

GDR Polymères et Océans

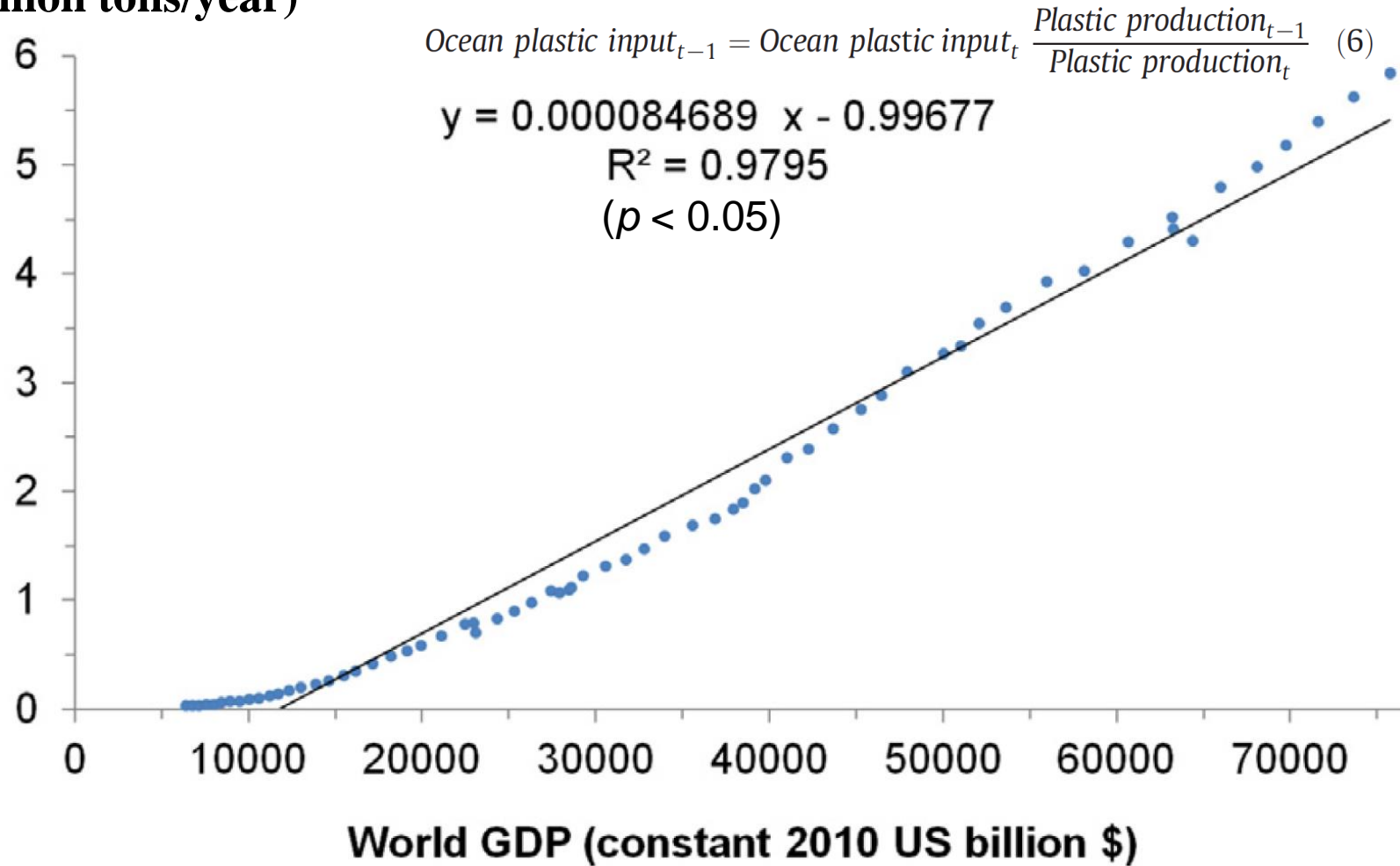
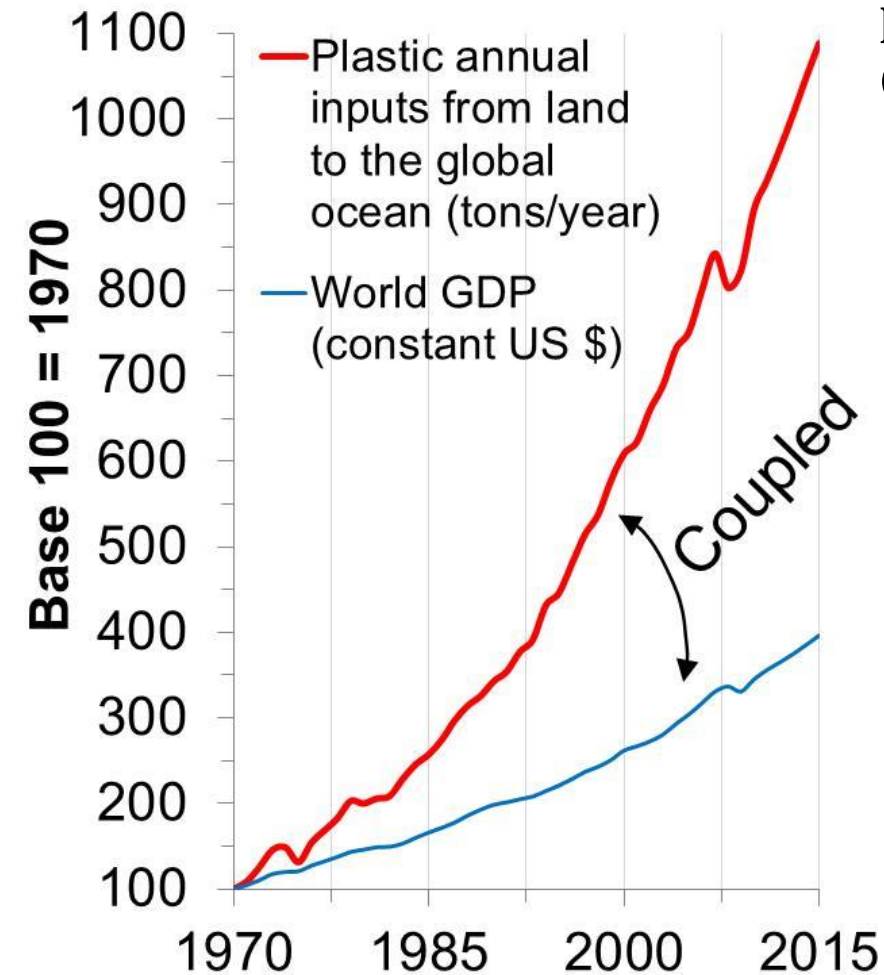
Premières rencontres
Université Paris-Est Créteil, France
24 – 26 Juin 2019

**A QUEL RYTHME FAUT-IL DÉVELOPPER LES TECHNOLOGIES
POUR PRÉSERVER LES OCÉANS DES PLASTIQUES ?**

Mateo Cordier
Takuro Uehara
Bethany Jorgensen
Juan Baztan

CONTEXTE : LA CROISSANCE ÉCONOMIQUE EST COUPLÉE AUX PLASTIQUES

Global annual inputs of plastics from land to ocean (million tons/year)





OBJECTIF

- Comprendre comment les socio-écosystèmes pourraient être modifiés pour **reduire la contamination plastique** des océans et parvenir à **découpler** le PIB de cette contamination.
 - Autrement dit, comment pourrions-nous modifier la façon dont:
 - nous **produisons et consommons** les produits en plastique?
 - nous gérons le **traitement des déchets** plastiques?
 - nous **nous comportons** en tant que citoyen?
 - nous **vivons** ?

