TO FILTER, OR NOT TO FILTER:

THAT IS THE QUESTION

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Ballast water treatment technologies must meet stringent performance standards at the point of discharge. Currently, no matter the technology used, a filtration step appears crucial to remove large organisms present in the intake water, to ensure a minimum but still sufficient residual biocide or oxidant concentration, and to decrease the sediment load. Organisms potentially able to survive the initial treatment are those benefiting from a behavioral or morphological refuge allowing them to temporarily escape from lethal or stressful environmental conditions, or those present in such unusually high concentrations that the treatment system is overwhelmed, or a combination of both conditions. Many different species have evolved a capacity to endure stressful environments, such as low dissolved oxygen concentration, desiccation, or toxins, by isolating themselves inside impermeable shells (e.g., mussels, clams) or organic coatings (e.g., egg capsules, cysts), or by burying themselves in sediments (e.g., bacteria, worms).

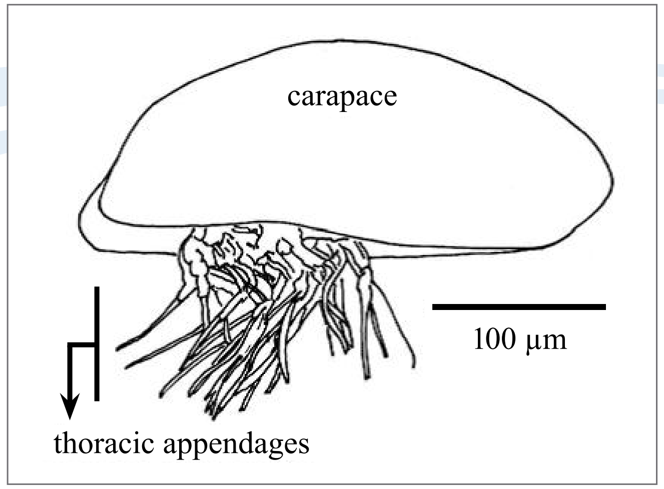

Figure 1. Barnacle 'Cypris' larva with appendages or legs extending beyond the carapace (drawn from Figure 2 in [9], with permission from John Wiley & Sons, Inc.)

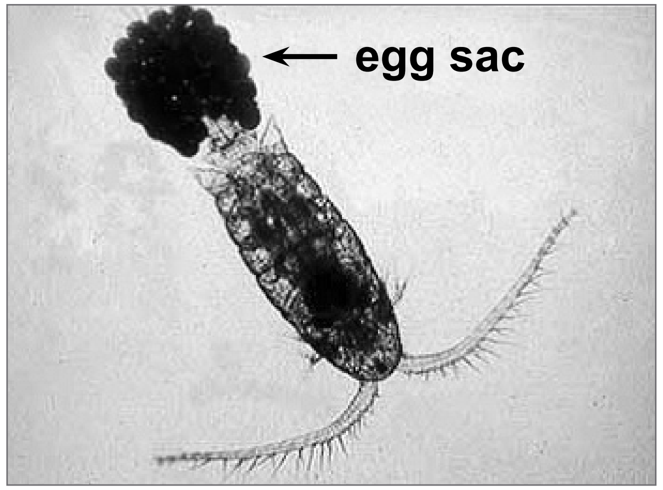

Figure 2. A healthy adult female Eurytemora affinis can reach over 1 mm in size and carry up to 30 eggs [8] (Photo by Carol E. Lee with permission, downloaded from http://life.bio.sunysb.edu/marinebio/plankton.html).

At the time and point of ballast water intake, high concentrations of organisms may be encountered when invertebrates are spawning, or when water column stratification favors accumulation of thin layers of organisms at a depth close to ballast water intake. Sustained intake of high biomass might incidentally over-task otherwise efficient treatment systems. Instances of high concentrations abound. A few examples follow. Barnacles are not only pests for fouling the hull of ships, but their prolific and, for some species, synchronous release of larvae can result in tens of thousands of individuals per cubic meter in the vicinity of water intake (e.g., [1]). Furthermore, barnacles metamorphose to the 'Cypris' larval stage that has a protective bivalved carapace which gives the larvae a temporary refuge against adverse conditions.

