Fighting the invasion

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Today, invasive species are one of the most serious threats to aquatic ecosystems worldwide. ECO speaks with Kim Lundgreen, Ph.D. Student at the University of Southern Denmark, as he reveals the extent of this international problem as well as the steps being taken to reduce the spread and restore the balance in favor of native communities.

ECO: The spread of aquatic invasive species is a well-known issue impacting coastal ecosystems around the world. But how serious is the problem?

I would say it is very serious, and I don’t think many people are truly aware of the extent of the problem; or the huge economic costs when combining both aquatic and land-based invasive species. It was estimated some years ago, that the negative impact of all invasive species put together was equivalent to five percent of the annual world economy – something in the order of $1,400,000,000,000. This is a number that is hard to grasp; even if the costs are overestimated and it is only perhaps half this value, it is still an astonishing number.

Today’s economic burden of land-based invasive species is estimated to be much higher than for aquatic but the continuous introduction of new invasive species in aquatic environments means this will likely increase. A 2012 report from the United Nations Environment Programme estimated annual global costs to be in the order of $100 billion for controlling and preventing the spread of aquatic invasive species. I find this number to be frighteningly high.

I don’t think people had foreseen that “just” moving some organisms around a bit would have such severe consequences, not only economically but also regarding harmful effects on ecosystems and human health.

ECO: What are the main ways organisms are being transported?

Organisms can be transported via hull fouling, where they attach themselves on the outside of the ship’s hull, but the major transport occurs in the ships’ ballast water. Not many people know what ballast water actually is or what it’s used for, and that it is the most important player in the spreading of aquatic invasive species.

Ballast water is a necessity for all large ships for safety and economic reasons. It is used for reinforcement of the hull and for adjusting and trimming the position of the ship during voyage in relation to cargo load for better stability and fuel consumption. Some of the biggest ships out there can carry up to 100,000 m$^3$ of ballast water. That’s the same as 40 Olympic sized swimming pools.

In theory, there can be thousands of different species and billions of planktonic cells inside ships’ ballast water tanks during voyages.

ECO: Are there species that are more likely to spread than others?

To be acknowledged as an ‘invasive species,’ an organism must first survive the treatment process during intake. The ballast water is cleaned by treatment systems which are very efficient in removing the larger aquatic animals, but also costly for the ship-owners: the price for some of the treatment systems that can handle large volumes of water are within the range $1-3$ million.

Some of the smaller and tougher species can potentially survive if treatment is not optimal, and they are therefore more likely to spread. This especially includes organisms with egg or larval stages such as crustaceans and mollusks, but some algal species have also shown to be robust towards treatment procedures.

Next, they must survive the potentially long passage in the dark ballast water tanks, and eventually a second treatment that happens before the water is discharged into a new environment.

Organisms must also be able to survive and overcome the new conditions where different ecological factors might dominate in relation to the area they originally came from. Finally, it must be able to adapt to a degree where it succeeds in reproducing and establish a population. Once an invasive species has established a reproductive population it can out-compete local species and multiply into pest proportions.

The damage invasive species exert on the environment and biodiversity is considered one of the most serious threats to aquatic ecosystems worldwide. These damages are often irreversible as it is almost impossible to eliminate an invasive species once a population has been established.

One of the most “successful” – and thereby least wanted – invasive species is the zebra mussel in the Great Lakes. It is native in Eastern Europe where the population is controlled by natural predators. Consequently, the absence of these predators in the Great Lakes and the perfect ecological conditions led to a population explosion after it was introduced via the discharge of ballast water. This caused the near extinction of some local species and, as the mussels consume large quantities of phytoplankton, there was a decrease in the food availability for commercial and game fish in the area. It is estimated that zebra mussels will outcompete 50 percent of the native species.
mussels, eventually causing extinction of more than 100 species. The major economic impacts include clogging the pipes of water treatment facilities and power plants, resulting in huge expenses and mobilization of resources in cleaning operations, as well as costly damages on boats and harbor areas.

Other successful invasive species that have caused major ecological and economic damage are the North American comb jellyfish, the European crab, and the North Pacific sea star which have all had devastating impacts on the fishing industry. The parasitic salmon flukes that infect salmon can cause catastrophic losses in aquaculture productions. And finally, toxic algal blooms can kill or harm other organisms – including humans – and blooms also cause huge economic losses for areas reliant on tourism due to the periodic damage and closing of beaches.

ECO: How has this issue evolved with the growth of the shipping industry?

Until the 19th century, ships’ ballast was solid, typically rocks, but with the introduction of steel ships the solid ballast was replaced by water which was more flexible and could be adjusted according to cargo load.

The use of water as ballast introduced the transportation of unwanted organisms to different corners of the world. Wherever ships were able to establish stable populations and became the first harmful invasive species.