MÉTHODE: MODÉLISER

- Développer un **modèle IO-SD** pour simuler les **flux mondiaux de plastiques** terre → océan
- Analyser avec le modèle les **impacts écologiques, sociaux et économiques** de mesures environnementales pour identifier celles capables de **découpler** le PIB des plastiques


Science of the Total Environment 670 (2019) 789–799

Contents lists available at ScienceDirect

Science of the Total Environment


ELSEVIER journal homepage: www.elsevier.com/locate/scitotenv

How much innovation is needed to protect the ocean from plastic contamination?
Mateo Cordier ^{a,b,*}, Takuro Uehara

 *sustainability* 2018, 10, 1765; doi:10.3390/su10061765

Article

Fully Dynamic Input-Output/System Dynamics Modeling for Ecological-Economic System Analysis

Takuro Uehara ^{1,*} , Mateo Cordier ^{2,3} and Bertrand Hamaide

Ecological Economics 140 (2017) 46–57

Contents lists available at ScienceDirect

Ecological Economics

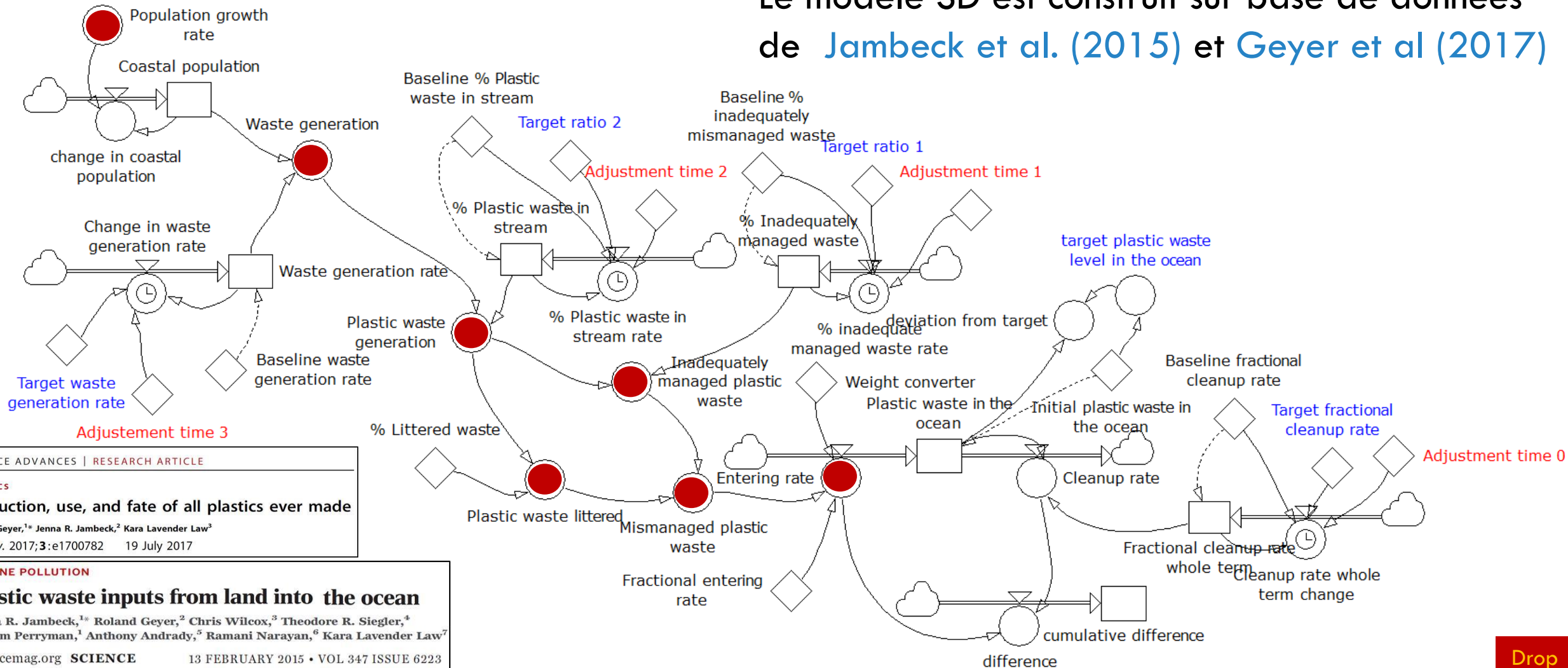
ELSEVIER journal homepage: www.elsevier.com/locate/ecocon

An Input-output Economic Model Integrated Within a System Dynamics Ecological Model: Feedback Loop Methodology Applied to Fish Nursery Restoration

Mateo Cordier ^{a,b,*}, Takuro Uehara ^c, Jeffrey Weih ^e, Bertrand Hamaide ^d

MÉTHODE: MODÈLE DE DYNAMIQUES DE SYSTÈMES (SD)

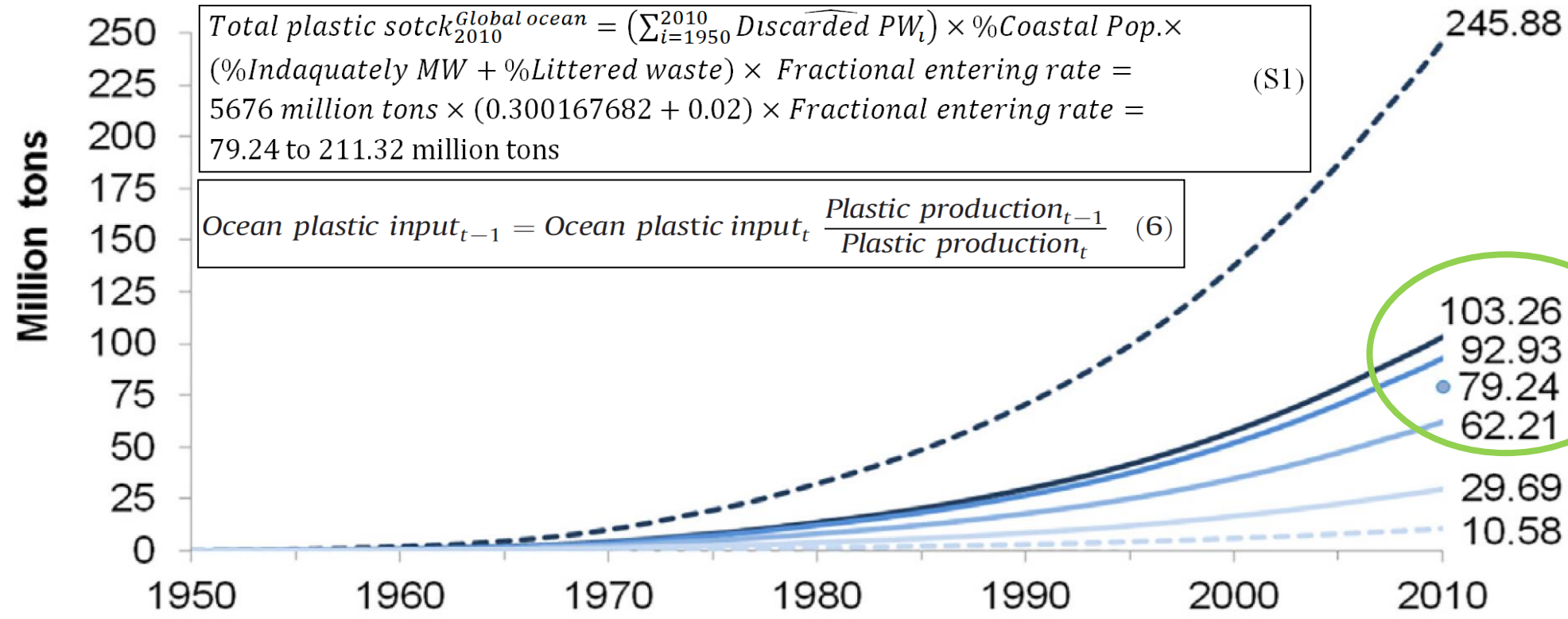
- Le modèle SD est construit sur base de données de [Jambeck et al. \(2015\)](#) et [Geyer et al \(2017\)](#)



