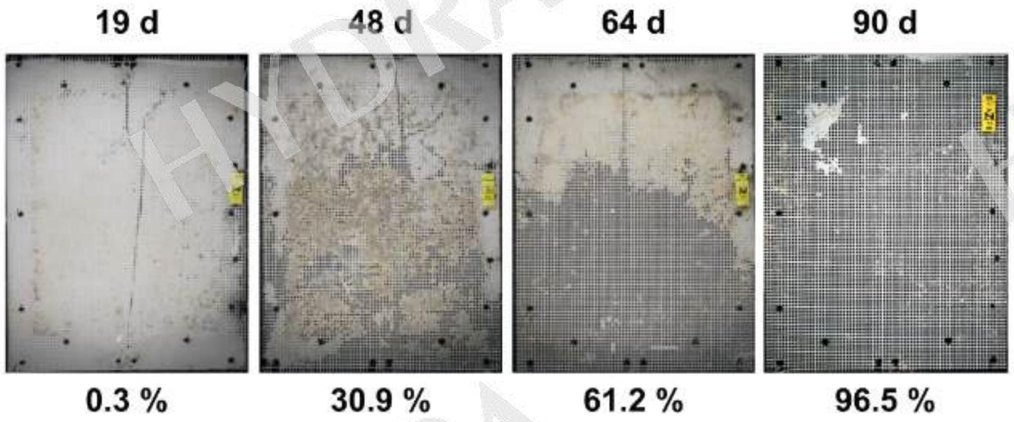
partner: BASF We create chemistry

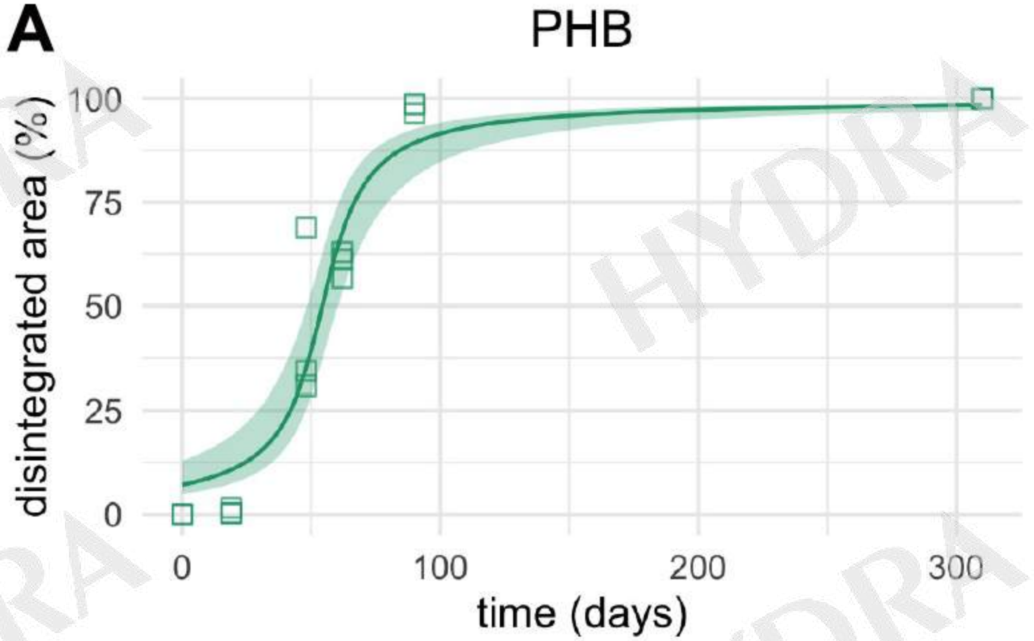
add. funding: OPEN BIO

Material loss is quantifiable as disintegration and is our proxy for biodegradation*.

* given biodegradability is proven

➔ Data are then modelled to assess half-lives.



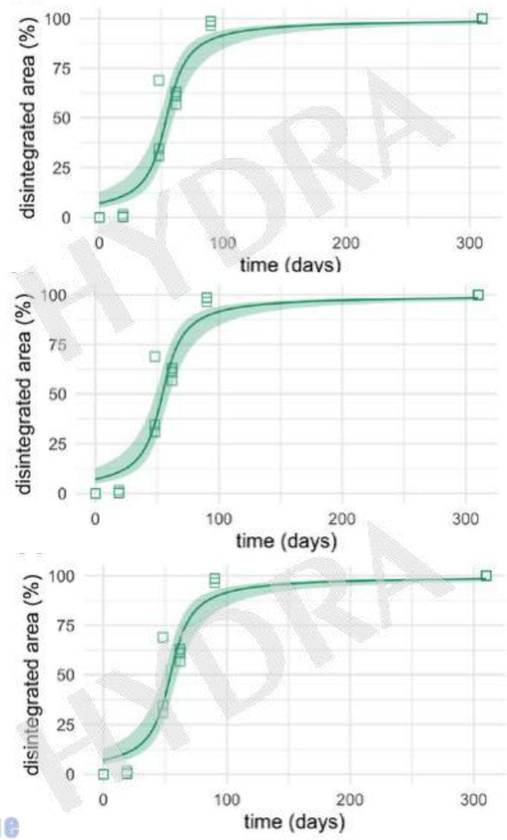


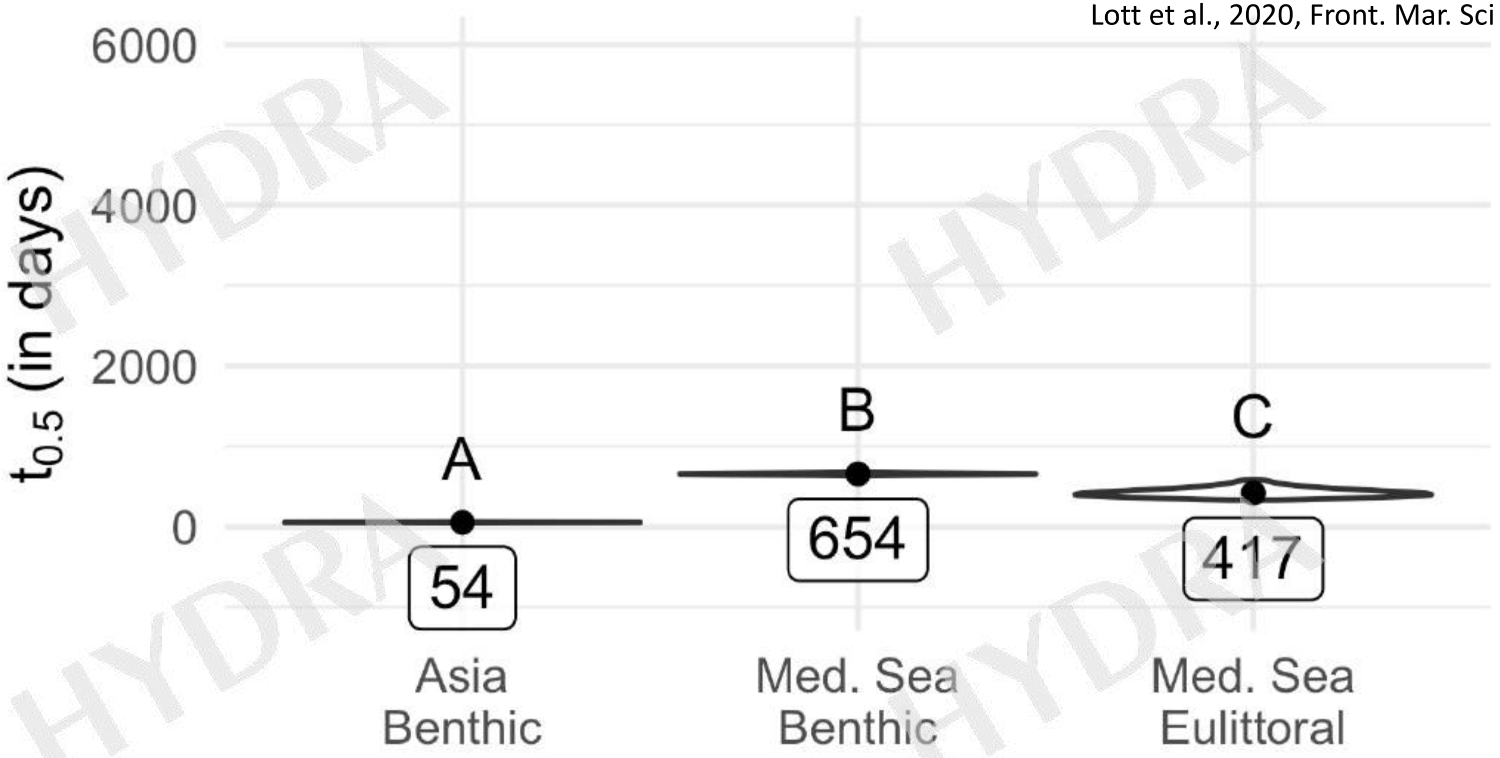
Lott et al., 2020, Front. Mar. Sci

Material loss is quantifiable as disintegration and is our proxy for biodegradation*.

