# Environmental Impacts of Seawater Desalination to Marine Life

Karissa M. Brunette

Department of Civil and Architectural Engineering and Construction Management

Milwaukee School of Engineering

Author Note

Karissa M. Brunette, Civil and Architectural Engineering and Construction Management Department, Milwaukee School of Engineering.

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Correspondence concerning this article should be addressed to Karissa M. Brunette, Civil and Architectural Engineering and Construction Management Department, Milwaukee School of Engineering, 1025 N Broadway, Milwaukee, WI 53202. E-mail: brunettek@msoe.edu

Abstract

This paper discusses the importance of coastal desalination plants, as well as their environmental impacts, specifically impacts to marine life. In this paper, the environmental impacts are explained with a focus on salinity increase in the discharge body of water, which can lead to adverse impacts on the marine life. The potential techniques for mitigation are explored using a case study on Tampa Bay's desalination plant. The method employed in this paper was a literature review. The main results show that the salinity in the brine reject will increase the salinity in the discharging body of water. The increased salinity can have a negative impact on the marine life in the discharging body of water; therefore, mitigation techniques need to be utilized to reduce the salinity increase. The environmental impacts of desalination plants need to be considered during the planning phase of a new desalination plant to try to eliminate potential impacts from actually occurring.

*Keywords:* desalination, environmental impact, seawater, mitigation techniques, salinity, salinity increase, Tampa Bay, public policy, brine reject, marine life, marine environment

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# Environmental Impacts of Seawater Desalination to Marine Life

Water is an abundant resource on Earth, but less than 2.5% of all of the planet's water is available for drinking (Liu, Sheu, & Tseng, 2013). As the world's population continues to grow, it will face a water shortage, as the current sources of freshwater used for drinking water are finite (Medeazza, 2005; Shannon, Bohn, Elimelech, Georgiadis, & Marinas, 2008). This state of affairs is why it is important to develop new sources for obtaining drinking water, such as desalination plants. Desalination plants can provide fresh drinking water – from seawater – and serve as an alternative freshwater source in conjunction with the world's current sources of freshwater – its aquifers and surface water. As of 2008, desalination accounted for 24.5 million meters cubed per day of the water produced worldwide (Lattemann & Hopner, 2008). Desalination plants are being used as a way of preserving the natural water supply, which can been seen as an environmental benefit (Sommariva, Hogg, & Callister, 2004). However, there are environmental impacts that also have to be considered because the impacts could potentially outweigh the environmental benefits. Specifically, the environmental impacts to the marine environment include problems associated with the brine reject being discharged from the desalination plants. In this paper, the environmental impact to marine life, specifically salinity changes from the addition of salt from the typical desalination plant process, is further investigated. Background on desalination processes is first discussed and then literature on environmental impacts from desalination plants is reviewed. In addition, a study of the desalination plant at Tampa Bay, Florida is considered. The findings from the literature review were analyzed to conclude that the discharge body of water associated with a desalination plant will experience a salinity increase, which has the potential to negatively impact the marine life in that body of water.

## Background

Water shortage problems are becoming more important as the world's population continues to increase and as industry and agriculture grow (Jirka, 2008). Water shortage problems are a, "…consequence from consumption growth combined with declining natural water resource stock mainly due to pollution and unsustainable resource exploitation" (Medeazza, 2005, p. 65). For these reasons, desalination is important and becoming more prevalent around the world, as it can tap into the largest source of water on Earth, the ocean (Voutchkov, 2013). The water in the Earth's aquifers is a finite source, whereas the water from the oceans is considered an infinite source (Shannon, Bohn, Elimelech, Georgiadis, & Marinas, 2008). The ability to capture even a small amount of that water to desalinate could make a large impact on mitigating the water shortage problems in the world.

Brackish water and seawater are two potential sources for desalination plants. Seawater is water captured from the ocean. Brackish water is found in groundwater aquifers and is caused by saltwater intrusion. Saltwater infiltrates the groundwater aquifer, contaminating the freshwater and rendering it no longer suitable for drinking without treatment.

Desalination is the process of removing salt from seawater or brackish water to create freshwater (Tsiourtis, 2001). The desalinated water is captured for use and the salts are concentrated in a stream of water called brine reject. The brine reject is then disposed of by discharging it back to the intake source or to a saline aquifer or to an evaporation pond (Tsiourtis, 2001). Figure 1 shows a simple process of desalination.

