The United States requires effective federal policy to reduce marine plastic pollution

Autumn R. Iverson

Department of Animal Science, University of California, Davis, California

Correspondence
Autumn R. Iverson, Department of Animal Science, University of California, Davis, 1 Shields Ave, Davis, CA 95616. Email: ariverson@ucdavis.edu

Abstract
The amount of plastic entering the ocean is expected to increase by an order of magnitude by 2025. Marine plastic pollution threatens biodiversity through entanglement, ingestion, and chemical exposure. The United States is in the top 20 of 192 coastal countries with mismanaged waste entering the ocean. This paper addresses U.S. policies regarding single-use plastics and fishing nets, two major sources of plastic pollution. Currently, the United States does not have a federal ban on most single-use plastics or on synthetic gillnets. This paper recommends a federal ban on single-use plastics, alternative material for fishing nets and/or increased regulations, more research into the ecological and policy considerations of plastic pollution, continuing cleanup efforts and learning from policy challenges faced by other countries. The United States can look to the recent European Plastics Strategy as a leading example of large-scale policy initiatives to reduce marine plastic pollution.

KEYWORDS
fishing nets, gillnet, marine, plastic pollution, policy, single-use plastic, United States

1 MARINE PLASTIC POLLUTION IS A GLOBAL THREAT TO BIODIVERSITY

Marine plastic pollution is a global problem that originates both on land and at sea (Figure 1). In 2010, 4.8–12.7 million metric tons (MMT) of plastic pollution were estimated to originate on land (Jambeck et al., 2015). At sea, abandoned fishing gear contributes the bulk of plastic waste, with fishing nets constituting 46% of the plastic waste by size in the Pacific subtropical gyre between California and Hawaii (the “Great Pacific Garbage Patch”; Lebreton et al., 2018). Data from 24 oceanic expeditions suggest that the total amount of ocean plastic pollution was at a minimum of 5.25 trillion pieces weighing over 250,000 tons (Eriksen et al., 2014). However, more recent estimates based on the Great Pacific Garbage Patch suggest that the amount of plastic may be four to 16 times higher than previous estimates (Lebreton et al., 2018). If other areas of the ocean have accumulated plastic at a similar or faster rate, then the global total may be much higher than previously estimated.

More concerning than the sheer amount of plastic pollution in the ocean is the rate at which it is increasing. The amount of plastic predicted to enter the ocean by 2025 is expected to increase by an order of magnitude, assuming a stable rate of pollution and accounting for population growth in coastal cities (Jambeck et al., 2015). However, this may be a low estimate, as new markets for plastics will likely increase production. For example, plastic production increased by 620% between 1975 and 2012 (Jambeck et al., 2015). The United States is the third largest plastics exporter in the world (www.worldstopexports.com), meaning that...
changes in U.S. policy could have far-reaching effects. In addition, as plastics break down to microplastics (<4.75 mm), they are lost from the ocean surface (Eriksen et al., 2014), making them not only more difficult to quantify but also enhancing their invasion of marine foodwebs. Much of the microplastics then sink into deep sea sediment where they have an unknown impact on sediment biota (Woodall et al., 2014).

Marine plastic pollution threatens biodiversity through entanglement, ingestion, and chemical exposure (Figure 2). Entanglement happens at sea when animals encounter discarded fishing nets or other plastics. This can include seals which dive and play with floating debris, fishes, sea turtles, and seabirds that get trapped in discarded nets, and whales that get caught in nets when attempting to catch fish (Derraik, 2002; Thiel et al., 2018). However, entanglement risk can also extend to the shore. For example, northern gannets (Morus bassanus) in a UK colony preferentially use synthetic rope for nesting material, which entangled 525 birds over 8 years, most of which were nestlings (Votier, Archibald, Morgan, & Morgan, 2011). Expert opinion identifies fishing gear, balloons, and plastic bags as the most important plastic pollution involved in entanglements (Wilcox et al., 2016).

Ingestion of plastic pollution is another important threat to marine biodiversity. Expert opinion identifies plastic bags and plastic utensils as the primary ingestion risks for larger marine animals such as seabirds, sea turtles, and marine mammals (Wilcox et al., 2016). In the northeastern Atlantic, 74% of seabird species studied were found to ingest plastic (O’Hanlon, James, Masden, & Bond, 2017). Mortality from plastic ingestion has been demonstrated for marine mammals, sea turtles, seabirds, and invertebrates (Rochman et al., 2016). After ingestion, organisms are also exposed to toxic, bioaccumulating, persistent organic pollutants, which are concentrated in plastics (Li, Tse, & Fok, 2016).