* given biodegradability is proven

➔ Data are then modelled to assess half-lives.





note: exemplary graphs only!

numerical *comparison* possible

3. Assessing the range of biodegradation rates

Measuring disintegration in tank tests
at selected relevant conditions

Marine Sciences

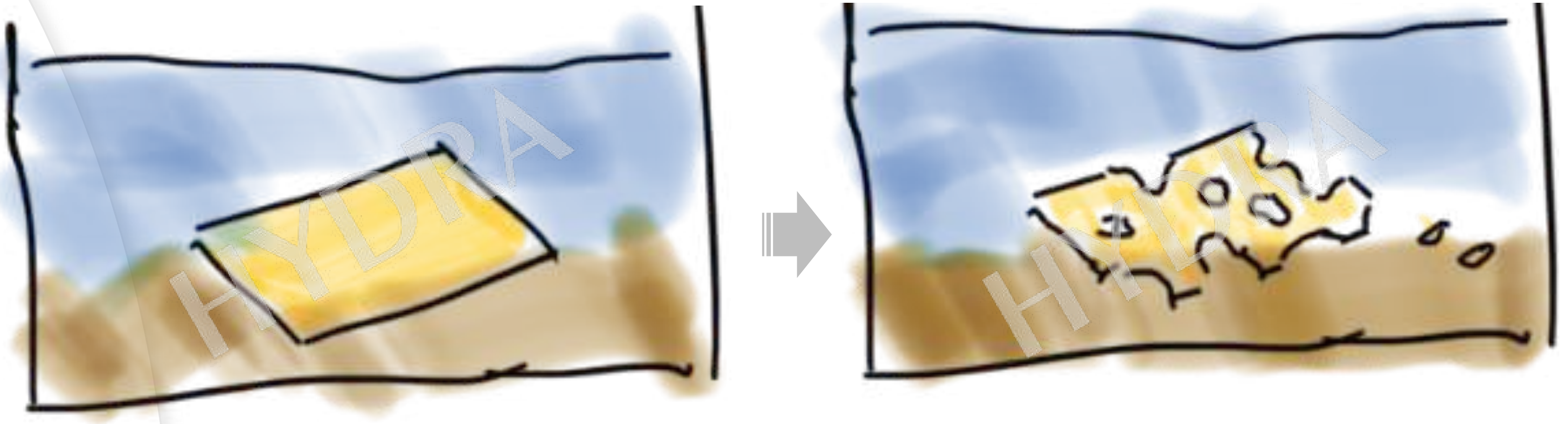
Tank Tests
Open system for simulation:

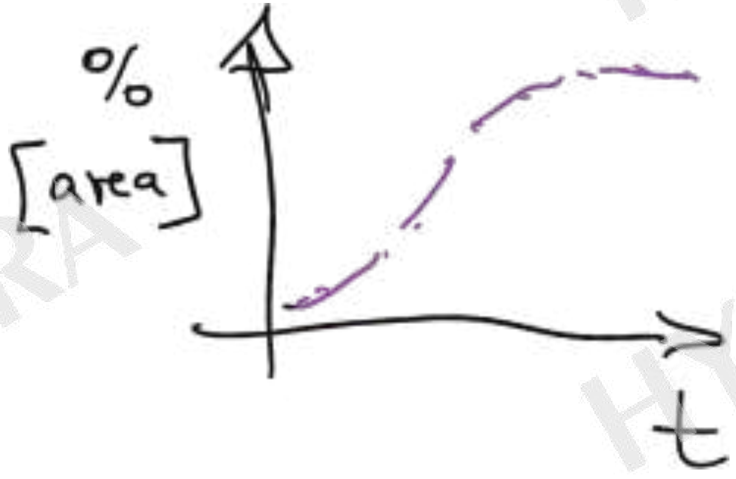
Aim is
assessing the biodegradation rates
under different
relevant conditions!

e.g. at different temperatures,
nutrient concentrations etc.