Certain opisthobranch gastropods, such as some sea hares, produce an enormous number of eggs encased within gelatinous free-floating masses [5]. Free-swimming 'Veliger' larvae of prosobranch gastropods (snails) are protected by an operculum, like a lid that can tightly close the shell [13]. Many adult female bivalves (e.g., the zebra mussel) can release over one million eggs in a single spawning event [12], with the potential to reach, a few days after fertilization, the 'Veliger' larval stage and the beginning of shell formation, thus affording a good refuge when the two valves are tightly closed. Mussel 'Veliger' concentrations of over half a million per cubic meter have been reported in the Netherlands waterways [11]. It has also been shown that, although egg-carrying copepod females were easily killed by a biocidal treatment, some eggs survived and hatched later on after the biocide had dissipated (Campbell and Maranda, unpublished data) (Figure 2).

Some planktonic organisms, such as many microalgae responsible for harmful algal blooms, form highly protected dormant structures, the cysts, to help them survive adverse conditions. Cysts settle out of the water column and accumulate in the sediments. When large ships dock or are helped by tugboats in shallow waters, sediments, along with cysts, can be re-suspended into the water column (Figure 3), and taken in during ballasting operations. Should the cysts be transferred to new coastal environments when the ships release their ballast waters, they could germinate and seed local waters, if conditions are favorable. The dangers to local resources by the release of such noxious species and their toxins are well documented, because of their transfer through the food web [6, 7, 10].

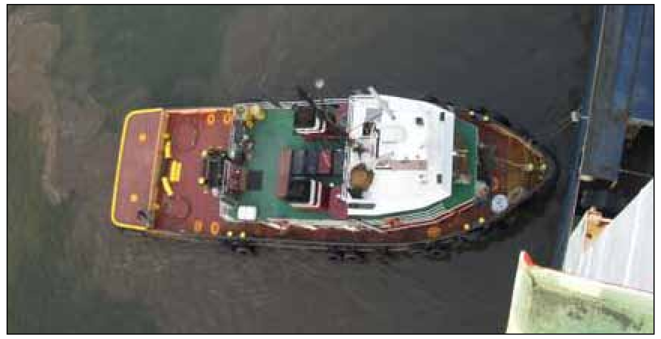

Figure 3. Upper-bridge view of a tugboat at work pushing a RO-RO vessel in theport of Newark, New Jersey, USA. Note the sediments being put back in suspension.

When the above entirely plausible but not necessarily usual situations are taken into consideration, it becomes obvious that a ballast water treatment system must be designed to handle not the average biomass, but the most severe challenges. A filtration step in a treatment system would thus ensure that total biomass and sediment load are somewhat reduced. Filtration systems down to a mesh size of 50 µm with backwash capabilities to minimize clogging are commercially available and have been shown to deliver on expected biomass reduction [2]. A mesh size of 50 µm would indeed be sufficient to remove most invertebrate larvae and eggs and reduce sediment intake [3, 4].

Acknowledements

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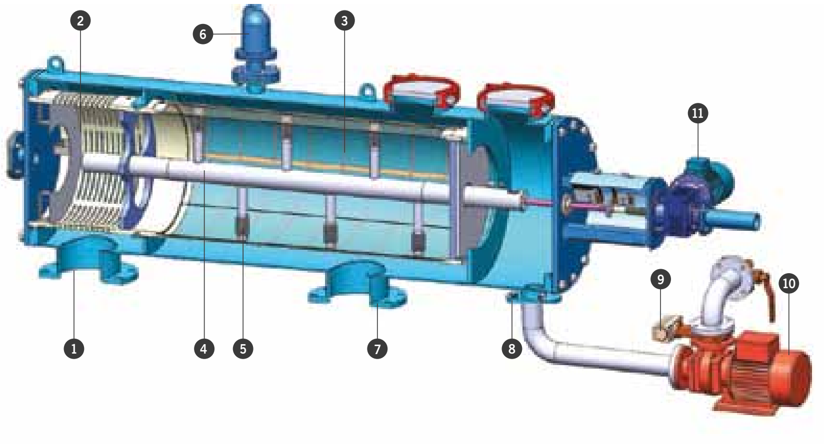

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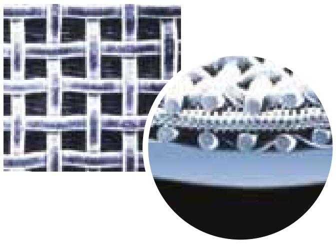

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