Previous papers have outlined the scale of plastic pollution and the threats to biodiversity from plastic, with a focus on global reviews or other countries. This paper focuses on policy reform options that would reduce plastic pollution the United States contributes to the ocean. Specifically, this is the first paper to address U.S. policy regarding single-use plastics and fishing nets, two major sources of plastic pollution that threaten marine biodiversity. This paper outlines the scale of these specific plastic pollution issues within the United States, current U.S. policy on plastics, and associated scientific gaps and opportunities.

2 SINGLE-USE PLASTICS, FISHING NETS AND THE UNITED STATES: THE SCALE OF THE PROBLEM

According to the U.S. Environmental Protection Agency (EPA), the United States generated over 31 MMT of new

FIGURE 1 Photograph of marine plastic pollution. Photo credit: Sergio Izquierdo, 5 Gyres

FIGURE 2 The effects of marine plastic pollution on wildlife (entanglement, ingestion, and chemical exposure) and the top plastic products that cause these problems. Top items from Wilcox, Mallos, Leonard, Rodriguez, and Hardesty (2016). Illustrated by Nathan Sartain and Erin Cinkant
plastics in 2015, about 14% more compared to 10 years prior (Figure 3). Only 9% of plastic waste was recycled that year, for ~3 MMT recycled and ~24 MMT landfilled (EPA, 2018). Compared to many other countries, the United States has a well-managed waste system. For example, Asian countries with poor waste management systems are estimated to account for 67% of plastic entering the ocean (Lebreton et al., 2017). However, the estimated mismanaged waste, including littering, from the United States is in the top 20 of 192 coastal countries considered. The United States produces 0.28 MMT per year of mismanaged waste, 0.04–0.11 MMT of which is estimated to become marine debris each year (Jambeck et al., 2015). This high amount of waste, despite being only 2% of mismanaged waste in the United States, is due to large coastal populations and a high amount of waste production per capita. Of the top 20 countries listed, the United States had the highest per capita generation of plastic waste, at 2.58 kg per person per day (Jambeck et al., 2015). Overall, plastic waste from the United States is expected to increase 22% by 2025 (Jambeck et al., 2015). Therefore, policies to reduce plastic waste originating from land in the United States would have an important impact on the total marine debris in the global ocean.

Plastic generated in the United States can also have international impacts; United States companies are responsible for spreading single-use plastics internationally and have acted against reducing single-use plastics in other countries. For example, new policy efforts by Coca-cola, the largest soft-drink company in the world, to reduce plastic waste were criticized by activist organizations such as Greenpeace as the plan did not include reduction of the 110 billion single-use plastic bottles produced each year. Greenpeace also takes issue with Coca-cola for being opposed to bottle deposit schemes globally, except in the United Kingdom where activists pressured the company to provide them (www.greenpeace.org).

The waste generated by single-use plastics also becomes part of the global economy. The United States is second in the world of countries exporting plastic waste and has exported 26.7 MMT to the global market between 1988 and 2016 (12.4% of global exports; Brooks et al., 2018). China is the only country that produces more than the United States and despite having 1 billion more people in their population, China produced only ~35% more plastic waste than the United States in 2010 (60 MMT compared to 38 MMT in the United States; calculated from Jambeck et al., 2015,

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**FIGURE 3** The U.S. plastic waste stream informed by Jambeck et al. (2015), Brooks, Wang, and Jambeck (2018), EPA (2018), Lebreton et al. (2018), and Penca (2018). Illustrated by Erin Cinkant
https://ourworldindata.org). China previously imported plastic waste to make products out of recycled plastics, but as of 2017 has permanently banned non-industrial plastic waste from being imported (Brooks et al., 2018). Until recently, plastics put into the domestic recycling stream within the United States were often sent to China for recycling; the United States sent 56% of plastic waste to China between 1988 and 2016, most of which was single-use plastic food packaging (Brooks et al., 2018). Sending plastic waste across the ocean means increased energy consumption and this also contributes to the 0.6 MMT of plastic litter entering the ocean each year (Penca, 2018). Now that China is no longer accepting this material, much of what consumers intend to recycle will likely end up landfilled (Brooks et al., 2018).

