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11 Sept 15.00-17.30h Retirement mini-symposium online ESRA website

Reflections on three decades of change in seagrass restoration.

Marieke M. van Katwijk

Arcachon 8 April 2025





Contents

- How did I see the field change
- Early records & my background
- Learning curves & scheme
- Seven cases ("jokers")

Interactions, feedbacks, unpredictability, (eco)types

• Encouragements

How did I see the field change?

- Seagrass was relatively unknown
- Small scale -> larger scale; more funding
- More knowledge of complexity
- Socio-Ecological Systems
- There seems to be less time for reflection
- (NL) Managers were experts in the field, not anymore.
- Donor shortage and regulations
- 'Everybody' was male

Written sources seagrass restoration: Harmsen 1936 NL Addy 1949 US

Early records

Web of science hits (unfiltered)











Ccasionally joining team Covers and sea rangers



Oosterschelde

Home town: Nijmeger (den Hartog lab until 1996

My background:

Seagrass restoration projects since 1980s. Commissioned to restore natural values (NL), later EU regulation.

- 1989-2011: Wadden Sea
- 2007-2016: Oosterschelde
- 2017-2024: Grevelingen

1970s-2019: applied scientists at the Ministry: Victor de Jonge and Dick de Jong (Non-restoration seagrass research Indonesia, China, Caribbean)

- Entry point: Restoration
- Involve biogeochemistry, biophysics and social sciences, in collaboration

Today: (poster alert) Group Laura Govers + consortia: -subtidal Wadden Sea: Katrin Rehlmeyer, Raven Cammenga -intertidal Wadden Sea: Lisa Bruil -Oosterschelde : Maite Vogel -Lake Grevelingen: Lea Hahn

Oosterschelde Lake Grevelingen

> Home town: Nijmeger (den Hartog Jab until 1996

Wadden Sea

My background:

Seagrass restoration projects since 1980s. Commissioned to restore natural values (NL), later EU regulation.

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Indonesia, China, Caribbean)

- Entry point: Restoration
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 and social sciences, in collaboration

Learning curve

?





Web of science hits (unfiltered)

There is no end to learning

The path?



The Joker



Archetype of trickster, fool, harlequin, clown, jester

-positive and negative, unbound by being either high or low

-wild card: powerful and desirable, turning a losing hand in a winning one

-as a trickster: challenging norms, revealing hidden

truths, help characters grow

-adding chance, excitement and complexity

Important role of the joker in the learning trajectory Warning: we can be fooled by complexity.

Jokers: complexity and unpredictability

Seagrasses: why present, why absent, why conflicting signals, why seeming contradictions..

This bothers our QUEST: to have seagrass back! Challenge: turn jokers into knowledge

Scheme







Harlin 1995, Burkholder et al. 2002, van Katwijk et al. 1997, Govers et al. 2014



van Katwijk et al. 1999; Kamermans et al. 1999, Lab Cadiz: Brun, Perez-Llorens and coworkers

In practice: example from the Wadden Sea



Nutrient – seagrass correlation is context dependent -account for this in habitat suitability models;

Seagrass performance

Optimal grow

-we should still advise nutrient reduction for seagrass!

-Note: tissue %N remains relatively low under optimal conditions, so not always a good indicator



Fine sediments: cause or consequence?

Consequence!





Available online at www.sciencedirect.com

cienceDirect

Estuarine, Coastal and Shelf Science 74 (2007) 344-348

ESTUARINE COASTAL AND SHELF SCIENCE

Short Communication

Ecosystem engineering by annual intertidal seagrass beds: Sediment accretion and modification

Arthur R. Bos^{a,*}, Tjeerd J. Bouma^b, Geertje L.J. de Kort^a, Marieke M. van Katwijk^a

^a Institute for Wetland and Water Research, Department of Environmental Science, Radboud University, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands ^b Netherlands Institute of Ecology (NIOO-KNAW), Centre for Estuarine and Marine Ecology, P.O. Box 140, 4400 AC Yerseke, The Netherlands

However, checking natural meadows:

Vegetated versus unvegetated areas in four natural meadows:

One annoying population showed the reverse: not muddification, but sandification... Mistake?

