An Actor Network Theory Approach to Analyze Sociotechnical Systems Operating to Reduce Ocean Plastic Pollution

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Sustainability transitions are necessarily about interactions between technology, policy, politics, economics, and public opinion. Researchers therefore need theoretical approaches that address the multidimensional nature of sustainability transitions

(Geels, 2011)

Plastic pollution in the world's oceans has proven a threat to the environment, society, and the global economy. Environmental issues such as ocean plastic pollution bring about daunting societal challenges which require socio-technical transitions to address effectively. Such socio-technical transitions involve alterations in the overall configuration of systems which entail technology, policy, markets, consumer practices, infrastructure, cultural meaning, and scientific knowledge (Geels, 2011, p. 24). Thus, the process of such transitions are comprised of complex networks involving multiple actors over a long period of time. Theoretical frameworks have proven efficacious in analysis of such multidimensional systems, and the use of actor network theory may provide insight on interactions between stakeholders, as well as their intended results.

A significant part of the problem of ocean plastic pollution is due to the large number of products which are packaged using plastics, resulting in an excessive amount of plastic that must be managed by the institutions responsible in the specific area where the waste is discarded. As a result of this waste management issue, approximately 8 million metric tons of plastic enter the world's oceans each year, on top of the estimated 150 million metric tons already circulating the marine environment (Jones et al., 2019, n. p.). At this rate, it is projected that there will be more plastic than fish by volume in the world's oceans by 2050 (Jones et al., 2019, n. p.). Macroplastic, or plastics which are greater than 5 millimeters in size, accumulate on the surface

of the ocean. These macroplastics are what the Great Pacific Garbage Patch is composed of, which is the largest accumulation of ocean plastic in the world. ("The Great Pacific Garbage Patch", n. d.).

When observing the matter of ocean plastic pollution, we seek to understand what technologies, policies, and resources are required to address the issue, as well as the corresponding interactions and implications of such a sociotechnical system. The cost and consequences of ocean plastic pollution could be ridiculously large; as the threat to the ocean poses a resulting threat to the survival of the human species. Thus, the cost of ignoring this issue may result in extreme consequences to the environment, economy, and society as a whole. In order to get a better understanding of the implications of sociotechnical systems operating to reduce ocean plastic pollution, we will observe the feasibility of certain proposed solutions, as well as a network of interactions between stakeholders and relevant technologies. In this paper, I argue that analysis of the implications of present and potential sociotechnical systems operating to reduce ocean plastic pollution through the implementation of an actor network will be beneficial in generating inferences on the feasibility and effectiveness of such systems. Using theoretical frameworks, statistics, and evidence from relevant sources provides assistance in determining the interactions between actors within our network, as well as their resulting implications. I argue that the various independent parties addressing the problem of ocean plastic pollution will require cooperation in order to make any of the available solutions effective.

Part I: Ocean Plastic Pollution has Adverse Effects on the Environment, Economy, and Society

The core analytical puzzle inherent of socio-technical transitions involves an understanding of how environmental innovations are brought about, and how these can "replace, transform, or reconfigure" existing systems (Geels, 2011, p. 25). What we seek to understand regarding ocean plastic pollution is what technologies, policies, and allocation of resources are prevalent and necessary in effectively addressing this problem. Determination of these elements through this research process provides us with the ability to generate inferences regarding how this socio-technical transition may be implemented and altered with respect to existing systems. Due to the magnitude and complexity of this issue, the system in which we are concerned with is comprised of a network of interactions between social and technological entities in order to alleviate adverse outcomes. An actor-network inherent of the theoretical framework of Actor Network Theory involves a process of combining technical and social elements which are continuously shaped by a range of heterogeneous forces within the network (Stanforth, 2006, p. 38). This framework is directly applicable to the issue of ocean plastic pollution in that this problem involves a magnitude of social and technical elements which are continuously changing over time. In order to help us understand the implications of a sociotechnical system operating under our previously defined objective within our actor-network, we must first understand the costs and consequences of our current situation on certain categories of stakeholders as a result of this matter.