SCIENCE ADVANCES | RESEARCH ARTICLE
PLASTICS
Production, use, and fate of all plastics ever made
 Roland Geyer,^{1*} Jenna R. Jambeck,² Kara Lavender Law³
Sci. Adv. 2017;3:e1700782 19 July 2017

MARINE POLLUTION
Plastic waste inputs from land into the ocean
 Jenna R. Jambeck,^{1*} Roland Geyer,² Chris Wilcox,³ Theodore R. Siegler,⁴
 Miriam Perryman,¹ Anthony Andrady,⁵ Ramani Narayan,⁶ Kara Lavender Law⁷
 sciencemag.org **SCIENCE** 13 FEBRUARY 2015 • VOL 347 ISSUE 6223

Stock (million tons) de plastiques accumulés dans l'océan: 7 estimations



$$Total\ plastic\ stock_{2010}^{Global\ ocean} = \left(\sum_{i=1950}^{2010} Discarded\ PW_i \right) \times \%Coastal\ Pop. \times$$

$$(\%Inadequately\ MW + \%Littered\ waste) \times Fractional\ entering\ rate = \quad (S1)$$

$$5676\ million\ tons \times (0.300167682 + 0.02) \times Fractional\ entering\ rate =$$

$$79.24\ to\ 211.32\ million\ tons$$

$$Ocean\ plastic\ input_{t-1} = Ocean\ plastic\ input_t \frac{Plastic\ production_{t-1}}{Plastic\ production_t} \quad (6)$$

- 12.70 million t/year - Jambeck et al. (2015)'s data entered in Eq. (6)
- 4.0 million t/year - Schmidt et al., (2017)'s data entered in Eq. (6)
- 4.80 million t/year - Jambeck et al. (2015)'s data entered in Eq. (6)
- 2.41 million t/year - Lebreton et al. (2017)'s data entered in Eq. (6)
- 1.15 million t/year - Lebreton et al. (2017)'s data entered in Eq. (6)
- 0.41 million t/year - Schmidt et al. (2017)'s data entered in Eq. (6)
- 79.24 million tons - Geyer et al. (2017) and Jambeck et al. (2015)'s data entered in Eq. (S1)

Le paramètre de départ du modèle SD est proche des estimations de Lebreton et al. (2017, Schmidt et al. (2017), et Jambeck et al. (2015)

MÉTHODE: CATÉGORISER

- Nous avons répertorié et **catégorisé 22 solutions** au problème des plastiques
- Nous allons tester au moins une solution par catégorie avec le modèle IO-SD

	Location across the social-ecological system	Location across the problem causal chain	Solution categories	Examples of solutions			
Upstream	Solutions at the source of the problem	Preventive measures	Avoid and reduce waste production	<ol style="list-style-type: none"> 1. Awareness raising campaigns and collaborative strategies (Benkler, 2011; Ostrom, 2010) to encourage households to reduce waste generation and overconsumption behaviors in general. 2. Inciting industries to substitute plastic materials with aluminum, glass, bio-plastics, etc. 3. Nurdle spillage prevention in plastic factories (nurdles are pre-production microplastic pellets). 4. Fiscal instruments and compulsory legislation to reduce the amount of packaging. 5. Compulsory legislation to ban micro beads in cosmetics or in toothpastes, or to ban single-use plastic products, etc. 			
			Reuse or repair old products	<ol style="list-style-type: none"> 6. Returnable glass or PET bottle systems. 7. Moving from an economy of ownership to one of service functionality. 8. Online systems designed to help to share, trade, exchange, lend or rent second-hand products between neighbors, including plastic products. 9. Legislation forbidding planned obsolescence of products. 10. Fiscal rules that favor longer lasting products, etc. 			
		Middle solutions	Middle solutions	Preventive measures	Recycling	<ol style="list-style-type: none"> 11. Recycling in closed cycles (e.g., recycling of plastic bottles, plastic bags, etc.). 12. Legislation for compulsory extended producer responsibility in the plastic industry. 	
					Improvement in waste collection infrastructure	<ol style="list-style-type: none"> 13. Invest in landfill sealing to avoid plastic waste leakages through rain, waterways or wind, from dumps or open, uncontrolled landfills, where waste is not suitably contained. 14. Invest in public garbage cans, waste collection system, awareness raising to reduce littering, etc. 	
				Curative measures	Middle solutions	Incineration	<ol style="list-style-type: none"> 15. Plastic waste incineration.
						Energy recovery	<ol style="list-style-type: none"> 16. Plastic waste incineration with energy cogeneration.
						Composting biodegradable plastic bottles	<ol style="list-style-type: none"> 17. Biodegradable (compostable) plastics made of starch that meet standards for biodegradability and compostability.
						Restore, e.g., remove plastics from ecosystems	<ol style="list-style-type: none"> 18. Collection of plastic debris in oceans, for example the Ocean Cleanup Project (Slat, 2014). 19. Beach cleanups. 20. River interception techniques before plastic wastes enter the ocean, or filters in water treatment plants, etc.
		Downstream	End-of-pipe solutions	Curative measures	Health measures	<ol style="list-style-type: none"> 21. Medical services to cure health impacts due to consumption of chemicals in plastic (e.g., Bisphenol-A and other endocrine disruptors). 	
					Palliative measures	<ol style="list-style-type: none"> 22. Final consumers purchasing glass bottles instead of plastic ones, switching from plastic bottles of mineral water to public tap water. etc. 	