Globally, derelict fishing gear is a serious problem and is considered to be the largest plastic pollution by volume and potential impact (UNEP, 2016). The amount of derelict gear in the oceans is unknown but fishing nets make up almost half of the plastic pollution by size in the Great Pacific Garbage Patch alone (Lebreton et al., 2018). One estimate proposes 640,000 metric tons of fishing gear at sea globally (UNEP, 2016). The U.S. National Oceanic and Atmospheric Administration (NOAA) states that the most common derelict fishing gear are gillnets and crab pots/traps. During the 1970s, the materials used for fishing gear transitioned from natural materials that degraded relatively quickly to plastics and steel that persist for much longer periods of time, with some plastic monofilament still “ghost” fishing after 20 years (NOAA Marine Debris Program, 2015). The total rate of lost gillnets and the amount of ghost fishing occurring in the United States is not known and regulations for these nets differ by state. However, an analysis from Puget Sound, Washington, quantified mortality from 870 derelict gillnets at 960 fish (22 species), 509 seabirds (15 species), 23 marine mammals (4 species), and 65 marine invertebrate species (NOAA Marine Debris Program, 2015), demonstrating that the entanglement risk from lost nets is high. Based on the potential impact of lost nets, their proper reduction within United States waters would be important to reduce the effects of oceanic plastic pollution on biodiversity.

3 | U.S. POLICY ON SINGLE-USE PLASTICS AND FISHING NETS

Currently, the United States does not have a federal ban on most single-use plastics. One exception is the ban of microbeads (<5 mm) in personal care products, which took effect in July 2018. Straws and utensils are not banned in any state, although California recently implemented a policy requiring plastic straws be given on request only (AB1884). Plastic bags are either banned or levied in only four states (Xanthos & Walker, 2017). This is in contrast with other countries in Africa and Asia which have initiated complete bans of plastic bags (Xanthos & Walker, 2017) and with France that banned plastic plates, cups and utensils (to take effect in 2020). However, smaller municipalities within the United States have introduced bans or taxes on plastic bags. For example, levies were placed on plastic bags in New York City and Washington DC. (Xanthos & Walker, 2017). The city of San Francisco banned the sale of plastic water bottles containing less than 21 ounces and Seattle has banned polystyrene, plastic straws and utensils (www.seattle.gov).

The NOAA Marine Debris Program is the U.S. federal lead in addressing marine debris. In 2017, the program removed >1,600 tons of marine debris, educated both teachers and students on the marine debris problem and continued assessment and monitoring of U.S. coastal sites (NOAA Marine Debris Program, 2017). They removed 4.5 tons of fishing gear in the northeast and 34 tons in California (NOAA Marine Debris Program, 2017). While the U.S. government is actively involved in marine debris clean-up, there is no federal ban on the use of gillnets, which have been identified as one of the most harmful types of derelict fishing gear. Gillnets are long walls of net that can be up to 2 miles in length. They are either allowed to drift, float at the surface, or are anchored. Gillnets are banned by the United Nations in international waters, however they are not federally banned in the United States. According to NOAA Fisheries, gillnet restrictions vary and include prohibitions on large mesh gillnets, time/area closures and nets with weak links that allow large whales to escape entanglement. In addition, some states have acoustic devices to warn cetaceans of the presence of active gillnets (www.fisheries.noaa.gov). California has recently proposed a ban on drift gillnets in the shark and swordfish fisheries (SB-1017), motivated primarily by detrimental effects on wildlife as over half the fish are discarded and over 70 marine species are caught as bycatch. Deep-set buoy gear has been proposed as a potential alternative for catching swordfish and reducing bycatch, and the proposed California ban on drift gillnets includes a plan to transition fishers away from this method, including payment for nets and permits (SB-1017). While gillnets are generally regulated, a NOAA report on derelict fishing gear lists only one state—Washington—that requires commercial fishers using gillnets to report lost nets (NOAA Marine Debris Program, 2015).

