A sustainability plan for the Arctic with a focus on the role of diatoms

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The Arctic Asteroids

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Abstract

Changes over the next 50 years impacting diatoms and their role in Arctic exploration and development are examined. As Arctic ice recedes, the resulting shift in diatom species composition causes a ripple effect changing the food web, and impacting the lifestyle of Arctic people. As the ice melts the oil driven economy of the world will spread into this newly exposed region to extract valuable resources putting at risk Arctic ecosystems through oil spills. Diatomaceous biofuels will be the key to curbing global climate change as greenhouse gas quantities continue to rise. As the geographical landscape of the Arctic changes so does the political landscape. Approaching the Arctic region through this inclusive sustainable management plan considerations were made for the following domains; environmental, socio-cultural, economic, technological, and public policy.
Introduction

Sustainability is defined as “Able to last or continue for a long time” (“Merriam-Webster,” n.d.). For the purpose of this analysis, sustainable will include: the limiting of extinction with special attention to endangered species, the preservation of ecosystem biodiversity, the conservation of peace foreign and domestic, the preservation of indigenous cultures, and regulating harvestable wildlife resources, within the next fifty years. However, as humans change so does our way of thinking. Commonly when looking at the sustainability of a resource focus is on what one species needs to survive instead of the entire ecosystem. Yet, this practice is falling out of style and an integrative approach is gaining momentum, a socio-ecological system.

In Steward and Kuska’s book Sustainometrics (Steward and Kuska, 2011) the socio-ecological system is defined as looking at five domains of sustainability. First, the environmental domain focuses on ecosystem effects and changes in the climate and habitat. Second, the sociocultural domain evaluates the predicted changes of the indigenous people and established local cultures. Third, the technological domain applies existing and innovative advances with emphasis on sustainable resource harvesting and development. Fourth, the economic domain examines financial aspects and considerations. Fifth, and finally, the public policy domain considers legislation and enforcement of policies for society's benefit. This model is represented by a flower with overlapping petals, demonstrating the interconnections of the domains (Fig. 1).

The Arctic has long been an area of inaccessibility. With the Northwest Passage opening and exploration possible a dynamic shift is underway. Human interests in the Arctic will affect the
present ecosystem. Diatoms as the base of the ecosystem will be impacted by Arctic changes, also impacting species that rely on them. Evaluating this shift from a socio-ecological perspective will give a better understanding of the impact of Arctic exploration and development.

![Figure 1: A visual representation of the socio-ecological model. Retrieved from (http://sustainometrics.org/index.html)](http://sustainometrics.org/index.html)

**Arctic Models**

The link between climate change and the formation of sea ice is becoming ever more apparent. Figure 2 shows the sea ice extent in square kilometers from 1950 to 2050. The dashed line represents the average ice model prediction. The solid red line represents the actual recorded extent of sea ice. Both lines show a downward trend representing the decrease in sea ice over time. For the data presented, the standard deviation grows larger over time as does the difference
between the predicted models and measurements. The ice extent decreases faster than expected.

Figure 3 shows Arctic ice extent using a map. Overlapping colors coincide with different years, visually giving a prediction of ice cover in 50 years. As ice levels decrease and more open ocean is revealed species in the Arctic must also change to adapt to their new ecosystem. Some species will be better fitted to this new environment than others. Diatoms are a group of key species that will be affected by the changes in the Arctic.

![Graph showing actual and predicted ice extent](image)

**Figure 2: Actual trend in Arctic ice (red) against the average predicted trend (dashed) with the standard deviation (light blue) for the month of September from 1950 to 2050. National Snow and Ice Data Center. Stroeve (2007).**

1. Environmental

Diatoms are planktonic photosynthetic algae that use silica to make their skeletons. Ranging in size from 20-200 microns diatoms are microscopic. Diatoms are either centric or pennate in shape. They can be unicellular or colonial linking together to make different shapes.
Reproduction is achieved through cell division limited by the amount of dissolved silica and other nutrients in the water and the size of the original diatom, taking place 8 to 12 times a day. Diatoms are found in every aquatic environment on earth from the Arctic to inside tree bark (“Ucl Miracle Diatoms,” n.d).

