STUDY OF SOCIOECONOMIC DRIVERS OF MARINE DEBRIS POLLUTION IN NORTH AMERICA

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF MARINE RESOURCES MANAGEMENT

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August 2017

Major Subject: Marine Resources Management

ABSTRACT

A majority of the world's oceans are increasingly getting threatened by marine pollution, causing losses to sectors and industries that rely on it, including fishing, shipping, tourism and seafood industries. This study focuses on marine pollution by marine debris, which constitutes any solid or processed material floating in the ocean, finding its way purely by anthropogenic factors. This research is aimed at understanding socioeconomic footprints on marine environment in terms of debris accumulation and how the existence of social capital, proxied by voter turnouts, can contribute to curbing marine debris pollution. The study area consists of coastal counties located in eight states of the U.S., and employs data from NOAA and the U.S. Census Bureau. The results from Poisson regression indicates that marine debris increases with income, however at higher income level the amount of pollution starts to decline, supporting the "Environmental Kuznets Hypothesis."

This study found overwhelming evidence of human impacts potentially threatening the quality of marine environment. The knowledge and awareness of human influences on marine environment is the crucial step for environmental managers to lay down policies and undertake preventive actions to mitigate them.

DEDICATION

This research is dedicated to my wonderful parents, Mr. Sushil Chhabra and Mrs. Veena Chhabra, who have always encouraged me to shoot for the moon and follow my passion. Their undying love and support from halfway across the world in India has kept me driven and going. My Master's degree at Texas A&M University of Galveston is the fulfilment of their dreams and result of their blessings.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the God Almighty for constantly watching over me and enlightening my path. My faith guided me towards the light in darkest of tunnels. This research and thesis appears in its current form due to assistance and guidance of several people. I would like to offer my sincere thanks to all of them.

I owe debt of gratitude to my amazing Committee Chair, Dr. Meri Davlasheridze, for her invaluable time, guidance and sincere investment in my research. Her unwavering passion for research is inspiring and infectious. I would also like to extend my gratitude to my committee members, Dr. David Retchless and Dr. Nikolaos Mykoniatis, for sharing their abundant wealth of knowledge and experience.

I would also like to thank my friends and family back in India for sending me their love and best wishes and, being very understanding of my time. I would especially like to thank my wonderful mom for cheering me on all through and believing in me during the trying moments of self-doubt.

I extend my deepest gratitude and appreciation for my friends in the U.S., Suzanne, Brittany, Lynn, Pranav, Tarun, who have been my constant pillars of support and my cheering audience. Their invaluable care and emotional support will forever be cherished in my heart.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Dr. Meri Davlasheridze (Chair), Dr. David Retchless (Member) and Dr. Nikolaos Mykoniatis at Texas A&M University at Galveston.

All the work done by the student was completed by the student, under the advisement of Dr. Meri Davlasheridze.

Funding Sources

There are no funding sources to be acknowledged pertaining to this research and it's compilation.

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1. INTRODUCTION

Marine and coastal resources are an important asset to the nations, aesthetically and economically. Nationwide, based on estimates provided by the U.S. Commission on Ocean Policy report in the year of 2000, contribution of ocean and coastal resources, including coastal watershed counties towards US economy is estimated to be more than $4.5 trillion, which includes revenues from commercial fisheries, tourism and maritime industries, real estate in coastal communities, and pharmaceutical companies (Ocean commission, 2004). These values, however, only capture the direct economic benefits or the direct use values associated with coastal and marine resources.

The total economic benefits go beyond these direct ‘use values’ and also include ‘non-use’ benefits albeit resources are not being directly consumed (Luger, 1991). The ‘non-use’ values are often the hardest to estimate and attempts have been made to assign values to these deliverables by estimating the amount of money people are willing to spare for environmental lobbying and maintenance (King, 1995; Barbier, 2007). However, valuable ‘habitat regulatory’ services, including storm surge protection, nutrient cycling, sustainability to biodiversity etc., which constitute a major portion of these ‘non-use’ values, are considered figuratively priceless (Barbier, 2007).

Water bodies of the world, ranging from small canals to oceans, are increasingly turning into dumping grounds of waste from air, land and water based sources (Halpern et al., 2008; Kennish, 1996; Chung, 1986). Ever increasing global population puts further strain on marine environment by increasing industrial growth and human settlements in coastal areas, and elevated exploitation of coasts to cater to tourism sector, thereby rendering the marine environment increasingly unstable and unsustainable (Kennish, 1996). Majority of the world's coastal resources have been damaged from pollution at varying degrees (Islam & Tanaka, 2004). Polluted waters adversely impact marine ecosystem and living resources within, sequentially generating economic losses to sectors directly acquiring the benefits of ocean, including fishery, tourism and seafood industries, as well as shipping industries (McIlgorm et al., 2011; Ofiara & Saneca, 2006). Marine pollution and degraded ecosystems are partially responsible for declining catch levels and underweight catches, disease outbreaks and mortalities, consequently adding more stress on the marine ecosystem (Ofiara & Saneca, 2006). Thus, giving rise to a vicious cycle of reckless demand and supply, fueled by greed for economic gains and narrowing the scope for contingency.

Furthermore, polluted waters negatively impact beach popularity, which directly affects livelihoods of local communities and tourism sector (Jang et al., 2014). In addition, shipping industries have been found to bear losses because of damages to ship propellers and cooling systems attributed to marine pollution (Takehama, 2009; McIlgorm et al., 2011).

Water remediation and clean up, as a way, to address the growing marine pollution problem generates yet another type of social cost to public, which could be sizeable. From a policy and coastal planning perspective, it is thus important to understand how the coastal development contributes to marine pollution and what could be the potential ways to mitigate unintended consequences of human settlements in coastal areas.

The objective of this research is to specifically focus on understanding the socio-economic footprints on marine environment, realized in terms of Marine Debris, which is best defined as “any manufactured or processed solid waste material (typically inert) that enters the ocean environment from any source” (Coe & Rogers, 1997). Its range of constituents can vary from rubber, paper, plastic, polystyrene, glass, to metal, wood, ceramics, fishing gears and lines (Sheavly, 2010). The debris particles enter from multiple sources in the ocean, with land based sources, rich in hard plastic materials being the most common (Slavin et al., 2012; Eastman et al., 2013). Marine debris is regarded as one of the most ubiquitous and highly understudied but solvable problem that plagues the world’s oceans today (Coe & Rogers, 1997; Hofer, 2008; Sheavly & Register, 2007). Estimating the amount and contents of debris floating in the world’s oceans remains challenging because of natural processes like ocean circulation patterns, ekman drift, tidal and intertidal currents that can move debris particles across the globe and over time particles are often fragmented into smaller constituents and eventually settling in oceanic sediments (Mansui, Molcard, & Ourmieres, 2015). Although there is a long line of research that has conducted marine debris modelling, majority of them have been at small spatial scales, often along small stretches of ocean basins, estuaries, islands and local beaches (Mansui, Molcard, & Ourmieres, 2015; Becherucci, Rosenthal, & Pon, 2017; Zhou et al., 2011; Pichel et al., 2012). Research conducted by Lebreton, Greer & Borrero (2012) is the only study to the best of our knowledge that has comprehensively assessed debris accumulation over 30 years and identified accumulation zones in five of the major world's ocean basins, which include Pacific, Atlantic and Indian oceans. Their estimate for the total number of the marine debris particles is approximately 9.6 million, with highest concentration of debris particles in North Atlantic and North Pacific Ocean (Lebreton, Greer & Borrero, 2012).

Additionally, wealth of literature estimates the damages to specific ecosystems and economic losses due to presence of marine debris, and quantifies costs associated with debris remediation and removal programs (Ofiara, 2001; Jang, Hong, Lee, Lee & Shim, 2014; McIlgorm, Campbell & Rule, 2008; McIlgorm, Campbell & Rule, 2011; Takehama , 1990), but the spatial scope of this past research has been very narrowly focused on specific coastal communities, beaches and segments of areas. Lack of comprehensive study is mostly due to the paucity of consistent data on marine debris. In this study we utilize a newly available data on marine debris from the National Oceanic Atmospheric Association (NOAA) and focus on U.S. coastal counties. Marine debris count data used in the study accounts for debris particles washed ashore on the beaches, which were manually collected, classified and counted, and reported on NOAA's database, by volunteers contributing to NOAA's Marine Debris Monitoring and Assessment Project.

Our research contributes and extends to prior research in several important ways. One important extension is that we provide an empirical evidence of the Environmental Kuznets Curve (EKC) hypothesis in the context of marine debris pollution. The Environmental Kuznets Curve explores that relationship between pollution and economic growth and postulates that at an early stage of economic development we may see an increase in the level of pollution, but at higher income levels, economic development contributes to environmental improvements (Panayotou, 1993). Empirical evidence of the EKC with varying degrees of success was reported in case of air and water pollution (Selden & Song, 1994; Shafik & Bandyopadhyay, 1992; Holtz-Eakin & Selden, 1995), however to the best of our knowledge, no prior studies have examined or provided empirical evidence of this hypothesis in context of marine debris pollution.

Another important contribution of this research is exploration of the mitigating role of social capital and good samaritanship, which entail a belief that the sense of collective responsibility over the use and maintenance of natural community resources will prevent their reckless use and exploitation (Aldrich and Meyer, 2015).

The results of this research indicate a statistically significant non-linear relationship between income and level of marine debris pollution, thereby lending the support for EKC hypothesis. Furthermore, significant effects of population growth and tourism are also found to proliferate marine debris pollution. The empirical evidence of social capital offsetting the effects of these contributing factors of marine debris pollution is also suggested by our results.

The rest of paper is organized in the following manner. Section 2 presents literature review related to marine pollution, Section 3 describes data, Section 4 lays out an estimable model and the hypotheses are postulated in Section 5, Section 6 presents the results, which are discussed in Section 7, followed by policy recommendations in

Section 8 and, data limitations in Section 9, last Section 10 concludes discussion concludes this thesis.

2. LITERATURE REVIEW

Growing human population and consequential increase in economic activities and urbanization is leading to augmented waste generation, which ultimately ends up in the oceans constituting marine debris. Marine Pollution is a broad concept that includes pollutants ranging from petroleum hydrocarbons, halogenated hydrocarbons, heavy metals, radionuclides and litter, also termed as Marine Debris, which is the focus of this study (Clark, Frid, & Attrill, 1989; Horowitz, & Herzog, 2013; Stemmler & Lammel, 2009; Zhou, Guo, & Liu, 2007; Callender, 2003; McIlgorm, Campbell, & Rule, 2011).

For a long time, oceans were considered invincible and the notion of 'out of sight, out of mind' was being followed in case of dumping of waste in them (Arthur et al., 2014). However, studies have emerged in the last few decades that revealed that all the world's oceans have been and continue to be polluted by marine debris and large 'patches' of floating debris have been discovered, suggesting that oceans are not that invincible after all (Carpenter & Smith, 1972; Arthur et al., 2014; Barnes et al., 2009; Kaiser, 2010; Kostigen, 2008; Law et al., 2010; Lebreton et al., 2012). This section reviews the contribution of previous research in the study of socioeconomic drivers of marine debris, and literature on Environmental Kuznets Curve Hypothesis and social capital.

