



# Regrowth in Ship's Ballast Water Tanks: Think again!

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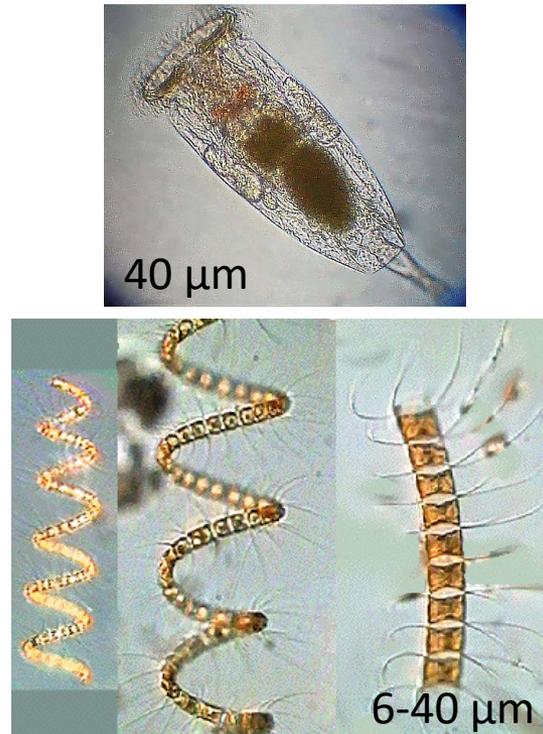
# LIFE IN BALLAST WATER

Meet the usual suspects:

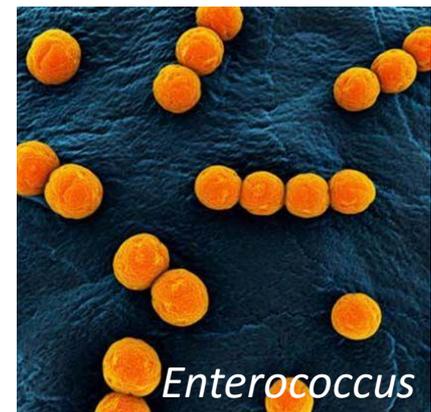
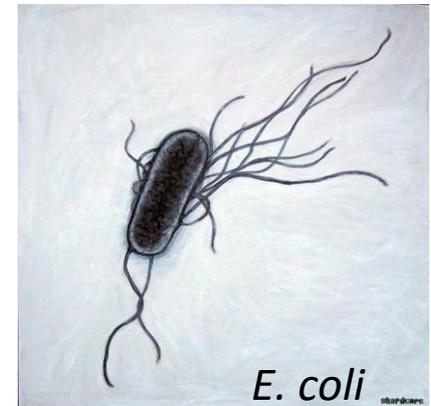
Organisms  $\geq 50 \mu\text{m}$   
→ mainly Zooplankton



$< 50$  and  $\geq 10 \mu\text{m}$   
→ Zooplankton +  
Phytoplankton



→ Bacteria (0.5-2  $\mu\text{m}$ )