5 yr later: same result..

Within meadow 35% fines

Adjacent bare area: 43% fines

Do others find sandification? Literature...

"A small eelgrass patch on an intertidal flat near Oakland, California, August 2003. Note the presence of coarser, sorted sediment within the patch as compared to the unvegetated, surrounding area."

Fonseca & Koehl 2006 ECSS



Flume studies Nepf & Koch 1999:

Enhanced flows behind single obstructions (like a seagrass plant)



Comparing 4 populations at 2 points in time..



Comparing A populations pt 2 points in time.

- Implications for carbon sequestration
- Positive and negative feedback

by seagrass beds: Muddification	ns Ra Netherlands	Sand	Mud
Short communication Short communication Sediment modification D' and envery envery Sediment of plant cover and envery envery induced by plant cover and envery envery envery induced by plant cover and envery envery envery induced by plant cover and envery envery envery envery envery induced by plant cover and envery	Dense	Muddi- fication	no effect
	Sparse	no effect	Sandi- fication



Classical example

Alternative stable states

state 1: seagrass present and clear water state 2: seagrass absent and turbid water under the same external circumstances



Wave energy (max. orbital velocity m s⁻¹)

Positive Feedbacks in Seagrass Ecosystems: Implications for Success in Conservation and Restoration Van der Heide et al. Ecosystems 2007

Tjisse van derHeide,^{1,2,*} Egbert H. van Nes,³ Gertjan W. Geerling,⁴ Alfons J. P. Smolders,^{2,5} Tjeerd J. Bouma,⁶ and Marieke M. van Katwijk¹





Also alternative stable states over depth gradient: US: Carr et al. 2010, 2012

There are many feedbacks

Maxwell et al. 2017

In practice: Seagrass where you dont expect it and vice verse... Restoration also involves restoration of the positive feedback



The fundamental role of ecological feedback mechanisms for the adaptive management of seagrass ecosystems – a review

Paul S. Maxwell^{1,†,*}, Johan S. Eklöf², Marieke M. van Katwijk³, Katherine R. O'Brien¹, Maricela de la Torre-Castro⁴, Christoffer Boström⁵, Tjeerd J. Bouma⁶, Dorte Krause-Jensen^{7,8}, Richard K. F. Unsworth⁹, Brigitta I. van Tussenbroek^{3,10} and Tjisse van der Heide¹¹







Unpredictability – natural variability

Example: Zostera noltii mitigation project Oosterschelde 2007-2014, The Netherlands



Foto's: Wim Giesen

Projectbureau Zeeweringen, Rijkswaterstaat, BTL, Radboud University Nijmegen, NIOZ-Yerseke



6 tidal flats

12-24 plots per tidal flat

5-9 patches per plot

Suykerbuyk, Govers, Bouma, van Katwijk et al. J.Appl.Ecol. 2016



Suykerbuyk, Govers, Bouma, van Katwijk et al. J.Appl.Ecol. 2016



Aug08 June09 `(first winter) June09 – Aug09 (next summer)











June09 `(first winter)

Aug08

June09 – Aug09 (next summer)

Suykerbuyk, Govers, Bouma, van Katwijk et al. J.Appl.Ecol. 2016





Failures & Successes





June09 – Aug09

(next summer)

Aug08 June09 `(first winter)

Suykerbuyk, Govers, Bouma, van Katwijk et al. J.Appl.Ecol. 2016

Key variables: sediment dynamics and desiccation

Ecological Applications, 22(4), 2012, pp. 1224-1231 © 2012 by the Ecological Society of America



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Journal of Applied Ecology

Journal of Applied Ecology 2016, 53, 774-784

Unpredictability in seagrass restoration: analys role of positive feedback and environmental st Zostera noltii transplants