③ TANK TESTS
SCREEN FOR
BIODEGRADATION RATES

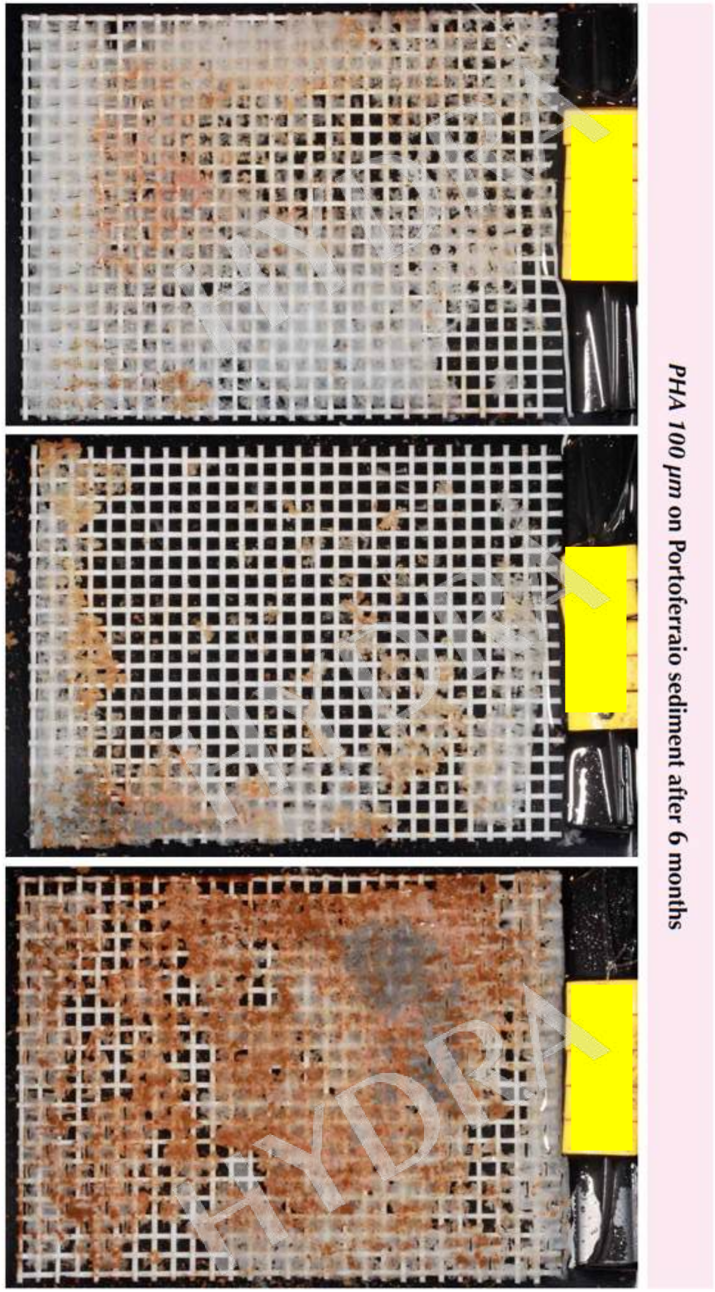
Manipulative experiments





Manipulative experiments e.g. with **different beach sands**

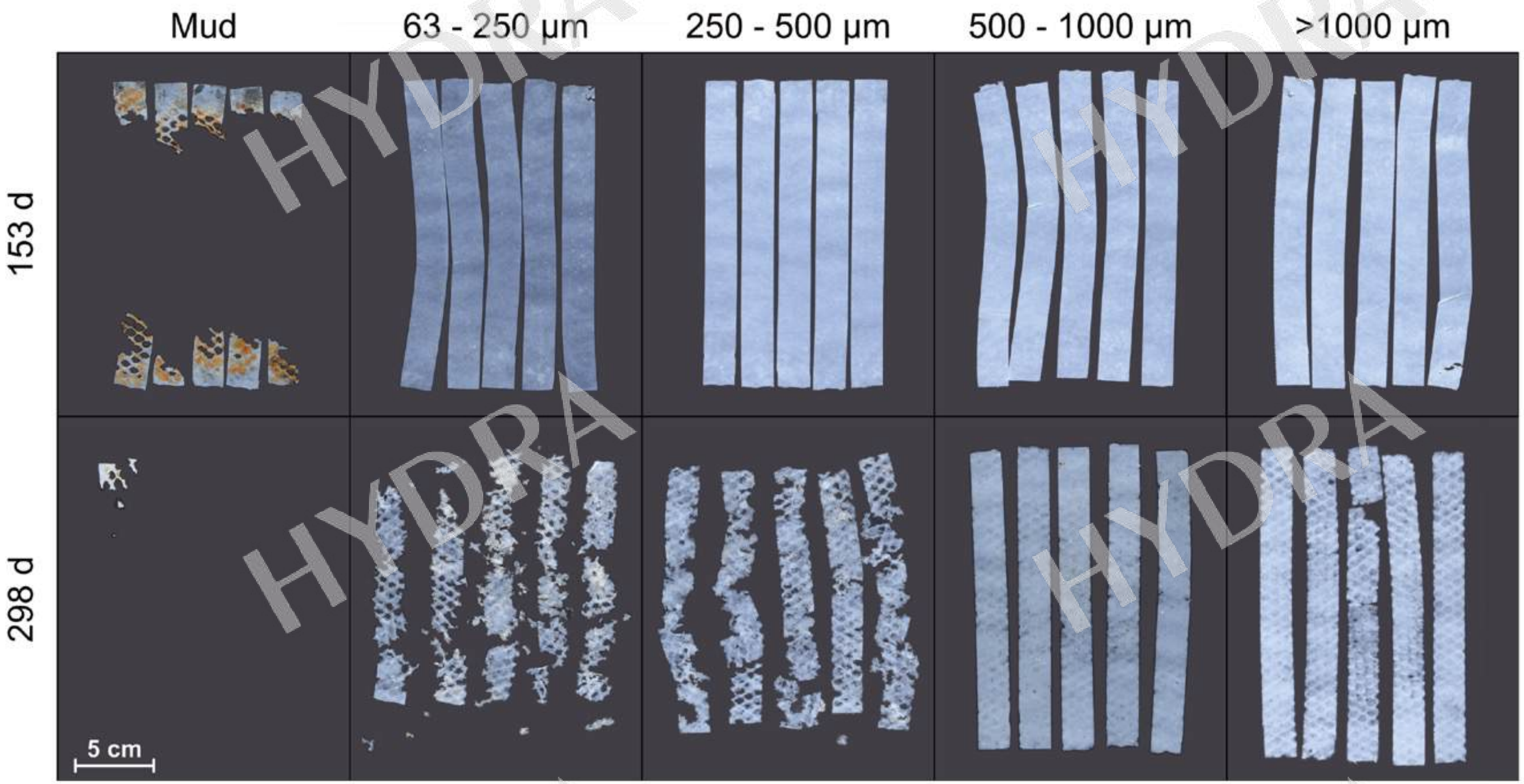
partner: NOVAMONT



EICH *et al., 2021,* PeerJ

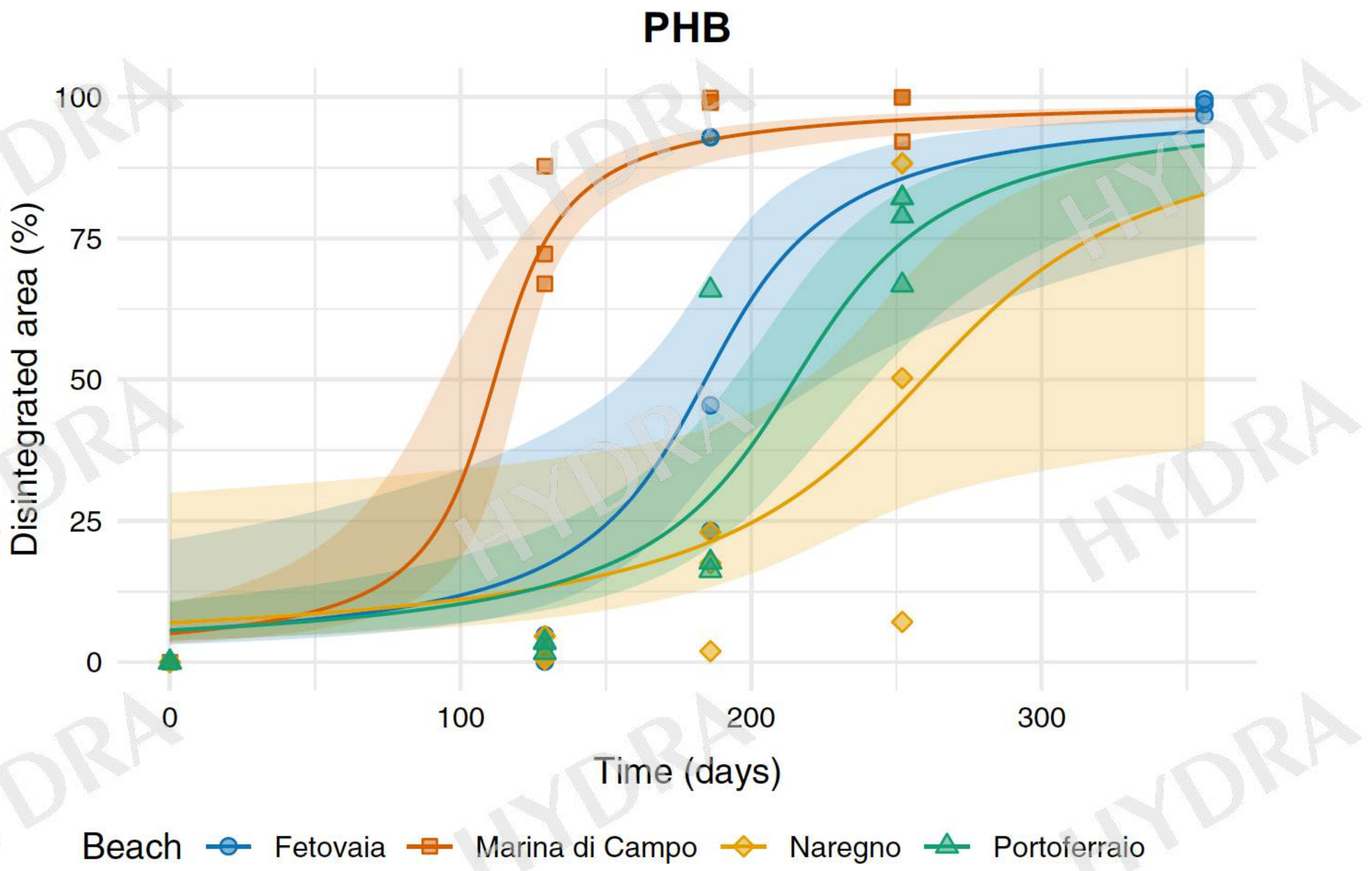
HYDRA Marine Sciences

Manipulative experiments e.g. with **different grain sizes**



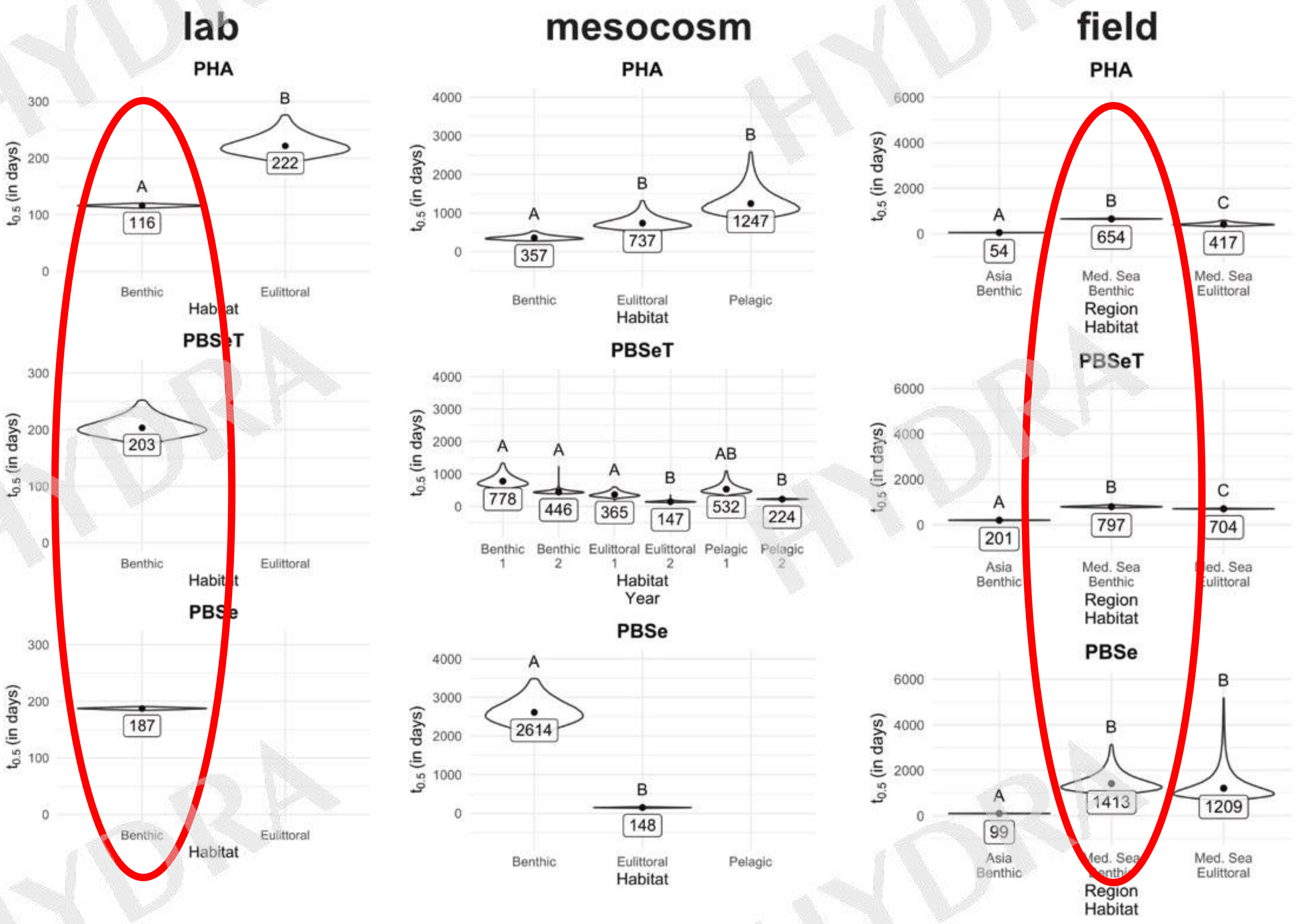
EICH *et al., 2021,* PeerJ