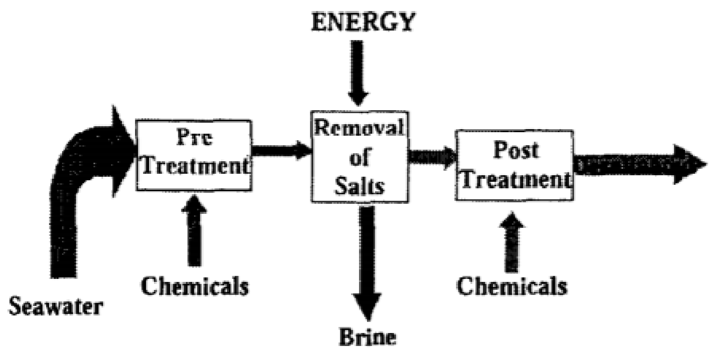


*Figure 1*. Desalination process. Adapted from “Desalination and Environment” by N. Tsiourtis, May 2001, *Desalination 141(3)*, p. 227. https://doi.org/10.1016/s0011-9164(01)85001-3

**Desalination technologies.** Desalination of seawater or brackish water typically occurs as a result of either, thermal distillation or membrane separation. Thermal distillation is the process of creating freshwater by separating it from the saline source through the use of evaporation (Voutchkov, 2013). The fundamental mechanism here can be considered similar to the hydrological cycle, where saltwater is heated, producing water vapor that is condensed to form freshwater free from salts (Tsiourtis, 2001). Desalination plants that have distillation processes typically have five streams (Voutchkov, 2013). The streams include the source water, steam, cooling water, distillate, and concentrate. Source water is the water being pulled into the desalination plant, the steam stream is needed for evaporation, cooling water is used to condense the water vapor, distillate is the freshwater being produced, and concentrate is the by-product brine that includes the salts and other impurities removed. There are three main types of thermal distillation commonly used, including multi-stage flash (MSF), multieffect distillation (MED), and vapor compression (VC) (Voutchkov, 2013). Figure 2 shows a typical process for thermal distillation.

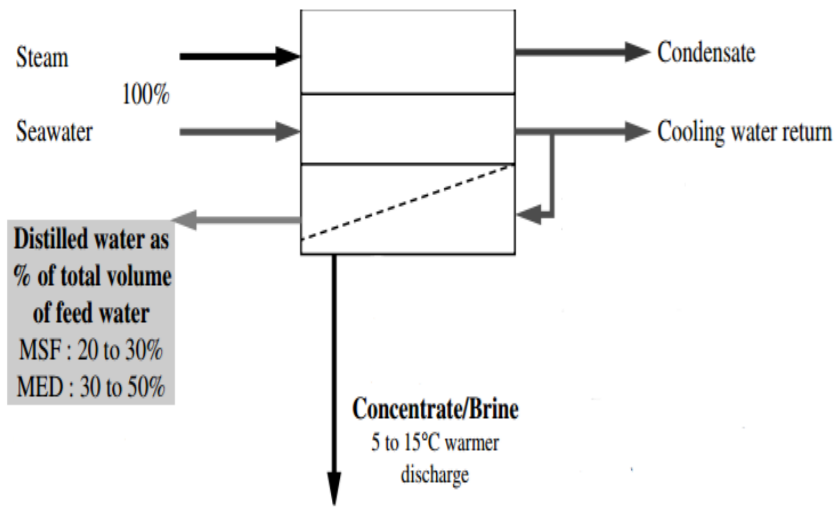


*Figure 2*. Thermal distillation process. Adapted from *Desalination Engineering: Planning and Design* by N. Voutchkov, 2013, p. 4. Retrieved from https://books.google.com/

Membrane separation is a process where freshwater is produced from a saline source by transport through semipermeable membranes (Voutchkov, 2013). The two types of membrane separation generally used are electrodialysis (ED) and reverse osmosis (RO). However, RO is more commonly used, as there have been many advancements in the past 10 years for RO membrane separation technology (Voutchkov, 2013). Figure 3 shows an RO process. Approximately 50% of desalination plants in the world use RO membrane separation (Greenlee, Lawler, Freeman, Marrot, & Moulin, 2009). Table 1 summarizes the common types of distillation and membrane separation and Figure 4 shows a breakdown of desalination technology usage in the industry.