RÉSULTATS PRÉLIMINAIRES

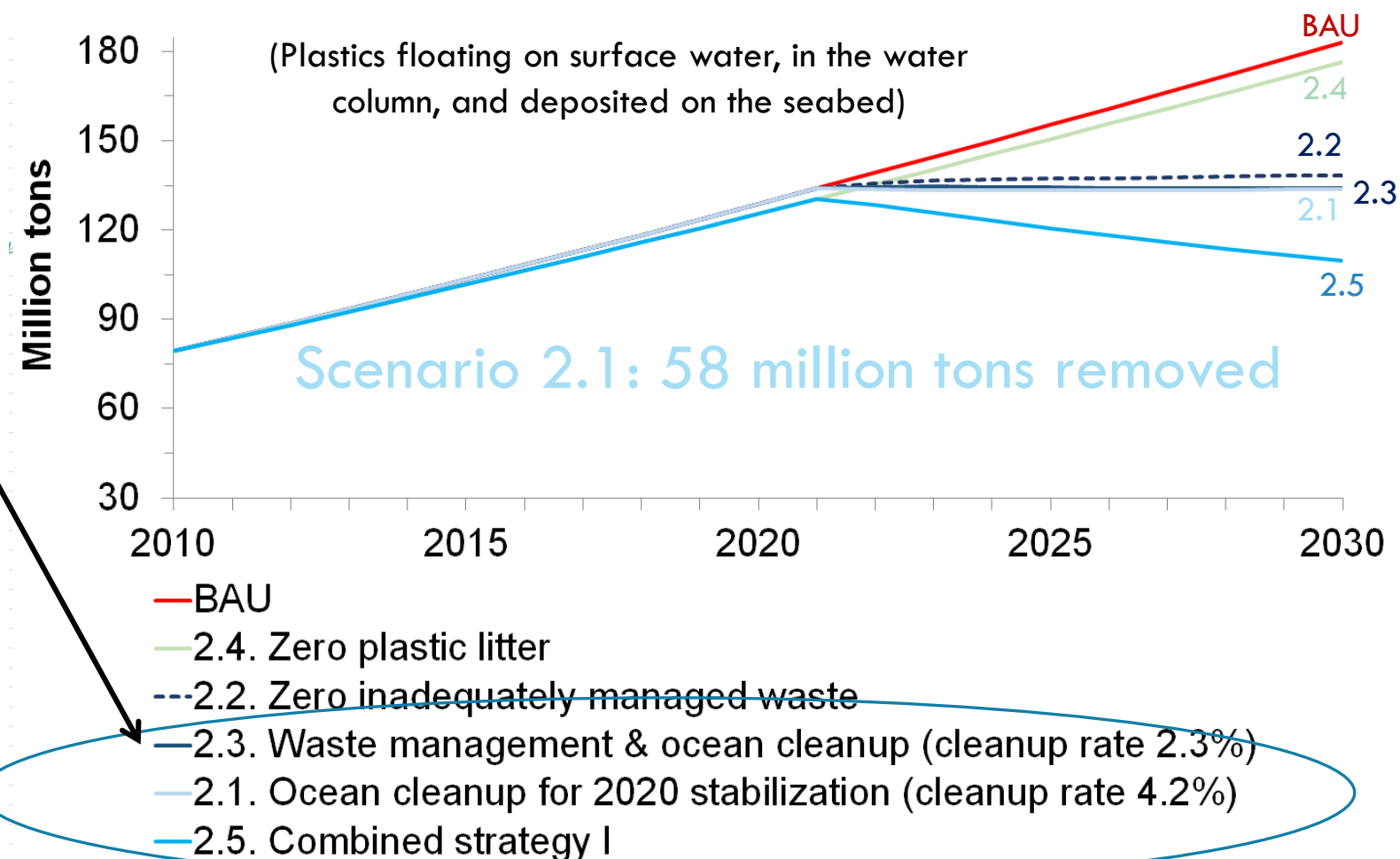
Scenarios 2: mesures environnementales conçues pour stabiliser le stock marin de plastiques

- Les technologies **ocean cleanup** sont-elles écologiquement **efficaces** et économiquement **plausibles** ?

➤ **Efficacité:** Les plastiques **flottant** à la surface (~250 000 t) constituent une **faible proportion** du stock total accumulé dans l'océan.

➤ **Plausibilité:**

- ces solutions peuvent-elles être mises en œuvre dans tous les pays (**197 pays**) ?
- Collecter $58 \cdot 10^6$ t, est-ce possible?

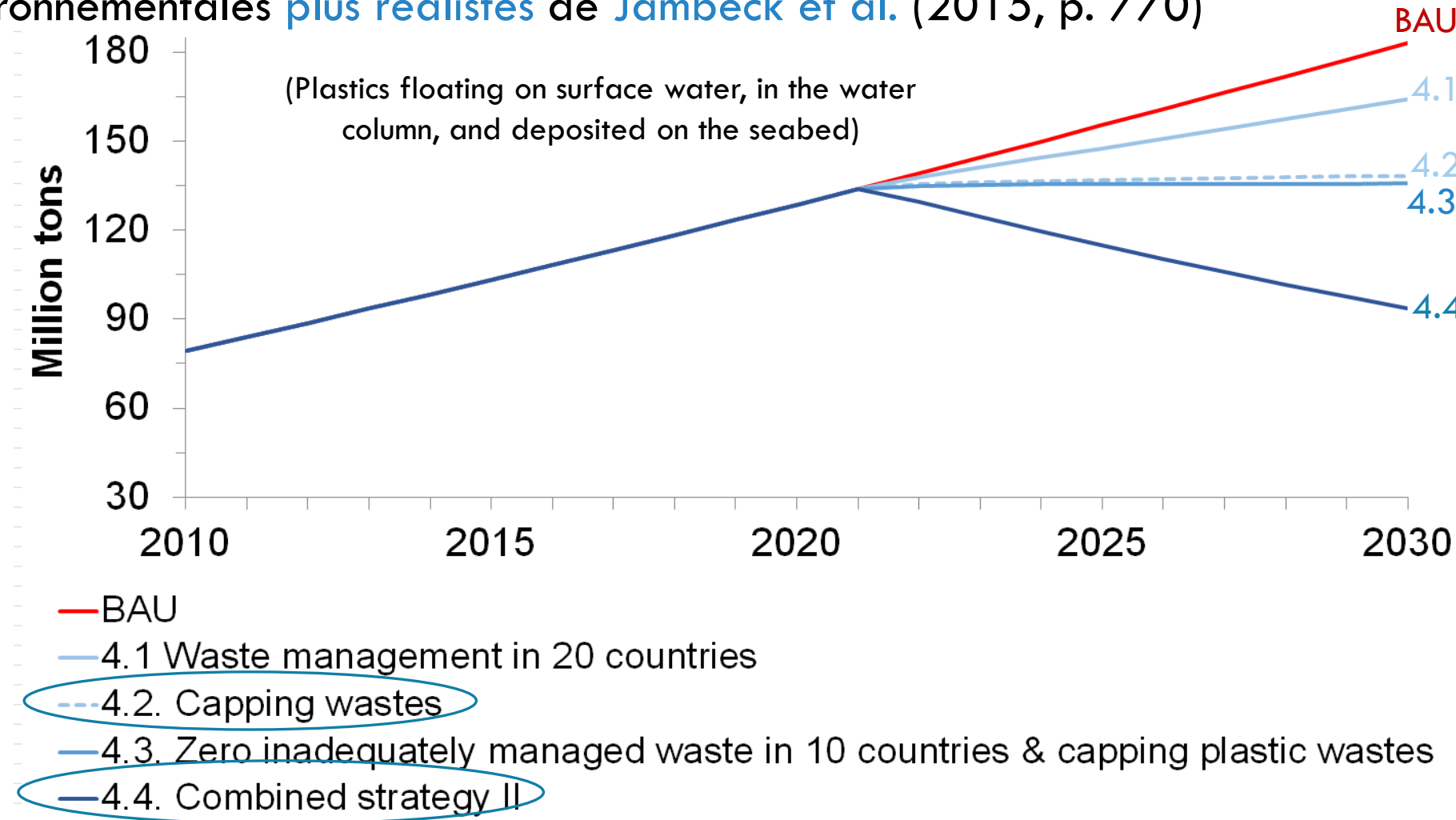


RÉSULTATS PRÉLIMINAIRES

Scenarios 4: mesures environnementales plus réalistes de Jambeck et al. (2015, p. 770)