partner: NOVAMONT



EICH *et al., 2021,* PeerJ

Meanwhile: Predictive model of specific half-lives for >100 scenarios



Lott *et al. (2021),* Front. Mar. Sci. 8:662074

partners:

BASF We create chemistry

NOVAMONT

OPEN BIO

AQUEIS.ORG ... promoting aquatic sciences

CORALEYE indonesianreefresearchoutpost

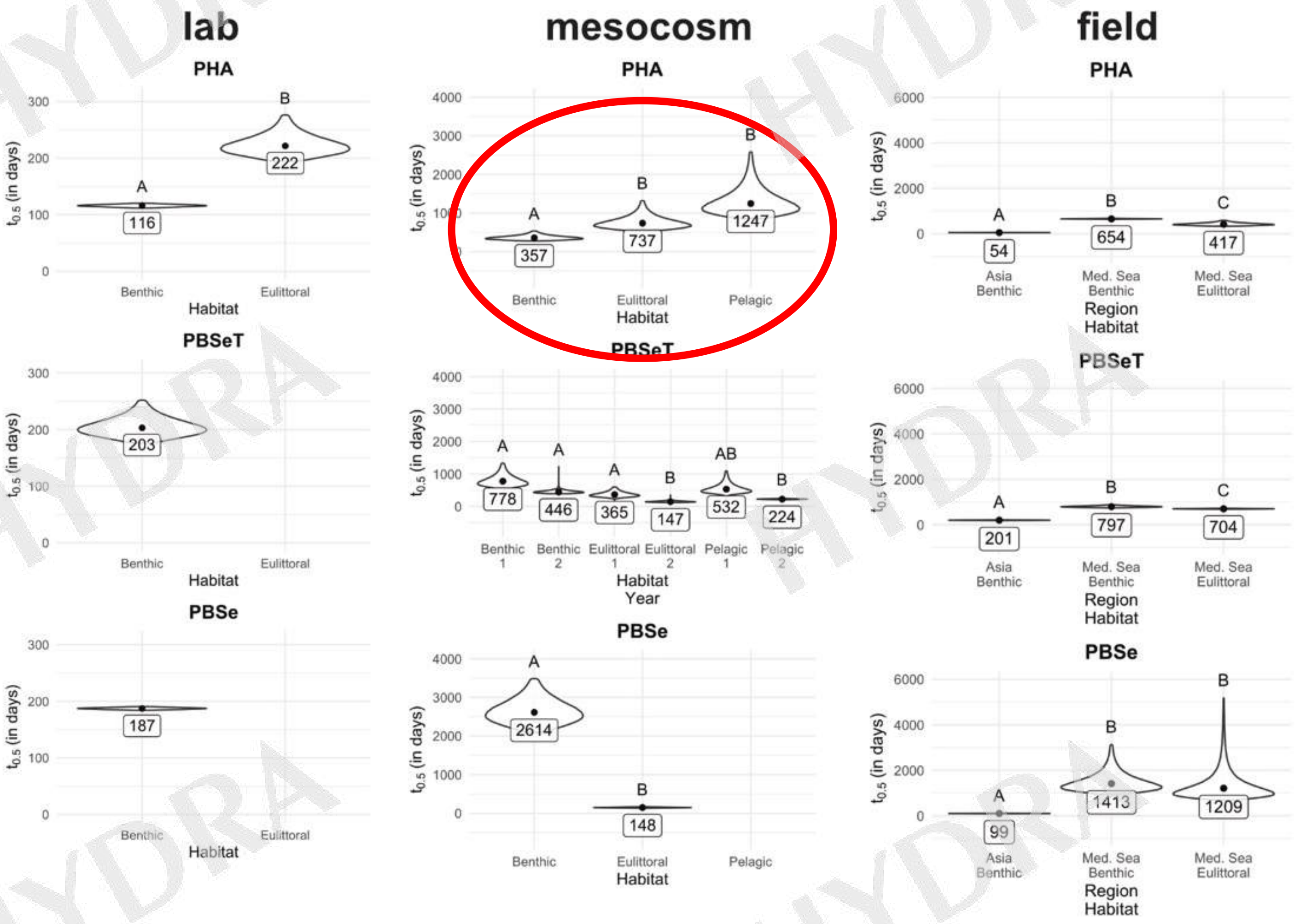
Marine Sciences HYDRA

and many others

Material catalogue for the selection of suitable polymers

Meanwhile:

