Tara Gadoua

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The effects of oil spills on zooplankton population on West Coast of Newfoundland

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Introduction

Zooplankton are incredibly important for marine ecosystem as they play a pivotal role in marine food web dynamics. (Almeda 201). Zooplankton are not a single type of organism, but rather refers to organisms that 'drift' in the ocean, comprised of invertebrates and fish larvae. For these organisms, size is no indication of value, as they are at the foundation of the marine food web, and an important source of protein in the ocean. According to Banse (1995), 'zooplankton play a key role in marine pelagic ecosystems as grazers on phytoplankton and microzooplankton, exporters of carbon and nutrients from surface waters, and vectors for carbon and toxins to higher trophic levels'. Zooplankton are incredibly important in marine pelagic ecosystems (Cohen et al. 2014). There are micro-& meso-zooplankton (depend on size), and they do a number of things. Zooplankton will graze on the phytoplankton and smaller zooplankton, making these available for higher trophic levels. While all zooplankton are important, I will be focusing on type of mesozooplankton called 'copepods'. These are often dominant in zooplankton food web, and are key sources of energy for other organisms. Furthermore, there have been many studies performed on this group of organisms, particularly in terms of what effects oil spills might have on them. Copepods are a dominant group of mesozooplankton that form calcium carbonate shells.

The effects of oil spills on copepods are not taken into account in environmental assessments. However, as will be demonstrated, impacts on these copepods could have far-reaching effects in the ecosystem, some that cannot be predicted. There is limited information available on this subject. Because they are so small and numerous, impacts on them are expected to be negligible. But this might be a false assumption, and could prove to be dangerous since effects on zooplankton could have an impact on the higher trophic levels that feed on it. For instance, there many organisms that feed on zooplankton, such as cod, particularly in the early stages of life, and so impacts on zooplankton could inadvertently harm these other organisms.

Data was missing for the west coast in terms of what zooplankton we have here. I looked at different areas of the gulf and obtained data on the type of zooplankton located there. The study I found recorded data for areas in the southwest as well as the Northwest Gulf of St-Lawrence (name these two areas). I also looked at information of zooplankton along the eastern coast of Newfoundland and Labrador, and in general of types of zooplankton in the Northern Atlantic. Oil spills can affect these buggers in a number of ways, not just from the immediate physical effects, but also in terms of the dispersants and the myriad of toxic compounds that they contain, and longer term effects, and sub-lethal effects that are often glossed over.

Since there is growing interest in oil development in the Gulf of St-Lawrence, and along the west coast of Newfoundland, this research comes at an important time. Also given that such oil spills as the Exxon Valdez spill, which we will touch upon later, and the BP oil spill, have proven to have catastrophic events. I will be seeking to answer the following questions:

-1) What is the role of copepods in the Gulf of St. Lawrence marine environment?

-2) What are the major aspects of oil and gas development in the gulf that could affect copepods and what are the implications of these factors?

Methodology

So this methodology is basically a literature review. I looked at a couple of papers that talked about the effects of oil spills on zooplankton. One of the papers I looked at studied the interactions between zooplankton and pollutants. Another looked at the sub-lethal effects of PAHs, and others looked at pyrene contamination, a PAH. I tried to relate this back to Newfoundland as much as I could, but information was lacking for Newfoundland mostly.

Types of Plankton on the Coast

There are two main types of plankton, and these are phytoplankton and zooplankton. Phyto refers to 'plank', and includes all those plants drifting on in the water such as diatoms and algae (OCEANIC.ORG). These organisms, under the right conditions, are responsible for the photosynthesis of the oceans, and important nutrients. From here, the other kind of plankton we heard about, the zooplankton, feed on the phytoplankton. These are the animal plankton, hence where the prefix 'zoo' comes from. The most common of these is the copepod, a very tiny crustacean. The North Atlantic has the highest plankton bloom in the world every spring (OCEANIC.ORG). There are micro-& mesozooplankton (depend on size), and they do a number of things. Zooplankton will graze on the phytoplankton and smaller zooplankton, making these available for higher trophic levels ( ). Copepods were dominant in all sampling dates in 1999, ‘accounting for more than 80% of the zooplankton community in both stations’ (DFO). The two fixed stations were at Anticosti Gyre and Gaspe Current. In general, smaller copepods such as *Oithona similis* and *Oncea borealis* dominated at both sampling stations at both dates, but larger copepods such as *C. Finmarchicus* and *C. glacialis* and *Metridia longa* were more abundant during July and August at the Gaspe Current. Also at this date, total zooplankton biomass was higher in both the Anticosti Gyre than in the Gaspe current. This remained true for the rest of the season – with the exception of May when it was equal. In general, abundance of adult copepods and copepodite stages, or integrated copepod abundance, followed the same trends in seasonal variation for both stations. Maximum abundance of copepod eggs were found in the spring, while the most number of adult coepods and copepodite stages were found in the fall. There was not a significant difference noted in the integrated copepod abundance between the two stations.

Commercially Important Species

This section will talk about the relevance of copepods to commercially relevant species, such as capelin, cod and herring.