Scénarios plus réalistes car:

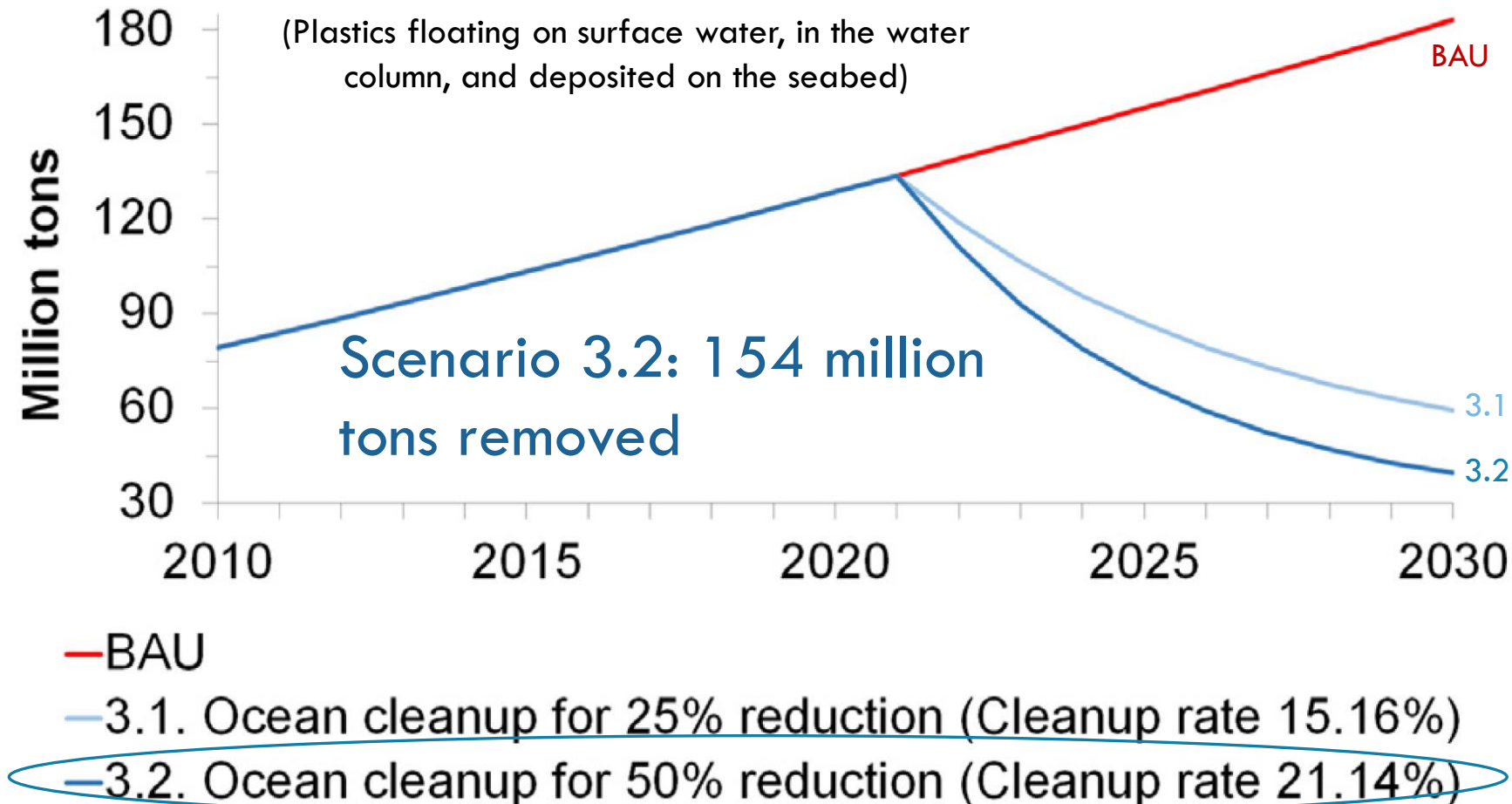
- Mis en œuvre dans 10 ou 20 pays seulement (scenarios 4.1 et partiellement 4.3–4.4).
- Tout ne repose pas sur l'ocean cleanup
- Ramènent les pays excédentaires au niveau de la moyenne mondiale de déchets par hab., pas plus (scenarios 4.2 et partiellement 4.3 - 4.4).



RÉSULTATS PRÉLIMINAIRES

Scenarios 3: mesures “ocean cleanup” conçues pour ramener le stock de débris plastiques sous le **niveau de 2010**

- Faisabilité économique?
 - Coût total des scénarios 3: **0.7-1.1% PIB mondial** (491-809 milliards €)
- Et la soutenabilité?
 - Que se passera-t-il après la phase de cleanup? **Les flux de plastiques vers les océans continueront de croître.**



CONCLUSIONS

- Pour atteindre une réduction significative des plastiques dans les océans, recourir à un seul type de mesure environnemental sera insuffisant.
- Il faut diversifier les solutions : Les solutions Upstream et downstream doivent être combinées