Predictive model of specific half-lives for >100 scenarios



partners: BASF We create chemistry, NOVAMONT, OPEN BIO, AQUEIS.ORG ... promoting aquatic sciences, CORALEYE indonesianreefresearchoutpost, HYDRA Marine Sciences

and others

Lott *et al. (2021),* Front. Mar. Sci. 8:662074

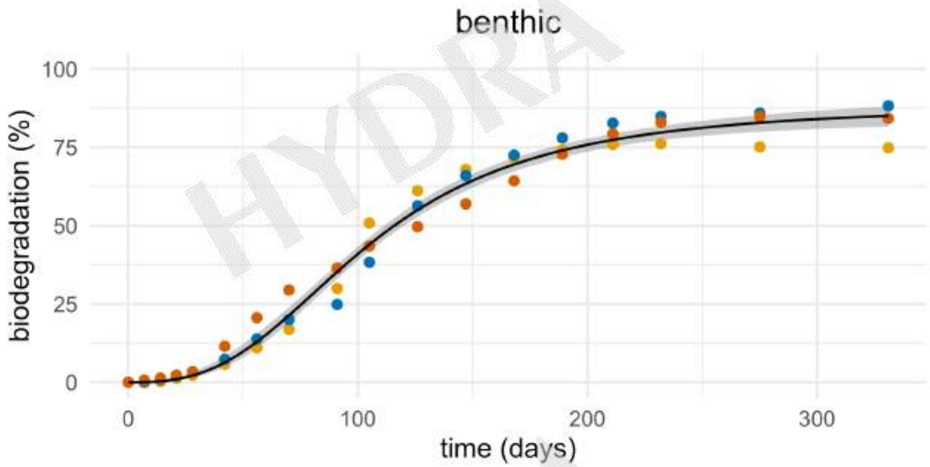
Example PHB film, 85 µm thick

Proof of biodegradability

Laboratory test

ISO 19679

21°C, dark, static

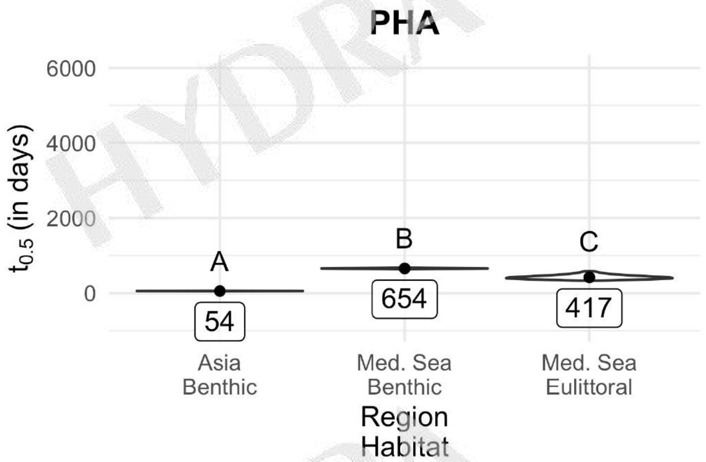


modelled half-life

Field test

ISO 22766

14-25°C (Med); 28°C (Asia), day/night, flow, low nutrients



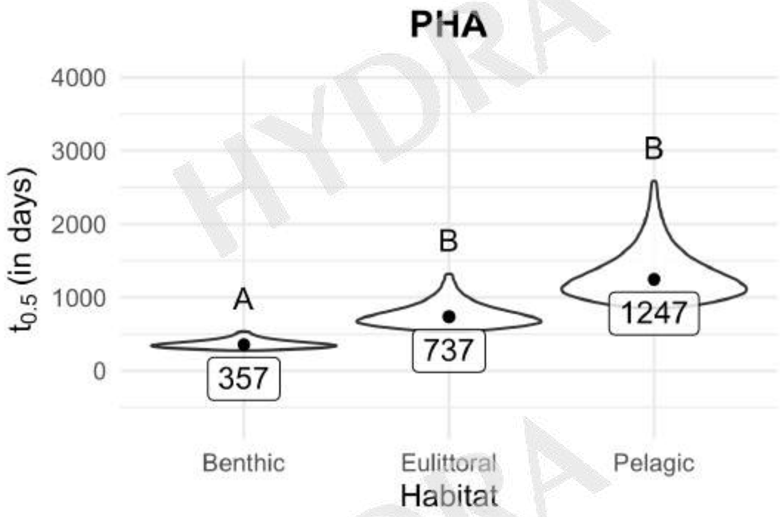
modelled half-life

Tank test

Adapted after ASTM D7473

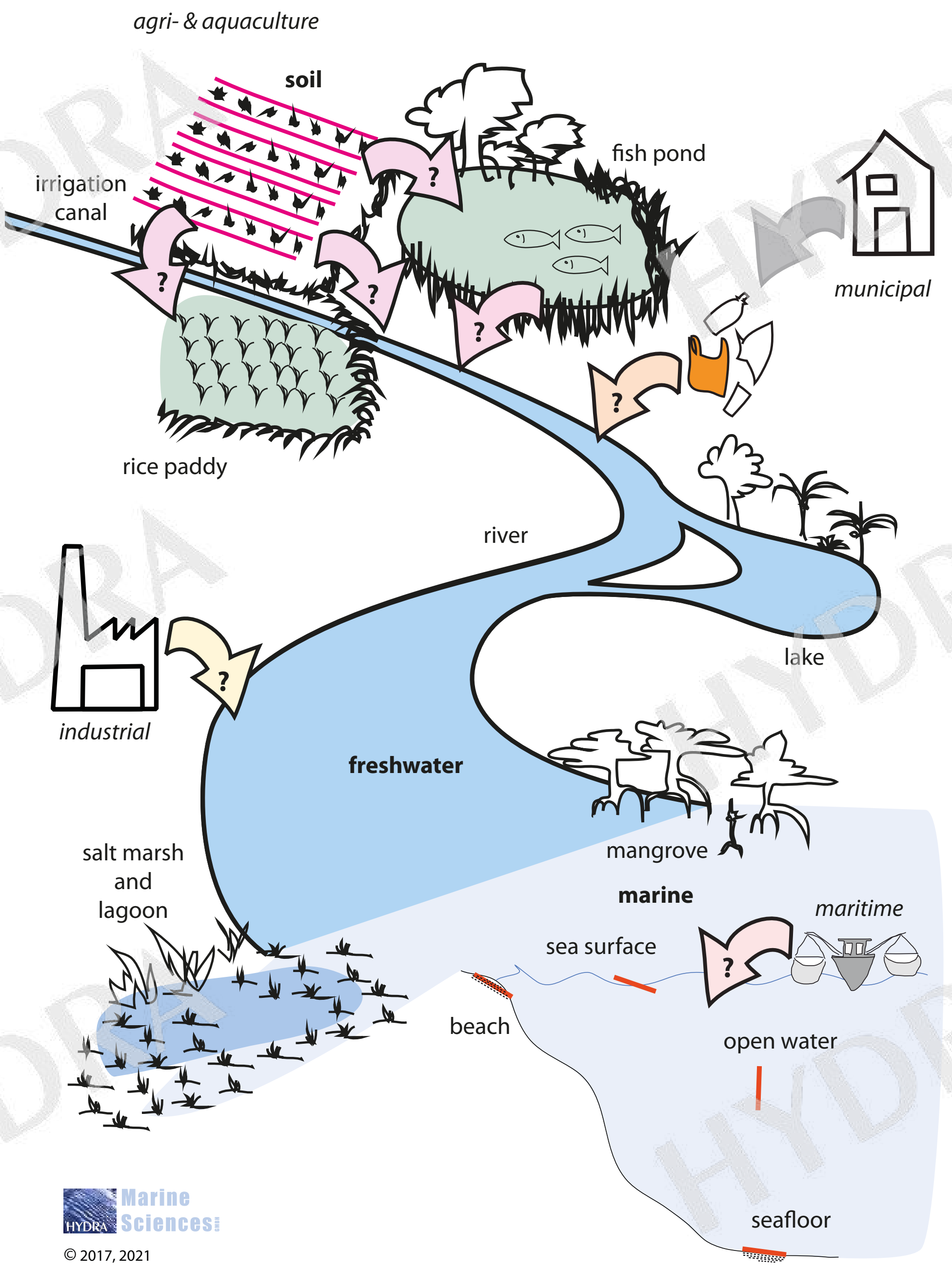
21°C, 12h light/dark, flow

elevated nutrients



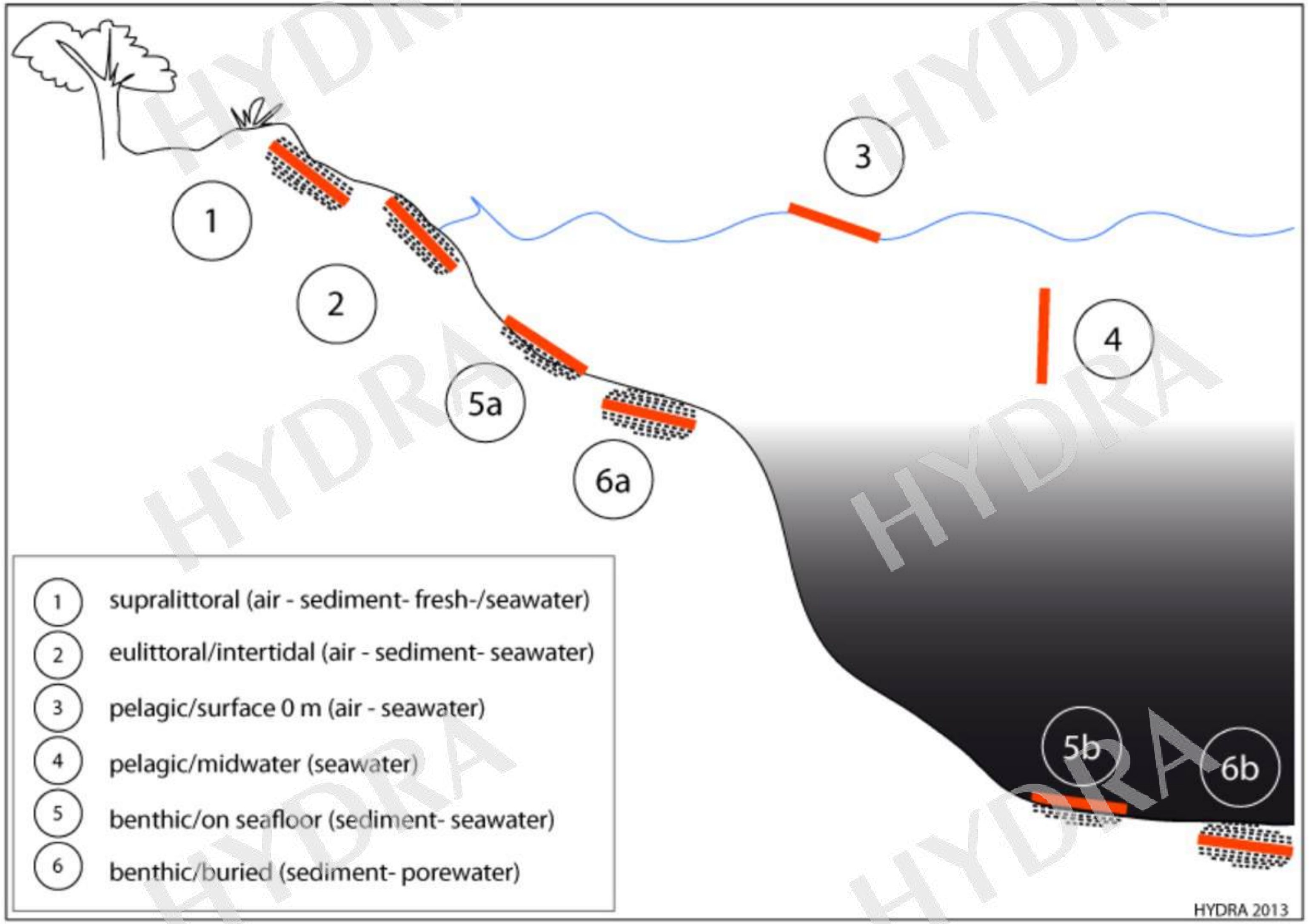
Data for Life Cycle Assessment

How to select the relevant conditions & tests:



Analyse the Materials

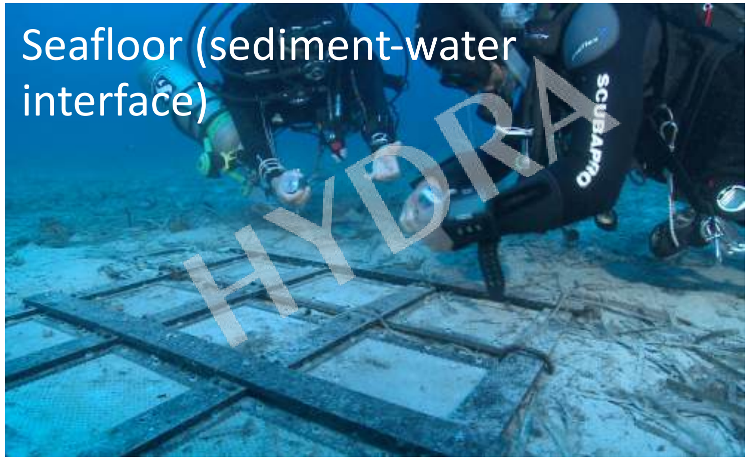
Tests: Habitats



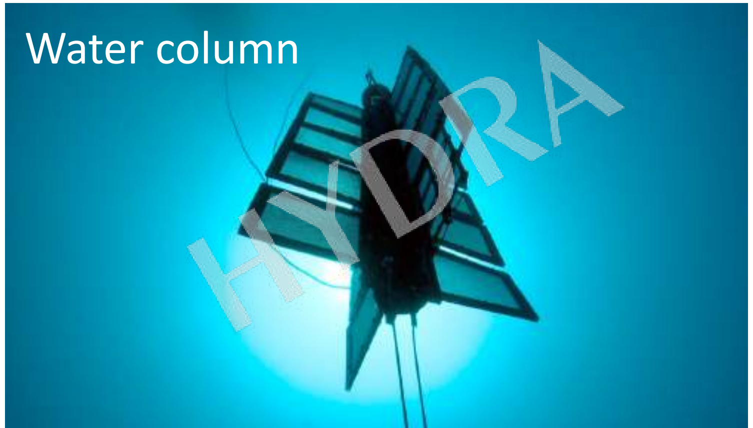
Simulation of the

2

5a



4



See Lott et al., 2020 and 2021

Marine Sciences

Select the relevant conditions & tests:

Application

- Select **application**: *FAD tropical East Pacific Ocean*

Habitat

- Estimate (or measure) the **habitat** the product will end up: *marine tropical water*

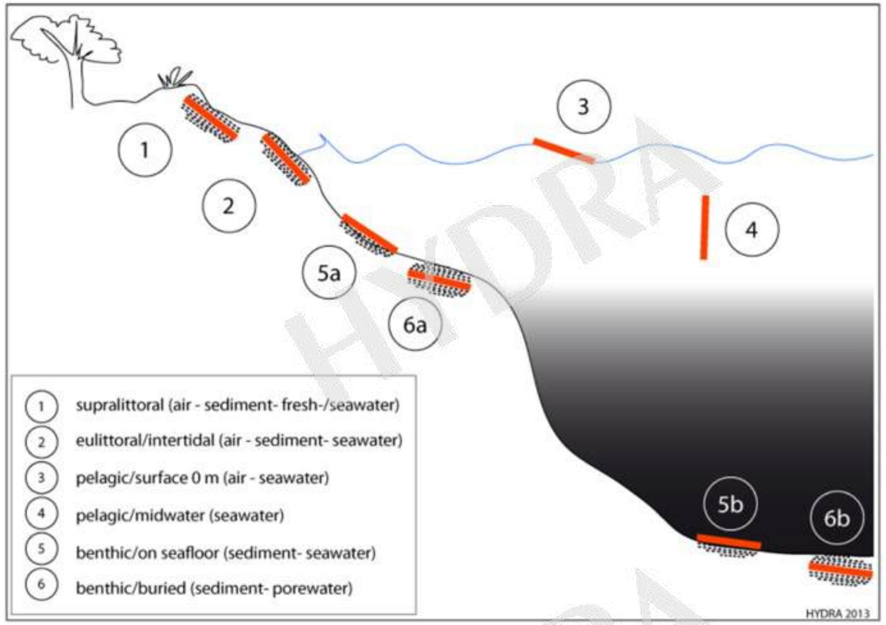
Conditions

- Describe habitat & environmental **conditions**: *e.g. open-ocean, pelagic water column, warm tropical sea temperatures, low nutrient concentrations, …*

Organisms/ Functions

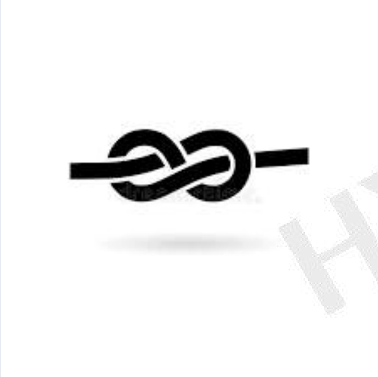
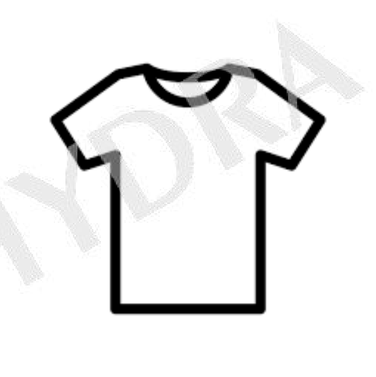
Method

- Choose suitable **method** reflecting best the scenario(s): *check available **standard test methods*** and/or adapt accordingly*



*SAPEA 2020 Biodegradability of plastic in the open environment.

Tests: Form

pellet	fibre	fabric	product
			

Additionally: Freshwater & estuarine environments

Oxygen-free habitats

'anoxic' environment (e.g. mangrove mud)

Deep-Sea tests

Adapt for e.g. products (3D objects)

HYDRA Marine Sciences

Application of the multi-tier testing scheme:

1. Inherent Biodegradability ✓

2. Environmental Biodegradability ✓

3. Biodegradation Rate in Reality ✓

4. Range of biodegradation Rates ✓

5. Model ‚no-accumulation scenario'

6. Ecotoxicity & impact on ecosystems of the biodegradation process

Ecotoxicity & impact on ecosystems by the biodegradation process = Assessment of **effects & recovery**

e.g. ecotox tests on specific organisms and settings

Evaluation

PEF, LC(I)A, ERA,
Risk & Benefit Analysis, etc.