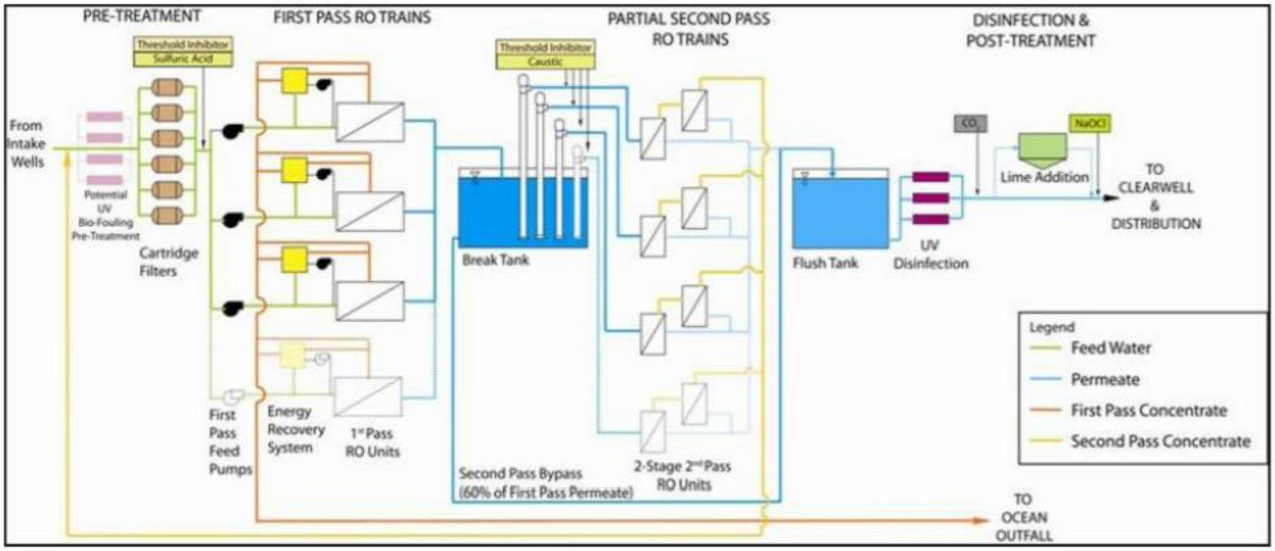


*Figure 3*. RO desalination process. Adapted from "Monterey Bay Regional Desalination Project" by L. Melton et al., 2011, *Proceedings of the Water Environment Federation,* WEFTEC 2011, p. 1335. http://dx.doi.org/10.2175/193864711802712929

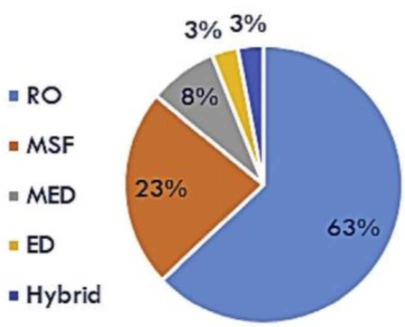


*Figure 4*. Desalination usage by technology. Adapted from "Desalination and Sustainability – An Appraisal and Current Perspective" by V. Gude, 2015, *Water Research 89,* p. 90. http://dx.doi.org/10.1016/j.watres.2015.11.012

Table 1

*Common Desalination Technologies*

| | |
|---|---|
| Reverse osmosis (RO) | Membrane processes, the most common system in use. A semi-penetrable membrane separates two solutions of different concentrations. |
| Electrodialysis (ED/EDR) | Membrane processes. A bundle of membranes is placed between two electrodes and an electric field is induced. It is mostly suitable for brackish water and for the remediation of polluted wells. |
| Multi stage flash (MSF) | Evaporation processes, in combination with power stations. The system includes a series of compartments. The flow of hot water into a compartment in which there is low pressure results in the evaporation of part of the water. |
| Multi effect distillation (MED) | Evaporation processes, based on the cycle of latent heat when generating steam, usually used in combination with power stations. |
| Vapor compression distillation (VCD) | Evaporation processes based on the principle of a heat pump. Repeated cycles of condensation and evaporation. |

*Note*. Adapted from "The Footprint of the Desalination Processes on the Environment" by R. Einav, K. Harussi, and D. Perry, April 2002, Desalination *152*(1-3), p. 143. http://dx.doi.org/10.1016/S0011-9164(02)01057-3

**Environmental impacts.** There are many technologies being used for desalination, but each one has environmental impacts that need to be addressed. These impacts can be related to how efficient the desalination plant is running (Sommariva, Hogg, & Callister, 2004). Typically, more efficient plant operations and technology mean fewer environmental impacts associated with a plant (Sommariva, Hogg, & Callister, 2004). The environmental impacts that the plants typically need to be concerned with are associated with the land used, noise pollution, the marine environment, groundwater, and energy use (Einav, Harussi, & Perry, 2003). However, the two greatest impacts are energy usage and the impact to the marine environment. Each one of these impacts should be considered to help mitigate the potential impacts when a plant is being designed.