Socio-economic drivers of Marine Debris

Marine debris pollution is regarded as purely anthropogenic form of pollution, making the phenomenon a direct reflection of attitude and perceptions of populations towards marine environment. These attitudes are shaped by varying individual attributes like nature of household and upbringing, level of education and awareness, economic status and standing in the society etc. Combination of these factors often shape and affect the choices individuals make and effect of these choices on society and environment. Understanding what role the above mentioned attributes play in contributing to marine debris pollution, i.e., socioeconomic footprints on marine environment realized in terms of debris accumulation, is an important first step in policy making and allocation of resources by public agencies to curb it.

Past literature has studied socioeconomic footprints quantified in terms of land-use change and patterns, population and urban growth and climate change. They have focused on various types of water pollution problems, commonly measured in terms of nutrient concentration and, air pollution. We briefly review and discuss the findings of past literature along these footprints.

Land Use Footprints

Literature that focuses on land-use patterns commonly examines the impact of different types of land use categories on watershed pollution. Typical land-use classifications include: urban areas, agriculture, forests, and wetlands (Halsted et al., 2014). Distribution of these different land use types changes based on patterns of development (Pickett et al., 2001). In recent years, the patterns of land use are steering towards urbanization, dictated by increasing human settlements and industrialization in cities and consequential clearing of other land cover categories to meet the demands of growing population and consequent economic growth (Pickett et al., 2001). The degree of urbanization can directly influence the soil and water contaminant levels in catchment basins and streams due to excessive enrichment and eutrophication (Walsh et al., 2005). It has been linked to pesticide and heavy metal pollution, alterations in soil and water chemistry by disruption of Carbon, Phosphorous and Nitrogen cycles, and changes in distribution of indigenous flora and fauna (Pickett et al., 2001).

Population and Urban Growth Footprints

The effects of increasing economic activity, driven by population and urban growth have been extensively studied on water pollution and levels of water quality indicators (nutrient levels, suspended solids, dissolved oxygen, temperature, plankton levels and pH) and these effects have been referred to as "Urban stream syndrome" (Walsh et al., 2005; Paul and Meyer, 2001; Dietz & Clausen, 2008; Halstead et al., 2014: Chen & Lu 2014). Urban steam syndrome is characterized by the alterations to water quality in streams, brought about by urbanization and prolonged contamination by urban and agricultural runoffs (Walsh et al., 2005). It can be concluded that urban stream syndrome is an interplay of urbanization and water pollution, catalyzed by economic activity, hence constituting an important measure of socioeconomic footprint.

Air Pollution Footprints

Additionally, studies have also explored socioeconomic drivers of air pollution and similar to water pollution, effects of increase in economic activities and population have been directly linked to increased particulate, mercury and ozone emissions in the air and an increase in air temperatures (Pickett et al., 2001; Guan et al., 2014; Liang et al., 2013). Air in highly urbanized areas has been found to have depleted ozone levels, and higher ambient temperatures as compared to neighboring, lesser urbanized areas (Pickett et al., 2001).

Application of Footprints to Marine Debris

Very little appears to be known about socioeconomic drivers of marine debris. Only a handful of published studies have attempted to explore socioeconomic footprints on marine debris (Santos et al., 2005; Slavin et al., 2012; Ribic et al., 2010; Eastman et al, 2013). Main focus has been on individuals' behavior related to littering (i.e. guilt associated with littering, or the compelling urge to clean up after oneself) on beaches, how the behavior was dictated by socio economic attributes of populations, including age, gender, income and education levels as well as providing specific solutions, presumably shaped by various socio-economic factors, to address the growing concerns about beach littering and marine debris pollution (Santos et al., 2005; Slavin et al., 2012; Eastman et al, 2013). The geographical extent of most of these studies has been spatially localized and focused on a specific beach or segments of a beach around a tourist town. For example, studying beach behavior of tourists visiting Tasmania beach in Australia, Slavin et al. (2012) suggested that older people, people in high income brackets, tourists, and females experienced more sense of guilt and were more likely to clean up after themselves (Slavin et al., 2012).

Another study, conducted in a popular, Cassino beach in Southern Brazil by Santos, et al. (2005), focused on how the level of awareness of people towards marine debris was influenced by socioeconomic variables and, contribution of tourism towards littering on a beach. It was found that people with higher incomes and higher literacy rates recognized marine debris as a major problem (Santos, et al. 2005). Importantly, the preference for learning tool as a method to curb marine debris appeared to be stronger among people with higher levels education relative to those with lower or no college degrees (Santos, et al. 2005). Similarly, Eastman et al. (2013) found higher education level decreased the likelihood to litter among visitors in coastal communities of Chile.

To the best of our knowledge, only one published paper studied socioeconomic drivers of debris pollution in the North America. Ribic et al. (2010) surveyed the US Atlantic Coast and observed significant contribution of population growth and economic activity (commercial fishing) towards marine debris accumulation pattern over the 10 year time span (1997-2007). This study also reported, albeit counterintuitive, relationship between urbanization and debris pollution and suggested that beaches located in close proximity to highly populated areas had less debris deposition, and were better managed as compared to less populated areas (Ribic at al., 2010).

Despite the high economic potential of beach tourism in the United States , there is a very little research done on how tourism related services and economic development in coastal areas impact and threaten marine environment (McIlgorm et al., 2011; Offiara, 2001; Jung et al., 2014). One reason for such a gap in the literature appears to be due to the lack of comprehensive marine debris monitoring data for all the coastal states in the U.S., more discussion on which is following in the policy implication section of this thesis.

Environmental Kuznets Curve Hypothesis

A very important aspect of this research is to estimate the empirical evidence of Environmental Kuznets Curve hypothesis (EKC) in case of marine debris pollution. EKC hypothesis states the evidence of a non-linear, exponential relationship between economic development and environmental quality (Munasinghe , 1999). A wealth of literature has investigated this relationship, which was originally derived from a similar relationship between economic growth and income inequality by Simon Kuznets (Kuznets, 1955). The concept of inverse relationship of economic development and environmental quality rests on the notion of scale effect, which states that in the process of absolute growth of economies of scale, rate of environmental degradation will go up, which will cause the EKC to rise up in the beginning (Stern, 2004). However, after the attainment of a threshold of economic development, a fall in EKC will begin due to the interplay of factors like shift to cleaner technology, adoption of sustainable and environmental friendly practices by different industries, heightened consciousness of environmental stewardship and lobbying and income levels high enough to afford clean technology (Lambin & Meyfroidt, 2010).

The measures of economic development have varied across past literature of EKC studies, ranging from different types of Gross Domestic Product (GDP per capita, GDP per square area), Gross National Product, and per capita income (Stern & Common, 2001; Panayotou, 1997; Selden, & Song, 1994; Stern, 2004; Torras & Boyce, 1998; Kai, Mao & Qi-xin, 2003; Lambin & Meyfroidt, 2010). The attainment of income threshold has been found to vary by developmental status of the countries and whether or not factors like Purchasing Power Parity (PPP), currency values, trade surplus ratio etc. have been controlled for in estimation of economic development (Stern, 2004).

Past EKC studies have mainly focused on measuring environmental degradation in terms of air (Stern & Common, 2001; Panayotou,1997; Selden, & Song, 1994; Stern, 2004) and water quality (Torras & Boyce, 1998; Kai, Mao & Qi-xin, 2003), reflected in terms of air quality indicators including sulfur dioxide emission, nitrogen dioxide and suspended particulates emissions, and ozone cover and water quality indicators including levels of Biological Oxygen Demand, Dissolved Oxygen, fecal coliform content and municipal wastes. A common factor in these studies is the nature of pollutant, effects of which have largely been localized and subject to regulation (Stern, 2004).

Research has found empirical evidence of EKC in all the above mentioned studies. However, the differences in individual findings persist in terms of threshold income, spatial scales of the study and nature of pollutants. For example, it was observed that inclusion of significant amount of low income data points in the sample can raise the threshold income level (Selden, & Song, 1994; Stern & Common, 2001). Additionally, the threshold value varied for developing and developed countries, owing to apparent differences in income, PPP, GDP levels and whether the pollutant samples were globally representative or not (Kai, Mao & Qi-xin, 2003; Shafik & Bandyopadhyay, 1992). Similarly, large spatial variations in pollutant data sites can mask the overall results. For example, pollutant such as sulphur dioxide are found in high concentration in urban areas than in lesser developed parts of the city, on the other hand, dumped municipal wastes are found to be more concentrated at the peripheral areas of the city (Torras & Boyce, 1998). Another observation made in the EKC literature was lack of studies on marine debris pollution. By drawing on these past findings, we aim to add apiece to the literature by investigating a similar empirical evidence for marine debris pollution.

Social Capital

Another major goal of this study is to investigate the mitigating effects civic engagement, a proxy for social capital, on marine debris pollution. Literature has viewed civic engagement as an important essence of social capital and also as an effective contraption to quantify it (Shortall, 2008; Stolle, & Hooghe, 2005; Rupasingha et al., 2000). Social capital is regarded as tool that can fortify the human capital and promote behaviors that result in effective realization of goals of a society (Coleman, 1988). The notion of social capital draws parallels on the pillars of civic engagement, i.e., being comprised of strong community bonding, social structures and the idea of building relationships that contribute towards fulfilment of community goals and allocation of resources required to achieve them (Aldrich and Meyer, 2015; Coleman, 1988; Putnam, 1995; Woolcock, 2002, Rupasingha et al. 2006).

Varying measures and proxies to measure social capital has been used in previous literature, like voter turnouts, enrollment in civic, religious, social advocacy, animal rights organizations etc. (Adler and Kwon, 2002 ; Rupasingha et al., 2000; Knack and Keefer, 1997; Alesina and La Ferrara, 2000). In the context of present study of marine debris pollution, literature has established a strong evidence of civic engagement promoting pro-environmental behaviors (Julian & Briony, 2003; Portney, 2005). People view civic engagement as a tool to voice their concerns and promote their causes. Literature also suggests that by the virtue of strong sense of social capital, people are able to come forward as community in promoting environmental lobbying against practices like deforestation, unsustainable resource use, water pollution, etc. (Selman, 2001; Portney,2005; Dagger, 2003; Rupasingha et al., 2000). We aim to investigate the possible role of civic engagement in mitigating marine debris pollution in coastal counties in our study.

3. DATA

Data for this research was available from multiple sources. Marine debris and wind-speed data was obtained from NOAA, data on various socio-economic and demographic variables were available from the U.S. Census Bureau. While the marine debris data are reported by sampling sites as discussed below, consistent data on socio-economic variables were available at the county level. Hence, our unit of observation is county and our sample corresponds to a pulled cross-sectional time series data over 2012-2016 period.