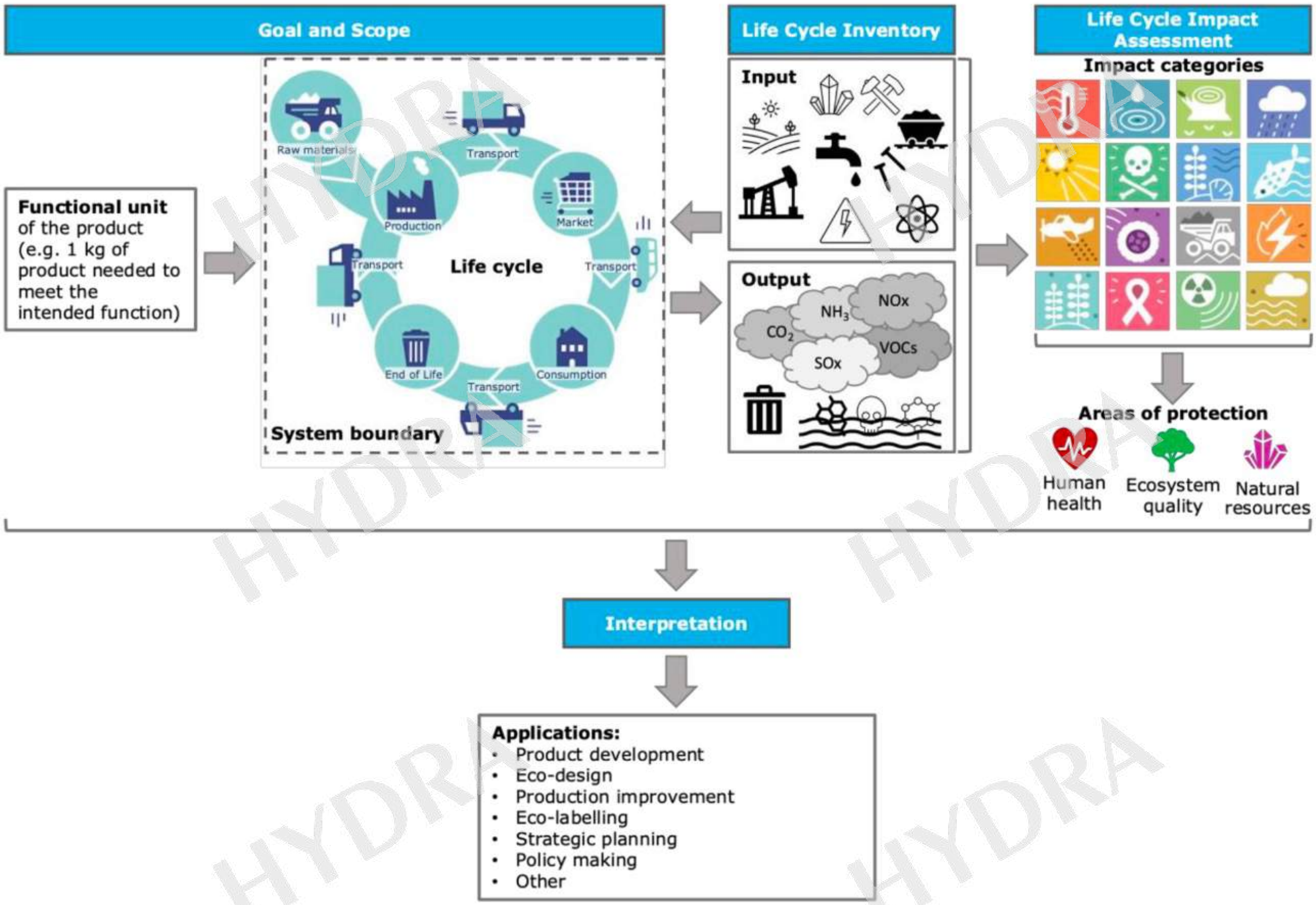


Figure 2. Generic workflow and applications of an LCA. The steps are detailed in Figure 3

https://eplca.jrc.ec.europa.eu/lifecycleassessment.html

Select the relevant conditions & tests:

Application
- Select **application**:

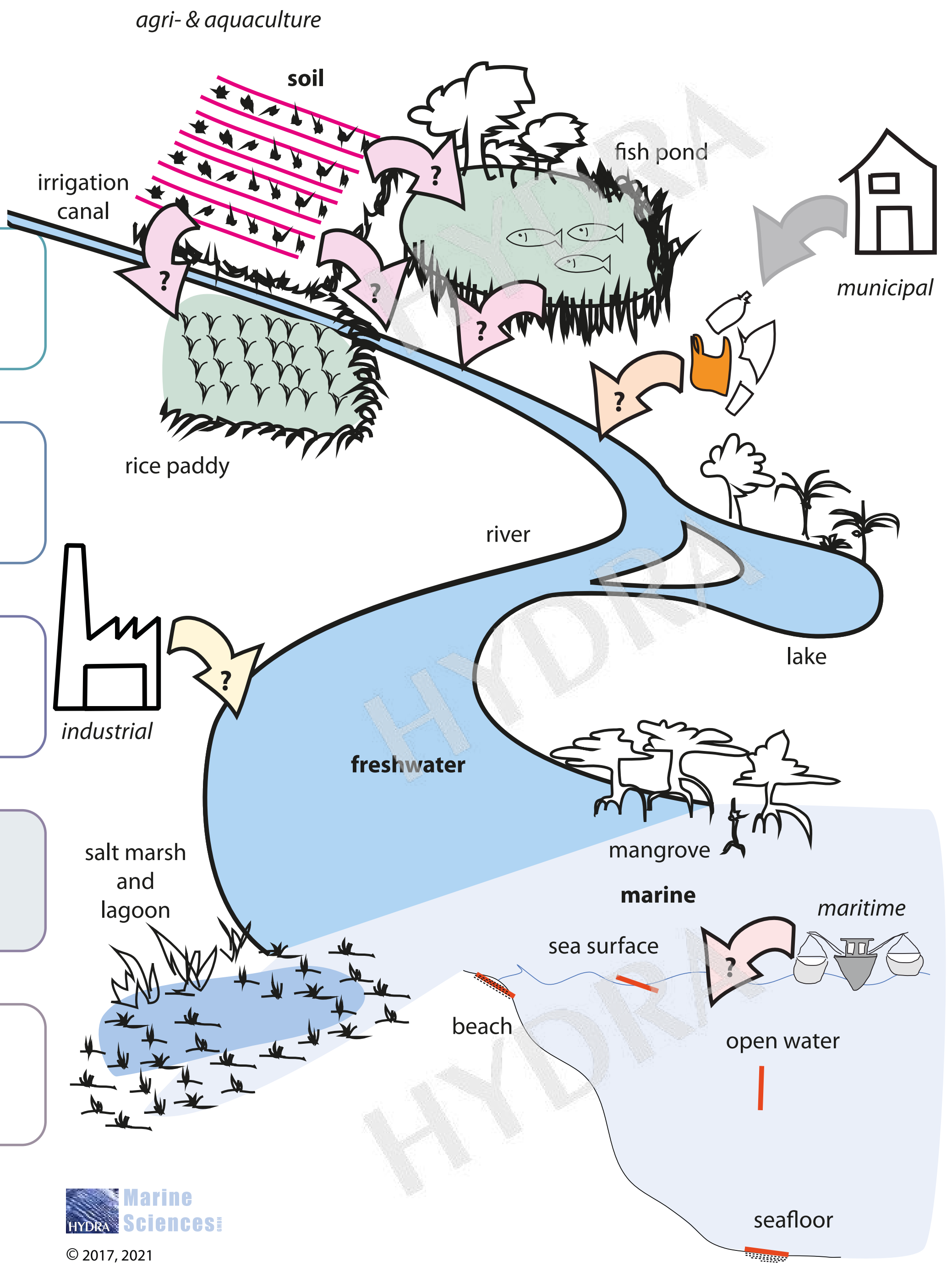
Habitat
- Estimate (or measure) the **habitat** the product will end up:

Conditions
- Describe habitat & environmental **conditions**:

Organisms/ Functions
- Describe **organisms** & **ecosystem functions**: *e.g. microbe, invertebrate, plant & soil and aquatic sediment respiration capacity*

Method
- Choose suitable **method** reflecting best the scenario(s): *check available **standard test methods*** and/or adapt accordingly*

*SAPEA 2020 Biodegradability of plastic in the open environment.



Application of the multi-tier testing scheme:

1. Inherent Biodegradability ✓

2. Environmental Biodegradability ✓

3. Biodegradation Rate in Reality ✓

4. Range of biodegradation Rates ✓

5. Model ‚no-accumulation scenario' ✓

6. Ecotoxicity & impact on ecosystems of the biodegradation process ✓

Available biodegradation standards: **marine**

	Standard test methods: Pelagic zone (water column scenario)	Standard test methods: Benthic zone (seafloor scenario)	Standard test methods: Eulittoral zone (intertidal beach scenario)	Standards specifications
Laboratory tests	ASTM D6691-2017		ASTM D7991-2015	ASTM D7081 (withdrawn 2014)
	ASTM D6692-2001 (withdrawn 2010)			ISO 22403:2020
	ISO 23977-1	ISO 18830:2016	ISO 22404:2019	
	ISO 23977-2	ISO 19679:2016		
Field tests	ISO 15314:2018	ISO 22766	ISO 22766	
Tank tests		ASTM D7473-2012 resp. ASTM WK7 1923*		
	ISO 23832:2021	ISO 23832:2021	ISO 23832:2021	

Marine Sciences

*under development

available biodegradation standards: **MARINE**

MARINE	Standard test methods: Pelagic zone (water column scenario)	Standard test methods: Benthic zone (seafloor scenario)	Standard test methods: Eulittoral zone (intertidal beach scenario)	Standards specifications	Related sta ASTM D7081:2015 (withdrawn 2014) ASTM WK75797*
Lab-oratory tests	EN ISO 23977-1:2021 (analysis O2) ★	EN ISO 18830:2017 (analysis O2) ★	EN ISO 22404: 2021 ★	EN ISO 22403:2021	ISO 5430:2023 (specification for ecotox on 3 trophic levels → all 3 test methods are on EN level !)
	EN ISO 23977-2:2021 (analysis CO2) ★	EN ISO 19679:2020 (analysis CO2) ★			ISO 5148:2022 (DT50)
	ASTM D6691-24a under revision by ASTM WK82370 ISO/DIS 24304 (for textiles)	ASTM WK75797 (includes estimations for complete biodegradation at lower temperature)	ASTM D7991-2022		EN ISO 10210:2017 (sample preparation) ISO 16623:2024 (matrices preparation)
	ISO/DIS 18957 (acceleration test)				CEN/TR 15351:2006 (vocabulary) CEN/TR 17910:2022 (Status of standardization and new prospects)
Field tests	ISO 15314:2018 (confirmed 2023)	EN ISO 22766:2021 ★	EN ISO 22766:2021 ★		
	ISO 16636:2025				
Tank tests	ISO 23832:2021 ★	ISO 23832:2021 ★	ISO 23832:2021 ★		
		ASTM D7473/D7473M-21			