Ever since the invention of plastic, the production and use of these products have grown exponentially. This problem of plastic pollution in the world's oceans has proven a threat to the environment, society, and the global economy. More than 300 million tons of plastic are

produced across the globe each year; an extremely significant increase from the estimated 1.5 million tons produced worldwide in 1950 ("Plastic Pollution", n. d.). Since plastic is extremely versatile, strong, and cheap to produce; several applications and uses have been discovered and utilized by packaging firms and other distributors, causing plastic production to increase exponentially since 1950 (Lee, 2018, n. p.). The figure depicted below helps to visualize this dramatic increase in production.

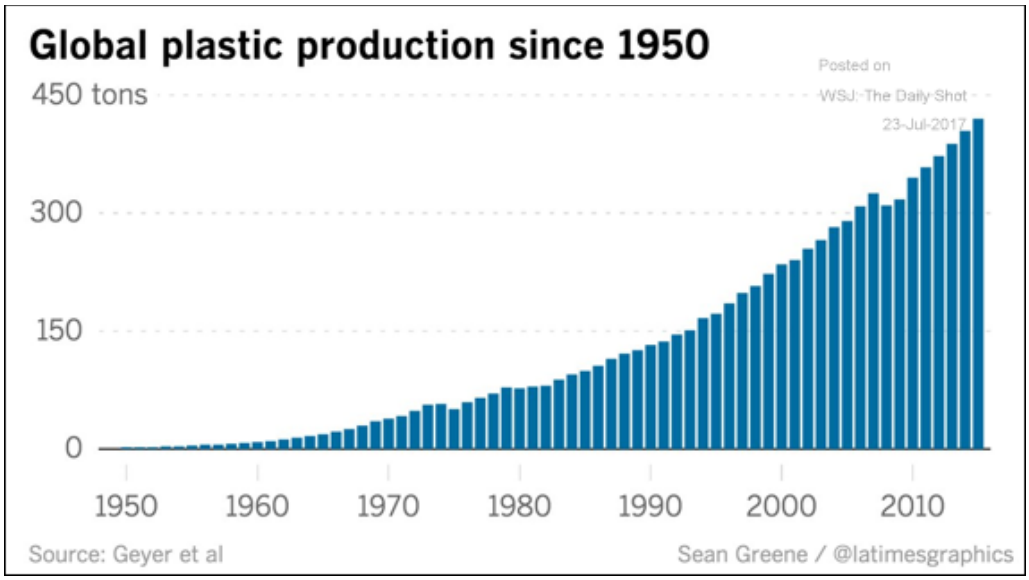

Figure 1: Amount of tons of plastic produced globally since 1950 (Geyer et al., 2017).

Focusing on the effect of this issue on the environment, plastics have proven to be a significant threat to ocean and freshwater ecosystems; and consequently, a threat to the benefits humans receive from these ecosystems (Lee, 2018, n. p.). More specifically, this pollution threatens the survival of hundreds of species, negatively impacting nearly 700 worldwide (Lee, 2018, n. p.). In many cases, ingestion of plastic causes blockages in the animal's digestive system which can prevent them from digesting other types of food, leading to starvation. Marine animals may also be entangled by plastic pollution which can cause either asphyxiation or entrapment. It has been estimated that 100 million marine animals are killed each year due to

plastic pollution (Henn, 2019, n. p.). Furthermore, as plastic breaks down over time, it becomes less buoyant and sinks to the ocean floor. This can cause hypoxia, or oxygen deficiency, and dead zones (Henn, 2019, n. p.). Dead zones also have a significant adverse impact on the ecosystem since these reefs support food networks of local marine life. The type of marine animal which humans benefit the most from are, as one might infer, fish. As a consequence of plastic pollution, economists and ecologists have predicted the oceans to be empty of marine life by 2048 (Marinelli, 2018, n. p.). Thus, the negative impact of plastic pollution on fish may have a significant negative impact on the benefits in which humans derive from the ocean over time.

Now focusing on the impact of ocean plastic pollution on society, we will first observe how the negative impact of plastic pollution on the fish population affects the benefits humans derive from the marine ecosystem. When plastic is mistaken as food and ingested by a marine animal, this plastic moves through the food web through a process known as bioaccumulation (Lee, 2018, n. p.). For example, in the North Atlantic, is has been estimated that 11% of North Atlantic fish ingest plastic regularly ("Plastic Ingestion by Fish", 2016, n. p.). An article from the Student Conservation Association claims that, due to the complexity of Earth's food chain, humans are still at risk of consuming microplastics even while avoiding seafood ("Microplastics", 2019, n. p.). Since this food chain has become so permeated with microplastics, it is likely that the majority of humans have ingested some form of plastic pollution at some point ("Microplastics", 2019, n. p.). Furthermore, the oceans of Earth are considered the primary life support system for humans, and thus, the survival of our species would be significantly threatened if the oceans become extinct (Hodal, 2019, n. p.). Besides the possibility of humans ingesting microplastics, as well as the long run threat to human survival, there are also adverse impacts on the economic aspect of society.

