

## **The Urban Whale**

A Serious Game about the North Atlantic Right Whale,  
And a Template for Future Endangered Species Games

A Major Qualifying Project Report:  
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## **Abstract**

Worcester Polytechnic Institute, in collaboration with the New England Aquarium, tasked the project team with creating a digital interactive experience about the North Atlantic right whale in order to evoke an empathetic response for the animal in its users, provide knowledge about what human actions are hindering the species' recovery, and engage players through entertaining gameplay. Over a nine- week period, the project team developed *The Urban Whale*, a prototype that aimed to meet all three requirements. In addition, the project team determined how *The Urban Whale* could be further developed into an aquarium exhibit or web-based game that would fulfill its original purpose, as well as how this project could serve as a template for a new genre of video game that evokes empathy for endangered species, provides educational content, and is also fun to play.

## **Acknowledgements**

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# 1 Introduction

The North Atlantic right whale is the most critically endangered species of whale on the planet. In fact, less than 500 individual whales remain in the world today (North Atlantic Right Whale Consortium, 2014). The right whale's current endangered status is a result of the population's significant depletion during the whaling era and the heavily commercialized urban coastal environments in which it lives. Several factors contribute to the steady decline in the population, preventing the species from recovering: right whales typically cannot see fishing lines and nets due to their colorblindness and limited vision, right whales lack the speed and agility to avoid oncoming ships, and right whales have a 12-14 month gestation period in which they suffer from even slower movement. As a result, many right whales suffer from entanglement and ship strikes each year (Kraus & Rolland, 2007, p. 4-8).

Although the endangered North Atlantic right whale typically inhabits coastal waters from Nova Scotia to Southeastern Florida, there is not a large awareness of the issue beyond the people and organizations directly involved in the right whale conservation effort (New England Aquarium, 2014). The New England Aquarium (NEAq), located in Boston, Massachusetts, is a non-profit organization that strives to educate the general public on the human impact to endangered marine species and help protect ecosystems of marine animals threatened by extinction (New England Aquarium, 2014). In order to raise awareness of the causes for the North Atlantic right whale's endangerment, the NEAq and another Worcester Polytechnic Institute (WPI) student team completing their Interactive Qualifying Project (IQP)<sup>1</sup> in 2014 suggested that a realistic video game depicting the right whales' current habitat and the dangers accompanying it would be an effective way to educate the general public about the current state of the species. The NEAq and WPI student team also determined that a realistic video game could potentially cause people to empathize with right whales. As such, the game could empower players to take actions that would help protect the species.

Through several discussions with the NEAq, the WPI IQP student team, and other North Atlantic right whale conservation experts, our team compiled a list of important aspects that

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<sup>1</sup> An Interactive Qualifying Project (IQP) is a student research project undertaken by an individual or group of undergraduates at WPI.

conservationists desired in a North Atlantic right whale video game. We refined these ideas into three important objectives that we want *The Urban Whale* to meet:

1. *Educate the audience about the North Atlantic right whale.* Exhibit the "urban" environment that North Atlantic right whales' currently inhabit with a high level of realism, including the dangers they face such as fishing gear, boats, and debris.
2. *Engage players through an entertaining, interactive experience.* Create entertaining gameplay that will engage players and inspire further research about the North Atlantic right whale.
3. *Evoke empathy from the player for the North Atlantic right whale.* Evoke empathy from the player for the right whale that may lead to activism in the future through the depiction of entanglement and up close encounters.

With these goals in mind, our team brainstormed several potential game concepts which would showcase the problems facing the North Atlantic right whale. We then presented these ideas to the NEAq where we obtained valuable feedback on the impact of each game idea. Through these evaluations, we determined that the most effective way to capture these important aspects was through an *open world*<sup>2</sup> North Atlantic right whale video game that contains multiple playable "adventures." In this design, the player would see and experience life in the ocean from the right whale's perspective, allowing the player the freedom to roam around a dynamic underwater environment or partake in one of the many educational adventures that contain more directed gameplay and lessons about the North Atlantic right whale. We initially brainstormed various other designs, such as a real-time strategy game where the player controls the fishing industry and she or he has to make a profit while killing as few right whales as possible and an endless runner game similar to *Temple Run* where the player has to drag obstacles out of the way of a right whale to prevent harm to the whale. We decided that an open world design model worked best for meeting our three objectives since we felt that a real-time strategy design would not evoke enough empathy and an endless runner was too unrealistic for educational value. In addition, an open world design gives players the most freedom since exploration is built in to gameplay. Working towards this final design, our team created a prototype that represents one of many possible playable adventures in *The Urban Whale*.

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<sup>2</sup> *Open world* is a gaming genre that allows the player to roam the game world freely.



During the development of *The Urban Whale*, our team re-scoped the design of the complete game into a prototype that was possible to accomplish within the limited time frame. A game prototype is a proof of concept or initial playable demo that contains most of the aspects that would be seen in a final game. Our final prototype throws the player into the role of a diver guiding a North Atlantic right whale in one of these adventures, which is designed to highlight entanglement, ship strikes, and conservation efforts. This particular adventure places the player in an underwater environment amidst many lobster trap lines. A North Atlantic right whale is nearby, and swimming towards a concentration of their food source which we term a “zooplankton ball.” The player must move these zooplankton balls in order to ensure that the whale avoids becoming entangled in the lobster trap lines. Our team determined this prototype could serve as a base for future development since the North Atlantic right whale, the act of entanglement, and the environment would all be depicted in any future iterations. The complete game would feature several adventures and each one could serve a different educational goal about the North Atlantic right whale, allowing the player to learn many different facts about the species ranging from its history to its modern day life. As long as the playtime for each adventure provides enough education while keeping the gameplay brief, the complete game or a portion thereof adventure could be featured in an exhibit at the New England Aquarium.

Our team used Unreal Engine 4 to build the prototype. The engine’s powerful graphics and built-in functionality ensured that the game would not only have a powerful visual effect on the player, but would also provide an entertaining, engaging experience. Although none of our team members had experience with Unreal Engine 4, many of us were knowledgeable in the use of other game engines, and we were allured by the power seen in many of the video demos of Unreal Engine 4. This meant we had to learn entirely new software, software that is in use in many high-profile games being created today. Our team also used Autodesk Maya, Autodesk 3DS Max, and Adobe Photoshop in the creation of the 3D models, animations, and textures created for *The Urban Whale*.

Our final design has the player control an underwater diver. The player can swim freely within the world as long as he/she does not swim too far away from the right whale. The whale will swim towards the closest swarm of zooplankton. In order to help the right whale, the player must move these zooplankton balls away from dangerous obstacles, such as lobster trap lines.

Through all of the design decisions our team had to make, we believe the final design is the best compromise between playability, realism, and player empathy for the right whale.

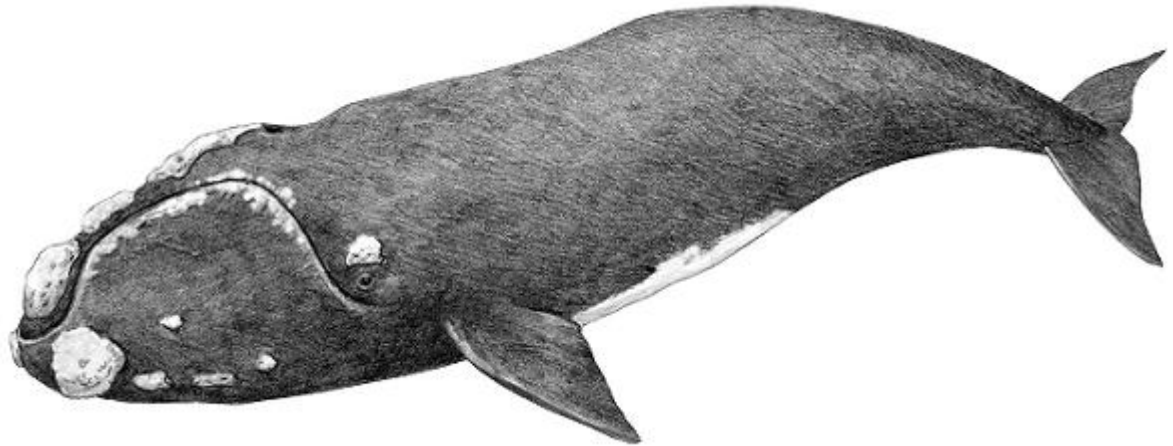
Through *The Urban Whale*, we hope that players empathize with the North Atlantic right whale and learn key features of its biology. In addition, we hope that the NEAq succeeds in raising awareness of the North Atlantic right whales' current endangerment status and the conservation efforts that are currently being implemented to prevent the species' extinction. We also believe that the mechanics in *The Urban Whale* could be extended to serve as a template for future games that seek to depict an endangered animal along with the environmental causes of its endangerment while still containing entertaining gameplay for players. We believe we can help the species as a whole by raising awareness of the issue and thus encouraging individuals to take action to render the whales' urban habitat less harmful to individual whales.

## 2 Background

### 2.1 North Atlantic Right Whale Appearance

Several factors separate the appearance of North Atlantic right whales from other whales. The first of these physical distinctions is the large callosities that form on the head of North Atlantic right whales. These callosities are actually raised epithelial tissue with a dark color, forming in places around the jaw and above the whale's eyes and lips. However, these callosities are infested with light colored amphipods called cyamids. These cyamids are casually referred to as "whale lice" and actually give these callosities a white, creamy appearance despite the actual callosities being of dark color (Hamilton et al., 2007, p. 79). The callosity patterns are unique to each North Atlantic right whale, almost serving as a whale's "fingerprint".