★ *with participation of HYDRA*

Missing topics: anoxic, deep sea, transfer scenario, variability (due to material and/or environmental reasons)

Marine Sciences HYDRA

Certifications & certificates

Compliance with (your) claims and expectations

Knowledge how to verify (or falsify them)

available certification schemes: **MARINE**

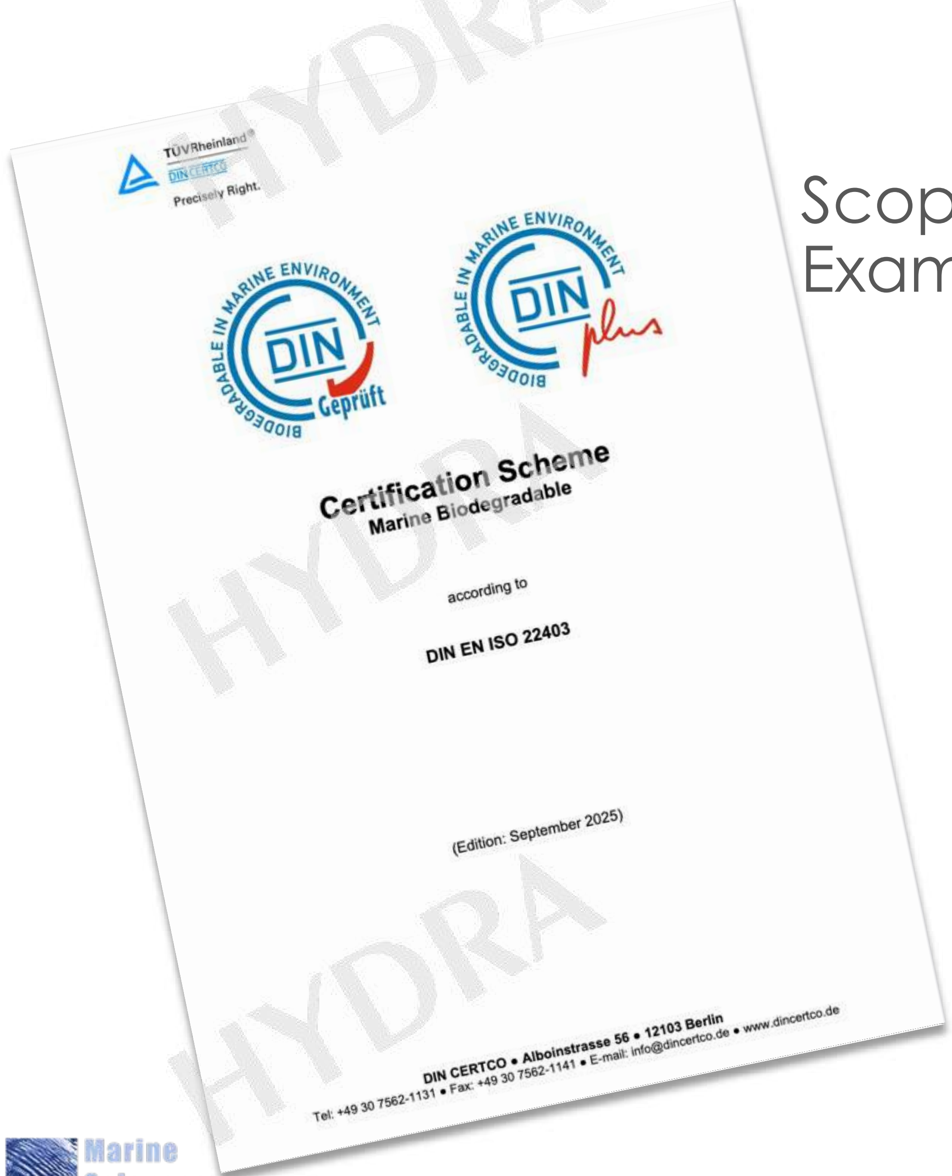
	DIN CERTCO		TÜV AUSTRIA	Japan BioPlastics Association
Criteria	90% in 2 years	90% in 2 years	90% in 6 months	90% in 2 years
Scheme	DIN-Geprüft Biodegradable in Marine Environment	DINplus Biodegradable in Marine Environment	OK biodegradable MARINE	Marine Biodegradable
Standards	EN ISO 22403*: EN ISO 18830, EN ISO 19679 EN ISO 22404 EN ISO23977-1 (-2) ASTM D6691 ISO 23832	…and ISO 22766	ASTM D6691	EN ISO 22403*: EN ISO 18830, EN ISO 19679 EN ISO 22404 EN ISO 23977-1 (-2) ASTM D6691
Label	https://www.dincertco.de/din-certco/en/main-navigation/products-and-services/certification-of-products/environmental-field/biodegradable-in-marine-environment/		https://okcert.tuvaustria.com/apply-for-certification/	https://www.jbpaweb.net/english/e-msp/

*specification; all others are test methods

Info added after our discussion in the meeting

It is not correct, that thick objects, ropes etc. cannot be certified. However, it is likely for some objects that they will not degrade fast enough to meet the pass criteria. We are confident that there is a way to overcome this hurdle.

Scope of certification scheme: Example DIN CERTCO


TÜVRheinland®
DIN CERTCO
Precisely Right.

MARINE ENVIRONMENT
BIODEGRADABLE IN
DIN
Geprüft

MARINE ENVIRONMENT
BIODEGRADABLE IN
DIN
plus

Certification Scheme
Marine Biodegradable

according to

DIN EN ISO 22403

(Edition: September 2025)

DIN CERTCO • Alboinstrasse 56 • 12103 Berlin
Tel: +49 30 7562-1131 • Fax: +49 30 7562-1141 • E-mail: info@dincertco.de • www.dincertco.de

This certification scheme considers the property biodegradability as beneficial for items from the following 4 product categories, covered by this scheme:

Category 1: Intentional release to the open environment and recovery not foreseen or impossible. Examples: weather balloons, emergency rocket/parachute, geotextiles, agricultural applications like mulch films, growing aids, polymers in liquid formulations (PLFs) for example in agri- and aquaculture applications, seed coatings.
Category 2: Unavoidable release into the environment and recovery is impossible. Examples: Abraded particles from feeding pipes, coatings or paints, fibres from ropes, textiles, nets, flags or outdoor textiles, play or sport grounds or wet wipes and detergents.
Category 3: High potential of loss to the environment and recovery often not possible or not feasible. Examples: Bait bags, fishing lures, traps, FADs (Fish Aggregating Devices), fishing nets, fish boxes and trays, feeding bags used in aquaculture, mussel nets.
Category 4: High risk of loss to the environment for systemic reasons (e.g. in regions where no or no adequate waste management system is in place). Examples: hygiene products, plastic bags, packaging like sachets and drinking bottles, tableware, cutlery, food container, textiles. In these cases, biodegradability serves as a safety measure to reduce further accumulation of persistent plastic.

Within these categories, certification is possible for materials, intermediates, additives or final products.

https://www.dincertco.de/media/dincertco/dokumente_1/certification_schemes/biodegradable-in-marine-environment_certification-scheme.pdf

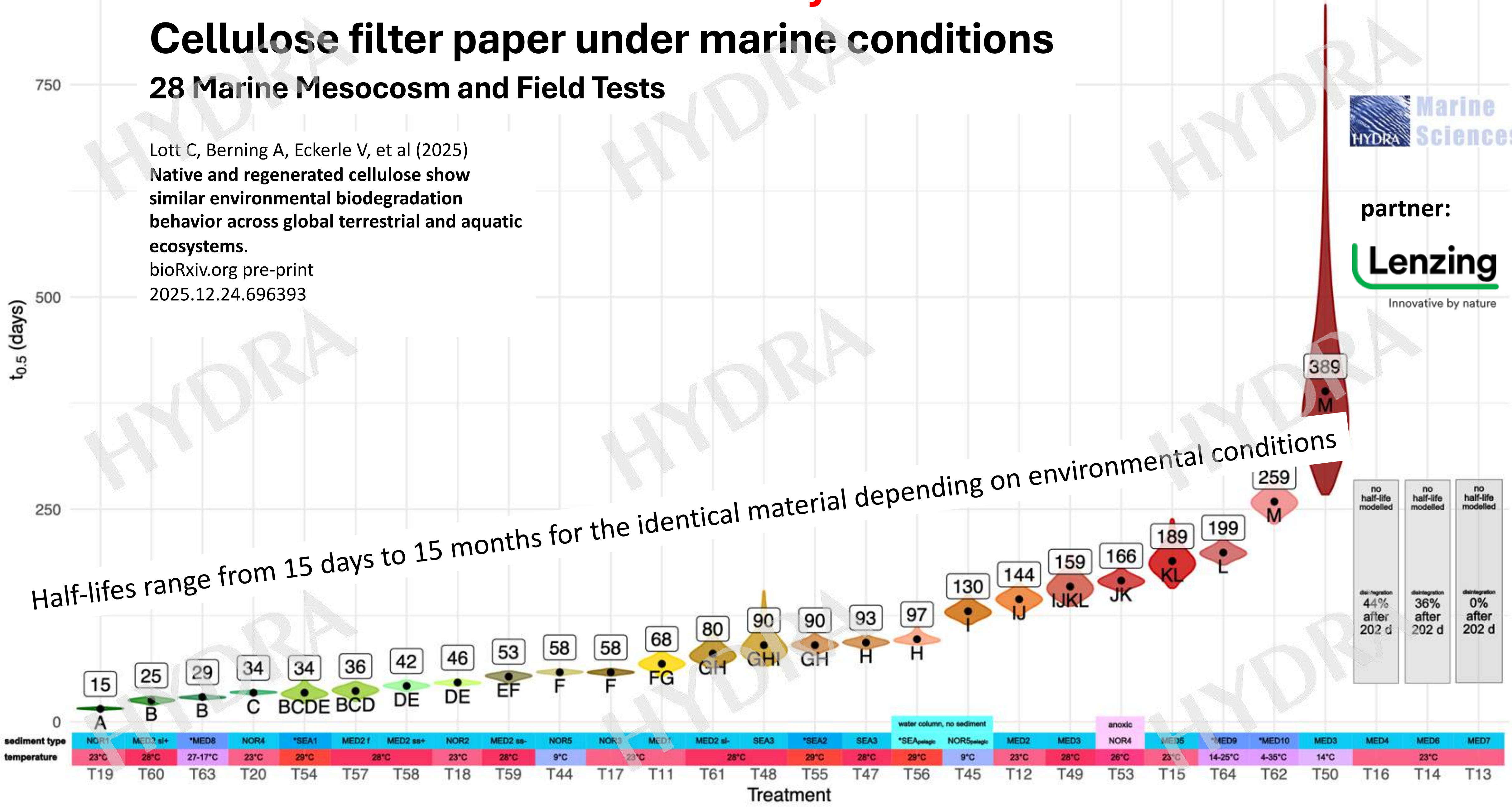
Consider Environmental variability

Cellulose filter paper under marine conditions

28 Marine Mesocosm and Field Tests

Lott C, Berning A, Eckerle V, et al (2025)
Native and regenerated cellulose show similar environmental biodegradation behavior across global terrestrial and aquatic ecosystems.
bioRxiv.org pre-print
2025.12.24.696393

partner: Lenzing – Innovative by nature



Half-lifes range from 15 days to 15 months for the identical material depending on environmental conditions