The impact on land use is related to the location of a desalination plant. Because the plant uses seawater, it needs to be located on or near a coastal region. This requirement, then, causes the shoreline to be unusable for other purposes, such as tourism (Einav, Harussi, & Perry, 2003). The plant could move further inland so the beach area is not affected, but then that scenario can lead to other environmental impacts.

Noise pollution could be one of the impacts associated with a plant that is moved further inland. Noise can be a problem because plants with specific types of technology, such as RO, need to use equipment that generates a lot of noise, which means the plants should not be located near a highly populated area (Sadhwani, Veza, & Santana, 2005). Alternatively significant noise abatement systems must be designed. The impact of noise pollution is one reason why it is a good idea for plants to be located near the shoreline.

Another reason to keep a desalination plant near shore is the potential for groundwater contamination. When a plant is moved inland, pipes have to be installed to carry seawater to the plant and to discharge brine concentrate, which is the desalination by-product, away from the plant. These pipes can leak, which can contaminate the groundwater with saline water (Einav, Harussi, & Perry, 2003). Groundwater is a source of clean fresh drinking water that does not require treatment, and therefore, it is necessary to ensure that desalination plants do not contaminate it.

The amount of energy needed to run some technologies in a desalination operation is large and this requirement leads to the need for more fuels to be consumed – yet another impact. Peter Gleick states, “Desalination is the most energy-intensive form of water supply” (Schiermeier, 2008, p. 260). The amount of thermal or electrical energy needed to run a desalination plant depends on the technology being applied as well as the source of water being used, brackish water or seawater (Miller, Shemer, & Semiat, 2015; Munoz & Fernandez-Alba, 2007). Energy cost is almost half the amount of product water costs, which means the cheapest energy source available is used, namely fossil fuels (Miller, Shemer, & Semiat, 2015). Once the fuels are consumed, air pollution is typically emitted, such as greenhouse gases, which contributes to global warming and can have influence on local public health (Sadhwani, Veza, & Santana, 2005). Table 2 shows the range of energy required in comparison with other water supply technologies. These data support the point that desalination is the most energy-intensive method among alternative water production technologies.

Table 2

*Energy Uses of Various Water Supply Technology*

| Water Supply Alternative | Energy Use, kWh/m³ |
| --- | --- |
| Conventional treatment of surface water | 0.2–0.4 |
| Water reclamation | 0.5–1.0 |
| Indirect potable reuse | 1.5–2.0 |
| Brackish water desalination | 0.3–2.6 |
| Seawater Desalination | 2.5–4.0 |

*1 kWh/m³ = 3.785 kWh per 1000 gal

*Note*. Adapted from *Desalination Engineering: Planning and Design,* by N. Voutchkov, 2013, p. 115. Retrieved from https://books.google.com/

The last impact to be considered concerns the marine environment, which is the most significant impact. The marine environment for a desalination plant will differ based on its location, and not all marine environments will handle the pollution from a desalination operation in the same way. Therefore, an impact analysis should be completed to determine which organisms the marine environment may include, and how they may react (Einav, Harussi, & Perry, 2003). Table 3 shows a sensitivity scale for marine habitats with respect to construction of new desalination plants. The hierarchy of Table 3 indicates that Number 1 habitat would be the least sensitive to the construction of desalination plants and Number 15 habitat would be the most sensitive. This information could be used to help determine how the installation of a desalination plant might affect the marine environment, because the higher in the hierarchy of Table 3 a habitat is (that is, the closer a habitat is to Number 15), the less suitable it would be for construction because of the diversity of species associated with those habitats (Einav, Harussi, & Perry, 2003). The impacts affecting marine life in a desalination operation come mainly from brine discharge – which may have other chemicals in it – back into the ocean (Einav, Harussi, & Perry, 2003). Although the brine portion of the discharge is similar to the natural components in most environments, there is typically an increase in the salinity, and sometimes, temperature (Einav, Harussi, & Perry, 2003). In addition, chemicals are used during the pretreatment and post-treatment stages of the desalination process. The high concentrations of chemicals lead to ecological imbalances in coastal waters (Gude, 2016). Brine concentrate from RO “is usually about 1.67 to 2.5 times the salt concentration of the source water” (Treanor & Frenkel, 2009, p. 5462). The increased salt content makes the brine heavier than normal seawater, and the brine then sinks to the bottom of the waterbody without proper mixing having occurred to dilute the high salt content. This state of affairs can contribute to hypoxia – oxygen deprivation – in the bottom layers of the source water (Koontz & Hatfield, 2016). Some marine life can tolerate the increased salt content and some cannot, so without proper dilution, the marine environment could be in danger (Einav, Harussi, & Perry, 2003). The screens on the intake pipes also harm the marine life as organisms can become trapped against the screen, which can cause harm (Heck, Paytan, Potts, & Haddad, 2016). Table 4 shows a breakdown of some of the environmental impacts.