Dependent Variable

Marine debris data was collected from the NOAA's Marine Debris Monitoring and Assessment Project (MDMAP) database (National Oceanic and Atmospheric Administration, 2016). MDMAP, utilizing citizen science approach, compiles the amount, number and type of marine debris reported voluntarily by different organizations all over North and South America by conducting shoreline marine debris surveys (National Oceanic and Atmospheric Administration, 2016). The datasets contained the count of marine debris reported in the form of Accumulation (Flux Data), Standing-Stock (Concentration Data), Standing-Stock (Raw Data), Large Items and Custom Data from monitoring sites. Composition of marine debris is also reported by nature of particles collected, classified in categories such as, i.e. metal, plastic, rubber, paper, glass, rubber, processed lumber, cloth-fabric and unclassified. Additionally, each category had a subcategory of specific articles collected, for e.g., beer cans, cigarette butts, tampon applicators, condoms, clothes etc. Datasets also contained geographical coordinates for sampling sites, shoreline width and length, designated survey ID, time and weather and wind conditions during sampling days. For the purpose of the study, we employed the Accumulation data for Marine debris count. Accumulation (Flux Data) includes data on all items in the size range 2.5-30 cm collected from survey site. As such, our dependent variable Marine Debris, corresponds to number of total debris items collected.

Map in figure 1 represents the original data points for which the data was available. It should be noted that not all coastal states are participating in the NOAA MDMAP initiative. In fact, our sample is overrepresented by the west coast. In Table 1, we report the number of sampling sites and time periods reported by states. The material of marine debris in our sample is classified into seven categories, namely, plastic, glass, metal, rubber, fabric, processed lumber and unclassified category. Plastic material constituted the highest amount, followed by metal, glass, cloth, unprocessed lumber, rubber and unclassified. Figure 2 represents the percentages of each category in a pie chart.

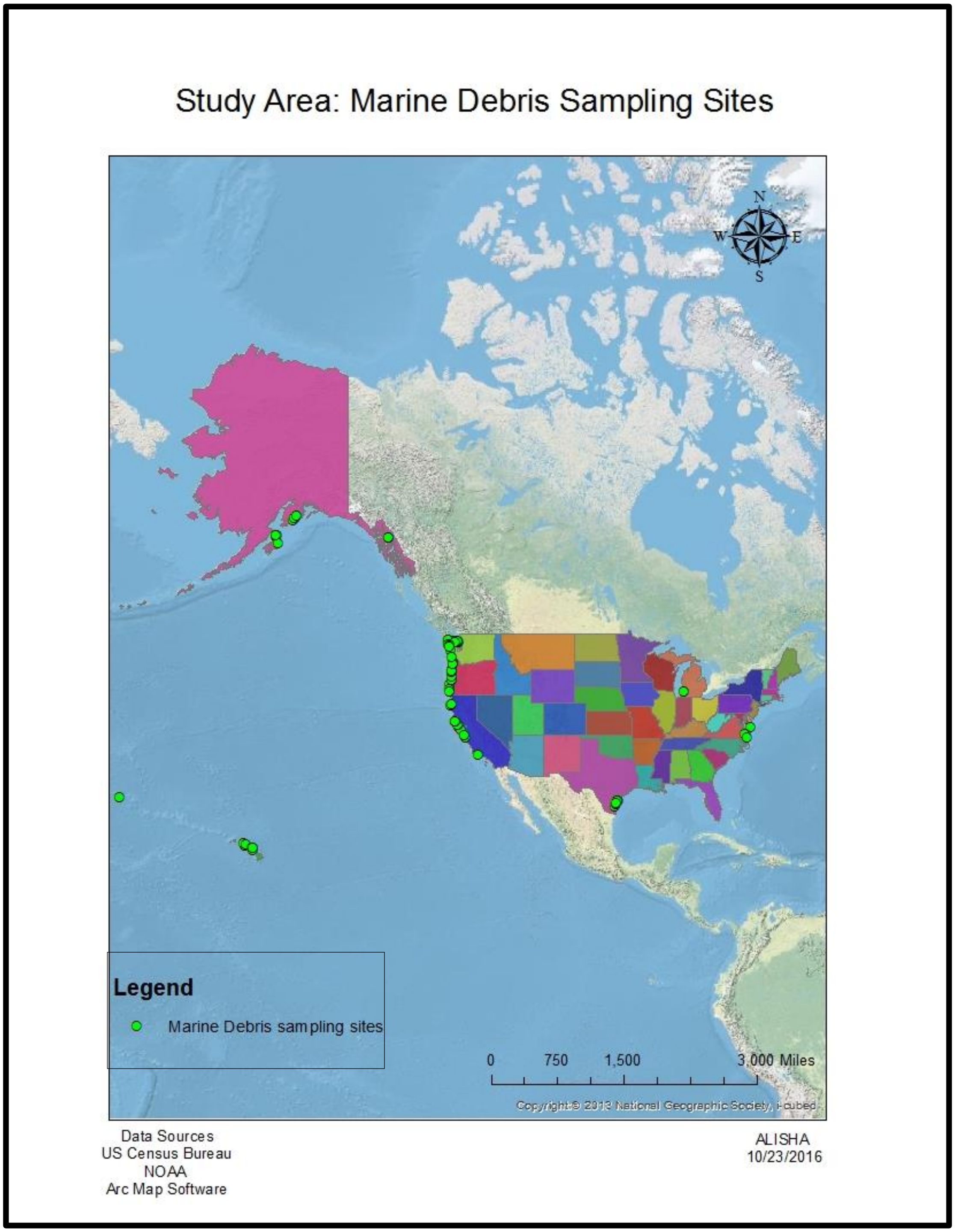

Figure 1: Sampling sites (National Oceanic and Atmospheric Administration, 2016)
Note: Created using ArcGIS software.

Table 1: Number of debris sampling sites by states

State	Number of Sampling cites	Period
Washington	700	2012-2016
Oregon	190	2012-2016
California	359	2012-2016
Texas	15	2015-2016
Michigan	3	2016
Virginia	7	2014-2016
Hawaii	134	2012-2016
Alaska	38	2013-2016

(National Oceanic and Atmospheric Administration, 2016)

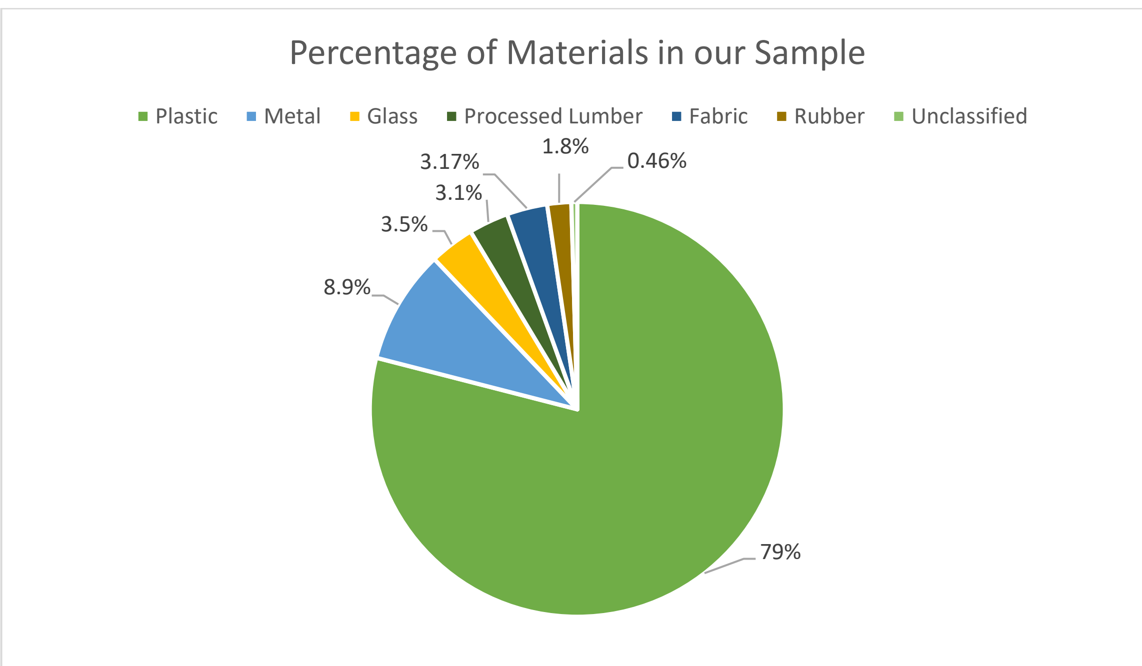

Figure 2: Percentage of each constituent of marine debris in our sample
(Author; National Oceanic and Atmospheric Administration, 2016).
Note: Highest concentrations of plastic materials were found in the sample

To create a county-level measure of marine debris, we first georeferenced sampling locations using geographic coordinate systems in Arc Map software and identified their locations relative to the county boundaries. For each county, we then aggregated number of all types of debris from different locations. Figure 3 depicts the marine debris data aggregated at county level, with debris counts reported by county. The average reported debris particles in the sample is 2,702, with a minimum of zero to maximum of 44,349.