Material perspective

Can we achieve the needed material performance &

‘magical’ biodegradation

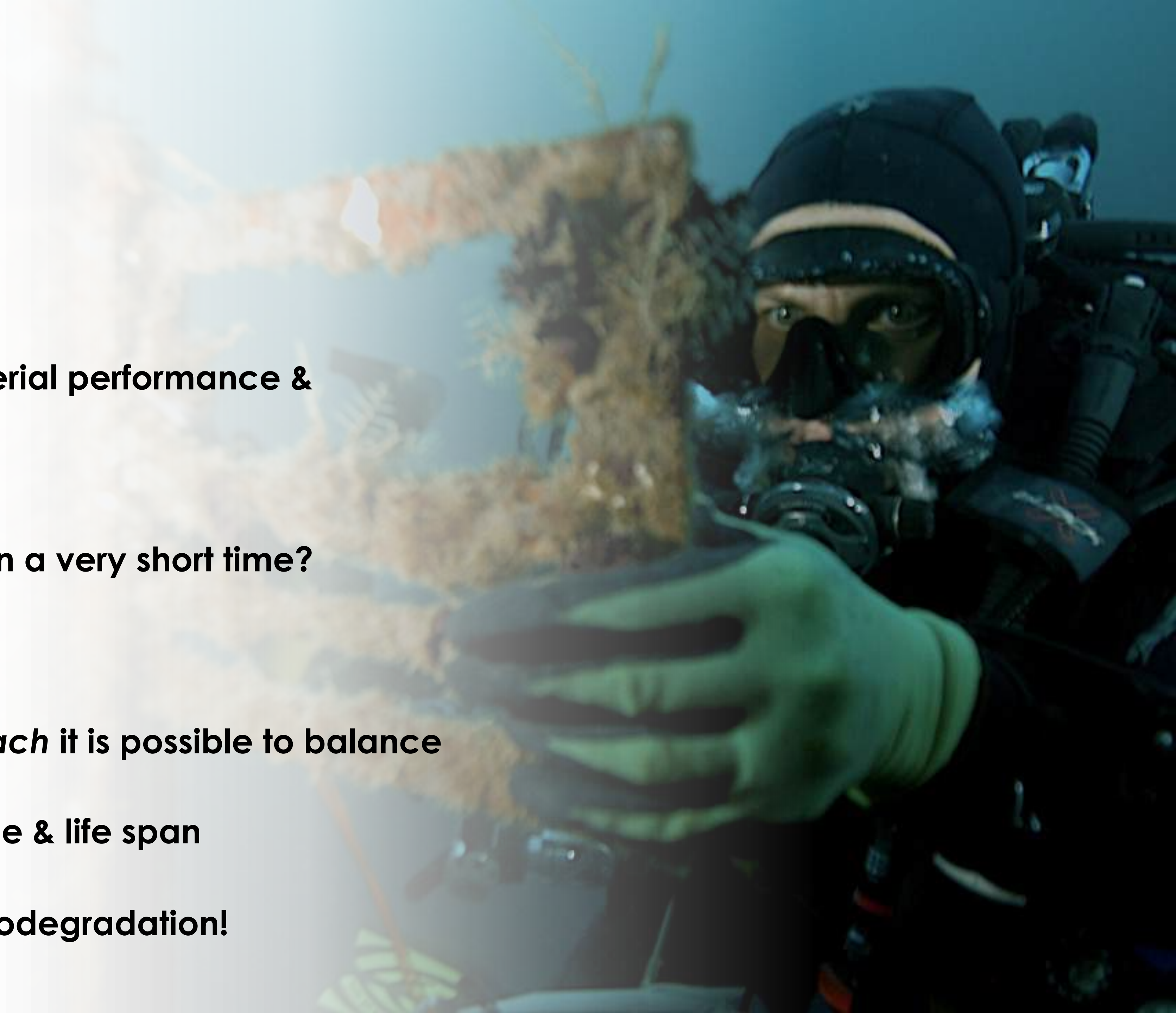
in the open environment in a very short time?

➔‘Magical’ is not possible,

With *an application-based approach* it is possible to balance

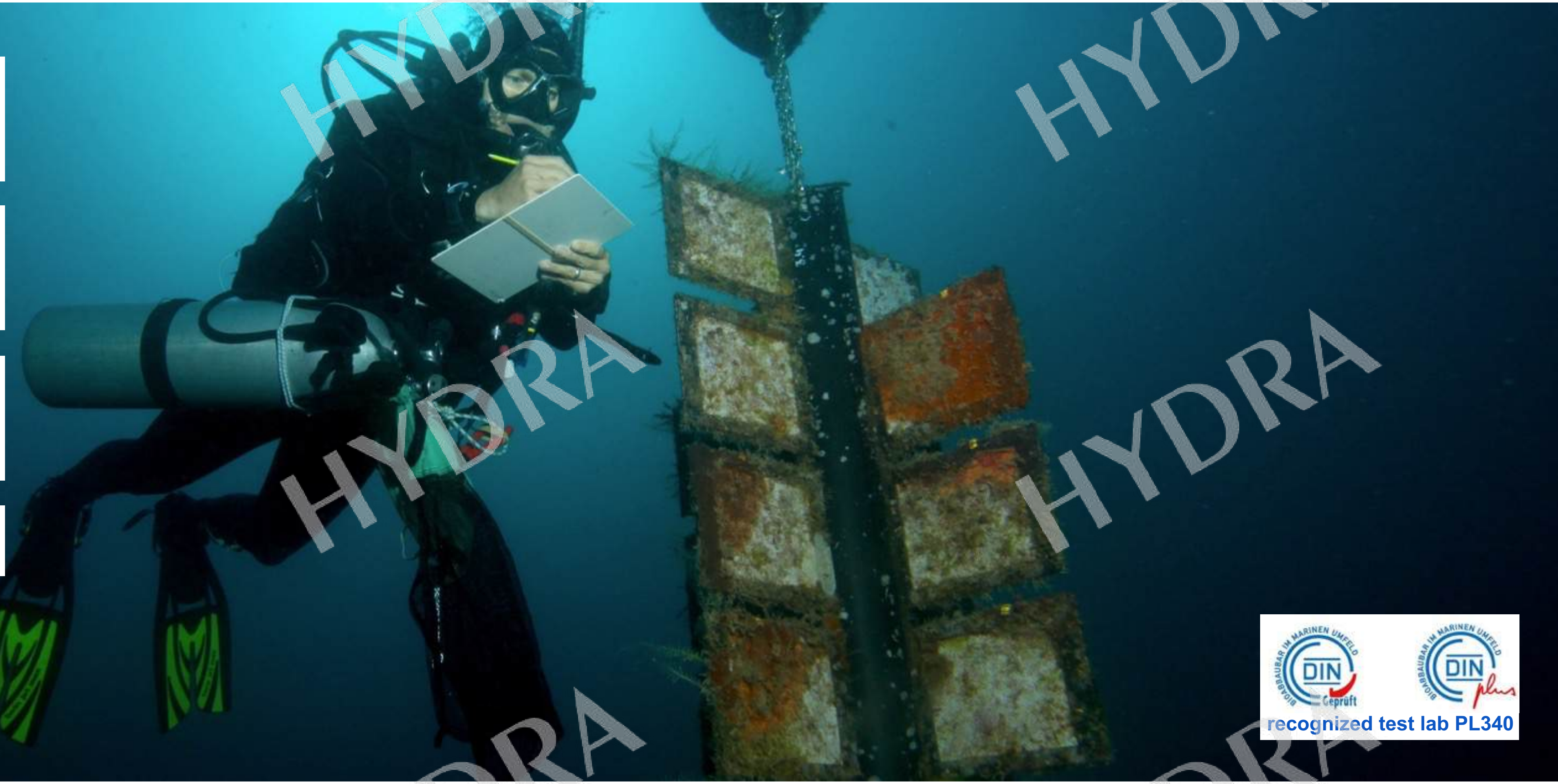
the needs for material performance & life span

with acceptable timeframes for biodegradation!



HYDRA Marine Sciences

Solutions through Science



Material Research & Customized Testing

Standard Tests for Soil, Marine & Freshwater

Visualization & Communication

Concepts & Consulting

contact:
Christian Lott
c.lott@hydramarinesciences.com

DIN Geprüft · DIN plus — recognized test lab PL340

partners

Max Planck Institute for Marine Microbiology · ETH zürich · NC STATE UNIVERSITY · AWI · Australian Institute of Marine Science · University of Basel Department of Environmental Sciences · CNR ISMAR · Carl von Ossietzky Universität Oldenburg · IKK · MATE Hungarian University of Agriculture and Life Sciences · IfBB

BASF We create chemistry · Kimberly-Clark · Nestlé Research · NOVAMONT · Lenzing · Alliance for European Flax-Linen & Hemp · AQUEIS · TotalEnergies · Corbion · NatureWorks · futerro · ECHO Instruments · nova Institute · FKuR · FNR

public funding

OPEN BIO · LEADER · Baden-Württemberg · Mittelbaden · Interreg Rhin Supérieur | Oberrhein · REBIOSTION · Bundesministerium für Ernährung und Landwirtschaft