Table 3

*Sensitivities of Marine Habitats to Desalination Plants*

| | |
|---|---|
| 1. | High-energy oceanic coasts, rocky or sandy, with coast-parallel current |
| 2. | Exposed rocky coast |
| 3. | Mature shoreline (sediment mobility) |
| 4. | Coastal upwelling |
| 5. | High-energy soft tidal coast |
| 6. | Estuaries and estuary-similar |
| 7. | Low energy sand-, mud- and beach rocks-flats |
| 8. | Coastal sabkhas |
| 9. | Fjords |
| 10. | Shallow low-energy bay and semi-enclosed lagoon |
| 11. | Algal (cyanobacterial) mats |
| 12. | Seaweed bay and shallows |
| 13. | Coral reefs |
| 14. | Salt marsh |
| 15. | Mangal (mangrove flats) |

*Note*. Adapted from "The Footprint of the Desalination Processes on the Environment" by R. Einav, K. Harussi, and D. Perry, April 2002, *Desalination 152*(1-3), p. 143. http://dx.doi.org/10.1016/S0011-9164(02)01057-3

Table 4

*Breakdown of Environmental Impacts from Operation*

| | |
|---|---|
| Sea water quality deterioration | Increase in salinity due to RO reject discharge |
| | Influence on density stratification |
| | Chlorine and chlorination by-products |
| | Increase in turbidity due to filter backwash water |
| | Antiscalants |
| | Decrease in dissolved oxygen levels due to sodium bisulfite used for dechlorination |
| | Accidentally spilled chemicals |
| | The intake of large quantities of sea water may affect water circulation |
| Groundwater quality deterioration | Salt water intrusion for below ground intakes |
| | Leakage from pipes may result in penetration of salt water threatening the aquifer. |
| Marine flora and fauna | Loss of marine organisms by entrainment, entrapment, and impingement |
| | Increased salinity, temperature can be harmful and even lethal |
| | Decreased oxygen levels may be harmful |
| | Chlorine and chlorination by-products may be harmful |
| | Metals may be assimilated by marine organisms, with the risk of bioaccumulation |
| | Accidental spills into the ground or surface water bodies or into sea may affect the local fauna and flora. |
| Noise emissions | From intake pumps, the RO high-pressure pumps and the energy recovery systems, and other pumps and equipment |
| Air quality and climate | Release of air pollutants into the atmosphere, including greenhouse gas ($CO_2$), acid rain gases (NOx, SOx), or fine particulate matter due to high energy consumption |
| Hazardous materials | From routine transport, storage and handling of hazardous materials. |
| Waste disposal | Screening from intake screens and solid waste produced during the pretreatment process |
| Visual amenity | Impair landscape properties due to buildings on coast and land use |

*Note*. Adapted from "Environmental Impacts and Impact Mitigation Plans for Desalination Facilities" by G. Bombar, D. Deniz, and A. Necdet, 2016, Desalination and Water Treatment 157, p. 11534. http://dx.doi.org/10.1080/19443994.2015.1089198

**Techniques for pollution mitigation.** There are multiple ways to address environmental impacts associated with desalination plants. Some techniques that could be used to combat the noise would be the installation of canopies over pumps and proper acoustical planning for the plant (Einav, Harussi, & Perry, 2003). Using alternative energy instead of fossil fuels, which produce gases, could be implemented for energy consumption (Sadhwani, Veza, & Santana, 2005). A plant could also use co-generation, which would decrease the energy requirement, lowering the amount of greenhouse gas emissions (Mezher, Fath, Abbas, & Khaled, 2011). Proper sealing of pipes to prevent leaks into groundwater would provide safety from contamination (Einav, Harussi, & Perry, 2003). There is also a tool, environmental impact assessment (EIA), which could be used to help determine how to mitigate environmental impacts. EIA is a process used to identify, evaluate, and then address possible mitigation procedures for proposed projects prior to major decisions being made (Bombar, Deniz, & Necdet, 2016).