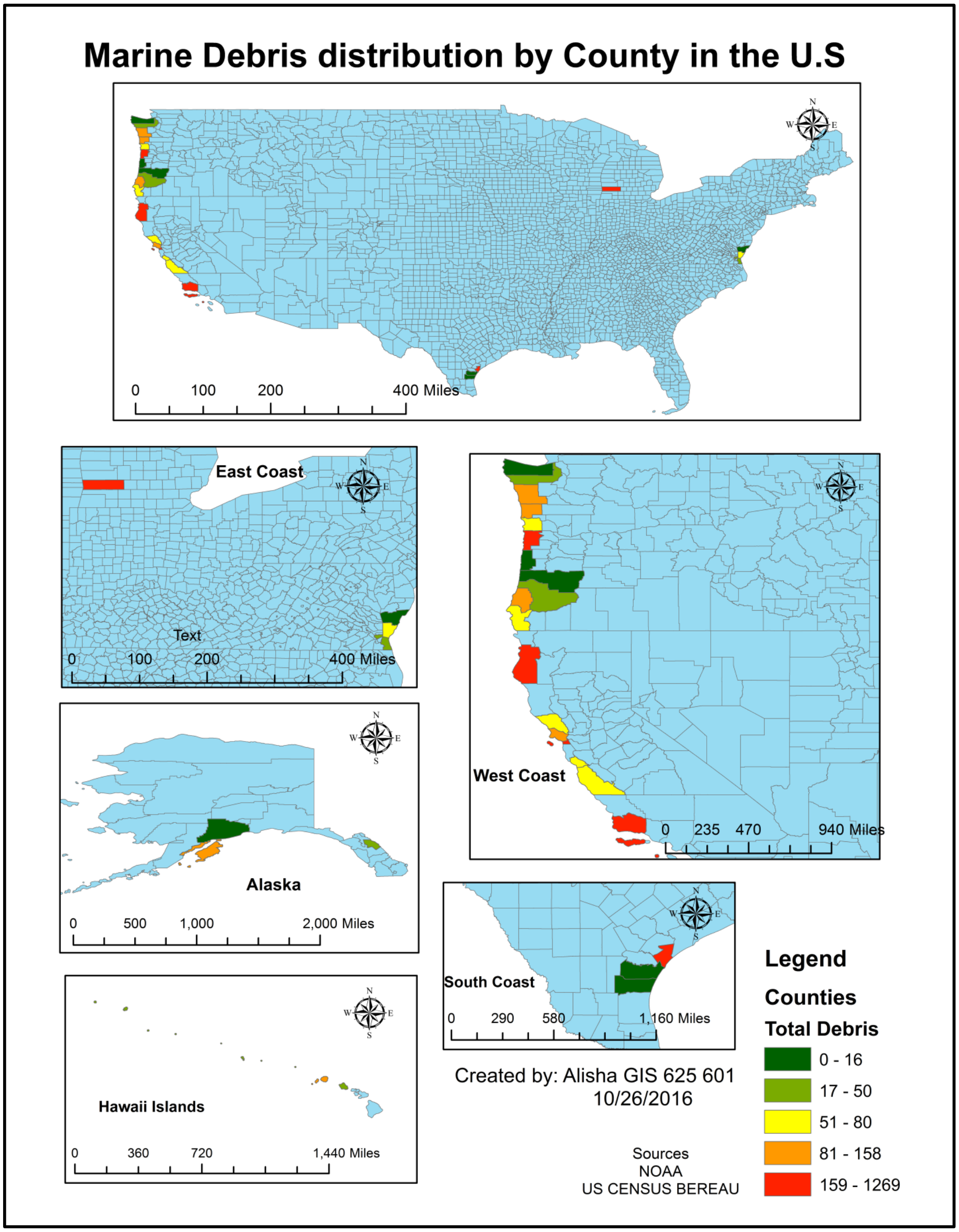

Figure 3: Counties in study area
(National Oceanic and Atmospheric Administration, 2016)
Note: Created using ArcGIS software, the map depicts marine debris data aggregated at county levels.

Figure 4 below presents the frequency distribution graph of Total Marine Debris and shows that debris distribution is skewed to the right.

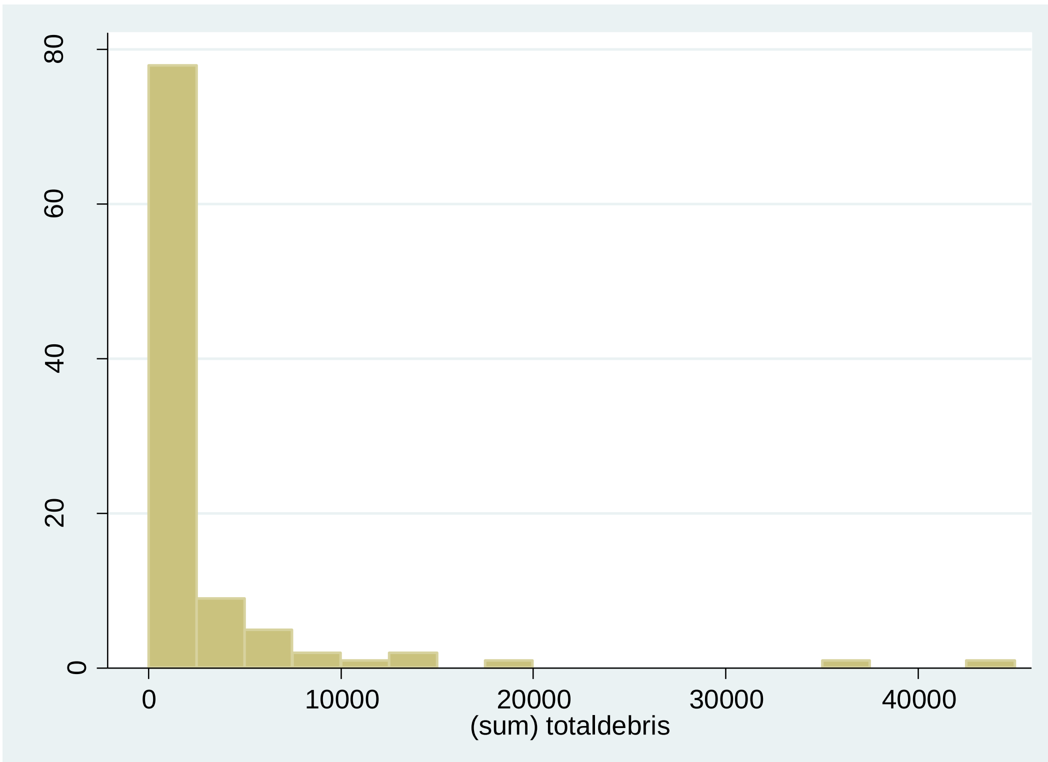

Figure 4: Frequency Distribution Graph of Marine Debris in the sample (Author; National Oceanic and Atmospheric Administration, 2016).

Independent variables

To capture the effects of economic development on marine debris we used per capita personal income as a proxy for wealth, population to capture the size of a county, percent white and percent black population, age distribution to capture the demographic effects, education as well as number of business establishments in tourism and recreational sectors. We included social capital, proxied by number of voter participation, to estimate mitigating effects of social capital on marine debris. Details are discussed below.

Personal Income & Population

Per capita personal income and population series data for U.S. counties were obtained from the U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Accounts. 2015 is the latest year for which data were available. We used Urban CPI to covert nominal income into real 2015 prices. The average per capita personal income for counties in this study is $ 41, 574.

Demographics

Population demographics including race and age are suggested to be important drivers for beach littering behavior (Eastman et al., 2013). We use data on race and ethnicity available from the National Center for Health Statistics of the Center for Disease Control and Prevention. Corresponding percentages for white and black population were calculated for each county-year. Age data was obtained from National Center for Health Statistics of the Center for Disease Control and Prevention. For the purposes of the study, age was grouped to two categories: percent Millennials (Age 22-34) and percent working age (Age 35-60) population.

Education

In order to study the correlation of education with marine debris pollution, we included data on percent of people with college degree and higher education. Education data were obtained from U.S. Census Bureau, American Community Survey and are reported in five yearly averages for each. To merge with annual marine debris data, we assumed the latest year in average education corresponded to the year debris was recorded.

Tourism

In order to study the effect of tourism on marine debris accumulation, number of hotels, and food establishments were used as proxy variables for types of industries commonly utilized by tourists in coastal areas. The data on county business establishments were obtained from the United States Census Bureau, Community Business Patterns (CBP). Number of business establishments were recorded by industry type, defined by the North American Industry Classification System (NAICS). NAICS uses a six-digit coding system to classify activities into 20 industry sectors, five of which are goods-producing, while the remaining 15 comprise service sectors. Out of those, we utilized data on (i) Total Food establishments, corresponding to NAICS Code 722, which are defined as " *Meals and beverages, prepared and served or dispensed for immediate consumption"* (United States Census Bureau, 2016-a); (ii) Total Hotels corresponding to NAICS Code 721, which are defined as, "*Accommodation for travelers"* were downloaded " (United States Census Bureau, 2016-b). Each establishment type is given by the total numbers per 100,000 people. The average food and hotel establishments per 100,000 in the sample is 254 and 83 respectively. For the purposes of this study, we created an additional variable, Total Tourism Sector Businesses, which is the aggregate sum of food and hotel establishments per 100,000 people.

Civic Engagement

Civic engagement in our model is proxied by the percent voter participation in the most recent presidential election. We utilized the County Level Dataset for 2012 Presidential Elections. The data was available from the Dave Leip's Atlas of U.S. Presidential Elections (United States President General, 2017).

Other Control Variables

Wind Speed

Studies document how oceanic currents contribute to movement and circulation of marine debris across the globe (Howell et al., 2012; Martinez et al., 2009; Pichel et al., 2007; Kubota, 1994). Some studies were even able to trace the exact sources of non-local debris particles in an ocean relative to geostrophic currents in circulation patterns (Ebbesmeyer, 2012). To effectively study the role of wind and oceanic currents, deeper inspection of local and regional wind patterns is needed.

NCEP/NCAR Reanalysis derived data for wind speed, provided by NOAA's Physical Sciences Division, as a part of NCEP/NCAR Reanalysis 1 project was used (Kalnay et al., 1996). Monthly mean data collected at 10 m surface at sigma level 0.995 for wind speed was used. The spatial coverage is 2.5 degree latitude x 2.5 degree longitude global grid (144x73) at 90N - 90S, 0E - 357.5E, measured in metre/second (Kalnay et al., 1996).

The global data, available in NetCDF format on NOAA's ESRL database was downloaded and raster layer was displayed using 'Multidimension tool' in Arc toolbox. Wind speed data for each month in our study period was extracted as a raster layer.

Then, we added the shapefile containing latitudal and longitudal coordinates of coastal counties in our sample (this shapefile was created separately). Monthly raster files containing wind speed with coastal counties shapefile using ‘Extract values to points’ tool from Spatial analyst tools. The attribute table of the new shapefile had a wind speed values for all the point coordinates, with monthly wind speed measure for each county. The monthly averages for wind speed were found to be highly correlated, so were seasonal and biannual averages (correlation matrices reported in Appendix A Tables A.1, A.2, A.3). In order to circumvent the multicollinearity problem in the estimation model, we created yearly averages of wind speed. While annual average is not an ideal proxy for wind direction and intensity, given the aggregate level analysis, this appeared to be the most feasible course of action to control for physical intensity of wind speed.

Area

Area of each sampling site was calculated using length and width given in the Marine Debris dataset, which were further aggregated at the county level. Area was included in the model to control for variability in debris deposition based on the size of a beach. Table 2 below represents summary statistics of all model variables as along with the description in Table 3. Correlation matrix of all model variables is shown in Table 4.