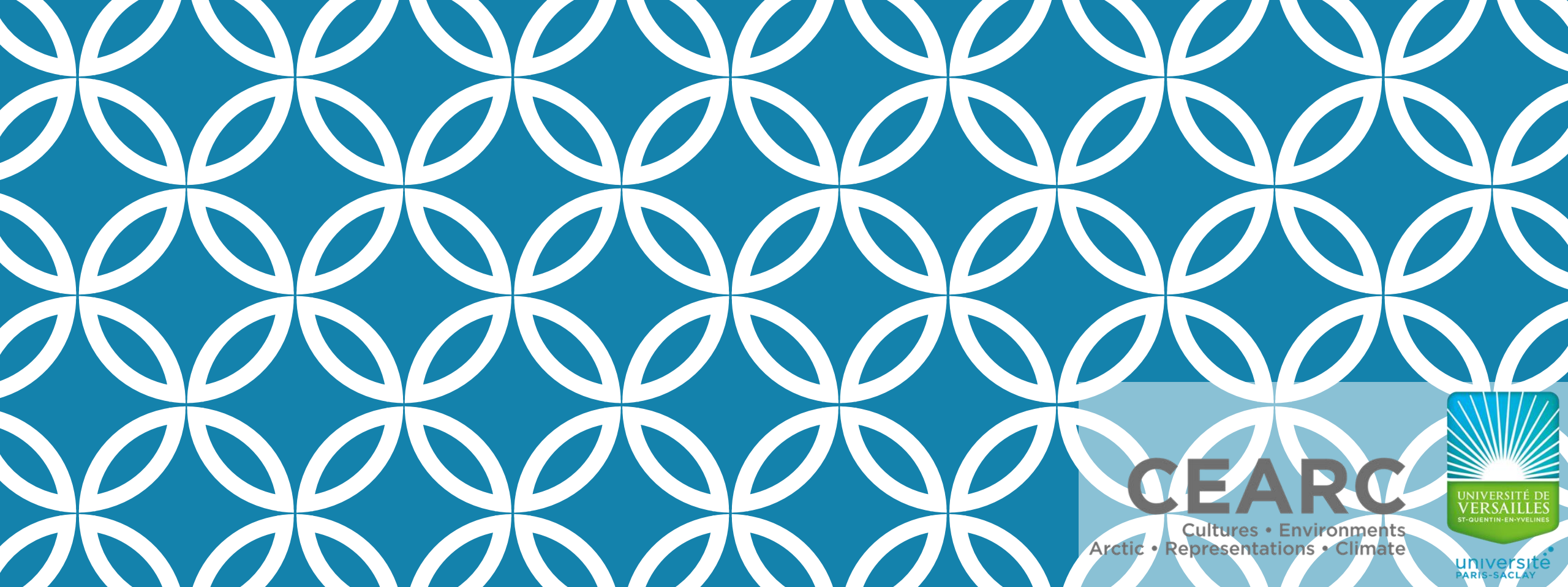
Location across the social-ecological system	Location across the problem causal chain	Solution categories	Examples of solutions		
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		Reuse or repair old products	<ol style="list-style-type: none"> 6. Returnable glass or PET bottle systems 7. Moving from an economy of ownership to one of service functionality. 8. Online systems designed to help to share, trade, exchange, lend or rent second-hand products between neighbors, including plastic products. 9. Legislation forbidding planned obsolescence of products. 10. Fiscal rules that favor longer lasting products, etc. 		
		Preventive measures			
	Middle solutions		Recycling	<ol style="list-style-type: none"> 11. Recycling in closed cycles (e.g., recycling of plastic bottles, plastic bags, etc.). 12. Legislation for compulsory extended producer responsibility in the plastic industry. 	
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			Energy recovery	<ol style="list-style-type: none"> 16. Plastic waste incineration with energy cogeneration. 	
			Composting biodegradable plastic bottles	<ol style="list-style-type: none"> 17. Biodegradable (compostable) plastics made of starch that meet standards for biodegradability and compostability. 	
		Downstream	End-of-pipe solutions	Restore, e.g., remove plastics from ecosystems	<ol style="list-style-type: none"> 18. Collection of plastic debris in oceans, for example the Ocean Cleanup Project (Sint, 2014). 19. Beach cleanups. 20. River interception techniques before plastic wastes enter the ocean, or filters in water treatment plants, etc.
				Curative measures	

CONCLUSIONS

Des principes économiques doivent être développés/adaptés et simulés à l'aide du modèle IO-SD pour comprendre comment vaincre les difficultés financières, sociales et politiques des solutions à la contamination plastique des océans:

- Polluter Pays Principle – *Principe pollueur payeur*
- Extended Producer Responsibility – *Responsabilité élargie du producteur*
- Shared Environmental Responsibility Principle – *Principe de la responsabilité environnementale partagée*





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APPENDIX

METHOD

PLASTICS

Production, use, and fate of all plastics ever made

Roland Geyer,^{1*} Jenna R. Jambeck,² Kara Lavender Law³

Sci. Adv. 2017;3:e1700782 19 July 2017

Plastic waste inputs from land into the ocean

Jenna R. Jambeck,^{1*} Roland Geyer,² Chris Wilcox,³ Theodore R. Siegler,⁴ Miriam Perryman,¹ Anthony Andrady,⁵ Ramani Narayan,⁶ Kara Lavender Law³

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- The SD model is designed based on data from Jambeck et al. (2015) and Geyer et al (2017) :

Jambeck et al. (2015)

Table S1: Annual and cumulative quantities (millions of metric tons (MMT)) of mismanaged plastic waste and plastic marine debris (assuming three different conversion rates) for 2010-2025.

Year	Mismanaged plastic waste [MMT/year]	15% marine debris (MMT)	25% marine debris (MMT)	40% marine debris (MMT)
2010	31.9	4.8	8.0	12.7
2015	36.5	5.5	9.1	14.6
2020	41.3	6.2	10.3	16.5
2025	69.9	10.5	17.5	28.0

Jambeck et al. (2015)

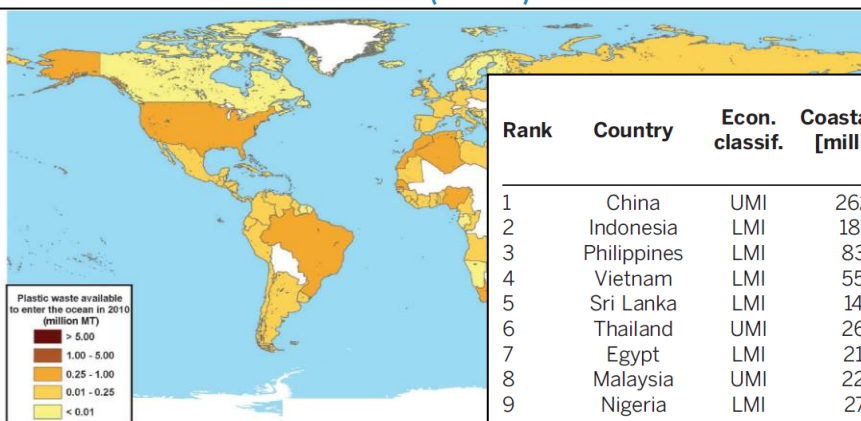


Fig. 1. Global map with each country shaded according to the estimated mass of plastic waste available to enter the ocean in 2010 by populations living within 50 km of the coast. We considered 192 countries.