Although not as obvious, the North Atlantic right whale's shape helps distinguish it from other whales. North Atlantic right whales are more rotund than other whales due to an extra layer of blubber. They also have a square chin and fairly large head which accounts for 25% of an adult's body length. North Atlantic right whales also have an arched, narrow upper jaw and a bent lower jaw which gives the impression that the whale is "upside down" (Kraus & Rolland, 2007, p. 12-13). Figure 2.1 shows an artist's depiction of a North Atlantic right whale which depicts the callosities and jaw outlines better than most North Atlantic right whale photographs. Figure 2.2 shows an actual North Atlantic right whale. It is important to note the white patches (callosities) above its eyes and around its jaw, the jaw shape, and the body shape in both of these images.



**Figure 2.1:** An artist's depiction of a North Atlantic right whale. The callosities and jawline are more clearly seen here than in most pictures of North Atlantic right whales



**Figure 2.2:** An image of a North Atlantic right whale

## **2.2 History of the North Atlantic Right Whale**

The North Atlantic right whale is the most endangered species of whale on the planet with less than 500 individual whales remaining in the world (Kraus & Rolland, 2007, p. 3). The species' endangerment began in the eleventh century, when a group of Europeans known as the Basques developed the first techniques for hunting whales and sparked the beginning of the whaling industry in the North Atlantic. The Basques primarily hunted a species of whale they named the "right" whale. Right whales were given this name because they were the right whale

to hunt since they were easily pursued in their coastal habitats. They were also the right whale to hunt due to their thick layer of blubber. Not only did the right whale's extra blubber keep it afloat if dead, but its blubber was also good for hunters looking to sell it for its oil (Kraus & Rolland, 2007, p. 4). Although right whale hunting began earlier than the year 1100, the majority of hunting occurred for a period of 300 years from 1600-1900, peaking during the early 1700s. During the early 1900s, right whales became commercially extinct, meaning they were hunted to the point where it became unprofitable to continue hunting them (Kraus et al., 2007, p. 46-49).

Although the exact number is unknown, the U.S. Department of Commerce estimates that the peak population of the North Atlantic right whale reached above 10,000 individual whales. During the mid-1600s, there must have been at least 1,000-2,000 right whales present in order to produce the documented oil and baleen exports from the American colonies" (Breiwick et al., 1984, p. 484-496). An in-depth analysis performed on the number of right whales killed in the North Atlantic during the years 1634-1951 yielded an estimate of 5,500 individual whales (Reeves et al., 2007, p. 65). This study took into account several factors; right whale hunting loss (instances where a right whale was killed but not recovered), age and sex selectivity in hunting (instances where Basque whalers hunted right whale calves selectively), and confusion in catch records with other whale species (Reeves et al., 2007, p. 62-63). In addition, this analysis yields a lower bound for the number of right whales killed, which implies that the actual number was probably much more. One proposed model representing the North Atlantic right whale population suggests the numbers may have been in the dozens sometime around the mid-17th century. Another model suggests that the number of individual North Atlantic right whales could have been as low as approximately 85 breeding individuals at some point in history (Kraus & Rolland, 2007, p.5).

During the late 19th century, right whale hunting heavily resumed until about 1912. In 1935, the species became officially protected from hunting when the *1931 Convention for the Regulation of Whaling* went into effect. This convention prohibited the taking or killing of North Atlantic right whales, among other regulations (International Environmental Agreements Database Project, 2015). However, only twenty-two nations signed this convention, which left many other nations free to hunt and kill whales. It was not until 1946 that the *International Convention for the Regulation of Whaling* was signed, which completely protected right whales from hunting (International Whaling Commission, 2015). Although the North Atlantic right

whales' history is not the only reason for its endangerment, the whaling era severely impacted the population of living North Atlantic right whales today.

### **2.3 Right Whales Today**

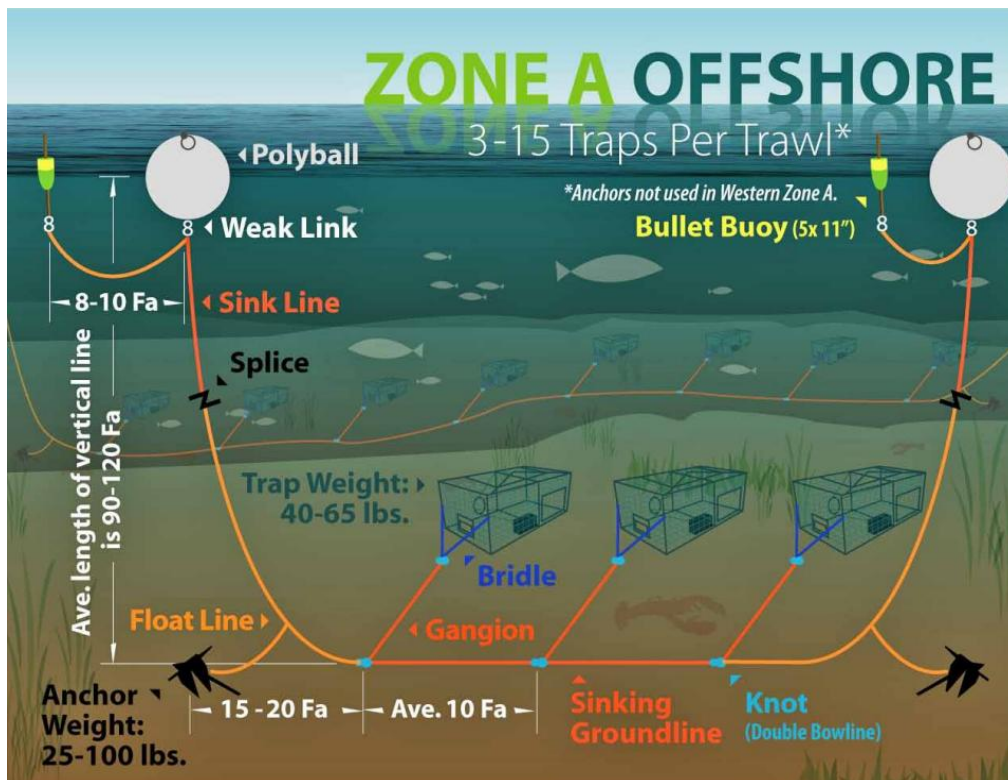
Even though the North Atlantic right whale has not been commercially hunted for over fifty years, many other factors have affected the population's ability to recover from whaling and have thus kept the species at risk of extinction. Even today, "50 percent of all confirmed right whale deaths are due to clearly identified anthropogenic sources", or sources originating from human activity (Kraus & Rolland, 2007, p. 23). Seventy-five percent of all right whales display scars resulting from entanglement at some point in their lives (Knowlton and Kraus 2001; Chapter 14). Also, North Atlantic right whales typically inhabit coastal waters spanning from the Bay of Fundy to parts of the Southeastern United States (New England Aquarium, 2015), which is heavily populated by both commercial fishing and shipping ventures. The state of Maine alone issues on average 9000 licenses for the lobster industry, and tags over three million traps annually (Department of Marine Resources State of Maine 2012). The eastern seaboard of the United States and Canada also hosts one of the highest shipping traffic areas worldwide (Knowlton & Brown, 2007, p. 410). As of 1998, there were approximately 87,000 registered ships weighing more than 100 gross tons worldwide with a majority occupying the North Atlantic (Southall, 2005).

### **2.4 Entanglement**

As mentioned above, over 75% of all well-photographed North Atlantic right whales show scarring from prior entanglements in fishing gear. At the current rate of entanglement and death, a right whale dies or disappears from entanglement nearly every year (Johnson et al., 2007, p. 382). Roughly 83% of right whales will be entangled at some point in their lifetime (Knowlton et al., 2012). Entanglements force right whales to drag fishing gear, which can cause tissue damage or infection. The massive amount of energy an entangled right whale spends dragging fishing gear can also lead to death from starvation, exhaustion, or asphyxiation, which can happen if the gear prevents the right whale from surfacing, essentially trapping the right whale underwater (Van der Hoop et al., 2013b). While there are several forms of fixed (stationary) fishing gear used in the Northeast Atlantic, the two most common types are pots

(also called traps) and gillnets. In the Northeast Atlantic, pots are commonly used for catching crustaceans, particularly the American lobster, but also various types of crabs. These pots are placed on the ocean floor in chains ranging from three to fifteen traps per line (Maine Lobstermen's Association, 2012). These pots are connected in sequence to each other using ropes called “ground lines” (See Figure 2.3).

The lobster industry spans from the Gulf of Maine and the continental shelf of Nantucket Island, Massachusetts to Long Island, New York (Johnson et al., 2007, p. 382). In the Gulf of Maine, fishing activities can range anywhere from the beach to more than 278 km offshore. Most right whales spend their lives within 80 km of the shore. Their range therefore overlaps with the area fishing industries use in order to obtain their catch.



**Figure 2.3:** Offshore lobster pot configuration (Department of Marine Resources State of Maine, 2009)

Adult North Atlantic right whales historically have shown little to no interest in fishing gear, meaning that they do not intentionally swim close to the gear in order to inspect it (Johnson et al., 2007, 385). Even so, studies suggest that right whale encounters with fishing gear come as

a surprise to the whale. As a result, most whales become startled by rope collisions and try to escape quickly. In order to escape, right whales typically turn and roll rapidly away from the ropes, but the whale does not always succeed in its escape and the ropes become entangled around the whale. Most right whale entanglements result in the rope wrapping around the tail stock, flippers, or body. Some entanglements have resulted in ropes passing through the whale's mouth and baleen (Johnson et al., 2007, 385).

In a study performed in 2005, there were fourteen cases of right whale entanglement in which the gear could be identified (Johnson et al. 2005). Eight of these whales were entangled in lobster pot gear, two were entangled in gillnets, and the remaining were results of pot-related, crab pot, Danish seine, and aquaculture gear entanglements (Johnson et al. 2005). In the two years that followed the study, seven right whales were reported as new entanglements (Whittingham et al. 2005).