4 | PLASTIC POLLUTION AND BIODIVERSITY: SCIENTIFIC AND POLICY UNKNOWNS

There are many important questions about marine plastic pollution. For example, while individual animals have died
or been injured due to plastic pollution, it is unclear how this scales to population-level effects (Wilcox et al., 2016). As plastic pollution is increasing, it follows that biodiversity impacts would increase, however, the extent to which this endangers whole populations is still an open question. Further exacerbating this, the number of species impacted by plastic pollution is also an unknown. For example, in the Northeastern Atlantic about half of 69 seabird species had not been studied for plastic ingestion (O’Hanlon et al., 2017). Similarly, for gillnets in particular, there is a lack of data on how often the nets are lost and also the number of organisms that die in the derelict gear (NOAA Marine Debris Program, 2015). Without knowing all the populations or species affected, it is hard to scale up even further to ecological effects. For example, one review found no ecological effects from plastic ingestion studies, something they attributed to studies not using systematic data (Browne et al., 2015).

Experts surveyed on the most important questions to mitigate impacts of marine plastic pollution on wildlife identified 16 questions for research priorities globally (Vegter et al., 2014). These 16 questions highlight information gaps and include basic ecology issues such as the impacts of plastic pollution on marine habitat but also touch on social issues such as education for the public as well as the effectiveness of policy and mitigation. Another important discussion point concerns what alternatives to single-use plastic are available to replace traditional plastic. Reusable bags, containers, utensils, and bottles that are made from stainless steel, cotton, paper or some other material are obvious alternatives. In some cases, such as with straws, simply refusing the product can be an option. A definition for what is considered “single-use” plastic will be necessary moving forward. Some single-use plastics are treated as “reusable” simply because they are made from slightly sturdier material (such as thicker plastic bags) and these should not be an acceptable alternative as they still present the same risks to the marine environment as single-use products. Similarly, there has been an increase in bioplastics which claim to be a good alternative to traditional plastic. However, some of these products have the same lifespan as traditional plastic. Only products that are certified as compostable will break down more quickly, and even then, only when they are taken to an industrial composting facility (5 Gyres Plastics B.A.N. list 2.0, www.5gyres.org) which are currently uncommon in the United States. As single-use plastics are embedded into society, these and other questions will need to be addressed when implementing new policy.

Ultimately, there are many unknowns about how effective plastic policy approaches would be to mitigate the risks to wildlife. Many policies described in this paper have either been recently introduced or are planned for introduction in the next few years. Therefore, opportunities to study different policy approaches in detail have been limited. However, some initial results are promising. In San Jose, California, plastic bags made up about 9% of litter in creeks and rivers. After a plastic bag ban, this was reduced to 2.5% (Thomas, 2015). According to Californians Against Waste (CAW; www.ca-wrecycles.org) local bans prior to California’s state ban reduced the use of plastic bags by more than 5 billion/year. Translating this to mismanaged waste, CAW states that San Francisco had an 18% reduction in plastic bag litter after their ban, southern California cities reduced plastic bags in their storm water runoff by one third, and beach cleanups in the Santa Cruz/Monterey area went from an average of 65 plastic bags per cleanup to only 6. These data support that banning single-use plastics may be an effective way to reduce plastic pollution litter, which is then less available to become marine plastic pollution.

Similarly, how effective international gillnet bans have been on reducing biodiversity mortality from ghost-fishing is unclear as little information is available on current global gillnet fishing or on the number of lost nets (Gilman, Chopin, Suuronen, & Kuemlangen, 2016). Data from fisher surveys globally estimated that on average 1% of gillnets are lost, however this was from only 10 sites. Even less data are available on gear discarding or abandonment (Gilman et al., 2016). The number of animals caught or dying in nets in any region, including in U.S. waters, comes as minimum estimates, as some animals may be removed through predation or escape prior to censusing. The number of animals that escape with injuries that eventually lead to mortality is extremely difficult to quantify. Biodiversity losses from ghost fishing can also obscure true effects on populations from active fishing efforts, which can compromise the accuracy of fisheries models.