The habitat of Arctic diatoms is diverse. Some species of diatoms are pelagic living in open water. Others such as *Fragilariopsis oceanica* and *Eucampia groenlandica* live within the ice itself. Diatoms that live within the ice are seasonal. Melting of the ice causes diatom sinking to be fed upon by benthic organisms (“Arctic Ocean Diversity,” n.d).

As displayed in the ice models above the amount of ice returning to the Arctic each year is decreasing. Ice dependent species will have less space to live, reducing the population and
affecting the species that consume the diatoms when the ice melts. In contrast, open water species will have more habitat allowing for an increase in population, and causing a shift in the Arctic food web.

2. Socio-cultural

One organism, the diatom, connects the thousands of different organisms that live in the frozen Arctic habitat. Changing climate and ice reduction will impact the Arctic ecosystem as a whole. For example, from the already melting ice, the extinct diatom species *Neodenticula seminae* has come back to the Arctic and researchers believe this won’t be the last resurrection of a species (Parry, 2011). For three decades, Arctic sea ice has been in decline. During more recent summers a passage has opened up between the Pacific and Atlantic. For the indigenous people, this newly ice-free area has opened up barge routes and is changing their hunting practices. In the Food Web there is a relationship between diatoms and the other Arctic inhabitants today. All the animals can be linked back to the diatom. Small zooplankton feed on the diatoms. Small fish feed on the zooplankton, and large marine mammals and birds feed on the small fish and larger zooplankton. Thus, humans being the apex predator are linked to the diatom.

Arctic summers in as little as 30 years, are predicted to become nearly ice free (Figure 2). Fifty years from now the diatoms will likely be more abundant due to the little sea ice left, which opens the ocean surface for more solar energy to penetrate into surface water. This will affect the ecosystem as a whole and cause a change in the population of many animals like the polar cod, seals, and polar bear. Ocean acidification will impact the zooplankton by limiting the calcium carbonate resource in the ocean water, which is important to the construction of exoskeletons.
The lack of predation by zooplankton will result in diatom blooms settling to the bottom to become detritus. Thus, the web will become more benthic dominated. In contrast, rising ocean temperatures open the possibility of species moving northward, and may increase fish diversity in the Arctic Ocean. (Mueter and Litzow, 2007).

Indigenous people’s rural communities throughout Russia, Canada and the United States the chance of sustainability of their way of life is low. Rural communities in the Arctic are facing policy enclosure that limits their resource rights to harvest certain animals and can impact the indigenous people’s subsistence way of living. These restrictions affect the opportunity of traditional living that can result in a loss in culture. During the climatic and economic transition in the Arctic indigenous people will be offered employment. Fisheries could result from the new abundance of fish. Arctic communities will increase with the development of canneries, fossil fuel extraction industry, harbors, supporting services and administration. This development will lead to employment for the residents of the rural Arctic communities. With a greater western presence in the Arctic, the traditional way of life will become displaced. Instead of harvesting for their family like the Arctic peoples do today, going to a supermarket will become more convenient.

3. Technological

Global warming is becoming a bigger problem in our world; we are producing higher quantities of greenhouse gases than ever before. Current quantities of carbon dioxide in the atmosphere have risen more than 35% since the beginning of the industrial revolution and, according to the EPA (The United States Environmental Protection Agency), the quantities will continue to rise
(How much carbon dioxide (and other kinds of greenhouse gas) is already in the atmosphere? n.d.). Diatoms as biofuels are being tested and looked at closer by scientific branches of the US government and many scientists around the world. The US government has been testing algal biofuels since the 1970s, but in 1996 the DOE (Department of Energy) shut down the program because it wasn’t producing desirable results. The algae research program was started again, a decade later, and continues to search for a solution to make affordable biofuel (Why are we not Drowning in Algae Biofuel? 2012, October 22). A statistic given by the DOE states “less than 20% of all algae research projects ever get completed” (ARPA-E halts algae project, citing missed milestones (2014, April 9) http://www.biofuelsdigest.com/bdigest/2012/02/16/arpa-e-halts-algae-project-citing-missed-milestones/).