Finally, focusing on the economic impact of ocean plastic pollution, there are several individuals, communities, institutions, and industries which experience the consequences of this issue. First focusing on individuals, several commercial and local fisherman experience lower revenues due to the decreasing number of fish available, as well as fish caught being contaminated with plastic or other types of pollution (Nash, 2003, n. p.). When observing how this affects communities, plastic pollution on beaches lower the aesthetic value associated with the area, and consequently, revenues for coastal communities and the tourism industry (Lee, 2018, n. p.). Many institutions attempt to deter this problem within their region at a cost. Beach cleanups are an attempt to make a dent in the severity of the issue, and these events cost coastal communities millions of dollars every year. However, the largest economic impact inherent of ocean plastic pollution is present in the financial impact on industries which are dependent on the marine ecosystem. It has been estimated that damage to the environment from all forms of pollution forces the global economy to incur an estimated $2.5 trillion a year in sunk resources within the marine environment. This value was calculated based on the approximate 1-5 % ($) reduction of economic benefits experienced by humans from the marine ecosystem as a result of environmental damage from pollution and anthropology (Hodal, 2019, n. p.). This is the consequence of declining market value of marine ecosystem services as a result of this pollution, and affects marine industries across the globe. Now that we have a better understanding of the issue at hand, as well as the magnitude of potential consequences, we now seek to understand methodologies behind resolution as well as their projected results.

Part II: Identification and Analysis of Methodologies to be Incorporated in Construction of Actor Networks

Flow Diagram of Methodologies to Generate Inferences and Contribution

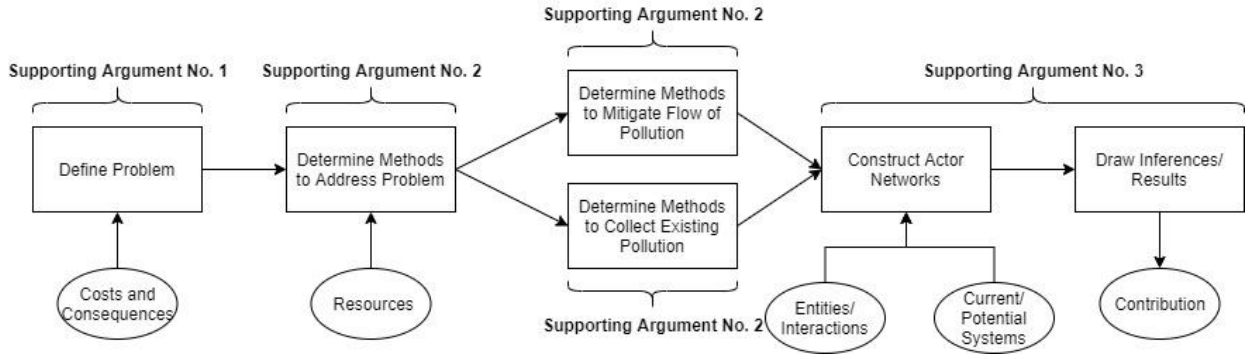

Figure 2: Flow Diagram of Methods: See breakdown of paper in bold to provide overview of approach and methods; Rectangles are actions, circles are inputs, contribution is output (*created by Author*).

The diagram above depicts the general approach to resolution, and how this process will generate inferences with respect to addressing the problem at hand. The method in the first supporting argument consisted of defining the problem, and determining the costs and consequences of the current state. This supporting argument is concerned determining methodologies to address the problem, as well as methodologies comprising our actor network and overall contribution. Finally, the last supporting argument consists transforming these methodologies into entities within our conceptual framework of actor network theory. Entities will be defined and their interactions will provide insight on potential sociotechnical transitions which may affect ocean plastic pollution. In order to do implement this methodology, we must observe the implications of the following propositions.