Table 2: Summary Statistics

Variable	Mean	S.D	Min	Max
Total Debris	1720.64	2523.085	0	13504
Log Income	10.6479	0.222	10.395	11.499
Percent Black	5.6583	11.177	0.762	51.831
Percent White	82.4086	19.290	26.500	96.210
Log Population	11.6141	1.261	9.403	13.807
Average Wind Speed	5.0705	0.951	3.151	6.673
Log Area	10.9969	1.588	7.515	15.936
Percent Voters	44.6152	9.442	24.951	66.489
Total Tourist Establishments	329.8751	119.055	183.580	680.472
Total Food Establishments	252.2754	71.824	155.472	499.013
Total Hotel Establishments	77.5997	61.212	10.486	230.009
College Degree	26.0761	8.738	14.3	54.6
Millennials	18.8075	4.682	11.677	29
Working Age	39.058	2.425	28.288	44

Note: Sample contains 88 county-by year observations in total
S.D in the table stands for Standard Deviation

Table 3: Variable Description

Variable	Description
Total Debris	Count
Log Income	Natural log of per capita personal income
Percent Black	% black population
Percent White	% white population
Log Population	Natural log of Population
Average Wind Speed	Yearly averages in meter/sec
Log Area	Natural log of area
Percent Voters	% total voters
Total Tourist Establishments	(Food Establishments+ Hotel Establishments)/Population)*100,000
Total Food Establishments	(Number of Food establishments/ Total Population)*100,000

Table 3 continued…

Variable	Description
	(Number of Hotel establishments/ Total Population)*100000
College Degree	% of population with college degree and higher
Millennials	% of people in Age group 22-34
Working Age	% of people in Age group 35-60

Table 4: Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.log Income	1												
2.%black	-0.0178	1											
3.%white	-0.2717	-0.4819	1										
4.Population	0.589	-0.0359	-0.4074	1									
5.Wind speed	-0.4582	-0.185	-0.0838	-0.2734	1								
6.Log area	-0.2821	-0.1891	0.3858	-0.1869	-0.0356	1							
7.%voter	-0.2803	0.0802	0.3909	-0.6239	0.0753	0.2679	1						
8.Food&Hotel	-0.1286	-0.2599	0.2581	-0.5319	0.2781	0.095	0.3323	1					
9.Food places	0.1488	-0.268	0.1021	-0.225	0.2217	0.011	0.1866	0.9114	1				

4. METHODS

In order to explore the socioeconomic drivers of marine debris pollution, we estimated the Random Effects Poisson's Regression Model. Poisson regression is suitable when the dependent variable is count, only taking nonnegative or positive values (Gujarati & Porter, 2009). The Total debris examined in this study represents the total number of debris item in a county. The Poisson distribution describes the number of events that happen in a given time period and its Probability Density Function is defined as:

$$Pr(Y = y) = \frac{\mu^{Y} e^{-\mu}}{y!}; \text{ for } y = 0,1,2, \dots N \qquad (1)$$

Where μ corresponds to the mean number of events (i.e. debris) and y! is the factorial of y. Poisson regression model is specified in equation (2) in terms a conditional mean (which also represents the exponential mean) of observation i given covariates (X), and could be estimated using the maximum likelihood estimation

$$E(y_i) = \mu_i = exp(x_i'\beta)\,, i = 1,2, \dots, N \qquad (2)$$

We specify the Poisson model as follows in equation (3):

$$E(y_{it}) = exp(\beta_0 + \beta_1 Econ_{it} + \beta_2 Dem_{it} + \beta_3 Educ_{it} + \beta_4 Phys_{it} + \beta_5 Civic_{it} + \lambda_t + \lambda_i + e_{it}) \qquad (3)$$

Where y_{it} is the dependent variable and measures the total number of debris item in county i at time t, $Econ_{it}$ corresponds to a vector of socio-economic variables including per capital income (and its square term), population, hotel and food establishments per

100,000 people. Dem_{it} corresponds to county demographic characteristics represented by the percent white and percent black population, age distribution. $Educ_{it}$ measures percent of population with college degree and higher. $Phys_{it}$ includes annual wind-speed measured in metre/second and log of beach areas, measured in metre squared. $Civic_{it}$ corresponds to the percent voter participation in 2012 presidential election. λ_t indicates year fixed effects and captures the common shocks to all counties that vary over time, including the changes in national level policy pertinent to marine pollution. λ_i is the county-specific effects, which we assume to be random. Finally, e_{it} corresponds to the error term. We cluster standard errors at the county level, allowing error correlations within each clustering unit (i.e. county) over time.

Coefficients estimated by the Poisson Regression do not represent the marginal effects associated with the unit change in corresponding covariates. Marginal effects are calculated by adjusting coefficients estimates with the mean of the dependent variables if the explanatory variable of interest is not log-transformed. This is defined in equation (4) that follows:

$$\frac{\partial y}{\partial x_j} = \beta_j \exp(X'_{it}\beta) \qquad (4)$$

In case of log transformed variables, the coefficient of independent variable represents approximate percent change in dependent variable, y corresponding to a 1% increase in explanatory variable of interest.

5. HYPOTHESES

Based on the extensive review of past research, we propose and empirically test the following three hypotheses.

Hypothesis I: Non-linear exponential relationship between income and marine debris

As per capita income will increase, the amount of marine debris will increase until a threshold of income is reached and subsequently the effect will start to offset. This proposition is based on the Environmental Kuznets Curve (EKC) hypothesis, which builds on Kuznets Curve hypothesis postulated by Simon Kuznets (Kuznets, 1955)[1]. EKC postulates a non-linear, exponential relationship between per capita income and environmental quality over a transitional time period in which an economy transitions from pre- to post-industrial era (Munasinghe , 1999; Paytou, 1993). It states the quality of natural resources is immaculate in "pre-industrial" era but as the economy develops, and industrialization starts, exploitation of these resources begins and the focus shifts on attaining higher levels of economic growth, often unsustainably which leads to deterioration in environmental and natural resource quality. However, as the economic development and per capita income reach a certain threshold and "post-industrial era"

[1] The hypothesis was derived from the study of relationship between income and economic inequality and its trends across developed and developing nations which suggests the evidence of a non-linear relationship between income and economic inequality, indicating that both increase steadily at first but eventually there comes a point where this relationship is inversed, i.e., as income increases, inequality decreases (Kuznets, 1955; Lynch, 2004).

begins, the attention shifts towards overall improvement of quality of environment and due to attainment of economic goals, populations are equipped with sufficient monetary resources to divert towards betterment and welfare of the environment (Munasinghe , 1999). Hence, a gradual rise and fall of the Kuznets Curve, plotted between economic growth and environmental pollution is observed, as depicted in Fig. (5).

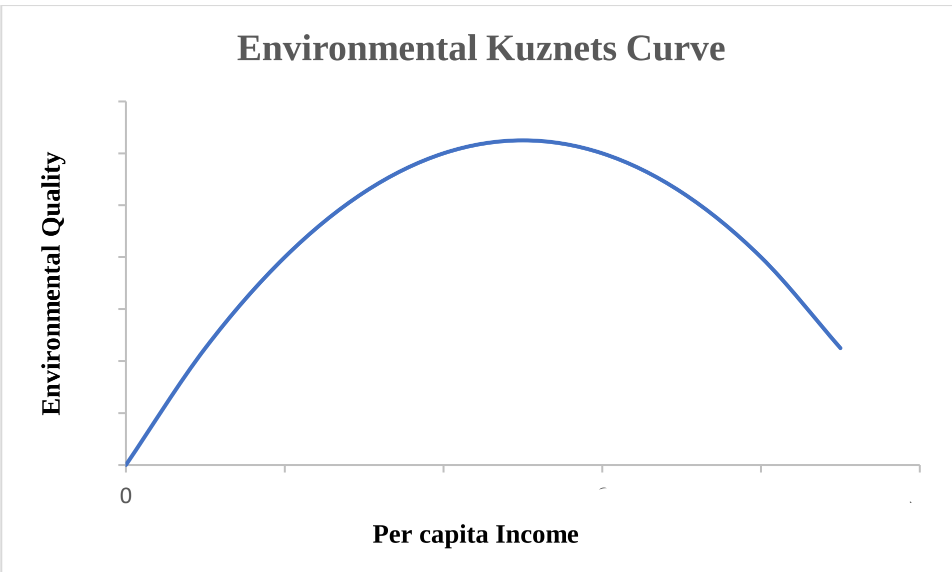

Figure 5: Environmental Kuznets Curve
Note: A general representation of relationship between Environmental Quality and Per capita Income. Increasing Environmental Quality indicates environmental degradation. Economies with higher incomes are postulated to lie on the right side of the graph and vice versa (Panayotou, 1993).

We thus hypothesize that marine debris pollution increases by income level, however beyond certain level it starts to taper down. To capture this non-linear effect our regression model specified in equation (2) includes a squared income as an additional regressor. In figure 6, we plot the actual marine debris and per capita income to explore the relationship between the two variables. An imprecise , however non-linear relationship is observed, which are further validated by statistically modelling this relationship.

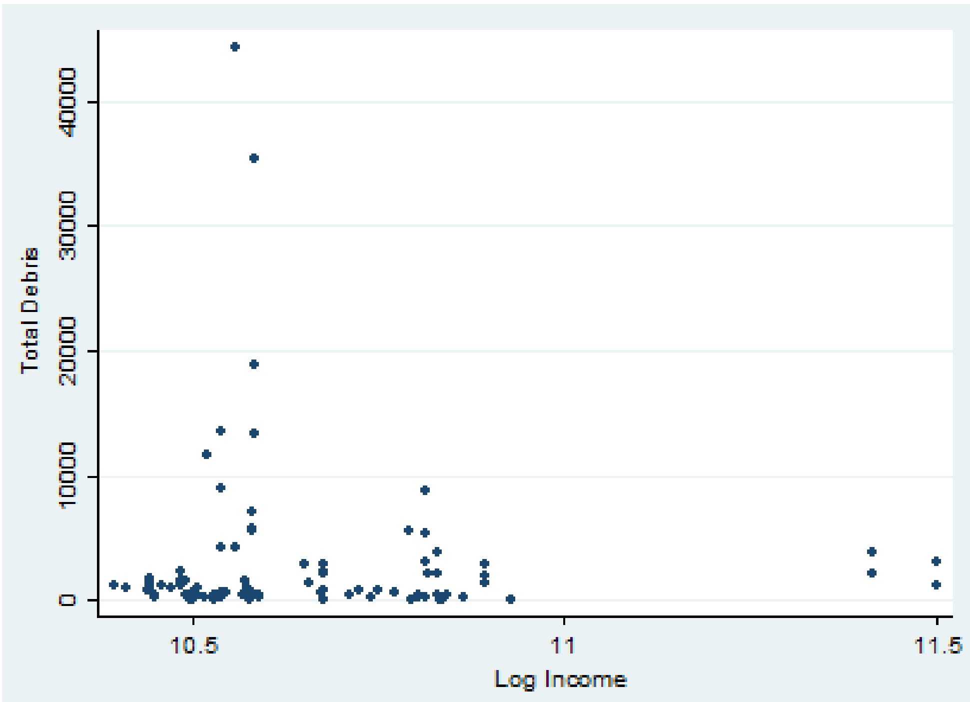

Fig. 6: Environmental Kuznets Curve for our sample
Note: Graph was generated using Stata IC software. the figure depicts a relationship between per capita income and debris pollution.

Hypothesis II: Increase in Tourism-related activities will lead to either an increase or decrease in Marine Debris Pollution

Tourists can be local or may visit from different locations, depending on the popularity of the beach destination. While it's hard to separate tourists by origin, we know all of them use hotels and restaurants upon visitation. Tourism can exert two different kinds of effects. On the one hand, tourism leads to more crowd on the beach and more littering. On the other hand, tourism brings revenues and part of these revenues (e.g. Hotel Occupancy Tax) often are used towards maintenance, upkeep and cleaning of local beaches (Texas Tax Code § 2.156.00). Hence, it is the matter of empirical estimation in the study to find out which effect would outweigh another.

Hypothesis III: More civic engagement will have the mitigating effects on marine debris.