Jambeck et al. (2015)

Rank	Country	Econ. classif.	Coastal pop. [millions]	Waste gen. rate [kg/ppd]	% plastic waste	% mismanaged waste	Mismanaged plastic waste [MMT/year]	% of total mismanaged plastic waste	Plastic marine debris [MMT/year]
1	China	UMI	262.9	1.10	11	76	8.82	27.7	1.32-3.53
2	Indonesia	LMI	187.2	0.52	11	83	3.22	10.1	0.48-1.29
3	Philippines	LMI	83.4	0.5	15	83	1.88	5.9	0.28-0.75
4	Vietnam	LMI	55.9	0.79	13	88	1.83	5.8	0.28-0.73
5	Sri Lanka	LMI	14.6	5.1	7	84	1.59	5.0	
6	Thailand	UMI	26.0	1.2	12	75	1.03	3.2	
7	Egypt	LMI	21.8	1.37	13	69	0.97	3.0	
8	Malaysia	UMI	22.9	1.52	13	57	0.94	2.9	
9	Nigeria	LMI	27.5	0.79	13	83	0.85	2.7	
10	Bangladesh	LI	70.9	0.43	8	89	0.79	2.5	
11	South Africa	UMI	12.9	2.0	12	56	0.63	2.0	
12	India	LMI	187.5	0.34	3	87	0.60	1.9	
13	Algeria	UMI	16.6	1.2	12	60	0.52	1.6	
14	Turkey	UMI	34.0	1.77	12	18	0.49	1.5	
15	Pakistan	LMI	14.6	0.79	13	88	0.48	1.5	
16	Brazil	UMI	74.7	1.03	16	11	0.47	1.5	
17	Burma	LI	19.0	0.44	17	89	0.46	1.4	
18*	Morocco	LMI	17.3	1.46	5	68	0.31	1.0	
19	North Korea	LI	17.3	0.6	9	90	0.30	1.0	
20	United States	HIC	112.9	2.58	13	2	0.28	0.9	

*If considered collectively, coastal European Union countries (23 total) would rank eighteenth on the list

Geyer et al (2017)

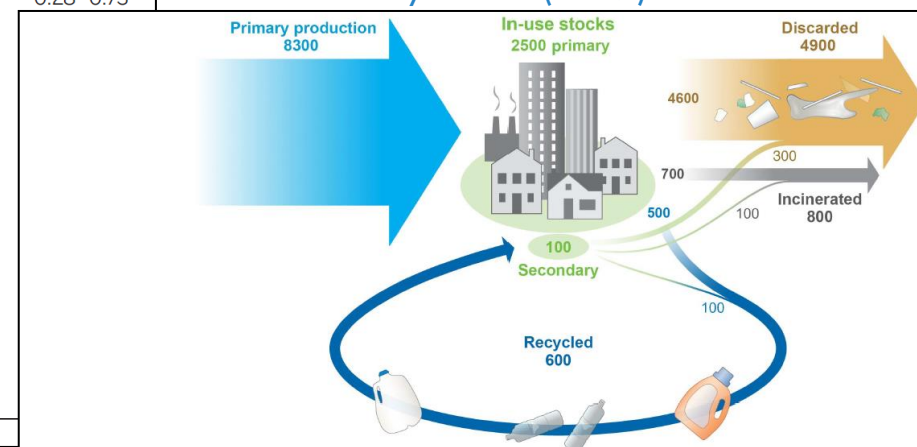
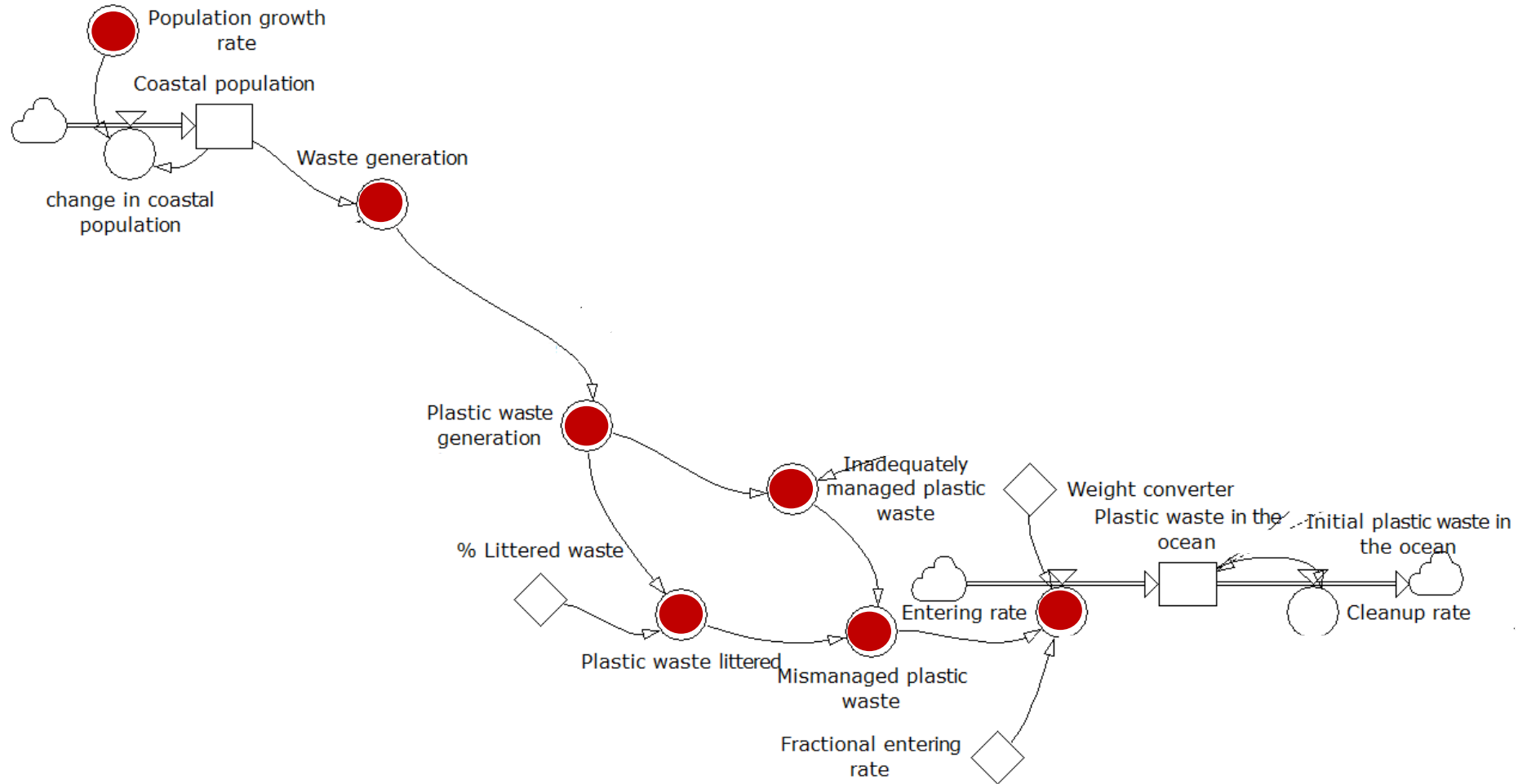
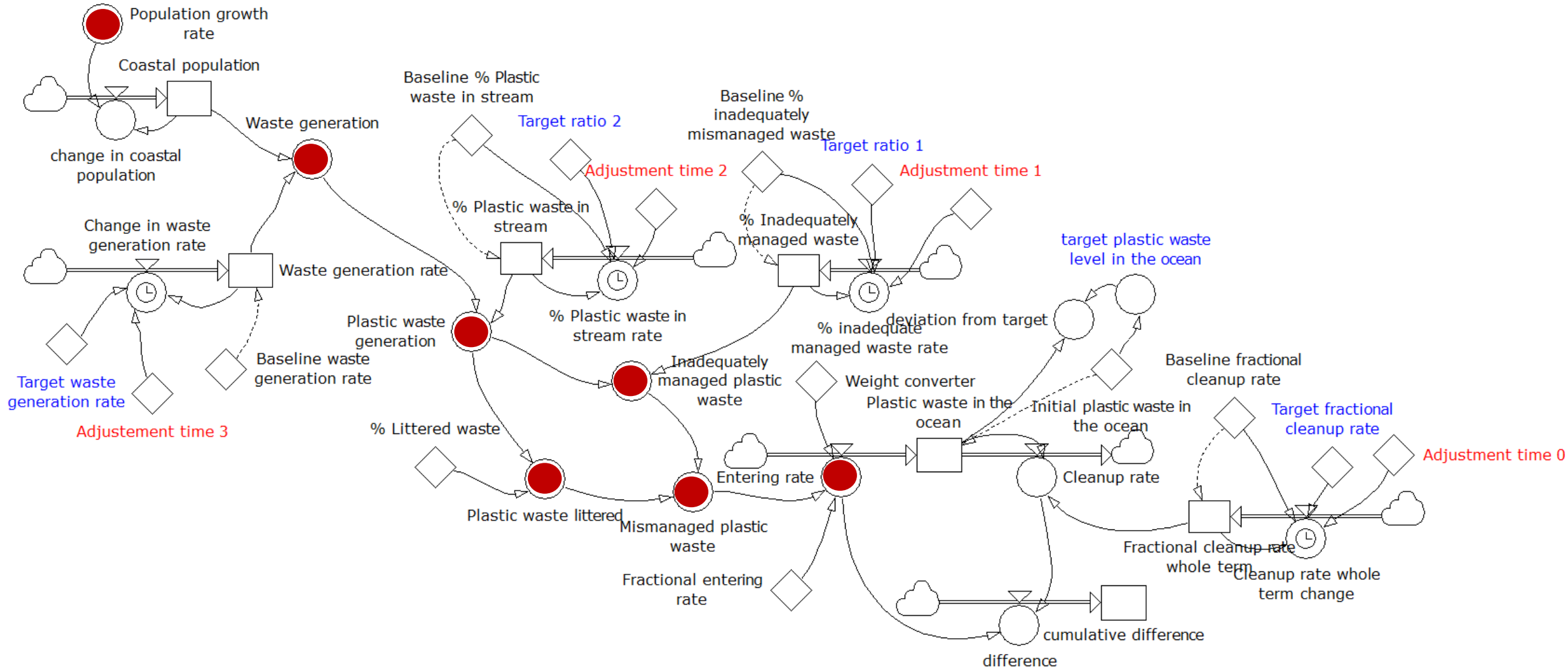