Effectively addressing this issue requires the implementation of a two part solution. There must be action taken in order to reduce the flow of plastic into the ocean, as well as cleaning the existing pollution already present. An idea proposed by several activists regarding

the mitigation of future pollution is a ban on the production of polypropylene products such as plastics enforced by local governments. As a matter of fact, certain plastics like disposable plastic bags require much fewer resources to produce when compared to paper, cotton, or reusable plastic bags (Stanislaus, 2019, n. p.). For example, a paper bag would have to be reused 43 times in order for it to have an environmental impact equal to or less than that of a disposable plastic bag (Stanislaus, 2019, n. p.). Thus, we can conclude that banning production and consumption of plastic is likely to negatively affect the environment in other areas, potentially creating further problems on top of the existing ocean plastic pollution issue. As a result, the World Resources Institute suggests the redesign of plastic products so that they can be readily broken down into molecular units, and remanufactured into new plastics, constructing a closed loop system (Stanislaus, 2019, n. p.). A company known as BioCellection is operating under the objective of, "protecting the environment through creating innovative recycling processes for post-consumer waste plastics that no one else can recycle and by converting them into virgin quality building blocks for sustainable supply chains" ("BioCellection", 2019, n. p.). This process allegedly involves the breakdown and conversion of each ton of plastic trash into more than $2,500 worth of chemicals, and may prevent up to 20 tons of carbon dioxide from being emitted ("BioCellection", 2019, n. p.). While this startup is in the beginning stages of implementation, the proprietors believe that this is a sustainable and profitable operation which could make significant strides in addressing the problem.

Another idea for mitigating future contributions to plastic pollution is raising awareness of the issue. Several programs have been created in order to inform the public about environmentally friendly waste disposal habits; however, they have not proven significantly effective in years past as a means of solving this issue. This leaves the responsibility on the

institutions in place within the corresponding region. When observing the issue under the scope of the U.S., hundreds of towns and cities have cancelled their recycling programs due to the cost of collecting recyclables skyrocketing. This is due to China refusing to import used plastics and paper (Corkery, 2019, n. p.). While simply raising awareness has proven costly and ineffective at mitigating the flow of plastic into the ocean on a global scale in years past, this will not be a significant factor in our approach to resolution. Finally, redesign of waste management facilities in order to filter out reusable containers, reprocess them, and redistribute them may also prove effective if implemented on a global scale. Analysis of these propositions in the construction of our actor network, along with the resources required for implementation will provide insight on adequate resolutions.

When considering potential solutions regarding the collection of existing ocean pollution, one specific idea is known as the Ocean Cleanup Project, which is a nonprofit organization located in the Netherlands. The Ocean Cleanup Project has an ambitious technological strategy with the objective of collecting 90% of the plastic pollution in the ocean ("The Great Pacific Garbage Patch", n. p.). The system is essentially a large net, which collects and prevents debris from escaping underneath. Furthermore, the Ocean Cleanup Project has claimed that it has developed and tested a scalable method of mitigating the flow of plastic pollution from rivers, claiming to filter out 80% of plastic pollution from countries' rivers within five years. While this may be technologically scalable in the sense that it is physically feasible, and may produce this intended result, this project still requires far more funding than it currently has in order to achieve the goals in which it claims. The Ocean Cleanup Project has currently accumulated approximately $35 million in donations, however, they require far more in order to accomplish their objective. Thus, in order for the Ocean Cleanup Project to be scalable, it will require a

large amount of capital funded from outside sources. Therefore, in order for this to work, it will require the cooperation of several independent parties who are motivated to spend a large amount of capital in order to address this issue, which could be countries who are interested in the long term benefits of this investment. Other solutions to collecting the existing plastic waste could be certain countries taking initiative at addressing the issue, or potentially a coalition between countries to work together on addressing the issue.