Civic engagement has been viewed as a symbol of expression and a voice for the people in a country to be able to advocate their rights and to reform and restructure existing political scenarios and aid in realization of goals and policies (Skocpol & Fiorina, 2004). History is amply evident of the power of civic engagement to bring about significant transformations in governance of countries and eradication of rudimentary laws and policies. Civic engagement is often expressed in terms of measures individuals partake to contribute to realization of community goals or to participate and tap into functioning of a community, and to be active as a member of a society, for example political participation, volunteering for social events, club memberships, organizations of blood donation drives, donating for social causes and many more (Adler, & Goggin, 2005). Social capital is regarded as tool that can fortify the human capital and promote behaviors that result in effective realization of goals of a society (Coleman, 1988). The notion of social capital draws parallels on the pillars of civic engagement, i.e., being comprised of strong community bonding, social structures and the idea of building relationships that contribute towards fulfilment of community goals and allocation of resources required to achieve them (Aldrich and Meyer, 2015; Coleman, 1988; Putnam, 1995; Woolcock, 2002, Rupasingha et al. 2006). In a nutshell, when social capital broadens the focus of individual members of population from ‘me’ to ‘we’, there’s efficiency in circulation of resources and heightened economic performance in a society (Adler and Kwon, 2002; Coleman, 1988). Present research draws on the approaches utilized by previous studies and employs proxy for social capital viz., Voter Turnouts in U.S., 2012 Presidential election in the coastal counties. We postulate that stronger social capital will affect community behaviors in a way to work in solidarity towards the responsible use and maintenance of beaches and view them as a valued community asset. Hence, social capital should have the mitigating effect on marine debris pollution.

6. RESULT

We first report the results of Ordinary Least Square (OLS) regression model along with Random Effects model for panel data, column (1) and (2) of Table 5 respectively, to study the relationship between the dependent variable, marine debris and independent variables. However, we found that overall results are insignificant, except for a few variables. Main variables of are model exhibit statistical insignificance. This could be due to the fact that the nature of dependent variable, which violates the basic assumption of OLS models, which states that true values are normally distributed around the expected value and can take any real value (positive or negative) (Gujarati & Porter, 2009). But in our model, dependent variable represents an expected count of marine debris, which has to be non-negative. Also, simple OLS model does not take into account the county-specific heterogeneity observed in panel data.

Table 5: OLS Results

	(1)	(2)
Log Income	-93,058.9929	-36,476.9355
	(69,031.3530)	(80,279.0542)
Log Income Square	4,352.6400	1,924.8096
	(3,131.5120)	(3,664.9654)
Percent Black	-28.8933	-34.5242
	(34.0415)	(35.9155)
Percent White	-48.6239***	-42.6802**
	(17.7957)	(20.6628)
Total Tourist Establishments	-3.1818	-3.8781
	(2.6013)	(2.9875)
Log Population	-709.2936	-680.9593
	(443.3953)	(518.9689)
Average Wind Speed	738.9943**	837.2028**
	(344.5417)	(391.9470)
Log Area	1,196.9488***	1,132.1030***
	(163.8743)	(177.6625)
Percent Voters	-71.3284	-53.7844
	(44.7051)	(38.6952)
College Degree	104.9487	
	(78.2966)	
Millennials (Age20-34)	-25.8033	19.1012
	(121.0780)	(129.8633)
Working Age (Age 35-60)	-332.9732**	-216.2289
	(159.0774)	(191.9253)
Year 2013	194.7391	442.5843
	(770.8861)	(726.4868)
Year 2014	-977.7638	-777.3667
	(831.4675)	(782.3656)
Year 2015	-812.1068	-562.8519
	(773.8465)	(736.2503)
Year 2016	214.5569	292.7493
	(765.6810)	(727.2838)
_cons	509,747.4284	178,633.3022
	(381,972.0884)	(440,756.0383)
R^2	0.57	
Sigma e		1543.601
Sigma u		751.52
N	88	88

* p<0.1; ** p<0.05; *** p<0.01

Notes: Dependent variable in both model is total number of marine debris county.

Column(1) corresponds to simple OLS model and Column (2) reports results from random effects model for panel data; Standard errors are reported in parenthesis and are clustered by county.

Hence, we utilized the Random Effects Poisson Regression Model as it takes into account the nature of the data and also accounts for unobservable county specific effects, assumed to be random (Gujarati & Porter, 2009).

We estimated four different Poisson models reported in columns (1) – (4) of Table 6. In Model 1 we include total combined tourism businesses (Food and Hotel), along with other control variables. In Model 2, we separate hotels and food establishments, respectively (given their high correlation of 0.9114 we cannot include them in the same model). Additionally, it should be noted that income and education variable are also highly correlated.[2] In order to see whether omitting education would change the effects of income variable, in column (4) we reported from model 4, which is equivalent to model 1 but drops educational attainment variable. We found the results to be consistent in terms of signs and significance of coefficients of all model variables, especially income variable, which it is highly correlated with.

In all models, the results indicate that population significantly increases marine debris. On the other hand, higher the percent white population, percent voters, college degree holders, and millennials significantly decrease marine debris pollution, total tourist establishments have a significantly negative relationship with marine debris.

Out of the two tourism variables, we only include Total Hotels per capita. Results indicate that hotels and population significantly increase marine debris and, percent black and percent white population, college degree holders, millennials, and voters lower the

[2] This high correlation can be explained by the fact that our sample is over represented by west coast, which is a hub of economic activity and also boasts of software industries and silicon valley, and income level is also higher than southern or north eastern coast.

marine debris. Furthermore, negative coefficient of log income square indicates the empirical evidence of EKC hypothesis.

Our results indicate that, in terms of total tourism businesses, there is evidence of negative relationship. However, when we estimate the effects of food and hotel establishments individually, we observe that hotels increase marine debris whereas food establishments decrease it. The overall decreasing effect of total tourist establishments indicate that significantly less contribution of food establishments mask the increasing effect of hotels on debris pollution. The difference can be attributed to the fact that, generally people dine at the restaurants where trash is relatively batter managed and is less likely to end up near or at the beach. While it partly confirms our hypothesis about tourism increasing marine debris, the significant positive effect of hotels on debris pollution indicates that contribution of taxes by local hotels, as discussed in hypothesis section, does not seem to counteract the pollution generated by tourists (Texas Tax Code § 2.156.00).

The coefficients associated with covariates enabled us to calculate associated marginal effects on marine debris. Specifically, for every additional hotel per 100,000 people, there are 32 debris particles added to the beach, whereas for every additional food establishments per 100,000 people, there are 59 fewer debris particles generated. In case of age variables, for every one percent increase in millennial population there are approximately 1.5% fewer debris particles. Working age population does not exert significant on marine debris pollution except in model 3, and suggests to significantly contribute to increased debris particles in beaches. Education is found to significantly reduce marine debris pollution, results indicating approximately 1.5% fewer debris particle for for every one percent increase in population with college degree and higher. Our results indicated mitigating effects of social capital, proxied by voter participation. For every one percent increase in voters in presidential election, there are 0.06% fewer debris particles.

The coefficient associated with income variables enabled us to calculate the marginal effect of per capita income and exact "threshold" level of income, following which the effect of income starts to reverse. It was estimated that for every 1% increase in per capita income, there is 11.45% decrease in debris. In terms of dollar value, for every $420 rise per capita yearly income, there is 309 fewer debris particles. It was estimated that at the attainment of threshold value of yearly average income of $ 28,878, and above, marine pollution will decrease in a county. The calculated threshold value is lower than the average per capita income in our sample as well as the median household income of the U.S., $51,371, for the year 2012 (United States Census Bureau (2013-d). Additionally, models include year dummies, which control for the overall trend in marine pollution over time as well as national level policies pertinent to debris deposition and regulation that affect all counties in a similar fashion.

Table 6: Random Effects Poisson Regression Results

	1	2	3	4
Log Income	281.8409***	322.8561***	244.5388***	276.3452***
	-28.0878	-26.523	-27.0044	-27.0582
Log Income square	-14.1473***	-15.7183***	-12.3237***	-13.8892***
	-1.318	-1.2465	-1.2713	-1.2703
Percent Black	-0.372	-1.1879***	0.0036	-0.1641
	-0.2825	-0.1437	-0.1401	-0.1262
Percent White	-0.9231***	-1.1469***	-0.9198***	-0.9699***
	-0.0718	-0.0562	-0.0508	-0.0494
Log Population	43.4987***	19.5455***	54.2250***	45.0327***
	-3.4216	-2.2456	-2.5289	-2.7936
Average Wind Speed	1.5084***	1.4204***	1.5201***	1.5120***
	-0.0223	-0.0217	-0.0212	-0.0217
Log Area	0.4295***	0.3970***	0.4502***	0.4294***
	-0.0061	-0.0056	-0.0058	-0.0061
Percent Voters	-0.0633***	-0.0638***	-0.0643***	-0.0633***
	-0.001	-0.001	-0.001	-0.001
Total Tourism Businesses	-0.0031***			-0.0031***
	-0.0007			-0.0007
College Degree Holders	-1.4745**	-1.1878***	-1.3648***	
	-0.6144	-0.2376	-0.3169	
Millennials (Age20-34)	-1.4801***	-0.3540***	-1.6467***	-1.5257***
	-0.1268	-0.106	-0.0894	-0.1099
Working Age	-0.0315	0.0389	0.1566***	-0.0437
Year 2013	0.8212***	0.9830***	0.8202***	0.7962***
	-0.0425	-0.0296	-0.03	-0.0294
Year 2014	0.0463	0.1981***	-0.0052	-0.0113
	-0.0883	-0.0535	-0.0597	-0.0551
Year 2015	0.2668***	0.4056***	0.2145***	0.2099***
	-0.0885	-0.0549	-0.0612	-0.0567
Year 2016	-0.2754***	-0.1569***	-0.3153***	-0.3332***
	-0.088	-0.0537	-0.0595	-0.0547
_cons	- 1,689.6123***	- 1,705.7980***	- 1,618.3221***	- 1,707.209***
	-143.8844	-142.4849	-144.1499	-143.6553

Table 6 continued.

	1	2	3	4
Log Income	281.8409***	322.8561***	244.5388***	276.3452***
Hotel Establishments per capita		0.0121***		
		-0.0011		
Food Establishments Per Capita			-0.0122***	
			-0.0009	
lnalpha	4.2253***	3.7510***	4.4004***	4.3034***
N	88	88	88	88
Log Likelihood	-10280.713	-10228.107	-10190.083	-10283.493

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

Notes: Poisson's regression results estimated in Stata IC software ; Dependent variable corresponds to the total number of marine debris; year 2012 is an omitted category. Standard errors are reported in parenthesis and are clustered by county

Dependent Variable is Total Debris

7. DISCUSSION

The first step in solving the peril of marine debris pollution, other than recognizing it to be a real problem, is to study the factors that are contributing to it. The anthropogenic nature of marine debris pollution led us to explore its linkages with socioeconomic drivers in this study. This research utilized the data on marine debris along eight coastal states of North America and analyzed its hypothesized relationship with socioeconomic drivers, including population, demographics, age, education, tourism, and the potential mitigating effect of social capital on debris pollution. This research further explored empirical evidence of Environmental Kuznets Curve hypothesis in case of marine debris pollution.