MARINE ECOLOGY PROGRESS SERIES Mar Feol Prog Ser Wouter Suykerbuyk^{1,2,*}, Laura L. Govers¹, Tjeerd J Dick J. de Jong⁴, Roy van de Voort⁴, Kris Resilience of Zostera noltii to burial Katwijk¹

Vol. 449: 133-143, 2012 doi: 10.3354/meps09532

© 2015 The Author(s). This article is published with open access a Ecosystems CrossMark Surviving in Changing Seascapes: Sediment Dynamics as Bottleneck for Long-Term Seagrass Presence Wouter Suykerbuyk,^{1,2}* Tjeerd J. Bouma,² Laura L. Govers,¹ Kris Giesen,^{1,2} Dick J. de Jong,³ Peter Herman,^{1,2} Jan Hendriks,¹ and Marieke M. van Katwijk¹ Living in the intertidal: desiccation and shading reduce seagrass growth, but high salinity or population of origin have no Wouter Suykerbuyk^{1,2}, Laura L. Govers^{2,3,4}, W.G. van Oven¹, Krie Giecon^{1,2}, Wim BIT Giecon⁵, Dial J. J. W.G. van Oven¹, Wouter Suykerbuyk ***, Laura L. Govers ****, W.G. van Oven, Kris Giesen 1,2 Wim B.J.T. Giesen 5, Dick J. de Jong 6, Tjeerd J. Bouma 1 and Marieke M. van Katwijk^{1,2}

Key variables: sediment dynamics and desiccation

Partly <u>unpredictable</u> (stochastics of the weather).

In practice: spread risks in space and time!





Today: one established population in Oosterschelde

Combining positive feedback and natural variability



van Katwijk et al. 2016

Synergy by combining spatial extent and planting



density

Recovery of feedback

i.e. planting density > density required to restore self-sustaining feedback



Best chance of recovery \/\//

Irony of the test plot: unlikely to succeed

Vulnerable to absence of positive feedback

Spread of risk

i.e. spatial or temporal extent of planting > spatial or temporal extent of environmental variability





van Katwijk et al. 2016

Synergy by combining spatial extent and planting density

Large scale is important!

Journal of Applied Ecology

Journal of Applied Ecology 2016, 53, 567-578

doi: 10.1111/1365-2664.12562

Global analysis of seagrass restoration: the importance of large-scale planting

Marieke M. van Katwijk^{1*}, Anitra Thorhaug², Núria Marbà³, Robert J. Orth⁴, Carlos M. Duarte^{3,5,6}, Gary A. Kendrick⁵, Inge H. J. Althuizen¹, Elena Balestri⁷, Guillaume Bernard⁸, Marion L. Cambridge⁵, Alexandra Cunha⁹, Cynthia Durance¹⁰, Wim Giesen^{1,11}, Qiuying Han¹², Shinya Hosokawa¹³, Wawan Kiswara¹⁴, Teruhisa Komatsu¹⁵, Claudio Lardicci⁷, Kun-Seop Lee¹⁶, Alexandre Meinesz¹⁷, Masahiro Nakaoka¹⁸, Katherine R. O'Brien¹⁹, Erik I. Paling²⁰, Chris Pickerell²¹, Aryan M. A. Ransijn¹ and Jennifer J. Verduin²²



Recovery of feedback

variability

i.e. planting density > density required to restore self-sustaining feedback





van Katwijk et al. 2016



Wadden Sea (Netherlands, Germany, Denmark), SW Netherlands, NW-coast US





Bayer 1979, Leuschner et al. 1998; van Katwijk & Hermus 2000; van Katwijk et al. 2000, 2009, Boese et al. 2005, Suykerbuyk et al. 2019)

Photo courtesy, vK, Dolch, vK

Wadden Sea (Netherlands, Germany, Denmark), SW Netherlands, NW-coast US



Bayer 1979, Leuschner et al. 1998; van Katwijk & Hermus 2000; van Katwijk et al. 2000, 2009, Boese et al. 2005, Suykerbuyk et al. 2019)

Photo courtesy, Dolch, vK

Wadden Sea (Netherlands, Germany, Denmark), SW Netherlands, NW-coast US



Desiccation and water dynamics...