Although disentanglement is a possible solution to aid right whales, this process is difficult. Most whales are freely swimming in the ocean and therefore they are difficult to find and approach. Some whales are too large for a human to make a safe approach without risking his/her life. Lastly, some ropes cut too deeply into the right whale for a team to remove the ropes without further damaging the whale (Johnson et al., 2007, p. 390-391). While some whales can be freed from entanglement with the help of an expert team, this method is not a viable solution for ensuring the survival of the species.

Adjustments to fishing gear is the most widely supported method for reducing right whale entanglements. However, it is important that these innovations do not disrupt fishing in significant ways. Several ideas for reducing right whale entanglements have begun research. These ideas include surface buoy systems, which would remove approximately 18.3 m of horizontal rope near the surface of the water; timed-release systems, which is a device located at the bottom of a buoy line that releases the line after reaching a load threshold; and vertical line reduction, which aims to reduce the amount and time a buoy line spends suspended from the water's surface (Kraus & Rolland, 2007, p. 399). Other modifications aim to change the buoy lines in fishing gear. Proposed methods have been illuminated rope, weak rope, and stiff rope. Illuminated ropes would allow North Atlantic right whales to detect ropes from farther distances, possibly giving these whales the chance to avoid the ropes entirely. Stiff ropes would prevent any creature from becoming entangled, but this concept poses a problem for fisherman who need



to coil the rope above the surface. Finally, weak ropes are ropes that would ideally break when placed under a load threshold (Kraus & Rolland, 2007, p. 400-401).

Federal regulations have been put into effect to modify fishing gear and help the survival of the North Atlantic right whale. Before 2009, ground lines, which are the lines between pots, could float approximately 20 ft. above the ocean floor. New regulations introduced in 2009 replaced the floating lines with “sinking ground lines” that rest on the ocean floor (see Figure 2.3). These new regulations lessen the possibility of entanglement of marine animals in the ropes between pots, but the vertical lines still remain a threat to right whales which is why research is being done in order to reduce entanglements with vertical buoy lines.

## **2.5 Ship Strikes**

As of 2007, entanglement was the second leading cause of North Atlantic right whale deaths, while ship strikes were the number one cause. Ship strikes account for about 38% of reported right whale deaths. Ship strikes can cause scarring, internal trauma, tissue damage, such as vertical lacerations from propeller strikes, and immediate death to right whales. As of 1970, there have been sixty-seven right whale carcasses reported, at least twenty-four of which died from a ship strike (Knowlton & Brown, 2007, p. 410).

Right whales spend large amounts of time near the surface of the water, especially while pregnant, nursing, or surfacing for air, which leaves them vulnerable to large commercial ships. Large cargo ships, ranging from 1,000-1,200 ft. in length, vastly surpass right whales in size, speed, and mass. As a result, many right whales idling at the water’s surface are hit by passing ships. Most right whale carcasses have been found close to shipping lanes and in dense ship traffic areas, these areas pose a high threat to North Atlantic right whales. The average distance a right whale carcass that died from a ship strike was found from a shipping lane was 18.3 km. As a point of reference, the average distance of a right whale that died of undetermined or natural causes was found from a shipping lane was 42.8 km (Knowlton & Brown, 2007, p. 412).

Most right whale ship collisions go unnoticed by humans. In fact, there have been only four witnessed right whale ship strikes. For one of the four witnessed ship strikes, the speed of the vessel was between 28 and 39 km/h at the time of the right whale collision. Jensen and Silber (2003) documented three right whale ship strikes where the vessel was traveling less than 18.5 km/h. This leads experts to believe that most whales might be able to avoid ship strikes and

consequently injuries or death if ships are travelling at less than 26 km/h (Knowlton & Brown, 2007, p. 416).

Although it is not well known due to the small number of witnessed or documented ship strikes, research shows that most right whales do not detect incoming ships until it is too late to avoid a ship strike. Of the various documented ship strikes, the struck whales typically lunge out of the way of an incoming ship at the last minute, which is usually too late to avoid some sort of ship strike (Knowlton & Brown, 2007, p. 418).

From the few witnessed ship strikes, right whale experts have concluded that most ship strikes occur with vessels more than 24.4 m in length traveling at speeds more than 26 km/h. Several approaches have been explored to reduce the number of right whale ship strikes which include educating mariners about right whales and how to take precautionary measures to avoid collision, developing technologies to detect right whales in danger of an oncoming ship, and altering ship operations via routing and speed restrictions. For instance, chip tracking devices placed on right whales have been proposed as well as sonar detection placed on vessels. However, these technologies are still being researched and could end up costing a lot of money.

At this moment, the most successful conservation effort being implemented is the altering of shipping operations. In fact, several policies have been implemented under the Endangered Species Act and Mammal Protection Act to reduce the number of right whale ship strikes. In 1993, Fisheries and Oceans Canada designated an area within the Bay of Fundy, which North Atlantic right whales largely populate, as a right whale conservation area (Brown et al. 1995). This area serves as a traffic separation area, which means that ships are separated into various lanes to provide more organization. In 1997, the National Marine Fisheries Service (NMFS) prohibited vessels from knowingly approaching right whales from within 457 m (Knowlton & Brown, 2007, p. 424-425). In 2008, NMFS established a federal regulation that limited all vessels of length 65 ft. or greater to a speed of 10 knots (18.52 km/h) (Federal Register, 2008). An analysis performed by Conn and Silber (National Marine Mammal Laboratory, Alaska) reveal that this new law should reduce right whale ship strikes by about 90% (Conn & Silber, 2013). From November 1, 2013 to October 31, 2014, there were no reported right whale ship strikes (North Atlantic Right Whale Consortium, 2014).

## 2.6 Open World Video Games

An open world video game is a type of video game design where players are given freedom to roam a virtual world. Open world video games give players more freedom than other genres such as real-time strategy games, where the player takes on a third person omniscient role in a limited game world where she or he control units and builders. Open world video games typically give the player the ability to decide when he or she completes objectives or goals to progress the game further. Several examples of well-known open world video games include the *Elder Scrolls* series, the *Grand Theft Auto* series, and *Minecraft*.

## 2.7 Serious and Educational Games

A serious game is a game specifically designed with a primary purpose other than pure entertainment. An educational game is a serious game with the purpose of teaching the player information or an important skill. For example, flight simulation games simulate the operation of a plane, and brain training games teach though patterns and techniques to learn, retain, and solve problems more effectively. Serious games have many applications in the real world. One example of a serious game is *Foldit*, which is an online puzzle game that presents the player with the objective of folding selected proteins. The game serves a scientific purpose since researchers analyze the highest scores and determine the feasibility of these solutions in the real world. Protein folding could eventually lead to cures of diseases such as HIV/AIDS, cancer, and Alzheimer's (Foldit, 2015). In fact, the game has already solved the crystal structure of a monomeric retroviral protease called Mason-Pfizer monkey virus, which causes simian acquired immunodeficiency syndrome (SAIDS) in rhesus monkeys (Gilski et al., 2011). *Foldit* is a serious game that has real life benefits to playing, which is what we strived for in the design of our game and meeting our three objectives.

Another application for serious educational games is educating users about endangered species. Although not a very large sub-genre of serious games, there have been a few games created depicting the lives of various endangered species. One serious game educating players of an endangered species is *WolfQuest*. *WolfQuest* is a 3D open world wildlife simulation game educating players on several species of the life and biology of the gray wolf (See Figure 2.4), an endangered species that is making a recovery in several states in the US. Through gameplay, players learn about wolf ecology and what life is like for a wild wolf living in Yellowstone

National Park (WolfQuest.org, 2015). For example, the game is currently broken into two episodes. In the first episode, players explore the wilderness while attending to basic survival needs, such as food. In this episode, players can interact with other wild wolves while on the quest for a mate. In the second episode, players must establish a territory and protect their pups from predators. According to a comprehensive summative evaluation that the Institute for Learning Innovation conducted in 2009, players were significantly more interested in, connected to, and knowledgeable about the gray wolves after playing *WolfQuest* (WolfQuest, 2015). The gray wolves have been endangered and made a remarkable comeback. Some regions and states have revoked the gray wolves' endangerment status since the wolves are now doing considerably better (WolfQuest, 2015). Unfortunately, right whales are not in the same position as the gray wolves. Current conservation efforts struggle to maintain the whale population. More people need to learn about and empathize with the right whales and a video game would greatly assist in that effort.



**Figure 2.4:** Screenshot of *WolfQuest* (2008) gameplay

### 3 Design Process

Our project team utilized an iterative design process throughout the course of this project. We began with an initial game idea of swimming around an open world as a North Atlantic right whale and completing adventures. Through development, testing, and feedback from the New England Aquarium (NEAq), our team refined this idea into a more meaningful and impactful interactive experience that could be played on standard desktop computers and could also be featured as a kiosk within a North Atlantic right whale exhibit at the NEAq. Our team went through several stages of refinement where we altered or further developed the game mechanics, game world, and overall experience to better suit our three objectives. Moreover, sometimes our objectives seemed to conflict: by emphasizing playability we would lose realism and vice versa. The following sections detail these stages of refinement, our thought processes in making critical decisions, and the outcomes of these decisions. The final prototype involves a player taking on the role of a diver aiding the right whale by modifying its path through moving around zooplankton. These design decisions are chronicled to improve the process for those looking to develop future iterations of this game, and to those who may encounter similar issues when developing a game about endangered animals.

#### 3.1 First Iteration: Player as Whale

Before development began, the NEAq and our project team decided upon the vision of an open world video game in which the player would play as a North Atlantic right whale. The player would be able to travel to different areas of New England's coastal waters in order to find and complete different adventures scattered around this area. However, while swimming around underwater, the player (whale) would have to avoid obstacles, such as lobster trap lines and ships. Additionally, since the game would have an open world model, the player would not be forced to complete any adventures and could just roam freely underwater. For our prototype, we decided to reduce this idea from an open world model to a game with a single adventure due to the scope of our project. This new design would also allow the prototype to be easily playable on a kiosk running Windows with little overhead to the NEAq. As we soon discovered, careful thought needed to be put into the core mechanics of the adventure in order to accurately portray realistic behavior and to display more of the right whale conservation efforts.