- *Capelin*

Capelin is an important resource for Newfoundland, having both economic and ecological importance. Most importantly, they are an important food source for cod. Although the capelin stock around Newfoundland has historically been high, there has been a recent decline starting in the 1990s. They have since not recovered to historic levels, though there was an increase seen in 2006 (Dalpadado and Mowbray 2013). In this study, copepods were found to be the dominant prey of capelin of the coast of Newfoundland, copepods such as, *C. finmarchicus, C. glacialis* and *T. inermis*. Of these, the former was found to be the dominant prey of small capelin (Dalpado and Mowbray 2013). As capelin grow older, they switch to larger zooplankton. Even larger capelin of the coast of Newfoundland and Labrador remain primarily dependent on copepod plankton.

-Cod

The cod stock is of vital commercial importance for Newfoundland and Labrador, along with social and historical importance. As such, activities that could negatively impact the stock should be taken into account. Copepod plankton are the corner stone of the diet of cod larvae, particularly on the copepod *C. finmarchicus* (Ellertson et al. 1989). Like the capelin, as the cod grow larger, they continue to prey on progressively larger copepods. Cod cohorts have several life stages that are planktonic – that is, they drift aimlessly in the ocean. Due to this limited mobility, their distribution is restricted horizontally as well as vertically, restricted to shallow (Olsen et al. 2010). Consequently, this makes this highly susceptible to the effects of oil spills (Brude et al. 2010). The results of these findings show that

The study found similar losses in terms of direct loss as compared to loss as a result of diminished number of zooplankton prey. Of course, it does need to be taken into consideration that the validity of these findings is contingent on how the cod model captures the dynamics of the cod population and the influence of zooplankton on these dynamics.

Furthermore, it was found that ‘NEA cod cohorts are similarly sensitive to hypothetical pollution-caused loss of zooplankton pretty in spring and summer as they are to direct loss of their larvae in the same period (Fig. 2)’. (Stige et al. 2011)

It also needs to be taken into consideration that planktonic cod cohorts could be more susceptible to disturbance than other plankton, such as *C. finmarchicus*. This may not be reflected in studies. To elucidate, studies could find that there are negligible impacts on certain zooplankton species. However, because these species tend to have a greater range, the study might report that there are negligible impacts on the zooplankton species, meanwhile planktonic cod cohorts are being devastated. So results are always skewed. Why this is important to know is because food conditions are incredibly important during the early life-stages of marine fish populations as it has been identified as an important driver of recruitment variability (Cushing 1989). The degree to which reductions in prey abundance occur depend on where and when these prey reductions occur. Stige et al (2011) conclude that determining the number of cod eggs or larvae that are killed by oil does not give a good indication of the cod larvae that are affected. The effect on these is not determined by zooplankton alone, but also requires research on phytoplankton, and up the food chain.

- *Herring*

The third species I have chosen for study that is reliant on copepod zooplankton is herring. Herring, incidentally, survive entirely on zooplankton. Although they are opportunistic feeders and will eat anything that comes their way, they prefer to prey on copepod zooplankton. Along the western coast of Newfoundland and the Great Northern Peninsula, there are a number of important herring sites that have been identified. Although herring as not as valuable commercially as cod, herring are eaten by larger organisms, and are thus an important part of the food chain, and why they are considered here.

The diet of a herring is quite similar to that of cod. In their larval stage, herring will feed on copepod nauplii (larvae), and will gradually move onto to larger, adult sizes of copepods and they age. Like cod, *C.finmarchicus* is an important copepod in their diet. The distribution and abundance of copepods is important for the survival and distribution of herring. For instance, herring growth rates vary with copepod availability and abundance. As well, Atlantic herring time their migrations around the presence of the copepod *C. finmarchicus*. It is therefore important to not underestimate the importance of the organisms, and to take any threats to them seriously. Such as an oil spill.

Effects of Oil Spill

This section discusses some of the effects of major pollution caused by oil spills. I will be beginning with a discussion on crude oil, followed by mentioning dispersants, and the effects of certain polycyclic aromatic hydrocarbons (PAHs) such as pyrene, and then relating these back to zooplankton.

- Crude oil in the ocean

Crude oil (a.k.a petroleum) is prolific in the environment. It enters into the ecosystem through a variety of means, such as seeping, extraction, transportation, and consumption [8].

Oil spills may not represent the largest source of crude oil into the sea, however these spills have strong acute and long-term impacts on marine ecosystems. Physical damages, such as contamination and smothering are concerns, as well as toxicity from the chemical compounds in oil have lasting damages (National Research Council). What is crude oil? Well, crude oil is ‘a complex mixture of both hydrocarbons, such as alkanes, cycloalkanes and aromatic hydrocarbons, and non-hydrocarbon compounds’ (Almeda et al. 2013). It is these polycyclic aromatic hydrocarbons (PAHs) that are considered the most acutely toxic component of crude oil as it interferes with membrane fluidity of organisms (National Research Council). Crude oil gets into the ocean through spills or natural leakage. It is dispersed through wind and wave action into smaller oil droplets, usually around 1-11 micro-meters in diameter. Once the oil droplets are this size, it is easy for zooplankton to interact with the. As will be discussed in the next section, oil dispersants are often used in conjunction with large spills to quicken the process of dispersal. However, these can cause plumes of stable dispersed oil droplets to remain in the water column (Lichtenthaler and Daling 1985). PAHs are particularly deadly, and it should be noted that they have been linked to ‘potential carcinogenic, teratogenic and mutagenic effects in aquatic animals and humans (De Flora, Bagnasco and Zanacchi 1991).