Finally, a concept which has proven effective among some European nations in mitigating the flow of plastic pollution into the ocean is known as Extended Producer Responsibility. The notion of Extended Producer Responsibility involves a shift of financial responsibility for end-of-life disposal to product manufacturers, thereby providing an incentive for improved product design, reuse, and recycling (Tibbets, 2015, n. p.). This process is usually implemented through legislation which requires manufacturers to incur the cost of tracking, managing, and recycling packaging after their product has been consumed. Many European nations who have implemented legislation for extended producer responsibility also divert recycled plastics to power plants for use as fuel for heat and electricity (Tibbets, 2015, n. p.). Furthermore, nine European nations have banned landfills as a result of population density and land scarcity, leading to 90 to 100 percent of plastic produced being recycled or used for energy production. Thus, this concept transfers the responsibility of managing plastic pollution from government to corporations. Steve Russel, vice president of the plastics division of the American Chemistry Council describes the motivation behind this robust system recycling system, "A primary driver for those systems has been the desire to capture energy and to remain as energy-independent as they can while dealing with landfill bans." He further demonstrates that the United States has more acreage to build landfills, and much lower prices for

conventional energy sources, making it much more economically feasible to continue with our current waste management system (Tibbets, 2015, n. p.). Therefore, while this process works in those European nations which have land scarcity and high prices for conventional energy, Russel claims that this system design does not reflect conditions within the United States. One may infer that in order for such a system to work within other countries, this would require a sociotechnical transition which would result in an increased demand for desired behaviors similar to extended producer responsibility (Geels, 2011, p. 26).

Part III: Construction of Actor Network to Observe Benefits of Sociotechnical Transitions on a Global Scale

In order to visualize the gap between existing systems with different sociotechnical structures, we will compare the case of the Germany utilizing extended producer responsibility with that of the case of the United States. This will provide insight on the construction of a more generic, global network consisting of potential interactions which may be effective at addressing the issue on a larger scale. The figure on the following page compares the entities and interactions present within the waste management strategies of Germany effectively using extended producer responsibility, and the waste management system present in the United States.

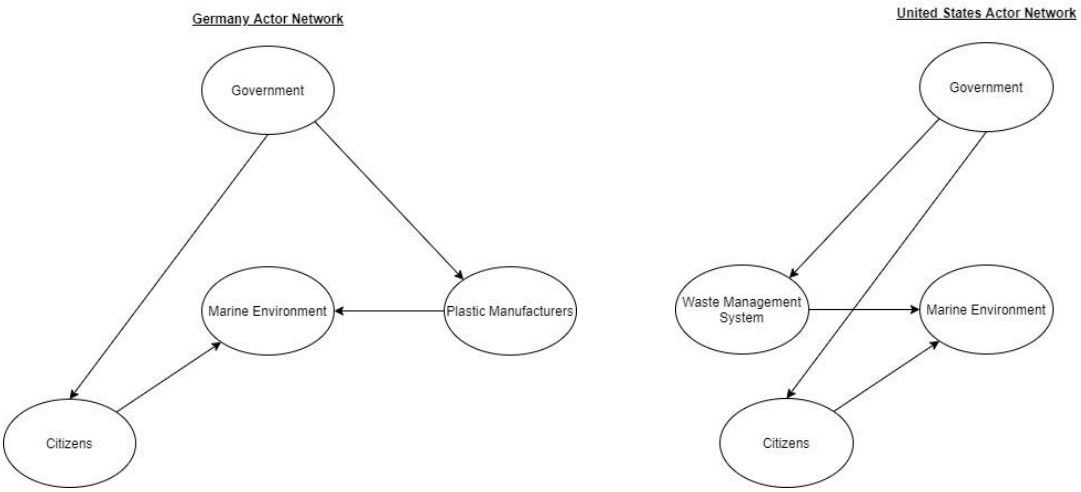

Figure 3: Comparison of actor networks between the U.S. and Germany, which have different sociotechnical structures. Germany was chosen because it was the first country to implement extended producer responsibility in the EU; the U.S. was chosen because it has a comparatively unique sociotechnical structure (Watkins et al., 2017). These are shaped the way they are to highlight the gaps between these countries networks, and the global cooperative network [presented in the following paragraph] (*created by Author*).

The diagram on the left of Figure 3 represents the current actor network present in Germany, which involves the application of extended producer responsibility. In this system, the producers are held responsible for collecting and allocating packaging products, which may be sent to powerplants for use as fuel for heat and electricity. This sociotechnical system is capable of repurposing or recycling 62% of plastics, where the structure of the United States only recycles or repurposes about 15% of plastics (Tibbets, 2015, n. p.). In both cases, governments implement legislation to discourage citizens from littering. However, the waste management system in the United States is the primary role player in managing plastics within the U.S., while government legislates taxation which cause citizens to bear the cost of managing plastic waste. While Germany does have a waste management system, this was not included in this network to highlight the role of plastic manufacturers in managing waste as opposed to federal collection methods. The biggest difference between these diagrams, is that the system in the U.S. is less effective, and sticks the cost with citizens, where the system within Germany is more effective, and sticks the cost primarily with plastic manufacturers. The main reason that this is effective in