The player's view in our original idea would have looked similar to the video game *Jaws Unleashed* (2006) if a North Atlantic right whale replaced the shark in Figure 3.1. Although the player's view for our original idea would have been similar, the gameplay would have been drastically different. The game is heavily based on the 1975 Steven Spielberg film, *Jaws*. In *Jaws Unleashed*, the player assumes the role of the shark "Jaws" and can attack other sea creatures and humans underwater. The player can also upgrade various aspects of Jaws, such as its speed, health, and attack power. None of our ideas had combat involved nor the player actively affecting the environment or any of its inhabitants in any negative way. In addition, none of our ideas had any sort of upgrade system since they would have complicated the game further and would have provided no educational benefits in our case. We had difficulties thinking of a realistic, entertaining game idea where the player assumed the role of a right whale. Since right whales are not agile or aggressive creating gameplay as the right whale would likely be unexciting. Also, while this design would allow the player to experience the habitat of a right whale and empathize with the animal, making the whale avoid obstacles would inaccurately remove responsibility from humans. We wanted to avoid the player believing it was the whale's job to not hit the manmade obstructions so we chose to change the design.

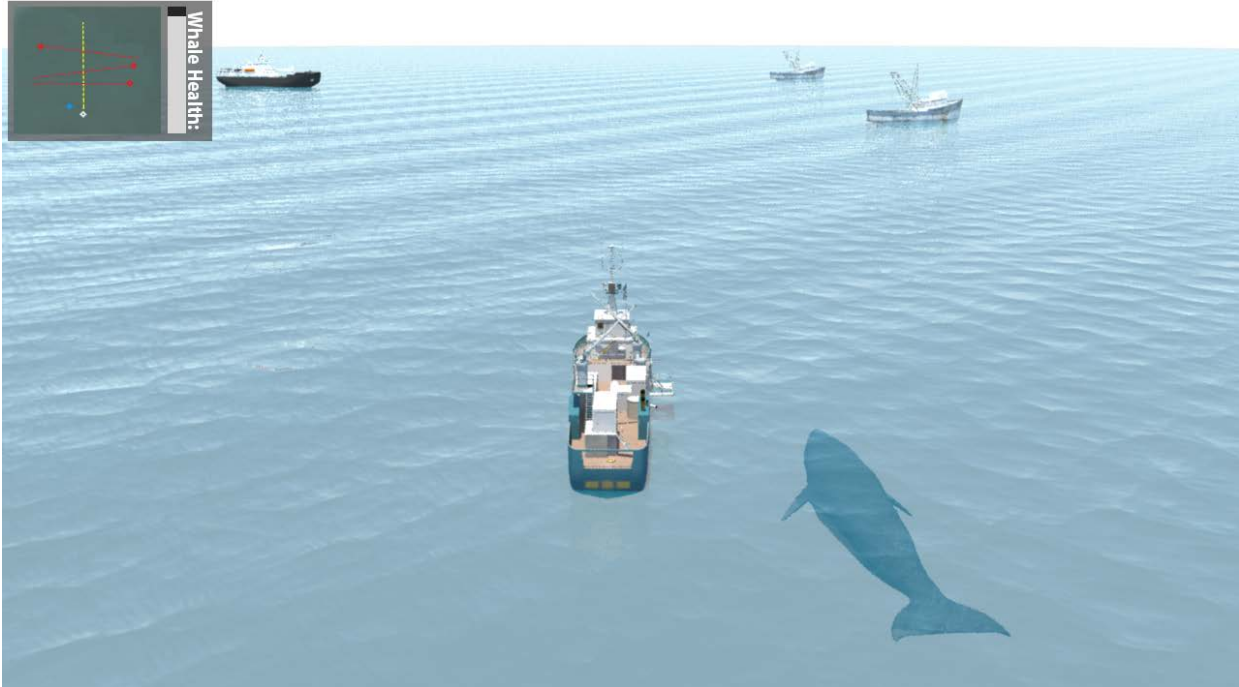


**Figure 3.1:** *Jaws Unleashed* (2006) screenshot of third-person player controlling Jaws

### **3.2 Second Iteration: Player as Ship**

Because of the lack of a realistic, entertaining idea where the player assumed the role of a right whale, the design of our prototype evolved into a game in which the player took control of a conservation research vessel and removed obstacles such as trap lines and gillnets from the path of the whale. The player would be able to remove obstacles from the ocean in two ways; in the first way, the player would assume the role of a diver on the research vessel, dive into the water, and cut the ropes by hand. In the second way, the player could mark the ropes so that a secondary boat would come and remove the gear from the ocean, which was an unrealistic depiction. Unfortunately, this model seemed to disparage the fishermen by implying the only way to save right whales was to remove the fishing gear. This model also made it seem feasible and legal to remove fishing gear from the ocean. This led us to eventually decide upon a way of representing the dangers of obstacles without depicting the removal of them. As a result, our final design features a core mechanic of guiding the whale through the ocean rather than moving obstacles to accommodate the whale's travel path.

Another idea we had was to allow the player to call a fisherman via radio to pull up the trap lines. The fisherman's boat would then appear and remove the line, causing the buoys to disappear. This idea would both solve the problem of vandalizing someone's property and show that fishermen are willing to aid in the protection of the North Atlantic right whale. Another suggestion was the idea of a "magic wand" that would make any traps and obstacles magically disappear from one push of a button. Many ideas were discussed as to how the magic wand would be represented and the realism of its depiction. However, both ideas of the fisherman removing their traps and the magic wand were discarded since they made it seem like the best option for the protection of right whales was to remove traps and lines from the ocean completely, which was not the message we wanted to give the players. The idea made it seem like protecting the whales was far easier than it really was, and made it seem like moving and removing fishing gear in this way was both legal and even possible. This model also did not incite action in the real world since the traps were too unrealistically removed. We determined that the game would not create empathy within players either since they cannot see the whale closely enough from above the surface. If we had decided to go this route, our game may have looked similar to this screen mockup our team created in Figure 3.2.



**Figure 3.2:** Initial screen mockup of *The Urban Whale* from conservation boat perspective.

### 3.3 Final Iteration: Player as Diver

We eventually decided on having the player controlling a diver and having the game take place primarily underwater. This allowed us to display the right whale and the underwater environment more closely, directly show the player the dangers the right whale faces, and allow the player to directly interact with and empathize with the right whale. While analyzing our previous ideas, we were disappointed with the lack of time the player is underwater. We wanted to allow the player to see the North Atlantic right whale close up in order to identify and become more familiar with the creature. Allowing the player an intimate experience with the North Atlantic right whale gives the player an experience that they would otherwise be incapable of having in the real world (Aaltola, 2013, 7). Eye contact has also been shown to inspire powerful feelings empathy and so we wanted to allow for that with the whale (Journal of Participatory Medicine 2013, Table 7). We also wanted to be able to show other kinds of underwater life and the beauty of an underwater environment.

Having the game take place underwater also allowed us to show the density of obstacles that the right whale has to navigate through constantly. For instance, the player would be able to see ships and buoys in an above water game, but the obstacles become much more dangerous



and apparent underwater where the player has to navigate obstacles his/her self. Finally, we wanted to create a unique experience with the player and the whale. We felt that having the player above water broke this emotional bond that the player might have with the animal. By having the player swim with the whale, we hoped to create an empathetic experience like one seen in *Endless Ocean 2* (2007) in Figure 3.3. Although *Endless Ocean 2* does contain these empathetic experiences, it does not focus on empathy or education, but rather entertaining gameplay. This game is set in an open world, not a closed adventure, and contains a wide variety of fish and underwater species that span across the planet. Unlike *Endless Ocean 2* where they give an experience that displays an ocean environment with many species of fish and environments, our game strives to have players empathize for, and come to learn more about only one species, the North Atlantic right whale. Other underwater creatures in our game are only meant to immerse the player in a more realistic environment, while *Endless Ocean 2* focuses on teaching the player about all underwater species they encounter. Moreover, *Endless Ocean 2* depicts mostly safe environments that value player interaction through “magical” items that can cure or stun fish directly, while *The Urban Whale* depicts a more unsettling North Atlantic environment that values interactions having real world consequences, such as failing to prevent the whale from becoming entangled, with no possible way to help the distressed whale. Ultimately, *Endless Ocean 2* serves as a great point of reference for an immersive, engaging underwater adventure, but it does not attempt to create a more educational, empathetic experience that *The Urban Whale* sets out to accomplish.



**Figure 3.3:** *Endless Ocean 2* (2007) Screenshot of diver interacting with a North Atlantic right whale

### **3.4 Development and Design**

During the design process, our team created art assets for the game, programmed core mechanics, and worked on building the main level. Since all three design iterations had certain aspects in common, such as the ocean, the North Atlantic right whale, and depictions of entanglement, our team was able to begin development without a finalized decision of our core gameplay. This gave us freedom to continue the design process into development, rather than having the game's development be delayed by the design process.

### **3.5 Design Decisions**

During development there were many decisions made about the environment, the player's role, the whale's pathing, and the camera view in order to best meet our objectives of creating an educational experience, instilling empathy within players, and entertaining players. These decisions were made before and during the development process. During the development process, we made several gameplay decisions to meet our three objectives but to also minimize conflict between objectives. For instance, we encountered several cases where a decision would sacrifice playability for putting more educational content in game. This section consists of a detailed account of how our team reached these final design decisions.