**Conclusion on impacts.** The review of the literature reveals that some of the previously discussed environmental impacts are not as significant as others are. The major environmental impacts are associated with marine life impact and energy usage (Morton, Callister, & Wade, 1997). However, environmental impacts from energy usage can be easily calculated by determining the amount of energy being used and relating that to how much fossil fuel is burned for production of that energy. Then the fossil fuel burned can be related to any environmental impacts that may be of concern. Since the environmental impacts from energy usage are only calculations, in this paper, the environmental impacts to marine life from the discharging brine reject from the desalination plants are explored. More specifically, the salinity changes that can occur from discharging the brine back into the source water, and how the brine discharge can increase the salinity of the body of water being discharged into, which can affect the marine species habitats and ability to survive, will be focused on. As a case study, the Tampa Bay desalination plant was used to help determine the possible salinity changes that could occur from brine discharge. This case study was also used to help determine species of fish that would be most affected by the possible increase in salinity.

## Tampa Bay Desalination Plant

The Tampa Bay desalination plant is located next to Tampa Bay's Electric's (TECO) Big Bend Power Station. TECO withdraws and discharges up to 1.4 billion gallons of seawater from Tampa Bay a day to use in its cooling towers (Tampa Bay Water). The desalination plant can take in up to 44 million gallons per day (MGD) of the discharging water from the cooling towers (Tampa Bay Water). The discharging water from the cooling tower is used in the desalination plant because the water is already warm, which makes the desalination process easier (Reinhardt). Up to 25 MGD of incoming cooling water is treated through the desalination plant and the rest, up to 19 MGD, is discharged along with the brine reject.

## Public Policy

Public policy is important because it can affect the public goods that the public needs and uses. With respect to desalination, the public needs to understand public policy implications as much as they need to understand the potential impacts from the implementation of a desalination plant. These two items, public policy and impacts from desalination, go hand in hand, as public policies can be used to intelligently guide actions with respect to desalination plants. From the lecture notes of Week 10 in CV-800, the Milwaukee School of Engineering (MSOE) research and writing course, some of the public goods that could be affected by environmental impacts from desalination include clean water, welcoming public spaces, and fresh air (G. Shimek, personal communication, November 7, 2016). Some of these public goods can be contributed to by desalination, and some can be environmentally impacted by desalination. For example, clean water is one public good that can be affected by desalination and at the same time, desalination can contribute to this public good. Desalination produces clean drinking water, but at the same time, the brine concentrate discharge can affect the marine life and pollute the discharge body of water. Desalination plants also can impact public spaces, as the plants are generally placed on the coast, which can take away from beaches and shoreline properties. Desalination can also impact fresh air, as it uses many fossil fuels for energy, which contributes to greenhouse gas emission.

The American Society of Civil Engineers (ASCE) Policy Statement 407 discusses desalination. This policy statement indicates that water resources are being stressed by increasing demands (American Society of Civil Engineering, 2016). Therefore, desalination can serve as an important technology to meet water demands. However, the public, legislators, and regulators should be educated about desalination and the costs and benefits associated with it.

“Public knowledge about ocean issues and management is typically low” (Heck, Paytan, Potts, & Haddad, 2016, p. 178). Direct experience with marine life, for example, often requires specific training, so people engage with marine areas differently than terrestrial ecosystems (Heck, Paytan, Potts, & Haddad, 2016). This state of affairs could be part of the reason that public knowledge about environmental impacts from desalination is low. Heck, Paytan, Potts, and Haddad (2016) state that “Compared to terrestrial areas, impacts on marine areas are also less visible and might be less known and understood by the public” (p. 178). It is important to know about the effects of desalination, and recently, there has been a move to increase public understanding. To ensure installation of desalination plants, it is crucial to have the public understand desalination as well as their support for implementation. Heck, Paytan, Potts, and Haddad (2016) further support this claim by stating that “Ocean literacy is also important for policy decisions on the use and protection of ocean resources and ecosystems” (p. 178). Citizens who live on the coast can also have significant influence in decision-making processes, which is another reason why they should be literate about ocean impacts from desalination plants.

Policy statement 407 also states that there should be more research aimed at improvements in desalination technology and disposal of by-products (American Society of Civil Engineering, 2016). This stance is in agreement with the literature on desalination, as much of the literature is concerned with the potential impacts of desalination and improvements in the technology for better efficiencies.

ASCE Policy Statement 286 discusses waste disposal in oceans and coastal regions. The policy focuses more on the impacts to the marine environment from waste discharge. Literature indicates that waste discharge is one of the more significant environmental impacts associated with desalination. The policy declares that it would be beneficial to have more research done on the pollutants being discharged in order to determine their ultimate fate and more effective ways of alternative disposal (American Society of Civil Engineering, 2015a).