- *Effect of pollutants on copepods*

This section will deal with effects of pollutants on copepods, including dispersants and PAHs

As I have already discussed, it is important to consider the effects of dispersants a dispersants and oil together because oil spills hardly occur without the addition of dispersants. Dispersants are a combination of surfactants and water soluble compounds. True to their name, they ‘disperse’ the oil, rather than eliminate it from the water column. Oil dispersants quicken the process of dispersal for oil that has spilled into the ocean, helping to make the oil droplets smaller and less harmful to marine organisms in less time. This is necessary because oil is lighter than water, and thus could remain at the surface for a long time. However, dispersants are incredibly toxic, and some studies have shown that dispersants are more toxic than the oil itself. New dispersants such as Corexit 9500 and Corexit 9527 have been found to be less toxic than spilled oil alone on most marine organisms. However, there remains a gap in knowledge on what the effects of dispersants or dispersant treated oil is on copepods, such as *C. finmarchicus*. There are still many questions that remain, especially given that studies have shown copepods to be particularly susceptible to oil and dispersant exposure.

In particular, copepods might be particularly susceptible to compounds in the dispersant (Cohen 2014). Further, compounds in the dispersants, such as naphthalenes, have been shown to accumulate in meso-zooplankton tissues during oil spills (Mitra et. al). Further, Barata et al. (2005), determined that alkylated naphthalenes are more toxic to copepods than their parent compounds alone. In fact, dispersants are shown to contribute more to a decline in zooplankton more so than just oil alone, although this may be ‘mediated by lower trophic levels and oil/dispersants’ (Almeda et al. 2013).

Copepods can interact with oil and other pollutants in a number of ways, and these can be lethal or non-lethal [4]. Furthermore, through absorption, transformation, and elimination, zooplankton are able to influence the physiochemical characteristics of pollutants in the water column (ALMEDA, 4-5). Also, zooplankton may play an important role in bio-magnification of pollutant up food webs [4-7]. There are many opportunities for zooplankton to interact with oil and other pollutants, and it is important to understand these. Some of the direct toxic effects on zooplankton can be lethal or non-lethal. There has been a greater concentration of focus of studies on the lethal effects of pollutants, ignoring the sub-lethal effects.

The long-term effects of oil are difficult to discern sometimes. Mesozooplankton in the Northern Gulf of Mexico have accumulated some PAHs, but the long-term effects are not yet known (Cohen et al). From the study conducted by Cohen et al. (2011), the results suggest a particular vulnerability on the part of copepods to dispersant toxicity. Almeda's study (2013) concluded that zooplankton populations are incredibly vulnerable to acute oil exposure, as well as to the commonly used dispersant, Corexit 9500A. From this study, both lethal and sub-lethal effects were noted, and shall be discussed in more detail presently. For the most part, it is lethal effects that have been studied. However, there are a number of problems that could arise (Jian et al. 2010, 2012). These sub-lethal effects could have severe impacts that we do not know about.

We've already discussed how large, accidental spills may not be the most significant source of petroleum discharge (NRC 2003), but this sudden discharge can cause strong short- and long-term effects/environmental impacts (Kennish 1996). What further affects the ingestion of crude oil are both environmental, such as sunlight radiation, and biological, such as microbial composition. These interactions can be extremely difficult to predict. Because although you must consider that natural UVB radiation increased toxicity of these compounds, the presence of protozoans in the water reduced these effects, including the bioaccumulation of PAHs in the copepods. These experiments do highlight the importance of performing further experiment that mimic the natural environment (a.k.a. mesocosm experiments). Otherwise, how do you expect to accurately evaluate the toxic effects and bioaccumulation of petroleum hydrocarbons in zooplankton. In the study conducted by Almeda et al. (2013), they found crude oil droplets in the fecal pellets of approximately 90-100% of the little copepods, and large amounts no less. They saw this as an indication that all copepods were ingesting dispersed crude oil. Not even copepod nauplii were immune, as crude oil droplets were observed in their belly as well, at least of three of the species. Most to of the effects that have been studied, and in fact they are the most easily studied. That said, it I important to consider sub-lethal effects because these can have further unanticipated effects. There is a study that explored these impacts. I do not remember which one it was.

Conclusion

The main conclusion of this paper is that we really don't know anything. There is limited data on zooplankton populations and what the toxic effects could be. Whatever research that has been conducted is certainly valid, but there are a number of ecological factors at play that are simply hard to predict for. What we do know that zooplankton are indeed extremely important to the environment as key protein sources to larger organisms, and are crucial to the transfer of energy up the food web. More research is needed to better determine what the effects of an oil spill would be on the west coast of Newfoundland.

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