Several important findings emerged from this study and below we discuss how they align with each of our individual hypotheses postulated above and previous research done in the field. The results of our study indicated the empirical evidence of non-linear, exponential relationship between per capita income and marine debris, confirming the Environmental Kuznets Curve hypothesis. The threshold yearly per capita income level at which detrimental effects of increasing wealth on environmental quality start to offset was estimated to be approximately $ 28, 878.

Our results align with findings of previous research done to explore this empirical relationship in context of water pollution, air pollution, ozone depletion and land use patterns (Stern & Common, 2001; Panayotou, 1997; Selden & Song, 1994;

Stern, 2004; Lambin & Meyfroidt, 2010; Torras & Boyce, 1998; Kai, Mao & Qi-xin, 2003).

Non-linear relationship between per capita income and debris pollution is more intricate, for its an interplay of various underlying factors that can affect the "convexity" of EKC (Panayotou, 1997). Panayotou (1997) further pointed that the curve could be affected by environmental policies and markets, including property rights, energy subsidies and externalities. In case of presence of energy subsidies and weak property rights, there will be unsustainable use of environmental resources and more pollution, which will delay the attainment of threshold level of income and would make the EKC "steeper" (Panayotou, 1997). On the other hand, if policies are improved and externalities are internalized, there will be less environmental pollution and early attainment of threshold level of income, making the curve "flatter" (Panayotou, 1997). Also, dominance of industrial sectors (primary, secondary or tertiary) can also affect the magnitude of effect of per capita income on environmental quality (Grossman & Krueger, 1994; Panayotou, 1997). The conventional EKC approach utilized in this study and many previous studies does not take into account these underlying factors. Hence, this approach has often been partly criticized in the literature and referred to as "reduced form relationship" (Grossman & Krueger, 1995; Stern, Common, & Barbier, 1996). Regardless, this approach can still serve as the primary building block in studying and quantifying how economic developmental matrices affect the environment and, opens up avenues for consideration of above mentioned underlying factors in pollution studies. We propose that the consideration of these underlying factors in future research is the key step in bringing new reforms and, formulation and strengthening of existing laws and policies and hopefully making the EKC curve more “flat”.

Partly consistent to hypothesis II, our results indicated significant footprints of tourism related activities, however the effects of hotel and food establishments were found to be varying. Only hotel establishments were estimated to have a contribution towards marine debris pollution. Tourism represents vital economic sector for many coastal towns and many beach towns strive to attract not only local but also tourists from elsewhere. More tourists generate more litters and oftentimes, it is hard to keep litter generation under control partially because local businesses not always impose strict restrictions on littering in order to not to risk losing business customers. As discussed in the hypotheses section about positive and negative aspects of tourism, finding significantly contributing effects of one of the tourist business on marine litter answers our empirical question that negative aspect of tourism (generating more debris) outweighs the positive (generating revenues for beach clean ups). Due to lack of consistent data available on taxes collected from hotels at county levels, we could not include them into our model to directly measure how much or if these revenues contribute to beach clean up. Additionally, our results indicated that food establishments do not contribute positively to debris pollution. This is could possibly be explained by the fact that restaurants and food places are often well equipped with dealing with trash. Hence, there is less likeliness of littering at the beach, with the exception of the case when people bring to go boxes from food trucks to the beach.

In support of enhanced coordination and cooperation at different levels and the hypothesis III, our results indicated that social capital (proxied by voter turn-over) play paramount roles in mitigating marine debris pollution. The role of different forms of social capital including social and political trust, voter participation, and neighborhood associations, and enrollment in religious, cultural, sports, arts, and business organizations has been successfully established in facilitating better maintenance, conservation and performance of ecosystems (Veenstra, 2005; Rydin, & Pennington, 2000; Cramb, 2005; Pretty & Ward, 2001). Existence of a strong individual and community bonds can lessen the burden on law and enforcement agencies and reduce the need for stringent laws as individuals look out for each other and work together as a team (Rupasingha, Goetz, & Freshwater, 2000; Pretty & Ward, 2001). On the other hand, week social capital and reduced public participation can lead to considerable loss of viable ecosystems and unsustainable development at the hands of organizations and individuals aiming to merely sought profit out of ecosystems, at the cost of their quality (Brondizio, Ostrom, & Young, 2009). Social capital and public involvement should be exploited for an effective aid in formulating laws and policies pertinent to environment as it leads to formulation of policies that resonate with general public and stakeholders, which further leads to better implementation and lesser conflicts among these groups (Rydin, & Pennington, 2000).

There has been an emerging literature on the relationship between environmental quality and social capital (Paudel & Schafer, 2009; Brondizio, Ostrom, & Young, 2009; Rydin & Pennington, 2000; Cramb, 2005; Pretty & Ward, 2001; Grafton & Knowles, 2004; Rodrıguez& Pascual, 2004), only few of them found empirical evidence of it (Brondizio, Ostrom, & Young, 2009; Cramb, 2005; Pretty & Ward, 2001). The effects of social capital vary in developed and developing economies and also within an economy based on the status of economic growth (Pretty & Ward, 2001). In addition to directly impacting environmental quality, social capital has been studied to affect economic growth. A study by Rupasingha et al. (2000), based in U.S. counties, found that social capital can enhance the economic growth positively, and "poorer counties" were suggested to especially reap higher benefits of it. This poses an empirical question for future research whether the notion of social capital can indirectly affect the environmental quality by flattening the EKC curve (Panayotou, 1997). However, the current study only takes into account the existing local social capital in a county. We do not include measures of social capital for tourists that come from elsewhere. Their sense of social capital can be week or strong, depending on areas, states or countries they belong to. This external social capital can either mitigate or contribute to marine debris pollution.

In addition of supporting hypothesis pertaining to above discussed variables, our results also indicated other determinants of marine debris pollution to be significant, that includes population, education, age and demographics. We found education to be a significant variable in decreasing marine debris. People with Bachelor's degree and above were estimated to have significantly negative relation with marine debris. Our results align with previous research done by Eastman et al. (2013) that modelled the relationship been marine litter and educational level of people in nationwide study based in Chile. They found people with college and university degree to be littering less as compared to their counterparts with relatively lower education (Eastman et al., 2013). Education has been linked to promoting pro-environmental and stewardship behaviors, starting at an early age (Zsóka et al., 2013; Torras & Boyce, 1998). Education level and major of degree is established to be an important determinant of environmentally conscious behaviors (Tikka et al., 2000). In addition to academic knowledge, college going experience in general exposes an individual to diverse ideas and wide range of interactions with people from different backgrounds and walks of life. Information is shared and spread across campus fast, especially in today's era of social media and technology, which is especially an integral part of campuses. One gets more tuned in to current affairs and issues of the world, including political, environmental, art and music events of the world. College also presents more opportunities to explore local natural environment in the form of activities like hiking and camping trips, beach visits, visits to local parks and zoos etc. (Jewell, 1978). These activities have been proven to create a sense of belonging and establishment of emotional connection with the environment, which is conducive in promoting pro environmental behaviors (Jewell, 1978). The importance of education nonetheless cannot be stressed enough to promote environmental stewardship especially in case of marine pollution, which is relatively less popular and less explored phenomenon, more discussion on which is in *Policy Implication* section of this thesis.

Another finding of this research is the effect of age on marine debris pollution. Our results indicate that people categorized in working class category (age 35-64) contribute significantly to marine debris pollution, whereas in case of people categorized as millennials (age 20-34), for the purpose of this study, contribution to marine debris is significantly negative. Our results contradict the findings by study done by Slavin et al. (2012) to study how age affects beach littering behavior and associated guilt. They reported that older people (exact age were not specified) littered less and were more conscious about maintaining the cleanliness of the beach as compared to younger people. The negative correlation of millennials and debris pollution aligns with findings of previous literature that has established that people in this generation have heightened sense of awareness and stewardship about the natural environment and the challenges it faces (Smith, 2014; Taylor et al.,2010; Van & Dunlap, 1980; Tulgan & Martin, 2001). The significant contribution of older, working age people in our model is attributed to general difference in attitudes and perceptions of this age group. It has been cited that "environmental reforms" are often considered as a challenging factor for rudimentary system and bringing these reforms often involves criticism and change of old norms and younger people are reported to accept and embrace these reforms more readily than older people (Van & Dunlap, 1980). However, significantly negative contribution of millennials towards debris pollution definitely looks promising for the present and as well as future as millennials are the largest generation with population of over 80 million in the U.S. and counting, as reported by a study in 2014 (Smith, 2014).

The effect of population growth on deterioration of environmental quality was found to be pronounced in case of marine debris pollution, supporting the argument throughout that the debris is purely anthropogenic in nature. Population growth can be viewed as a chain reaction that sets off urbanization, demand for more resources, habitat destruction, more waste generation, discharge of pollutants into streams, basically all the phenomenon that ultimately increase the stress on natural resources (Crain, Kroeker & Halpern, 2008). Growing human population is driving drastic changes to natural environment so overpoweringly that it is giving rise to a new geological epoch, termed as “Anthropocene era” (Sanderson et al., 2002). It is, therefore, crucial to buffer the natural ecosystems from the disastrous effects of population explosion, which calls for strengthening of existing laws and policies against environmental pollution, among other measures, more of which is discussed in the following section.

8. MARINE DEBRIS POLICY RECOMMENDATIONS

In the United States, discharges of marine debris from sea and land based sources are regulated by Marine Debris Research, Prevention and Reduction Act (MDRPRA) to identify and determine the sources of marine debris and its adverse impacts on marine environment and regulate navigation safety (S. 362, 2017). Passed in 2006, the MDRPRA established Marine Debris Prevention and Removal Program (MDMAP) within NOAA (Civic Impulse, 2017). Under MDMAP, guidelines are laid down regarding maintenance of an inventory of marine debris and its impacts in the waters of the United States and the U.S. Exclusive Economic Zone, including its location, material, size, and effects on marine environment, sea life and human health as well as formulation of strategies for the prevention and removal of marine debris (S. 362, 2017). Additionally, guidelines are also laid against abandonment of fishing gears and development of approaches for tracking of lost fishing gear (S. 362, 2017; Civic Impulse, 2017). The outreach program under MDMAP promotes education and awareness programs for “marine dependent” industries (Civic Impulse, 2017). The Coast Guard Program under MDMRA lays down guidelines for the implementation and violations of MARPOL Annex V and prevention of ship pollution (S. 362, 2017). The law, however, does not specify any limits for discarding of waste in the ocean. In addition, there are various national and international laws and policies that regulate protection of coastal waters and beaches from illegal dumping of waste.[3]

While existing policies are important in setting the guidelines against marine debris pollution, there are many arenas in which they can be improved. The improvements could be sector specific (i.e. tourism, fisheries, etc.), while others could target education. For example, given a significant contribution of tourism towards marine debris pollution, suggested by our research, following policies for tourism sector could help further curb marine debris pollution. A voluntary monetary contribution towards "Beach Clean up" at hotels could aid local authorities with beach upkeep and maintenance, in addition to raising awareness of tourists and general public towards the problem of marine litter on the beaches.