Until recently, diatoms were being used just for filters, fillers, insulations, optical image quality, and mild abrasives (Diatoms in Industry. 2009, February 5). The abundance of these single-celled eukaryotic microalgae make them an exemplary means for a large expanse of different applications (Applications of Diatoms as Potential Microalgae in Nanobiotechnology. 2012, May 10). Engineers and scientists are just now exploring the diversity unique to single-celled algae (Engineering and medical applications of diatoms. 2005, January 5). The biofuel industry for algae has developed significantly with growing technology, organizations, and the greenhouse gases in the atmosphere.

Only one problem limits diatom biofuel use; algae biofuel is costly to produce while fossil fuels still have continuously low prices. According to a study conducted by the Lawrence Berkeley National Laboratory, producing fuel from algae would cost between $240-$332 per barrel, while
crude oil is about $92 a barrel (Why are we not Drowning in Algae Biofuel? (2012, October 22) http://oilprice.com/Alternative-Energy/Biofuels/Why-are-we-not-Drowning-in-Algae-Biofuel.html). If scientists and industry find a way to produce diatomaceous biofuel without having a high cost, then biofuel use would be on its way to becoming a reality.

The Arctic is possibly one of the best places to grow diatoms for industry. As ice melts from global warming, more space to grow diatoms becomes available. The almost unlimited hours of sunlight in summer and the rich nutrients will help the diatoms grow exponentially and in turn create more product to make into biofuel. In a study done by Britain’s leading green energy supplier, it was estimated that we would run out of fossil fuels by 2088 (The End of Fossil Fuels. n.d.). As oil productions run dry, they will leave behind the infrastructure that will have to be developed with Arctic oil exploitation. “In order for biodiesel to become a mainstream fuel, distribution costs have to be reduced and consumers need to have better access to the fuel. Pipelines, which are fast, reliable, and inexpensive, offer a solution” (Biodiesel Magazine. 2007, January 24). This might be the key to making biofuels a real possibility in the near future.

4. Economics

Wars have often been fought over resources. The fight for oil and the land to extract it is the war we face today. In the 1800’s crude oil was discovered in the United States to be used first for the production of kerosene for heating lamps and later gasoline for the internal combustion engine. The need for it has only grown, with transportation such as cars, trucks, boats and planes. It is not until recently that we as consumers have taken interest in the fact that oil is a non-renewable resource and a need for new renewable way to fuel our lives is required.
Today, the Arctic is too cold and dangerous for safe and clean oil drilling. With changing conditions and less ice the idea becomes more feasible for major oil companies. The United States Geological Survey (USGS) estimates that there could be as much as “13% of the world’s undiscovered oil in the Arctic” with “30% of the world’s undiscovered natural gas” (Arctic Oil and Gas. (n.d.). Retrieved November 23, 2014, from http://www.ey.com/Publication/vwLUAssets/Arctic_oil_and_gas/$FILE/Arctic_oil_and_gas.pdf, Assessment of Undiscovered Oil and Gas in the Arctic. (n.d.). Retrieved November 23, 2014, from http://energy.usgs.gov/GenerallInfo/EnergyNewsroomAll/TabId/770/ArtMID/3941/ArticleID/713/Assessment-of-Undiscovered-Oil-and-Gas-in-the-Arctic.aspx). In a study done by the Ernst & Young (EY) Global it was found that the U.S. alone could hold up to “65% of the oil in the Arctic and 26% of the natural gas” (Arctic Oil and Gas. (n.d.). Retrieved November 23, 2014, from http://www.ey.com/Publication/vwLUAssets/Arctic_oil_and_gas/$FILE/Arctic_oil_and_gas.pdf). That is approximately 30 billion barrels of oil, and at $74.58 a barrel it would equate to over 2.2 trillion dollars. In this study it was also found that these deposits could be accessible as soon as the year 2020.

Table 1: National Arctic Market Evaluation; Arctic Oil and Gas. (n.d.). November 23, 2014, Retrieved from (http://www.ey.com/Publication/vwLUAssets/Arctic_oil_and_gas/$FILE/Arctic_oil_and_gas.pdf)
Table 1 shows some of the challenges companies and countries will face when extracting resources from the Arctic, with every country having their own tax regime each company will face different challenges. No matter the economic challenges these resources must be extracted in a sustainable manner, to ensure the survival of the ecosystem and our way of life for generations to come.