5 | THE EUROPEAN PLASTICS STRATEGY: COMPARISONS AND GUIDANCE

The European Union (EU) has a foreign policy agenda to exhibit leadership on globally important environmental issues, and in 2018, the EU initiated the forward-looking European Plastics Strategy (Penca, 2018). The Strategy is comprehensive, with a goal-oriented timeline, recommendations to both industry and national authorities, and a Pledging Campaign (Penca, 2018). An overarching theme of the Strategy is a focus on a more circular economy where the entire life cycle of plastic products are considered, with the goal of greatly increasing EU plastic recycling through changes in all aspects of the cycle from product design to consumption to waste management (Penca, 2018).
In May 2018, in line with the goals of the Plastics Strategy, the EU began consideration of a proposal that specifically addressed single-use plastics and fishing gear. By December 2018, this proposal had been approved by the European Parliament and Council and was in the final stages of approval by ambassadors of member states. This new policy would embrace bans on single-use plastics that are found most often on European beaches including plastic cotton bud sticks, utensils, plates, straws, and stirrers. For other single-use plastics such as food containers and bottles, they have set targets for consumption reduction and deposit schemes to encourage return and recycling (Bourguignon, 2018). Notably, the proposal also requires “extended producer responsibility” where the producers of single-use plastic products cover the costs associated with waste management, clean-up, and measures to raise public awareness. Similarly, for fishing gear the producers pay for the transport, treatment, and waste management of gear collected at port facilities as well as public awareness measures (Bourguignon, 2018). As these measures are still in the approval process and may take up to two more years to implement, an evaluation of their effectiveness to reduce marine plastic pollution is not yet possible. However, the United States should share the motivations of the EU to pursue a comprehensive strategy at the federal level as the marine plastic pollution crisis is a global problem. Economically speaking, the United States may be motivated by these changing standards on products accepted into EU markets and competition with EU businesses that can provide potentially more sustainable and desirable alternatives, especially as developing and promoting more sustainable materials are goals of the Plastics Strategy (Penca, 2018). The United States should look to the European Plastic Strategy as a template for building a similar plan domestically to both reduce marine plastic pollution and intelligently address a changing global economy.

6 | CONCLUSION AND RECOMMENDATIONS

Based on the mortality risk to wildlife from marine plastic pollution, the persistence of plastic in the environment, and the exponential growth of plastic pollution expected in the next few years, this paper recommends some policy reform in the United States (Table 1). Specifically, the United States should issue a federal ban on single-use plastics, including plastic bags, utensils, straws, and other similar items. The United States must create legislation that focuses on industry regulations for both producing and selling of single-use plastics and should consider extended producer responsibility schemes similar to the European Plastics Strategy. These recommendations are in line with recent policy recommendations from the United Nations Environment Programme (UNEP) report on marine plastic debris that encourages a “drastic reduction or ban of single-use plastic” (UNEP, 2016). Research and marketing of biodegradable plastic alternatives will likely become fruitful areas for economic growth.

For fishing nets, this paper echoes a NOAA recommendation for the implementation of a central repository on derelict fishing gear and the impacts to wildlife from these (NOAA Marine Debris Program, 2015). Additionally, this paper recommends biodegradable material be used in place of synthetic nets. Biodegradable nets tested in the Korean yellow croaker industry show promise as a feasible alternative with shorter ghost-fishing times (Kim, Kim, Lim, An, & Suuronen, 2016). This could increase costs to fishers as nets may need to be replaced more often, and the United States may consider subsidies or incentive programs to offset these costs. Even with alternative net materials and/or fishing methods, gear may still present a threat to biodiversity. Therefore, in addition to biodegradable gear, labeling gear with the owner’s information can help ensure accountability (Gilman et al., 2016). Marking gear with satellite-linked Global Positioning System (GPS) devices may also aid in recovery efforts for lost nets. Requiring imports from foreign fisheries to match these standards of sustainability domestically could encourage further reduction in ghost gillnet fishing globally. Lastly, a consumer label for fishing practices that prevent marine plastic pollution may encourage more fisheries to participate through consumer choice of sustainable products.

Until sufficient reduction and prevention measures are in place, regular mass clean-up efforts will remain necessary to prevent as much existing plastic as possible from reaching the ocean, beaches and waterways. There are efforts around the country for these activities that already make impacts on the amount of waste entering the ocean. For example, in 2016, with over 59,000 volunteers, about 320 metric tons of trash and recycling was picked up during California’s Coastal Cleanup Day (www.coastal.ca.gov). Depending on the timeline of policy implementation, these efforts will be even more important in years to come as plastic pollution is expected to increase. Marine cleanups should also continue to remove lost nets and other debris (e.g., the NOAA Marine Debris Program) until the input ceases.