Some U.S. states have been pioneers in undertaking environmental friendly steps for coastal maintenance. For example, the State of California became the first state in the U.S. to enact a complete statewide ban on plastic bags, while the state of Hawaii has a de

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[3] Dumping of municipal and industrial wastes by vessels is regulated by Shore Protection Act, created by Title IV of Ocean Dumping Act in 1988 (Shore Protection Act of 1988). Coastal Zone Management Act, created in 1972, is another national-level act that protects natural resources from hazardous waste (Coastal Zone Management Act of 1972). Recreational coastal waters of the US are protected as a part of the amendment of Clean Water Act, implemented in 2000, termed as The Beaches Environmental Assessment and Coastal Health (BEACH) Act (BEACH Act of 2000). It promotes microbiological testing and monitoring of floatable materials in coastal recreational waters of the US by local and state governments and enables EPA to provide assistance to government bodies performing these tests (BEACH Act of 2000).

Internationally, regulations against ship generated pollution are implemented by International Maritime Organization in MARPOL, International Convention for the Prevention of Pollution by Ships Convention of 1973. The convention has 6 Annexures that lay down guidelines for sources of ship pollution, which includes Oil, Noxious Liquid Substances, Packaged Substances, Sewage, Garbage and Air, with guidelines for each of this source listed in each Annexure respectively (Civic Impulse, 2017). Currently US law implements Annexes I, II, III, V and VI (United States Coast Guard, 2017).

facto ban on plastic bags and paper bags containing less than 40% recyclable materials (National Conference of State Legislature, 2016). Needless to say, nationwide ban on plastic bags can go a long way in keeping the environment clean and reducing non-biodegradable waste generation.

While few suggested improvements can help reduce marine debris, they will not likely eliminate the problem without public awareness and education about the urgency of the issue. “Education is the most powerful weapon which you can use to change the world”, as quoted by Nelson Mandela, emphasizes on the importance and strength of education as a tool in solving problems of the world (Nelson Mandela, n.d.), including Marine debris pollution (Santos el., 2005; Slavin et la., 2012). The first step in curbing debris pollution is to educate people on what constitutes marine debris, its impacts and effects on marine ecosystem. As suggested by our results, formal education does play a paramount role in environmental awareness and promoting pro environmental behaviors. In addition to formal education, more efforts are needed to educate everyone in the general public, who are outside the realm of colleges and universities.

Involving famous figures, movie and sports celebrities to advocate for the cause of marine debris pollution, is one way to raise awareness. People are more likely to be persuaded and tend to pay attention to the causes supported by people they recognize, trust and look up to and have a mass appeal, the qualities often possessed by famous celebrities (Choi et al., 2005; Elberse & Verleun, 2012). This approach has been widely used by different national and international organizations to attract attention towards many important social and environmental issues ranging from animal cruelty, female feticide, women and LGBTQ rights, vegan lifestyle, poverty, HIV in third world countries, climate change, global warming, etc. (Yovino, 2016). Recently, there has been growing involvement of movie and TV celebrities to advocate for marine pollution but the attention has majorly been focused on dumping of plastic and microbeads in the ocean, reef conservation, and recycling of waste dumped in the ocean (Petkov, 2013; Dufault, 2014). This tool can also be effectively utilized on a local scale by getting local sports teams and local celebrities involved in promoting litter free behaviors on local beaches.

In order to attract more attention towards marine debris pollution, local agencies can employ the use of creative posters and art installations on the beaches. For example, recently Greenpeace created a 50 foot installation of whale with gut contents filled with common plastic waste discarded in the ocean including straws, plastic bags, water bottles etc., and it was displayed at a popular seaside resort in Philippines to create awareness towards plastic litter in the ocean (Morales, Yvette, 2017). Similar installations reflecting the impacts of marine debris pollution can prove to be very effective tool in attracting the attention of general public and having people to re-evaluate littering behaviors at the beach. Additionally, enactment the knowledge of debris pollution at grassroot level by including the term “Marine debris pollution” in school curriculum will contribute to raise awareness at an early age.

Another effective way to spread awareness is to organize Regular Beach Clean up programs and getting wide range of people involved in them, including school children, their parents, local politicians and environmental groups and NGOs. Additionally, there remains an urgent need for educating the fishermen community about responsible fishing and making them aware of hazards of discarding fishing gears in the ocean and ghost fishing[4].

In the end, given the complexity of the problem, the management of marine debris pollution calls for comprehensive and combined efforts by general public, tourists, local governments and business communities and other stakeholders. There is a growing need to adjust individual perceptions towards oceans and reevaluation of the footprints we are leaving on our environment.

[4] Phenomenon where lost or discarded fishing gear in the ocean continues to actively trap marine organisms and responsible for choking, entanglement and mortality of organisms (Donohue et al., 2001).

9. DATA LIMITATIONS

There were various limitations pertinent to this research, mainly revolving around the Marine Debris monitoring data that was utilized. First and foremost was the lack of data coverage in terms of number of coastal states that were participating in NOAA's Marine Debris Monitoring and Assessment Project. Marine debris monitoring data was not available for states that are highly popular for tourism, including Florida, North and South Carolina, New Jersey etc. The results would certainly have been different if more states were to be included, owing to variations in local policies, income and education levels across the states. Our sample was overrepresented by west coast, which raises the potential concerns about the validity of results owing to overestimation bias.

Another major limitation was the lags in reported data. There were inconsistencies in reporting of data in given states of the sample. For example, in Hawaii, the data was available for the period of Jun, 2012 to April, 2016 whereas for Michigan, the data was only available from July, 2016 to September, 2016. The time intervals for which the sampling was done was also inconsistent and hence there was a lot of missing data observations. The gaps in data reporting were evident in terms of varying number of observations available for each state, for instance, there were a total of 14 observations available for the state of Texas, in comparison to 700 observations for the state of Washington.

There was also a lack of spatial coverage of participating states. Data was not available for all the beaches in states. Hence, the available data was not representative of the particular state. Additionally, there was also the lack of socioeconomic data available for individual sampling sites, which necessitated us to employ the county level data and adjust marine debris accumulation to a much larger spatial scale (i.e. to county).

Contribution of fishing activity towards marine debris was not accounted for in our model owing to lack of consistent data available on number of fishing licenses issued. Based on past research and findings, commercial fishing represents to be the leading contributors of marine debris pollution (Ribic et al., 2010; Moore et at., 2009; Hong et al., 2003; Tomas et al., 2002; Bugoni et al, 2001; Laist, 1997; Bronjal et al., 1994; Ryan et al., 1988; Day et al., 1985; Harris & Osborn,1981; Bunyan & Page, 1978; Jefferies & Parslow, 1976; Carpenter et al., 1972; Friend & Trainer, 1970; Peakall & Peakall, 1973) and accounting for the effects of this sector would be an important extension for this research.

10. CONCLUSION

This study adds a piece of literature to the existing line of research in the field of marine debris pollution. What set the study apart is the spatial coverage and wide range of socioeconomic determinants of marine debris pollution that were studied, along with the possible effect of mitigating factors included in the model. The study was based in coastal counties of eight states of the United States, including Washington, Oregon, California, Texas, Hawaii Alaska, Michigan and Virginia. We employed Poisson Regression Model and found significant evidence of population, demographics, and tourism on increasing the marine debris pollution. Empirical evidence of EKC hypothesis was also established and we calculated that if a county has yearly average income of $28, 878 and above, marine debris pollution will decrease. We also found mitigating effects of social capital, in the form of voter turnouts in 2012 Presidential elections in the counties. We suggested policy recommendations for tourism sector, mainly focusing on curbing littering behaviors and encouraging monetary contributions towards local beach clean-up projects. We also suggested educational tools, including celebrity endorsements, art installations and introduction of marine debris in school curricula, to attract attention towards this issue and educate public.

Socioeconomic drivers of marine debris pollution have been highly understudied and there is a lot of scope to explore these drivers in developing and developed countries in order to find effective solution to this problem and to buffer our marine and coastal resources from the impacts of exploding world population growth and ever increasing urban development. The essence of this is that it’s our decisions and choices that define the kind of legacy we would leave for our future generations. We need to weigh and reflect on our actions and the kind of footprints we are leaving on our environment and as the ancient Indian proverb goes, “We don't inherit the earth from our ancestors, we borrow it from our children”.

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APPENDIX A

Correlation Matrices for Wind Speed

Correlation matrices, as generated in Stata IC software, are presented below. Table A.1 presents correlation matrix of monthly wind speeds, where WS stands for "Wind Speed", followed by the abbreviation of the month it corresponds to.

	WS_jun	WS_jul	WS_aug	WS_jan	WS_feb	WS_mar	WS_apr	WS_may	WS_sep	WS_oct	WS_nov	WS_dec
WS_jun	1											
WS_jul	0.7829	1										
WS_aug	0.7156	0.7803	1									
WS_jan	0.1079	0.3531	0.4486	1								
WS_feb	0.3884	0.4111	0.5739	0.7484	1							
WS_mar	0.4251	0.6067	0.6321	0.7641	0.5772	1						
WS_apr	0.5584	0.5884	0.4148	0.3073	0.37	0.5164	1					
WS_may	0.7861	0.7525	0.5982	0.2384	0.3599	0.4775	0.5745	1				
WS_sep	0.6146	0.6412	0.67	0.4504	0.5954	0.5423	0.609	0.586	1			
WS_oct	0.3589	0.4644	0.4833	0.6717	0.6961	0.6801	0.513	0.3979	0.6881	1		
WS_nov	0.2483	0.4676	0.4999	0.7168	0.7235	0.6798	0.5107	0.2394	0.5979	0.7996	1	
WS_dec	0.4579	0.4946	0.622	0.7084	0.7256	0.7168	0.3321	0.4144	0.5005	0.6626	0.6845	1

Correlation matrix of Monthly Wind Speed

Table A.2 presents correlation matrix of seasonal wind speeds, corresponding to spring (spring_wind), summer (summer_wind), fall (fall_wind), and winter (winter_wind).

Table A.2

	1	2	3	4
1.spring_wind	1			
2.summer_wind	0.791	1		
3.fall_wind	0.7223	0.5873	1	
4.winter_wind	0.64	0.5073	0.7875	1

Correlation Matrix of Seasonal Wind speeds

Table A.3 presents correlation matrix of 2 variables of biannual wind speeds, calculated by calculating the average of wind speeds of March to August (WS_SS) and September to February (WS_FW).

Table A.3

	WS_SS	WS_FW
WS_SS	1.0000	
WS_SS	0.6747	1.0000

Correlation matrix of Biannual Wind Speeds