# LIFE IN BALLAST WATER

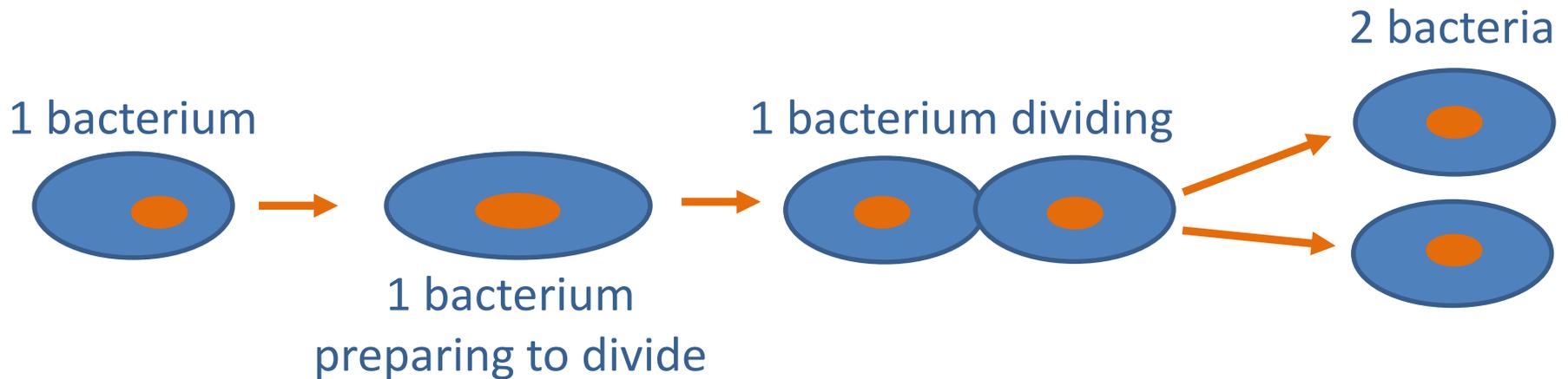
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- Individuals from all these categories are present in ballast water, in one form or another
- In general, the number of individuals decreases with increasing size, so small organisms such as bacteria are much more abundant than larger organisms such as adult zooplankton
- The BWTS of choice has to be effective & robust in killing all of these organisms!

# THE PROBLEM WITH REGROWTH

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Why should we care?: **IT ONLY TAKES ONE!**

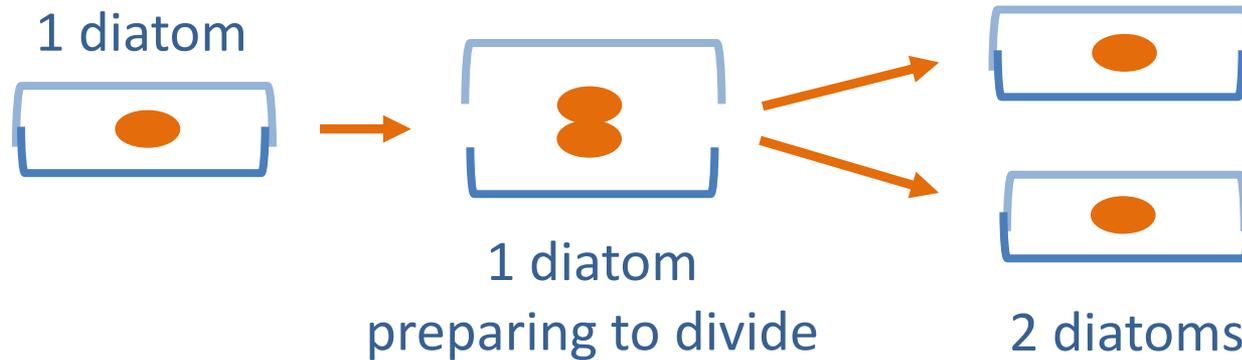


...then **MANY bacteria** in a very short period of time!

# THE PROBLEM WITH REGROWTH

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Why should we care?: **IT ONLY TAKES ONE!** (most of the time)



# THE PROBLEM WITH **REGROWTH**: Zooplankton

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→ Mainly in the  $\geq 50 \mu\text{m}$  size category

→ In productive coastal regions, copepods (a dominant zooplanktonic group) can reach **180 per  $\text{m}^3$** , depending on their sizes [Escribano *et al.*, 2015]

→ **Easier to determine viability**, by testing for movement and response to stimuli, and testing for organ activity (e.g. heartbeat) [BWM.2/Circ.42/Rev.1, 2015]

# THE PROBLEM WITH **REGROWTH**: Zooplankton

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- Provide **shelter for bacteria** & can therefore allow them to survive certain ballast water treatments [Tang *et al.*, 2011]
- **Not all** are **retained by filters** in BWTS [Gregg *et al.*, 2009]
- Many zooplankton species are **likely to survive** certain ballast water treatments [Gregg *et al.*, 2009]