In addition to new policies and continuing cleanup efforts, research is needed to address the many unknowns surrounding both the environmental effects of plastic pollution and the most effective social engagement. Once the policy recommendations are implemented, plastic pollution should be monitored closely to assess which policies are the most effective, what type of social resistance they encounter, and ways to overcome social resistance. Following the lead of the European Plastics Strategy, efforts
to raise public awareness of the marine plastic pollution crisis through extended producer responsibility plans could potentially help overcome consumer resistance. This paper also recommends standardized, multi-jurisdictional monitoring efforts (both within the United States and between other countries) in line with other studies (Avery-Gomm et al., 2012; O’Hanlon et al., 2017) as this is a global problem. Knowing how plastic pollution scales up to affect populations and ecosystems will be important baseline information for informing policy as well as for monitoring ecosystem changes in response to the varying amount of plastic pollution.

Lastly, learning from other countries that have implemented policies to reduce plastic pollution will be useful in framing the United States’s approach, especially the recent comprehensive European Plastics Strategy. It is unknown how effective new policy will be in the United States even with encouraging initial studies. While progress in Europe is encouraging, other countries have policies in place yet are not seeing only positive impacts, and so offer...

| TABLE 1 | A summary of the plastic pollution issues addressed in this paper and current U.S. policy regarding those issues |
|---------|-------------------------------------------------------------------------------------------------------------|
| **Issue** | **Current U.S. policy** | **Recommendations** |
| Single-use plastic bags | No federal ban | Full federal ban |
| | Four states have bans or levies | • Some success already seen in CA due to ban |
| | New York City and Washington DC have levies | • Many other countries have complete ban on plastic bags |
| | No federal ban | Full federal ban |
| | No state bans | • The EU is initiating a ban on single-use plastic utensils as part of the European Plastics Strategy |
| | CA proposed AB1884 to limit straws to “on request only” | • The United Nations recommends drastic reduction/ban of single-use plastics |
| | San Francisco partial ban on plastic bottles | |
| | Seattle banned plastic utensils and straws | |
| Gillnets: New | No federal ban | Nets made of natural, biodegradable material |
| | Restrictions vary: Time/area closures, prohibitions by type of gillnet, modified nets to allow easier escape or to warn animals | • The United States may consider a way to offset cost to fishers for replacing nets more often |
| | CA proposed a ban on drift gillnets (SB-1017) | Where possible, consider alternative fishing strategies that reduce the likelihood of losing plastic gear |
| Gillnets: Lost | Not required federally that lost nets are reported | Central repository of information on lost nets and the impacts to wildlife |
| | WA requires fishers to report lost nets | Continued clean-up efforts at sea |
| Other | Various research and clean-up efforts already occur. These will need to be continued until input ceases | Expand bans beyond single-use bags and utensils mentioned above to include other single-use plastic items |
| | | Implement industry regulations on both producing and selling single-use plastics |
| | | Apply extended producer responsibility to raise public awareness and cover costs at the end of use (see European Plastics Strategy) |
| | | Conduct multi-jurisdictional monitoring and research efforts on pollution at-sea and effects on wildlife populations and ecosystems |
| | | Conduct monitoring on effectiveness of policy implementation and social resistance |

*Note: This paper’s recommendations are listed for each issue with some notes and justifications for the recommendations.*

*Abbreviations: CA, California; GPS, Global Positioning System; WA, Washington.*
learning opportunities. For example, Argentina has policies and institutions to reduce plastic pollution from coastal areas, industry and ships, yet due to low enforcement and public awareness, the policies are ineffective (González Carman, Machain, & Campagna, 2015). In addition, in Canada, despite legislation, improved policies and practices are needed to address microplastic toxicity, including outreach to the public, research into sources of pollution, and better policy and waste management (Pettipas, Bernier, & Walker, 2016). As the United States takes initial steps of policy implementation, it will therefore be vital to concurrently increase public awareness, continue research, monitor policy effectiveness and reevaluate waste management strategies. Ultimately, the United States requires strong federal action to reduce its large plastic footprint and reduce marine plastic pollution.

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AUTHOR CONTRIBUTION

A.R.I. is responsible for developing the paper concept, designing figure layouts, writing the initial draft and all editing.

ORCID

Autumn R. Iverson 🔗 https://orcid.org/0000-0002-8353-6745

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