Shipping is the most cost-efficient way of moving goods and, for that reason, shipping accounts for about 80 percent of the global transportation of goods today. It has been estimated that between four and ten billion tons of ballast water is moved around the world annually. With the growing maritime trade caused by globalization, the demand for more and larger ships will, in my opinion, also increase the risk of transporting potential invasive species in ships’ ballast water.

One of the most recent concerns today in terms of invasive species is focused on the opening of Arctic Ocean shipping routes. The Arctic has, until now, been isolated from potential invasions due to its harsh climate but with the opening of the shipping lanes, the pristine Arctic eco-systems may now become vulnerable.

ECO: What is being done to reduce the spread?

I think it is fair to say that the impact of aquatic invasive species was underestimated, and our efforts to implement control and management systems to encircle and contain the problems were initiated too late and too slow.

The “International Convention for the Control and Management of Ships’ Ballast Water and Sediments” was adopted by the International Maritime Organization (IMO) in 2004 – many years after it was globally accepted that this was a huge environmental and economic issue. It wasn’t until September 2017 that the convention was ratified. All ships are now required to have a ballast water treatment system on board that has been thoroughly verified by testing facilities approved by the IMO.

But many invasions have already occurred, and it seems like there is no saturation tendency in the accumulation of aquatic invasive species. However, it is important to keep complying with current regulations regarding ballast water treatment systems. The regulations are constantly being evaluated and work done by initiatives such as Global TestNet and GlBlueast Partnership Programme are central in optimizing current regulations for better protection. Both initiatives aim to increase levels of standardization, support development of new technologies, as well as uphold transparency and openness in testing of ballast water management systems.

ECO: What challenges does the industry face in stemming this issue and meeting new regulation requirements?

Implementing new technologies for treatment systems onboard existing ships is always a challenge, both regarding space limitations and economy. The so-called retrofitting is necessary in thousands of ships, so dry dock capacity is also a challenge.

When a treatment system is installed and running onboard a ship, there isn’t currently enough technology to help verify the effectiveness of the system. The pristine Arctic environment is challenging to evaluate by whether ships comply with the regulations set by the IMO and U.S. Coast Guard.

It’s my impression that research communities and the industry are working closely together to find solutions. And it’s important that the maritime community closely works with the scientific community to succeed in the most relevant and pressing technical and biological issues that science needs to address to keep improving treatment systems and testing procedures, and help limit any further spreading of aquatic invasive species.

For example, my Ph.D. project at University of Southern Denmark is a collaboration with DHI Water & Environment, which is an IMO approved testing facility. Together, we are addressing the question: Does the use of laboratory cultured standard test organisms mixed with natural algal populations reduce the sensitivity of the testing procedures for organisms in the size class 10-50 μm?

The use of a standard test organisms is necessary for most testing facilities because natural algal population concentrations are not always high enough to fulfill the concentration requirements for testing ballast water treatment systems. Because of this, it is common practice to add algal species to reach the requirements for testing. But it has also been asked if these organisms are “weaker” than natural algal species and whether the use of them lowers test water quality.

If that is the case, the result will be less conservative testing and there is a risk of approving treatment systems that are too weak. On the other hand, if standard test organisms turn out to be as or even more robust than natural species, the practice of mixing can be considered safer. Our research has shown that standard test organisms are promising candidates to use together with natural algal populations for sounder validation of treatment systems. All treatment systems need to fulfill some discharge standards set by the IMO and U.S. Coast Guard. This means that the treatment process water samples must be collected and analyzed for number of living organisms in different size classes. The current method for quantification of the size group 10-50 μm, which mainly consists of phytoplankton, requires labor intensive microscopic counting, is relatively slow, requires specialized personnel, and is challenged by subjectivity.

In my research, we are currently developing an automated, faster and more objective method by using a high content screening platform and image analysis software and have produced some promising results for an alternative quantification assessment method for validation of treatment systems.

ECO: Do you think with continued collaboration between science and industry, we can one day stop the spread of invasive species?

Overall, I think the scientific community is very interested and motivated in helping the industry as the shared goal is protection of the environment, human health, and the conservation of pristine ecosystems. And the industry can benefit a lot from collaborations with researchers: often in a highly competitive industries like the shipping industry lack the resources to explore the technical and biological challenges they face. In the scientific community, that resource can be mobilized if the outcome of the collaborations results in publications. But for these mutual collaborations to bloom it is essential that there is effective communication between the two communities.

Still, I do not think we will ever be able to stop the spread of aquatic invasive species. With the right attitude and the combined use of expert knowledge from the IMO, U.S. Coast Guard, initiatives such as GlobalBallast Project and Global TestNet, the industry, politicians and the scientific community, I am optimistic about at least slowing down the flow of invasive species and result in partial recovery of some affected habitats and improve conditions for sensitive native species worldwide.