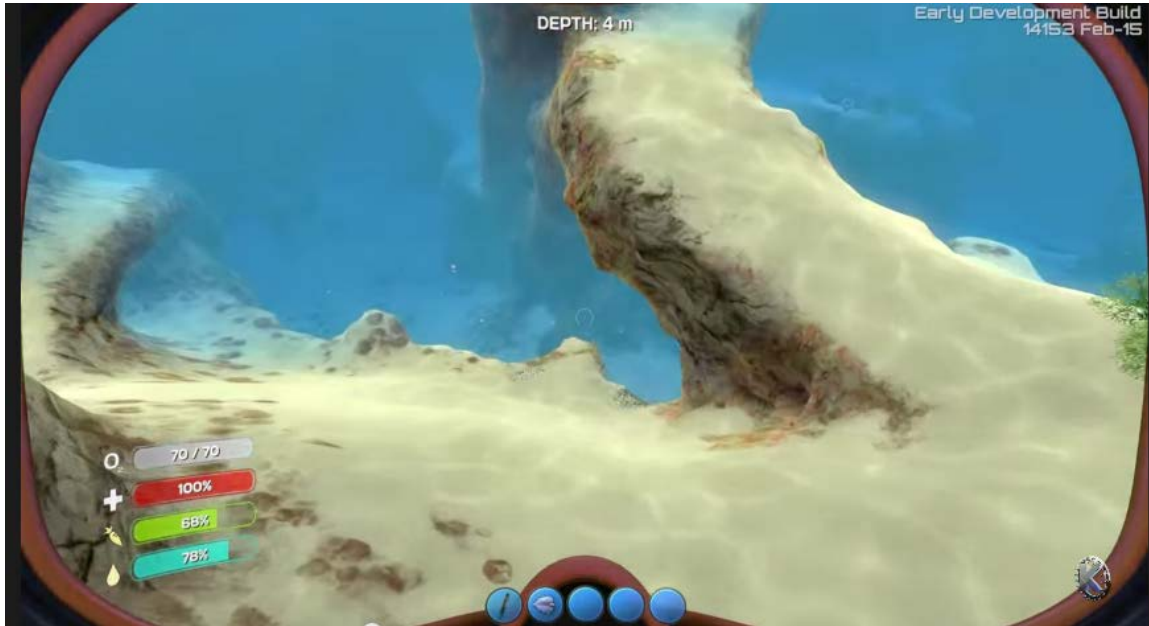
### ***3.5.1 The Environment***

Through meetings with the New England Aquarium, we determined that both the underwater and surface environments would play an important role in our game. The surface would serve to enforce the concept that the whale's environment is often chaotic; buoys that are attached to trap lines would be floating on the water, while oil tankers and shipping vessels would pass by the player. The water's surface would also give the player a sense of scope; hundreds of buoys and ships that line the North Atlantic waters seem to make the problem inescapable. In the waters below, we wanted to create a realistic environment that would make players feel that they are swimming in North Atlantic waters. Underwater lighting effects and camera effects, fish endemic to the North Atlantic powered by artificially intelligent steering behaviors, and deep ocean audio cues helped to produce an immersive underwater environment for our game.

#### *a. Underwater Lighting and Camera Effects*

The underwater caustics, or the effect of visible light rays and light patterns underwater due to the refraction of light by the water's surface, are extremely important for creating an immersive underwater environment. Light patterns seen by looking at the ocean floor and light rays seen by looking towards the sun while underwater both create a realistic underwater effect. Having a slightly dark aquamarine light filter also adds to the underwater atmosphere. This filter gives the environment a realistic Atlantic Ocean water color. Without these lighting effects, the player can easily lose the feeling that there is an ocean around them. Underwater camera effects also play an important role in establishing an underwater environment. Limiting the player's visibility to realistic distances and blurring far away objects establish the player's role as an underwater diver. Adding an exponential fog to the game achieves this limited visibility. An exponential fog also specifically decreases this viewing distance as the player descends. This means the player can see objects farther away near the surface of the water. The game *Subnautica* (In Development) in Figure 3.4 serves as a good example of exponential fog and caustics. One can see the caustics as the web-like patterns of light on the ground as well as the exponential fog in the distance limiting visibility. In addition, the aquamarine blue tint on distant topography adds to the underwater scene. The foreground is fairly realistic,

although clearly not as blue as the background. By contrast, our prototype features an aquamarine blue tint in both the foreground and background.



**Figure 3.4:** *Subnautica* (In Development) Screenshot for example of caustics and exponential fog

One final camera effect that we used but was not completely necessary was a ripple effect on the player's camera. We achieved this by creating a moving, transparent texture and using it as a filter on the player's camera. This caused the underwater environment to slightly distort, giving the effect of moving water. This effect is not completely necessary. When viewing through glass at an underwater environment, such as through a pair of goggles, the water does not naturally create a ripple effect on the viewing lens. We decided to have this in game anyways as a subtle reminder of the underwater environment the player is swimming in. The effect is not completely noticeable unless the player is specifically looking for it and the effect is not distracting to gameplay. Still, the effect distorts the underwater environment slightly as if a viewer was looking at an underwater environment from above the surface of the water, giving the view of the environment a slight ripple.

### *b. North Atlantic Fish and Steering Behaviors*

Fish play a huge role in conveying an underwater environment to the player. Without fish, the player would not only feel out of place, but the environment itself would be quite empty. We used fish found in the right whale's habitat in our game to further enforce the player's location in New England's North Atlantic Ocean. We researched the speed, size, predators, and prey of each fish featured in our game and applied them accordingly (See Appendix C). Utilizing the boids steering behaviors proposed by Craig Reynolds, we were able to create realistic schooling for various fish types, and created a system for quickly implementing different fish with different attributes into *The Urban Whale* (Reynolds, 1987). We modified the original model Reynolds proposes to allow for more efficiency when dealing with large amounts of fish, allowing our game to display many species of fish without computational lag while playing. In the original model, each fish must keep track of every other fishes' location and determine if they are too far away to consider them "neighbors" that they use in their own calculation for movement. In our modified version, neighbors are determined by sphere collisions, essentially reducing the number of calculations the game must compute by removing the need to keep track of every other fishes' location. When another fish of the same type enters into a certain pre-set radius of the fish, they will be added to a "neighbors" list that the fish will refer to for movement calculation, rather than having to account for every fish. *Endless Ocean 2* (2007) uses similar steering behaviors and real fish types to emulate a coral reef in Figure 3.5. Our system uses species only found in the North Atlantic and is contained within a smaller area of gameplay, allowing us to have more dynamic interactions between creatures, such as chase and flee behaviors between predators and prey.



**Figure 3.5:** *Endless Ocean 2* (2007) Screenshot of schooling fish, caustics, and exponential fog

### *c. Deep Ocean Audio*

Audio plays a fundamental role in immersing the player in any environment. Our game contains multiple audio cues that provide the basis for what players would hear when underwater. Among these are the diver’s breathing sounds, the right whale’s upcalls<sup>3</sup>, ocean sounds, and a sea scooter sound for when the player is moving. A study conducted by Raymond Usher, “How Does In-Game Audio Affect Players?” split players into two groups playing three different games. One group played selected levels from these games with sound, while the other group played these games without sound. The study found that in all three games players had increased immersion measured through increased heart rate and perspiration when playing games with sound compared to those players who played without sound (Usher, 2012). With this in mind, our team created and found audio resources. The audio resources we used, but did not create, were found on [freesound.org](http://freesound.org) and [sounddogs.com](http://sounddogs.com), royalty-free providers of sound effects and music.

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<sup>3</sup> A type of “contact call,” the up-call is a little like small talk--the sound of a right whale going about its day and letting others know it’s nearby. In this recording the up-call is easy to hear--a deep, rising “whoop” that lasts about a second. ([listenforwhales.org](http://listenforwhales.org))

Adding audio to our game resulted in a more immersive, believable environment, thus speaking to our empathy and entertainment objectives.

Since the underwater coastal environment is meant to exhibit the real-life dangers faced by North Atlantic right whales, we also added many lobster trap lines. This was easily done without breaking the realism of our environment since these lines are densely placed in the North Atlantic waters. Unfortunately, due to the short duration of our project, we were unable to develop as complete an above surface environment as we originally planned. This occurred as a result of our game design refocus from an above water game played as a research vessel to an underwater game focusing on the life of a North Atlantic right whale. Figure 3.6 and Figure 3.7 are screenshots of our prototype's underwater and surface environments.



**Figure 3.6:** Underwater environment in *The Urban Whale*





**Figure 3.7:** Surface environment in *The Urban Whale*

### ***3.5.2 Player Role***

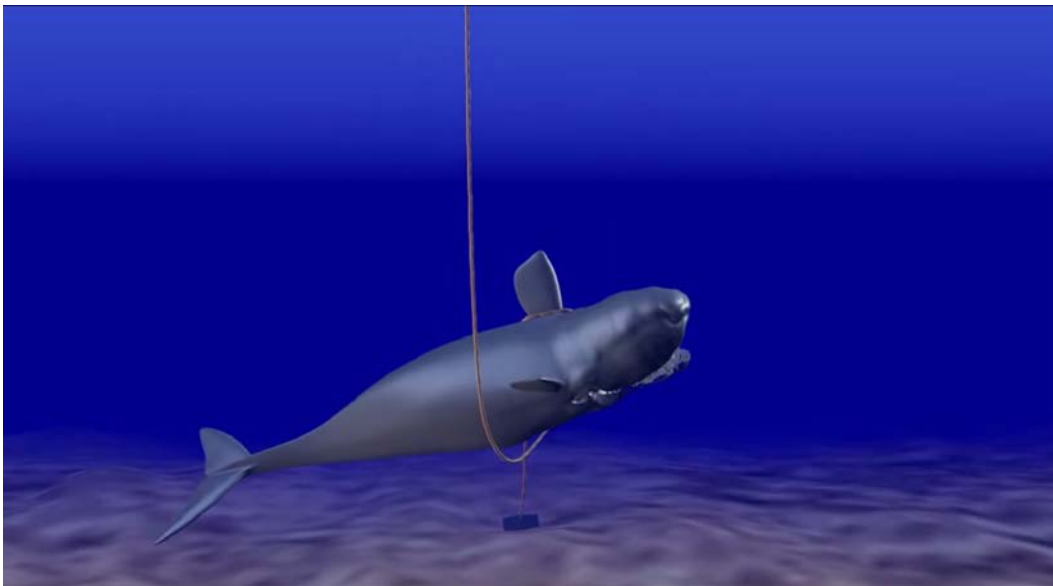
There was much discussion among team members as to exactly what role the player would assume while playing *The Urban Whale*. Our initial idea was to have the player assume the role of a North Atlantic right whale in order to create empathy by allowing the player to see the world from the perspective of the whale. However, this initial idea was altered several times throughout the design process until we decided upon having the player assume the role of a diver. The diver was close enough with the whale to facilitate empathy, but far enough so that it was clear that it is the responsibility of humans to protect endangered species.