Bayer 1979, Leuschner et al. 1998; van Katwijk & Hermus 2000; van Katwijk et al. 2000, 2009, Boese et al. 2005, Suykerbuyk et al. 2019

Photo courtesy, Dolch, vK

Is this genetic?

Perfect abiotics, no recovery?



Salinity



van Katwijk et al. 2023, Sustainability

Perfect abiotics, no recovery?

J Salinity

van Katwijk et al. 2023, Sustainability





Salinity

-Salinity changes likely selected the
'wrong' ecotype
-Isolation likely prevented the
colonisation by nearby suitable types.

In practice: introduce suitable ecotype

van Katwijk et al. 2023, Sustainability



Perfect abiotics, perfect ecotype, still low restoration success?

Biotic interactions!



Ν



Perfect abiotics, perfect ecotype, Biotic interactions!













Illustration and photo's: Rens Cronau PhD thesis 2024 Cronau et al. 2022, 2023, 2025 online Collaboration Field Work Company & RU Groningen Slikken van Flakkee 7 aug 2024, Laura Govers. No ragworms. Planted 2023

Cointroduction Littorina and invasive grazer Presently: success!

University of Groningen, The Fieldwork Company, Witteveen+Bos and many more See poster Lea Hahn group Laura Govers

Veermansplaat 2024

Planted 2023

Foto Nadia Hijner, Stampersplaat, Grevelingen, geplant 2023 genomen op 3 juli 2024. Herkomst Limfjorden

Veermansplaat 17 juni 2024 Pleiades-NEO RGB



Seed availability / 'propagule pressure'

Red areas: -most suitable? -most hit by seeds?



13 years of monitoring.

Red=*Z.marina* present in all 13 monitoring years; Blue= only once



Fig. 2. Distribution map of Zostera marina in the Ems estuary showing the frequency of occurrence (number of years) within the period 1995–2009 (excluding 1998)

Valle et al. 2013; Suykerbuyk et al. 2016b

Seed availability / 'propagule pressure'

Likewise: Is the dike area really suitable, or merely seed accumulation?



13 years of monitoring. Red=*Z.marina* present in all 13 monitoring years; Blue= only once



Fig. 2. Distribution map of Zostera marina in the Ems estuary showing the frequency of occurrence (number of years) within the period 1995–2009 (excluding 1998)

Likely: combination of suitability & seed availability

Restored meadows Virginia Bays, US:

(Oreska et al. 2021 ESCO)

In practice: for long-term restoration success: a suitable restoration site is also a potential sink of seed...

(~metapopulation dynamics, vK ea 2024)

There is no end to learning..



Oreska et al. 2021 ESCO

Encouragements: improve learning curve $P_{4b/i_{sh}}$ embrace every opportunity to generate knowledge, from any trial!

Publish! embrace every opportunity to generate knowledge, from any trial!

Management/funder	Science jargon	Restoration activity
jargon:		

embrace every opportunity to generate knowledge, from any trial!



Management/funder jargon:	Science jargon	Restoration activity
Advance Technology Readiness level	Science	Use and generate knowledge

embrace every opportunity to generate knowledge, from any trial!



Management/funder jargon:	Science jargon	Restoration activity
Advance Technology Readiness level	Science	Use and generate knowledge
Use best available knowledge	Generate hypotheses	Thorough desk study

embrace every opportunity to generate knowledge, from any trial!



Management/funder jargon:	Science jargon	Restoration activity
Advance Technology Readiness level	Science	Use and generate knowledge
Use best available knowledge	Generate hypotheses	Thorough desk study
Spread risks regarding: -natural variability -remaining knowledge gaps -year-to-year differences	Apply replicates & treatments	Experimental setup of trials -assign a special place for left-over plants, do not plant them IN a trial -have ≥ 1 treatm identical over years

General: Embrace jokers: you may be at the brink of a new discovery: your jokers will turn into knowledge.





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