Germany is due to their landscape which discourages the use of landfills, in turn encouraging efficient allocation of plastic waste. In order for the U.S. to benefit from operating under a similar system, a sociotechnical transition must take place in which there is an added incentive to behaving in this manner. However, even though Germany may be doing relatively well at addressing the issue within their own territory, there are still several missing entities within these networks if the problem is to be resolved on a global scale. This defines the gap between our current and ideal global cooperative network, and provides insight on which sociotechnical transitions may be required in order for this global conceptual framework to be implemented.

Now that we have a better comprehension of both the effects of the current situation of individual parties along with their corresponding sociotechnical systems; we seek to understand the interactions between entities within our large scale actor network. The actor network is displayed and briefly described on the following page in “Figure 4”.

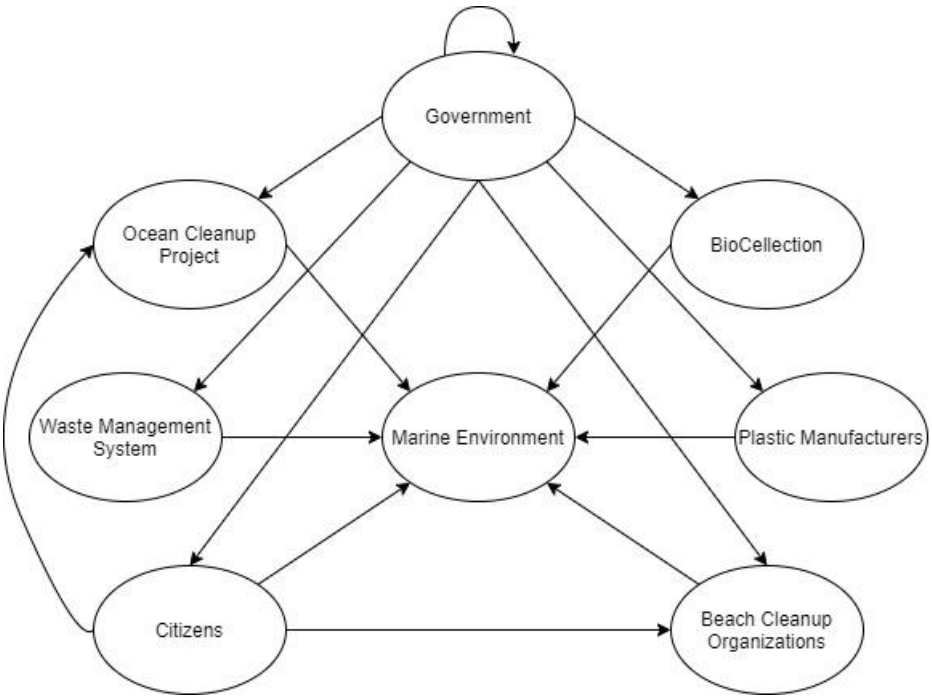

Figure 4: Actor Network displaying potential interactions between entities with respect to the marine environment. Includes entities transformed from methodologies, fills the gap between a large scale network and individual networks seen in Figure 3. (*created by Author*).

Description of Interactions

When observing the government entity, we see an arrow emulating which loops back onto itself. This arrow describes potential interactions between governments of different countries cooperating to address the issue. Either individual governments, a combination of governments, or citizens could potentially fund technologies such as the Ocean Cleanup Project or BioCellection. Individual governments will also interact with their waste management system by setting standards regarding plastic waste. They will also interact with their citizens by implementing and enforcing legislation regarding littering, or potentially funding education for citizens pertaining to environmentally friendly waste disposal habits. Individual governments may also implement "take-back" legislation which requires plastic manufacturers to track, manage, and recycle their packaging after the product has been consumed (Tibbets, 2015, n. p.).

Finally, citizens and governments may also fund local beach cleanup organizations to address pollution on their own coastal shores.