Many problems are associated with Arctic oil drilling. The biggest problem that is faced is oil spill response. If oil were to spill in the Arctic under extreme temperatures, it could freeze over, trapping it until the following year. If an oil spill in the Arctic occurred, the diatoms would be directly affected. Since diatoms live in the photic zone to convert sunlight they would be one of the first to be affected. In small concentrations of oil the phytoplankton like diatoms will thrive while the zooplankton populations will decline, but in high concentration of oil, both phytoplankton and zooplankton populations will decrease. If an oil slick covered the water surface the sunlight that the phytoplankton convert will not be able to pass through as easily (Tas, S., & Oku, E. (n.d.). Zooplankton populations will decrease due to the oil clogging their feeding apparatus. Moreover, the zooplankton would be affected over more than one generation, because they absorb and accumulate the low concentrations of dissolved oil into their system.
Cold water copepods possess a lipid sack and absorb the oil into its wax esters. When they lay eggs later in life, the toxic oil in the eggs could create problems for the offspring. Zooplankton like krill with predominantly phospholipids die almost immediately, because the toxins are absorbed much quicker into the body (Duesterloh, *pers. comm.*).

Once the Arctic begins to open up and private interest corporations move in, the governments of Arctic nations will be right alongside, creating tension between countries. The military from all Arctic nations will play a key role in protecting interests for their respective countries. For the United States, the Department of Defense (DoD) has already created strategy and protocols for establishing “Arctic-America”. Currently, military movement in the Arctic is minimal. The DoD will be installing missile defense and early warning systems to defend America (DoD Arctic Strategy. (2013, November 1)). According to the Washington Post in 2011 the U.S. spent about 718 billion dollars on the defense budget (Plumer, B. (n.d.). America’s staggering defense budget, in charts.) . About 149.9 billion dollars were spent on the Navy (Military budget of the United States. (2014, November 16)). With the Arctic opening the Navy will have to spread its budget even further to police and defend American waters. The U.S. Navy currently has only three active ice breakers while Russia has up to 20 (List of icebreakers. (2014, November 15)).

5. Policy

The Arctic is of great significance not only in the realms of biology and economics but also in the realm of politics. This significance is due to two key factors: the region's position on the globe and the region's resources, such as minerals and oils. A need for legislation and management rises as interest in an ice free Arctic does. In 1996, the Arctic Council was established with participation of 8 Arctic Nations and the representation of indigenous people of
Arctic regions. “The Arctic Council contains Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Russia, Sweden and the United States.” (Arctic Council, 2011). This group of nations is in charge of Arctic decision making. While public interest may be slow to realize the upcoming changes, international economic interests are established. This is driven by the abundance of strategic resources including oil and minerals, fisheries and hunting resources, and shipping passages. An increase in management of the Arctic shipping industry would be beneficial to its sustainability. Restrictions would limit damage done by boats going through this region. Currently, the abundance of ice naturally restricts ship traffic, but over the next 50 years, traffic will increase substantially. The realm of policies should include strict anti-pollutant policies as well as even stricter anti-invasive species policies. As the Arctic changes, it will be vulnerable to invasives because local flora and fauna will have trouble and other species could capitalize on the opening of ecological niches. For these reasons we believe that strict international policies are a necessity.

Conclusion

Diatoms are going to be both winners and losers under the changing Arctic environmental conditions of the next 50 years. As the amount of ice decreases the key species of diatoms will transfer from ice dependent to pelagic, forcing a shift in the food web to the benefit of the pelagic community. With increasing ocean acidification zooplankton grazing may not control phytoplankton blooms. Benthic organisms in turn benefit from an increased number of deceased phytoplankton sinking to the bottom. Similar to the change in species of phytoplankton, other ice dependent species will be forced to change their ecological niche or suffer a decrease in population. In regards to people their once rural communities will become popular ports for existing and new commercial industries, leading to a shift in culture. New legislation and policies
must follow this dynamic change to protect the Arctic’s sustainable and finite resources and maintain domestic and international peace. The prospect of diatoms as biofuel creates the pathway toward energy sustainability, possibly shifting global economies away from oil dependency.

Literature cited


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Other resources

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