#### ***a. The Whale***

Since one of our objectives for the game is to give the player a unique experience that evokes an empathetic response for the North Atlantic right whale, creating a realistic whale that would leave a lasting image for the player was a high priority. Our team evaluated several ways in which the player would either take on the role of a North Atlantic right whale or have close encounters through game mechanics.



Through open discourse, our team decided that having the player take on the role of a diver that aids the whale would be the ideal way to exhibit dangers that the North Atlantic right whale faces. We were able to obtain an anatomically correct 3D model of the North Atlantic right whale from Dr. Lars Howle, the CEO of BelleQuant. This model was created for use in Dr. Howle’s “Large Whale Entanglement Simulator,” a program that allows scientists to study how whales become entangled and to test types and strengths of ropes, shown in figure 3.8. The whale model, once received, went through several variations. The original animations and textures were imported and used in early versions of the prototype, but we soon created a new set of textures for it, being careful not to evoke an existing individual right whale or one of the species’ close relatives. Individual right whales are typically identified by their callosity patterns since it serves as a “fingerprint” for the whale (Hamilton et al., 2007, p. 79). If the whale in game too closely resembled an individual right whale, the game might carry unfortunate implications if something tragic happened to the whale it resembled. Part way through the design process, the whale was given a new rig and set of animations.



**Figure 3.8:** Dr. Lars Howle’s Large Whale Entanglement Simulator

Once we had a high fidelity North Atlantic right whale to work with in our development environment, we were able to model, through code, some of the more

advanced interactions the whale would have with its environment such as rope entanglement and ship strikes. Perhaps the most advanced mechanics we have in our game are the rope physics and entanglement simulation. Most game engines do not have a simple way to simulate ropes. They are long, dynamic objects and most games simply do not have a need for them. This is the case with the Unreal Engine 4 as well; however, we were able to make ropes using the engine's built-in functionality. Essentially, a rope in our game is a sequence of cylinders in line with each other. This forms the basic shape of our rope. We then have physics constraints connecting each of the cylinders to each other. These constraints bind each cylinder to its two neighbors but still allow for free rotational movement. This type of simulation allows for complex interactions with our rope and created the perfect balance of realism and performance. These interactions form some of the most hard-hitting images in our game, creating the empathetic response for the right whale our prototype aims to evoke (see Figure 3.9).



**Figure 3.9:** Extremely entangled North Atlantic right whale in *The Urban Whale*

### *b. Player Boat*

During the second design iteration, our team decided that a boat avatar based on a research vessel operated by the NEAq would be suitable as the player avatar. The research vessel carries three to five persons, including a captain and scientists, and this would be reflected in game. The player boat would be responsible for staying ahead of the right whale, ensuring lobster trap lines and cargo vessels were clear of the whale's path.

One of the issues we had with the boat avatar was that it was hard for the player to interact with the environment. The boat could remove obstacles somehow, but the details never solidified and the NEAq was worried about the depiction of removing fish and lobster traps. This also removed the ability to see the right whale fully, only being able to see the right whale through the ocean's surface.

### *c. The Diver*

The diver was decided upon as the final playable character midway through the development of *The Urban Whale*. The diver acts as a guide for the whale, navigating and modifying the whale's path by moving clusters of zooplankton, the right whale's main source of food. Our team decided that a third person point of reference would give the player the best view of the whale and underwater environment. We also decided to use a gender neutral diver. In addition to reducing development time by only needing to create one diver model, having a gender neutral diver allows the player to focus on gameplay without the interruption of a character selection screen. Since a diving suit already covers up most of the diver's body, it was not overly challenging to create a silhouette that could be both interpreted as male or female. This decision also appealed to our objective of creating empathy within players since players of both genders can easily identify with the diver avatar.

### **3.5.3 Whale Pathing and Zooplankton**

Early in the development of *The Urban Whale*, whale pathing was one of the most discussed topics of our project. Originally, after deciding the player would assume the role of a diver, we planned that the player would place zooplankton balls in the level to

modify the path of the North Atlantic right whale. In this design, the whale would have a pre-determined path that was obscured to the player. The player would try to predict when the whale was in danger of running into an obstacle and strategically place a zooplankton ball in the world to ensure the whale avoided the obstacle because in the real world whales often move toward food. We created this system using a spline, which is a continuous, smooth line connected via points. The whale's waypoints would be created at the start of the level, and the whale's default path would be calculated based on those waypoints. The whale would follow this default path regardless of obstacles. Placing a zooplankton as the player would snap the closest waypoint to where the zooplankton was placed. Through development, we decided to add visual placeholder lines and points along the spline to keep track of the whale's destination and how placing zooplankton would modify it (see Figure 3.10).



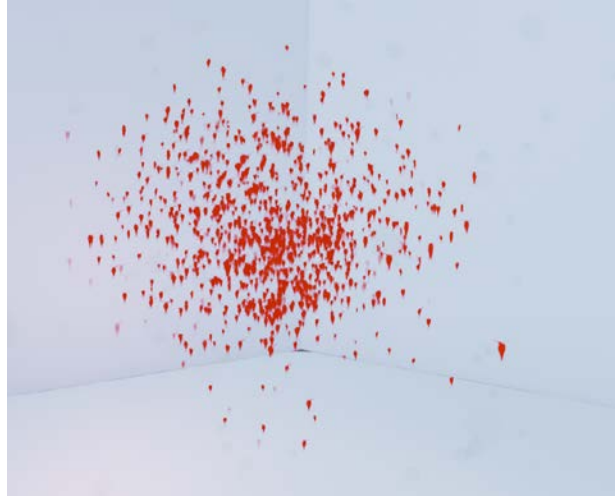
**Figure 3.10:** Original prototype whale path with spline

When we showed the NEAq and our advisors our initial prototype, there was controversy about displaying this spline since it took away from the realism of our game.

Our team further discussed this issue, and we decided that we needed to redesign how the whale's path would function. Since obscuring the whale's path caused player confusion and exposing the path decreased the game's realism, our team set out to find a solution that was both realistic and kept player confusion to a minimum. Ultimately, our team decided that the zooplankton would exist in the world at the start of the game as it does in real life and the whale would always swim towards (and eat) the nearest zooplankton. However, unlike real life, the player would have the ability to pick up these zooplankton, move them, and drop them to lead the right whale away from dangerous obstacles. This gave the player a better idea of the whale's path without completely breaking immersion and realism, and the player would no longer be able to generate zooplankton out of thin air. This also gave the player a better sense of how his or her actions affected the whale. Although this solution is not completely realistic since clusters of zooplankton are much larger and cannot be moved by humans, we deemed it the best option for the amount of time allotted for development, and was less outlandish than showing spline path throughout the entire level, and having these zooplankton balls (see Figure 3.11, 3.12, and 3.13).



**Figure 3.11:** Final prototype whale path



**Figure 3.12:** Up-close image of in-game zooplankton swarm



**Figure 3.13:** Real life image of a zooplankton swarm

### ***3.5.4 Inverse Difficulty Scaling***

*The Urban Whale* becomes less difficult from level to level. This was done purposefully so that level one is the most difficult level, ending inevitably in a ship strike, and level two is the least difficult, having all breakable ropes. Our team wanted to show how conservation efforts in action can reduce the threat to the right whale from its environment. Since level one is where the player will be using the game mechanics they learned in the tutorial, it will also serve to ensure that almost every player must come face

to face with an entangled right whale, since the player will not be fully capable of protecting the right whale from environmental dangers having just learned how to play. This design decision was made to more fully achieve both our empathy and educational objectives. This decision helps us achieve our empathy objective because it requires the player to see the right whale in distress, while it also helps us achieve our educational objective by introducing breakable ropes.