Another ASCE policy statement dealing with desalination is Policy Statement 162, which discusses the development of coastal areas. Its concern is with the protection of public health, safety, welfare, and the environment and making sure these issues are addressed in all coastal projects (American Society of Civil Engineering, 2015b). This policy statement is another reason supporting the environmental impact assessment that should be completed before construction and the permitting process that desalination plants must go through. This policy indicates that there needs to be proper regulation of coastal development to ensure protection and sound conservation practices (American Society of Civil Engineering, 2015b).

## Methods

One method employed in this paper was a literature review with a specific case study on the Tampa Bay desalination plant. The literature review was used to help understand desalination and the environmental impacts associated with it. The case study was used to help determine salinity increase and indicator fish species.

First, Equation 3-4b from Metcalf and Eddy (2014) was employed to determine the mass loading rate of salt in the source water. Thus,

$$lb/d = Q*C*8.34, \qquad (1)$$

where

lb/d = mass loading rate,

Q = flow rate (MGD), and

C = salinity concentration (mg/L).

Equation (1) was next used to determine C for the brine reject combined with the 19 MGD of discharge from the Tampa Bay plant. Salinity concentration in mg/L was determined from 1 part per million (ppm) = 1 mg/L. The percent of salinity increase was found using 1% = 10,000 ppm.

## Results

### Salinity Increase

The review of the literature and the case study on Tampa Bay's desalination plant indicates that there will be an increase in salinity to the receiving water from the brine discharge. Using data from Tampa Bay's desalination plant, it was found that Tampa Bay has the potential for a salinity increase up to 8.1% from the discharging brine reject. Some assumptions were made to conclude the potential of up to 8.1% salinity increase, including the assumption that all the salt from the source water coming into the desalination plant leaves in the brine reject, and the assumption that the salinity of the source water is 35,000 ppm (3.5%) (Chen, Wang, Yang, & Zheng, 2010).

## Marine Species

The potential increase of salinity to the discharging body of water could affect the marine life living in that particular body of water. A study conducted before the construction of Tampa Bay's desalination plant had identified a list of fish species that typically live in the bay and would be sensitive to changes in salinity (Coastal Environmental/PBS&J, Inc., 1998). The list of fish identified is presented in Table 5. The salinity in parts per thousand (ppt) column indicates the maximum salinity the fish species can survive in. Salinity changes could affect the juvenile fish, but they also have the possibility of affecting the food source – for instance, worms, shrimp, and small crabs for these sensitive fish (Coastal Environmental/PBS&J, Inc., 1998). The list of fish sensitive to salinity changes could be considered indicator fish, as they could be a sign of impacts occurring to other marine life. With the potential of up to 8.1% salinity increase, these species and their habitats could be affected.

Table 5

*Typical Fish in Tampa Bay Sensitive to Salinity Changes*

| Species | Salinity (ppt) | Critical Life Stage |
|---|---|---|
| menhaden (*Brevoortia spp.*) | 2-3 | post-flexion larvae |
| bay anchovy (*Anchoa mitchilli*) | ≤ 10 | early juvenile |
| skilletfish (*Gobiesox strumosus*) | 10-12 | early juvenile and juvenile |
| rainwater killifish (*Lucania parva*) | <1 | early juvenile |
| tidewater silverside (*Menidia beryllina*) | 7.7 | early juvenile |
| snook (*Centropomus undecimalis*) | <10 | juvenile |
| majarras (*Eucinostomus spp.*) | 5.4 | early juvenile |
| sand seatrout (*Cynoscion arenarius*) | 16 | early juvenile and egg or newly hached young |
| striped mullet (*Mugil cephalus*) | 0.5-18 | juvenile (Haddad *et al.*, 1992) |
| silver perch (*Bairdiella chrysoura*) | 10.3 | juvenile |
| clown goby (*Microgobius gulosus*) | 15.6 | juvenile |
| spotted seatrout (*Cyunoscion nebulosus*) | 16 | juvenile |
| hogchoker (*Trinectes maculatus*) | <2 | early juvenile |
| lined sole (*Archirus lineatus*) | <5 | early juvenile |
| red drum (*Sciaenops ocellatus*) | <5 | early juvenile |
| spot (*Leiostomus xanthurus*) | <5 | early juvenile |

*Note*. Adapted from “Cumulative Impact Analysis for Master Water Plan Projects” by Coastal Environmental/PBS&J, Inc., April 1998, St Petersburg, FL: Coastal Environmental/PBS&J, Inc, p. 3-2

The tidewater silverside minnow (*Menidia beryllina*), specifically, could experience significant mortality rates— up to 50% of the species could succumb when exposed for 48 hours to a 4.5% increase in salinity (Pillard, FuFresne, Tietge, & Evans, 1999). Table 5 shows that the tidewater silverside minnow would start to die at a salinity of 7.7%. The increase of 4.5% salinity onto the current salinity of 3.5% in Tampa Bay would result in a salinity up to 8.0%, potentially precipitating a death rate of 50% for the species.