At first glance, one might notice within this network that every entity is acted on by the government, except the marine environment. Furthermore, every entity which the government acts on, in turn, acts on the marine environment. As is with sociotechnical transitions, private actors have limited incentives to address sustainability transitions because the objective pertains to a collective good and do not offer user benefits. "It is therefore unlikely that environmental innovations will be able to replace existing systems without changes in economic frame conditions" (Geels, 2011, p. 25). In the case of ocean plastic pollution, this sociotechnical transition towards sustainability seems unlikely without a change in the frame conditions of global politics and the global economy. The United Nations was created in response to a global threat to society, which is essentially what we have with the projected consequences of ocean plastic pollution. A potential change in global politics could be the assimilation and cooperation of large countries attempting to resolve a global issue, similar to that of the United Nations. However, this sociotechnical innovation is unlikely to be implemented until such countries recognize this issue as a global threat, which could be the catalyst to such a sociotechnical transition.

Results

As previously described, I have found that the most efficient and effective way to address this issue requires the cooperation between several different independent parties. More specifically, I have inferred that solutions such as raising awareness, banning production of plastics, enhancing waste management facilities, beach cleanup organizations, implementation of the Ocean Cleanup Project, and BioCellection are ineffective at addressing the issue when

implemented independently. Thus, I have concluded that using the analytical framework inherent of Actor Network Theory provides insight on how these previously defined entities may interact with each other with the objective of mitigating the flow of plastic pollution into the ocean from their respective territory, as well as attempting to remove existing ocean plastic pollution. Actor network theory should be used as a mechanism of telling a story or describing the unfolding of an innovation process as opposed to a "heroic episode" (Stanforth, 2006, n. p.). In this case, the story evolved from a narrative of analysis and methodologies into a heroic episode of discovery. This discovery in particular was that sociotechnical transitions are capable of creating an increased demand for desirable behavior with respect to a previously defined objective. Inferences are generated from such discoveries, and provide further insight on the implications of such findings.

Description of Inferences

I have inferred based on this evidence that many countries are not currently motivated to expend resources regarding this issue, because extreme adverse effects have not been yet experienced by said countries, and this expenditure may reduce a country's economic competitiveness. Thus, the largest issue inherent of this problem is the ability to motivate entities, or provide a catalyst for sociotechnical transitions, within our actor network to expend time and resources to address this matter. I believe one way to motivate the actors described above is for a country similar to the United States to take initiative in attempting to form a coalition of these previously mentioned countries cooperating under this objective. The main contribution that was made here was an analytical bridge between areas with different sociotechnical structures which may be used by individual countries in order to assist in addressing the global issue as a whole. In order for certain groups to be effective, a

sociotechnical transition may be required to bring about demand for desirable behavior with respect to this objective. For example, a sociotechnical transition which makes it beneficial for the United States to implement extended producer responsibility legislation may significantly reduce the amount of ocean plastic pollution contributed by the United States alone. Ultimately, as more countries make sociotechnical transitions towards sustainability over time, it will be easier to share the responsibility of addressing this issue among countries, and increase the likelihood of resolving the issue.

Conclusion

Evidence has shown that there are significant adverse effects within economies, environments, and societies across the globe as a result of the magnitude of plastic pollution in the ocean. Analysis of this evidence suggests that the long term benefits to the stakeholders in this actor network outweigh the short term investment. After determining this, observation of the Ocean Cleanup project as well as other proposed strategies operating under the objective of addressing this issue provide insight on inferences which could be drawn regarding the feasibility under the constraint of limited resources. Through analysis of these proposed strategies with regard to the actor network framework as well as relevant stakeholders, I have inferred that in order for this large scale issue to be effectively addressed, it will require the cooperation between several independent organizations and institutions across the globe.

An inference I have made as a result of this evidence analysis is that the majority of countries which are able to make an impact, are not motivated to do so, as it may reduce economic competitiveness in the short run. The contribution which I believe my research has provided is the observation that sociotechnical structure is a primary factor in environmental sustainability. I believe that there must be a catalyst which provides additional incentive to

motivate countries to experience sociotechnical transitions towards sustainability, which assist in resolving environmental issues on a larger scale. Thus, the next step of this research would be to understand catalysts of sociotechnical transitions, and which catalysts would prove effective at motivation of desirable behavior in which areas. Inferences generated from our global perspective actor network provide overall insight towards the next steps of resolving this problem, which brings about the challenge and limitations associated with motivating those capable to take action before the consequences associated with this problem are too large to address.

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