### ***3.5.5 Camera Views***

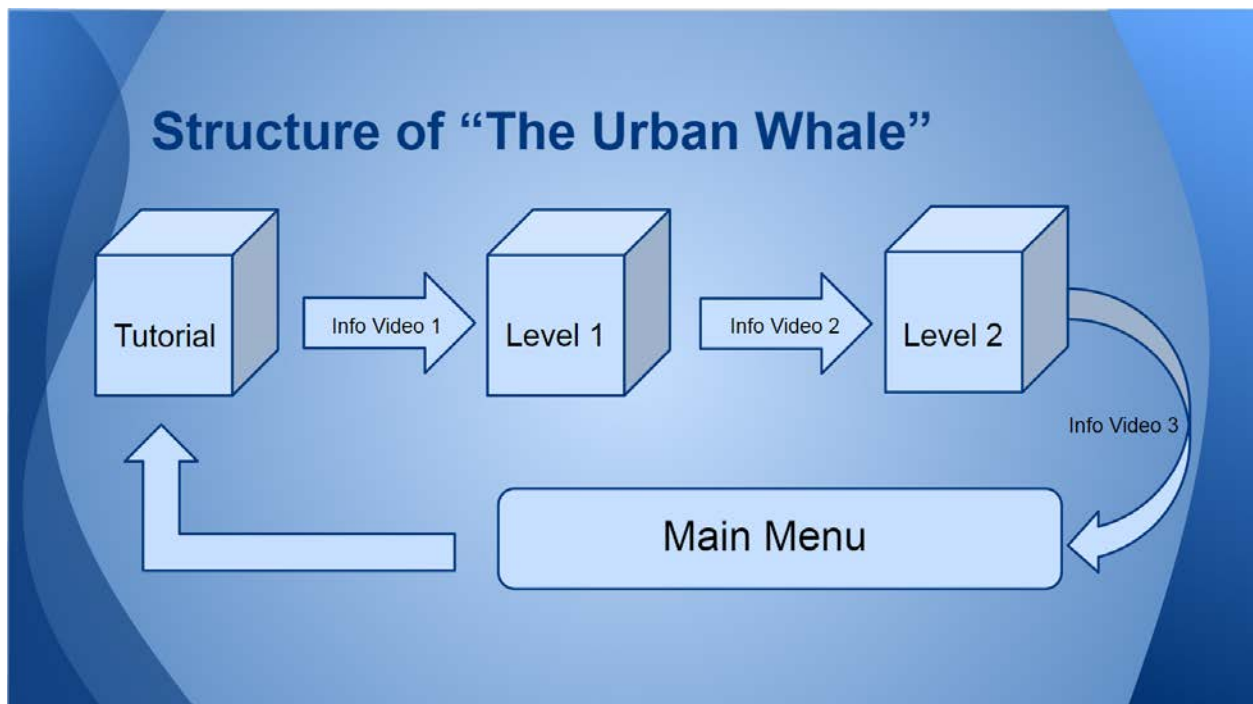
Along with the discussions of what the player avatar should be, there were discussions and ideas on how the player should view the game world to maximize empathy without compromising playing experience. Our first idea was the standard “third person” view, with the player looking at the scene from several feet behind his or her avatar. Unfortunately, this camera view sacrificed the empathy of being able to see the whale up close for playability, making the game easy enough to control but making the whale harder to see from above water.

There was also a lengthy discussion of having a split-screen effect, which would entail seeing the player avatar and the boat at the same time. This idea was eventually discarded after we concluded that the angle needed to see both scenes properly was impossible and that the surface would be hard to navigate when seen from so close to the water.

Another suggestion was to have the camera always point at the whale, submerging when the whale was underwater and surfacing when the whale breached. Our team decided that we wanted the player to have as much freedom as possible. This method would take away from the player being able to control his or her own camera and diver. Our final version gives the player full control over the camera, with one exception: the camera automatically turns the player back towards the right whale if you stray too far. This allows the player the ability to roam a fair distance away from the whale, but never so far as to lose sight of it.

## 4 Final Model

As discussed previously, our final design is as follows: the player controls an underwater diver. The player can swim freely within the world as long as he/she does not swim too far away from the right whale. The whale will swim towards the closest ball of zooplankton. In order to help the right whale, the player must move these zooplankton balls away from dangerous obstacles, such as lobster trap lines. This final design was the best compromise between playability, realism, and player empathy for the right whale. In this section we cover our final prototype for *The Urban Whale*, and how each aspect relates to our original three objectives: engaging the player, empathizing with the right whale, and education of the audience. The overall structure of our game can be seen in figure 4.1, each level having an informational video sandwiched between each level.



**Figure 4.1:** Overall structure of *The Urban Whale*

### 4.1 Playability

We made several design choices that forces the player to focus on the whale. First, we created a set distance that the player could swim away from the whale. The player can still



surface and swim to the bottom of the ocean, but if the player swims too far away from the whale our game forces the diver to face the whale. This means that the diver will never swim too far away from the whale since he/she will always be turned around into the direction he/she should swim towards. Second, we decided to offset the diver from the main camera. Most third-person perspective games place the player's avatar in the center of the screen, such as in *Endless Ocean 2* in Figure 3.5. We decided to place the avatar towards the right of the screen to allow the player to view the underwater environment and focus on the whale and its path. We took this forced turning functionality and also used it as a mechanic that the player controls. In our game, the player can hold down the "SPACE" key at any time to force the diver to rotate towards the whale. This can be useful for quickly turning towards the whale or finding the whale's location if the player loses sight of it.

In addition to the above mechanics, we added a tutorial level that slowly introduces these mechanics to the player. We start by introducing how to move using the mouse and the "W" key. Then, we introduce the mechanic of moving the balls of zooplankton and guiding the whale through lobster trap lines using the "E" key to pick up and drop a zooplankton ball. Once the player has completed the tutorial level, it loads the first level which is designed to be more challenging.

## **4.2 Empathy**

Our project team implemented several carefully crafted design decisions in order to achieve the empathetic response we desired from our players for the North Atlantic right whale. Our team wanted to present the most realistic environment we could develop and portray the whale's behavior as realistically as possible. This meant that we would need an accurate portrayal of a whale entanglement. Research shows that because fishing gear encounters startle right whales, they try to escape quickly and end up turning and rolling rapidly away from the ropes. Because of this, the fishing gear becomes wrapped around the tail stock, flippers, mouth, baleen, or body of right whales (Johnson et al., 2007, 385). We strived to make our levels difficult for players, so that they would be forced to encounter right whale entanglement first-hand. While it is possible to guide the whale through without it ever getting entangled, it is extremely difficult. If the whale is never entangled, our message is lost and the player may not feel as empathetic toward the North Atlantic right whale. However, if the whale becomes

entangled during the game, the player experiences right whale entanglement. Additionally, the player can hold his/her self somewhat accountable for the whale's entanglement since it is the player's duty both in our game and in real life to protect the right whale from the environmental dangers we create. Even though this point is not explicitly stated in game, it is one of the main messages we hope players take away from our game.

Empathy is fostered through similarity, familiarity and proximity (Aaltola, 2013, 7). As humans and whales are very dissimilar, empathy should then be forged via familiarity and proximity. Whale watches can provide proximity and certainly can provide evocative encounters, but not necessarily familiarity. The New England Aquarium cannot keep a North Atlantic right whale as an exhibit so showing their behaviors and environment through a video game is certainly a more feasible solution. This strategy of fostering familiarity through video games or other simulations can also be used for other species that cannot be kept in zoos or aquariums, especially endangered species.

#### **4.3 Educational Videos**

*The Urban Whale's* short videos serve as a way of both educating players about the right whale and anchoring the game's message back to reality. In our final prototype when either of the whale's pectoral fins gets hooked on a rope the whale spins 360 degrees in a thrashing motion. Because of this spinning, the rope becomes wrapped around the whale's body and can occasionally get caught on its pectoral fin, or fluke. This realistic portrayal served to both educate the player on right whale entanglement and inspire an emotional connection from the player with the North Atlantic right whale.

Our educational videos between levels also contain pictures and clips of actual right whale entanglement. We purposefully selected these pictures and clips so the player can compare our depiction of right whale entanglement to actual entanglement in real life. We also wanted the player to understand that entanglement is a stark reality that all North Atlantic right whales face. In order to leave a lasting impact on our players, the last video poses a rhetorical question to the player, questioning what actions he/she will take to aid right whale conservation efforts,.

## **4.4 Game Message**

With any serious game, one of the most important aspects is what the participant takes away from the experience of playing the game. Our initial design focused on bringing to light the effects commercial fishing and shipping ventures have on the ocean and right whales while attempting not to demonize both industries. We later implemented highlights of conservation efforts currently being used to help save right whales in the form of videos between levels of our prototype.

### ***4.4.1 Human Impact***

The first issue we wished the participant to take away was the extent that humans affect the ocean along New England's coastline. In-game, the proliferation of fishing gear and shipping vessels is evident, and in future iterations of the project this would be even more prominent. Players working to navigate the whale through the maze of ropes, traps, and oncoming vessels would notice just how congested the oceans have become while playing. We highlight right whale entanglement and show the process of entanglement in real time should the player fail to clear a path for the whale. We hope players realize that fishing is unavoidable and fishing gear will not be removed from the ocean in a foreseeable future, but also the effect current fishing practices have on right whales.

### ***4.4.2 Connection to play mechanics***

Although the player is given the power in *The Urban Whale* to change the path of a North Atlantic right whale, the player only has this power since he/she can move the right whale's food source. This mechanic is a suspension of disbelief that allows us to address our objective of creating an entertaining, engaging experience. Besides this ability, the player has no way of affecting the right whale's path in game, which is the case in real life. We hope players realize that we cannot and should not directly change the lifestyle of a North Atlantic right whale. As mentioned previously, the player is held accountable for how entangled the right whale becomes in *The Urban Whale*, although this is not stated explicitly in game. In our prototype, the player alone has the power to save the right whale and make sure it does not become entangled in any ropes. This is a key message in our prototype and one we hope carries over to real life. Currently the

prototype also exposes players to breakable ropes through the second play-through. Fishermen have adopted polymer ropes which are lighter than their cotton counterparts, have increased breaking strengths that reduce gear loss, and are more resistant to wear. The increased breaking strength of ropes has a direct correlation to the number of increased entanglements over the period that these ropes have been adopted (Knowlton, 2012, p. 22). Therefore, reversing the trend of increased breaking strength could also reverse the trend of increased entanglements. We represent these “weaker” ropes as breakable ropes in our game, which is just the first of many possible conservation techniques that could be implemented into the game to help educate the player about possible practices that could help save the whale. Further iterations of the prototype might showcase more of these conservation efforts which will directly lower the difficulty of the game. This mechanic would highlight the positive effects conservation techniques have on right whales and expose players to possible solutions to the problems faced by the right whale.

#### ***4.4.3 Other decisions***

For our final prototype, we set the camera view linked to mouse movement. We felt this was the easiest way for a player to look around the world since a player just has to move the mouse in the direction he/she wants to look. We linked the player’s forward movement to the “W” and “UP Arrow” keys, which are standard for forward movement in most computer video games. We also linked the “A” and “LEFT Arrow” keys for turning left and “D” and “RIGHT Arrow” keys for turning right (See Appendix H: Controls). This allows players used to computer video games an extra option for movement. We used the “SPACEBAR” for turning towards the whale because it is one of the more obvious buttons on a keyboard and easy to reach. Finally, we linked the “E” key to picking up/placing zooplankton balls since it is fairly close to the “W” key and also a standard button for interacting with objects in most computer video games.

