



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

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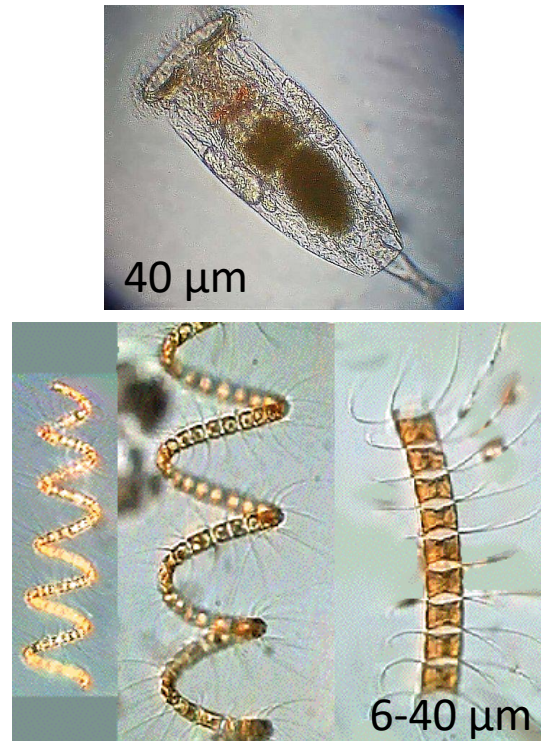
LIFE IN BALLAST WATER

Meet the usual suspects:

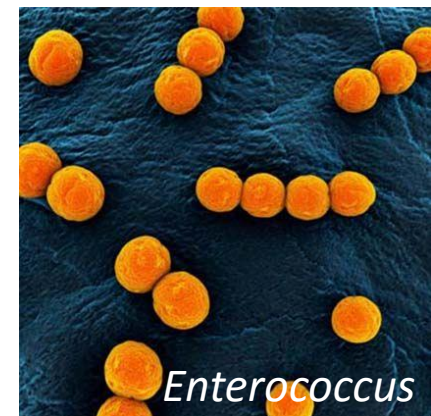
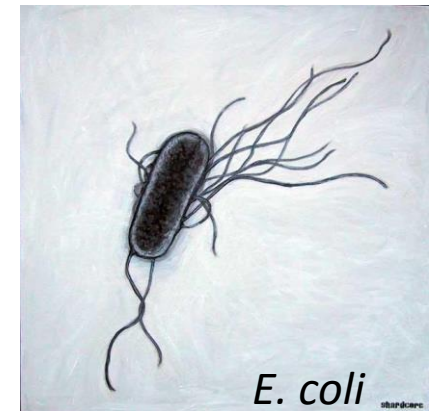
Organisms $\geq 50 \mu\text{m}$
→ mainly Zooplankton



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



→ Bacteria (0.5-2 μm)

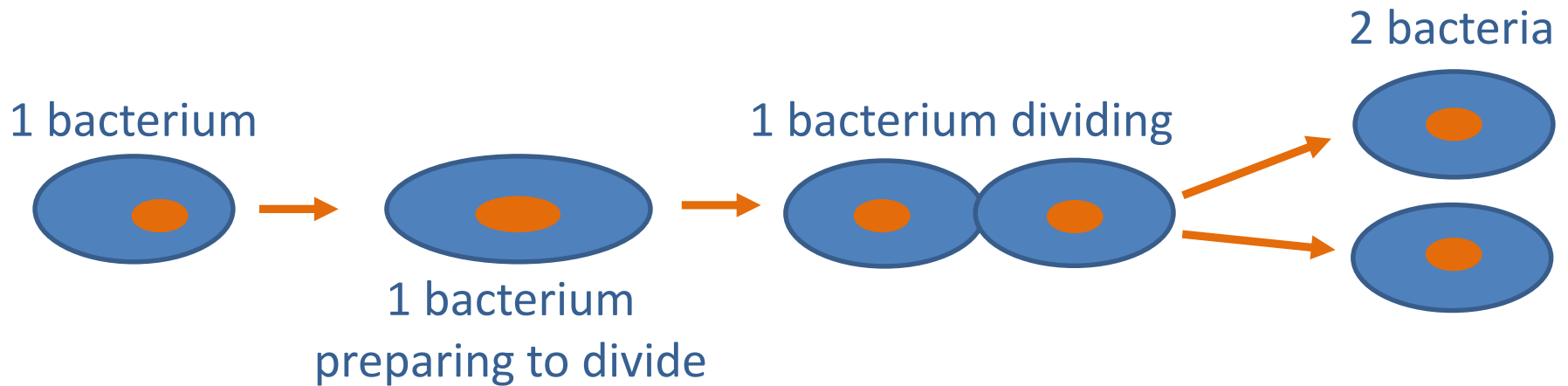


LIFE IN BALLAST WATER

- 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**

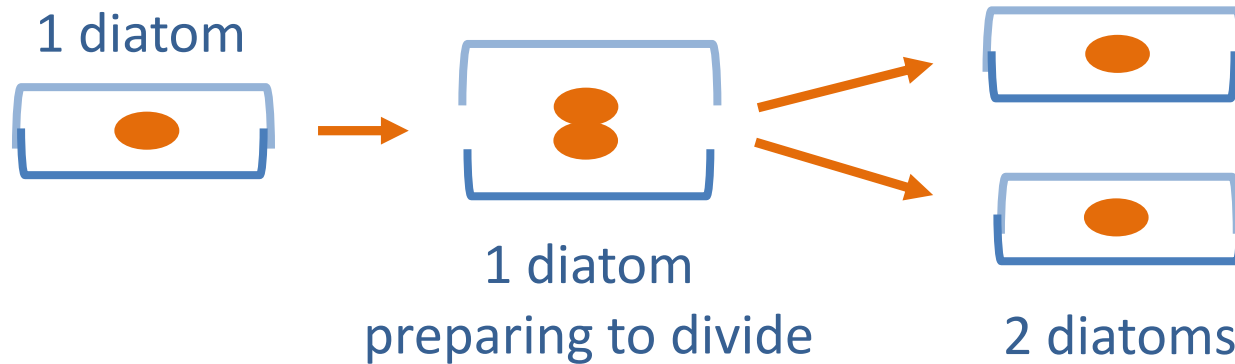
Why should we care?: **IT ONLY TAKES ONE!**



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

THE PROBLEM WITH REGROWTH

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



THE PROBLEM WITH **REGROWTH**: Zooplankton

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

→ In productive coastal regions, copepods (a dominant zooplanktonic group) can reach **180 per 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

- 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

→ Mainly in the < 50 and ≥ 10 μm size category, but also many are $\ll 10$ μm (important consideration for the future)

→ In productive coastal regions, phytoplankton can reach $>10 \times 10^9$ cells per 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

→ **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

→ 0.5-2 μm 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

→ **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

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**

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

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

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

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

Thank you very much for your attention

Any questions?

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