## Discussion

The findings of the Tampa Bay desalination plant case study indicate that the salinity increase of up to 8.1% would be harmful to marine species near the plant. Tidewater silversides are one example from the list of fish in Table 5 that would be affected by the salinity increase, as 8.1% is more than twice the amount of salinity increase this species could tolerate. If the tidewater silversides are showing signs of being affected, that could also indicate the salinity increase is affecting more than that species of fish. The salinity increase could be affecting food sources, as previously mentioned, and the increase could also indicate more marine life might be affected that may not be monitored.

### Techniques for Salinity Mitigation

To mitigate salinity increases, the Tampa Bay desalination plant combines the brine reject with the discharging cooling water to achieve dilution before being discharged back into the bay (Tampa Bay Water). After the two streams have combined, they are discharged to a discharge canal, which allows for more dilution, and then discharged to Tampa Bay. All the combining of streams allows the desalination plant to achieve a blending ratio of 70:1 before releasing into Tampa Bay (Reinhardt). The dilution makes the brine reject only 1% to 1.5%

higher than the typical salinity in the bay, which lands within the normal seasonal changes in salinity (Tampa Bay Water). The dilution allows the desalination plant to discharge the brine reject without substantial increase in salinity. In turn, the marine life has less potential for environmental impacts from any salinity increase.

Other options could be used to reduce the environmental impacts to marine life from the discharge of the brine reject from the desalination plants. The plants could discharge into an adjacent sea that may have a marine environment that could handle the brine discharge, or a loop-channel could be used that would dilute the brine before it was discharged (Sun, Yang, Wang, & Li, 2012). The brine concentrate could also be disposed of inland in evaporation ponds or brackish aquifers (De Buren & Sharbat, 2015). The brine disposal can be a significant cost – anywhere from 5% to 33% of the total desalination costs (Koontz & Hatfield, 2016). However, agriculture and aquaculture can provide some financial relief, as the brine solution can be used to irrigate certain crops or for growing tilapia. The brine in liquid, solid, or slurry state can also be used as road base and in the manufacturing of dust suppressants (Koontz & Hatfield, 2016). The production of hypochlorites can be another use for brine concentrate (Abdul-Wahab & Al-Weshahi, 2009). Desalination plant personnel could also look at how the brine is being dispersed when discharged and potentially change the angle of dispersion or the equipment to ensure proper mixing for dilution (Jirka, 2008). There has also been recent research that shows that it is possible to precipitate and recover metals and nutrients (salts) from the concentrate. This removal of metals may help to lower the $CO_2$ pollution produced through the desalination process (De Buren & Sharbat, 2015).

## Conclusion

Desalination is providing significant benefits to regions struggling for fresh drinking water (Fuentes-Bargues, 2014). However, there are many environmental impacts that a desalination plant can create, and the more significant impacts are associated with the energy usage and brine reject affecting marine life. Management of the environmental impacts can mean an improved standard of living for those getting the water (Sadhwani, Veza, & Santana, 2005). Investigating current desalination techniques is essential to advance the technology in order to lower or eliminate the environmental impacts associated with this important new source of freshwater. When considering the implementation of a new desalination plant, it is important to study the marine life in the discharge body of water, because as the results of this review demonstrate, salinity increases can affect marine life. As the Tampa Bay desalination plant case study revealed, the brine reject has the potential to increase the salinity of the body of water being discharged to. Determining the indicator species, which would be affected by salinity change, if any, facilitates the implementation of a technique to mitigate the possible increase of salinity. Proper dilution, as a mitigation technique, for instance, can lower the discharge stream to almost the same salinity as the salinity of the body of water being discharged into.

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**Civil Engineering**

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**Master of Science in Engineering – MSCVE**

**Milwaukee School of Engineering**

This capstone report, titled "Environmental Impacts of Seawater Desalination to Marine Life," submitted by the student Karissa M. Brunette, has been approved by the following committee:

Faculty Advisor: ______________________ Date: ____________________

Professor Douglas Nelson, M.A.T.

Faculty Member: ______________________ Date: ____________________

Dr. Jay Karls, Ph.D.

Faculty Member: ______________________ Date: ____________________

Professor Jeffrey MacDonald, M.S.