Fig. 2. Global production, use, and fate of polymer resins, synthetic fibers, and additives (1950 to 2015; in million metric tons).

METHOD: THE SYSTEM DYNAMICS (SD) MODEL



METHOD: THE SYSTEM DYNAMICS (SD) MODEL



Preventive measures “at-the-source” solution

Measures that could reduce Plastic waste generation:

- **Changes in consumption mentalities**, e.g., reducing consumption of goods by a better control on advertisement, creating a cooperative context instead of individualism with Y. Benkler (2011) and E. Ostrom (2010) approaches

Preventive measures “at-the-source” solution

Measures that could reduce the % Plastic waste in stream:

- Plastic material **substitution** by aluminum, glass, etc.
- **Changes in consumption behaviours** towards less plastic consumption, e.g., reducing consumptions of over-packaged products through eco-tax and creating a cooperative context instead of individualism (Yochai Benkler, 2011; Elinore Ostrom, 2010)

Preventive measures “middle” solution

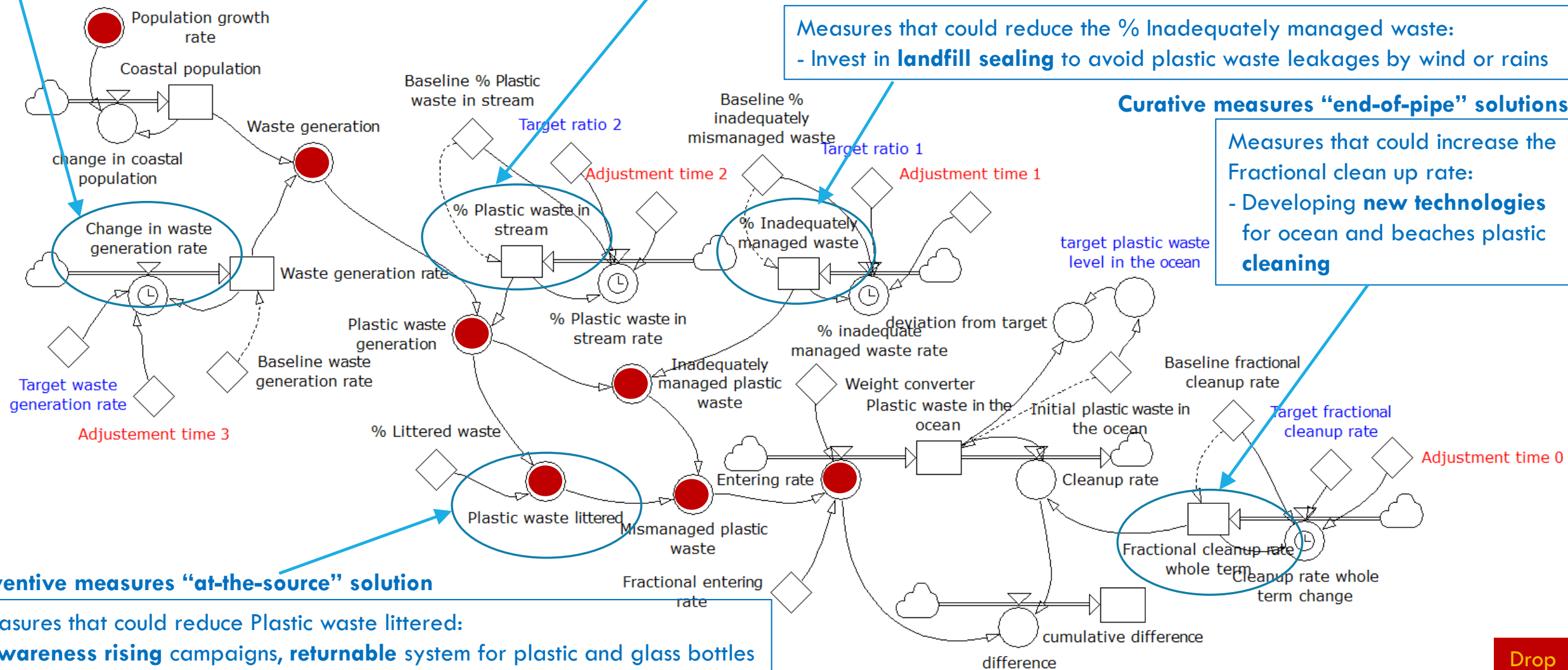
Measures that could reduce the % Inadequately managed waste:

- Invest in **landfill sealing** to avoid plastic waste leakages by wind or rains

Curative measures “end-of-pipe” solutions

Measures that could increase the Fractional clean up rate:

- Developing **new technologies** for ocean and beaches plastic **cleaning**



Preventive measures “at-the-source” solution

Measures that could reduce Plastic waste littered:

- **Awareness rising campaigns**, **returnable** system for plastic and glass bottles