**Zooplankton could potentially feed on bacterial regrowth and in turn increase in numbers**

# THE PROBLEM WITH **REGROWTH**: Dead or Alive?

Dead



Alive



Dead



Alive



# THE PROBLEM WITH REGROWTH: Phytoplankton

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→ Mainly in the  $< 50$  and  $\geq 10 \mu\text{m}$  size category, but also many are  $\ll 10 \mu\text{m}$  (important consideration for the future)

→ In productive coastal regions, phytoplankton can reach  $>10 \times 10^9$  cells per  $\text{m}^2$  (integrated over 40 m)

[Morales et al., 2007]

→ **Viability** can be assessed using PAM Fluorometry, but this is not quantitative [BWM.2/Circ.42/Rev.1, 2015]

# THE PROBLEM WITH **REGROWTH**: Phytoplankton

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→ **More difficult** to analyse by **visual inspection**

[BWM.2/Circ.42/Rev.1, 2015]

→ Can survive in the darkness of ballast tanks for **23 days** [Kang *et al.*, 2010]

→ Can **regrow within 4-20 days** of being put back into **benign conditions** [Stehouwer *et al.*, 2010; Stehouwer *et al.*, 2015; van der Star *et al.*, 2011; Liebich *et al.*, 2012; Martinez *et al.*, 2013]

**Clear evidence of high phytoplankton potential  
for regrowth after ballast water treatment**

# THE PROBLEM WITH REGROWTH: Bacteria

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→ 0.5-2  $\mu\text{m}$  in size

→ In productive coastal regions bacteria can reach abundances of  $10^8$ - $10^9$  cells per Litre [Cuevas et al., 2004]

→ Death of other organisms benefits bacteria growth through the release of nutrients in the form of Dissolved Organic Matter (DOM) [Carney et al., 2011 ; Lasternas & Agusti, 2014; Buchan et al., 2014] and through a decrease in the number of predators [Hess-Erga et al., 2010]

# THE PROBLEM WITH **REGROWTH**: Bacteria

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→ **Viability** tests for indicator bacteria are time-consuming

→ **Bacteria regrowth** has been observed after **18 hrs to 7 days** of using different ballast water treatment technologies [Hess-Erga *et al.*, 2010; Waite *et al.*, 2003; Tryland *et al.*, 2010; First & Drake, 2014; Rubio *et al.*, 2013; Wennberg *et al.*, 2013]

**Clear SCIENTIFIC evidence of bacterial regrowth after treatment**

# THE PROBLEM WITH **REGROWTH**: Bacteria

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How quickly can it happen?

**For Bacteria = 18 hrs to 7 days after treatment**

**From Phytoplankton = 4 to 20 days after treatment**

**For Zooplankton = anytime after regrowth of their  
food supply**

# THE PROBLEM WITH **REGROWTH**

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## What can we do about it?

→ **NO** single BWTS is **100% efficient** in killing all ballast water organisms [GOV. UK., 2012; Tsolaki & Diamadopoulos, 2009; Stehouwer *et al.*, 2010; Chase *et al.*, 2009]

**Choose the technology that is appropriate for the duration of the ship's voyage, because it could only take ONE surviving cell to EXCEED Discharge Standards!**

# THE PROBLEM WITH REGROWTH

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**For example:**

→ According to the evidence presented here, if ballast water treatment takes place only at intake then **bacteria** regrowth could occur in ballast water tanks between:

**18 hrs to 7 days**

→ Therefore, the longer the ship's voyage, the higher the probability of regrowth leading to discharge numbers exceeding the limits established by IMO and USCG

# CONCLUSIONS

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**It would only take ONE surviving cell for regrowth to occur**

**Scientific evidence presented here supports the idea that it is not an issue of “IF regrowth” but “WHEN regrowth”**

**The issue of regrowth should be taken seriously & into consideration when choosing an appropriate BWTS**

# SUMMARY

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## The problem with **REGROWTH**

- We should care because it is **inevitable!**
- It is only a matter of time and it can occur in as little as **18 hrs after treatment**
- Should be taken into consideration when choosing an appropriate BWTS

## The 'take-home' message

- REGROWTH....**THINK AGAIN!**

# THE END

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Thank you very much for your attention

**Any questions?**

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