The environment of the game is based on the waters of the North Atlantic Ocean. Most underwater games take place in or feature clear water from tropical areas with perfect visibility, as pictured in figures 3.1, 3.3, 3.4 and 3.5. The North Atlantic Ocean contains extremely low visibility and green-blue waters. For our game, we increased the

visibility for playability, but the water is still not as clear as the water is in games we referenced. The NEAq confirmed that our depiction is fairly realistic and gives the player the sense of diving in the Atlantic Ocean.

The diver avatar was created to be gender neutral to improve identification with the player and to eliminate an unnecessary player option of choosing a male or female character. The diver was originally a more contrasting color, to show up clearly against the dull ocean background color, but it was changed to not distract too much from other entities on screen so that the whale would remain the focus of the game.

During our design, we thought of the idea of a reverse reward system. Typically, games reward players for succeeding in completing a goal. However, we decided against this kind of model in our game in order to give the player an educational experience. We strived for a level design in which the game gets more and more difficult as the player progresses through the level. This becomes evident in both the amount of fishing gear in the level and the strategic placement of that fishing gear. Also, at the end of our first level, we depict the North Atlantic right whale getting hit by a passing ship. This occurs when the whale surfaces after a set amount of time in order to breathe. This sequence of events also leads into an educational video, but this design is not the typical reward system that games have.

Each level ends with a video featuring a real-life whale and educational content about the environment and situation of the North Atlantic right whale. These videos serve to connect events in game into the real world. This effect achieves the opposite of what most games seek to do, which is to draw players in and immerse them in the game world.

The game ends with a call to action for the player, asking what they can do to help the situation of the right whale.

## 5 Results and Recommendations

### 5.1 Development Observations

Overall, the development of our project met our overall objectives. We created a working prototype of a game featuring the North Atlantic right whale, and we developed a feasible template to create games for other endangered species. In retrospect, we would have accomplished more during our nine week project if we had solidified a design idea sooner. As we discussed, we began the project with a design idea in mind but changed that original idea throughout development due to the complex and often conflicting demands of our objectives. Although we cannot say for certain, we are fairly confident that we would have created a complete game rather than a prototype had we not changed our original design. However, because we iteratively changed our design, we were forced to delete functionality from our game and implement new functionality from scratch several times, delaying progress on a complete game. This said, our goal of creating a playable prototype of a game was completed and was delivered to the NEAq.

On the technical side of the project, we come from experienced game development backgrounds. However, none of the programmers on our team had used Unreal Engine 4 (UE4) before beginning the project. Because of this, we spent the first couple of weeks learning the engine, which we planned for. However, we ran into several obstacles during development that were ultimately caused by a lack of knowledge in certain engine functionality. For instance, we had one week of development setback where we were trying to get collisions working between the rope and collision boxes on the whale's fins. We also had several other instances where a simple task estimated to take one hour of work would end up taking the whole day or longer. With our knowledge of the engine now, we are confident that redeveloping this game from scratch would not take us as long as it did the first time.

On the artistic side of the project, development proceeded rather smoothly. Models, textures, and animations were made for enough art assets to make the ocean environment feel alive. We had some initial struggles working with the anatomically correct whale model which was sent to our team. Implementation of the art assets took longer than expected. This prevented us from knowing immediately how the art assets appeared in the environment. Fortunately, the assets looked good when implemented and helped scope the rest of the work for the artists.

## **5.2 Recommendations**

Given that our team had limited time to develop *The Urban Whale*, there are many additions that were not featured in the final prototype. Below, we have listed future possible additions that could expand and enhance the current prototype in terms of furthering its guiding objectives.

### ***5.2.1 Playtesting and Gameplay Focusing***

As mentioned previously, due to the time constraints on our project, we were not able to perform extensive playtesting that determined the effectiveness of our prototype in creating an educational, empathetic, entertaining experience. After some brief, informal playtesting we determined that our prototype has the potential to meet these goals, but extensive playtesting is required to confirm our initial observations. In addition, more playtesting would allow us to address gameplay issues to improve the overall experience as well as focus gameplay to maximize the effectiveness of our three objectives. We also recommend multiple iterations of playtesting to provide continuous feedback from players if refinements are being made with gameplay. This way, the final game can be assured to provide an optimal educational, empathetic, entertaining experience.

### ***5.2.2 Additional Levels***

Currently *The Urban Whale* features a tutorial that introduces players to the controls and zooplankton pathing, a first level with a high degree of difficulty that contains entanglement and one boat collision, and a second, easier level that introduces breakable ropes. The mechanics we implemented for the tutorial, level one, and level two could be used to create additional levels that feature varying degrees of difficulty. We recommend that these levels have an inverse difficulty scaling, which means that as more levels are played, there are more breakable ropes and less boats. This will help display that more participation among the community and policy implementation could lead to less entanglement and ship strikes in the future.

### ***5.2.3 Additional Art Enhancements***

Currently *The Urban Whale* features geographically correct fish species, a high fidelity North Atlantic right whale model, and a player diver. Improving the existing 3D models and textures of underwater plants and animals could achieve a higher level of realism. Creating subtle animations for the smaller fish and adding extra animations to the larger fish would make them appear more organic. Further graphical improvements could be made by creating more particle effects, further populating the underwater scene with vertical ropes to show the severity of the condition of the habitat, and creating new videos to be shown before the game starts and in between levels. Professional videos made by the New England Aquarium could carry the importance of the information presented currently much more powerfully and clearly. The audio in the game is fairly scant and, in a much more polished version of the game, could be much more robust. There exist fully voiced lines for the scenarios that are currently playable in the game, and more sound effects such as diverse kinds of North Atlantic right whale calls and blows could be added.

### ***5.2.4 Additional Tech Enhancements***

Currently *The Urban Whale* features dynamic ropes that can entangle or be broken by the North Atlantic right whale, a simple ocean shader for the surface environment, and artificially intelligent schooling and shoaling of fish. Throughout the development process, many performance enhancements were added to increase frame rate and allow *The Urban Whale* to be played on a wider range of computers. Currently *The Urban Whale* can only be played on mid-range to high-range Windows machines. There are many improvements and additions that could be made to increase playability, entertainment, and variability to every playthrough of *The Urban Whale*. We recommend implementing a dynamic ship spawning and collision system in order to add more obstacles and challenge to each level. A well done implementation of boat spawning and collision would result in the environment being more dangerous to whales and therefore in line with a realistic, urban environment. We also recommend building *The Urban Whale* for HTML5, which would allow anybody with a mid-range to high-range computer to play in a web browser, such as Mozilla Firefox or Google Chrome. We



recommend expanding the surface environment in order to include a more realistic ocean surface with buoyancy for buoys to further enhance the realistic feel of *The Urban Whale*. Our final recommendation is to make further performance enhancements in order to allow for longer, more interesting levels with a higher level of detail, also allowing lower range computers the ability to play *The Urban Whale* (See Appendix G for Bugs, Issues, and Recommendations).

## 6 Endangered Species Game Template

Not only does our game design help raise awareness of the North Atlantic right whale, but our design could be used as a template for games about other endangered species. By breaking down and generalizing the mechanics involved in our prototype, one could easily modify the design to extend to other endangered species. The basis of our endangered species game template consists of a few key aspects including:

- A player working to directly save an endangered species from the threats it faces.
- Close interaction with the species in its natural environment to build empathy.
- Direct exposure to the threats the species faces, in order to passively learn about the effects these threats have on the species.
- Helping the species and/or its habitat/environment.
- Inverse difficulty scaling to educate the player about conservational efforts and to give the player hope that his or her actions are positively affecting the species or its habitat.
- Real-world video cut scenes to anchor the player in the reality of the problem

Given that all these aspects are implemented into a given game, we believe the goals of spreading awareness about the endangered animal and the problems it is facing, while simultaneously giving exposure to conservation efforts can be met. Such a game will meet all three of our objectives: education, empathy, and entertainment.

An example of a game based off this template could be one designed around the northern white rhino. Poaching has all but wiped the species off the face of the planet, leaving just one male northern white rhino in existence. Currently the rhino is kept under guard at all times to protect it from poachers (Figure 6.1).



**Figure 6.1:** Northern white rhino protected by armed guards

Building a game with the mechanics above in mind, one might come up with a design where you play as one of the guardians to this last male rhino. This would meet the first and second requirement by having the player actively defend the rhino from poachers, forcing a close proximity between the player and the white rhino. Poachers could be introduced as the direct threat to address the third requirement, with the possibility to learn about why they are hunted and the constant dangers they face. The final requirement is addressed through the act of guarding the rhino itself, which is what is currently happening in Sudan at the moment. Altogether, this game would help bring awareness to just how close the white rhino is to becoming extinct, while presenting the conservation information in an active, engaging medium.

## 7 Conclusion

The North Atlantic right whale is one of the most critically endangered species on the planet with less than 500 individual whales currently remaining today (Kraus & Rolland, 2007, p. 3). In order to raise awareness of the species, the New England Aquarium (NEAq) tasked us with creating a video game depicting the right whales' current habitat and the dangers accompanying it in order to educate players on the North Atlantic right whale, instill empathy for the whale in players, and create an engaging, interactive experience. Our final prototype aims to meet these three objectives while balancing realism with entertainment.

We hope this game will successfully bring awareness to the issues surrounding North Atlantic right whale endangerment, while still containing engaging gameplay that encourages further research and activism. We have also envisioned this game as an item within a North Atlantic right whale exhibit at the New England Aquarium and we believe that this game could reach a broad audience if placed in a high traffic area like at the New England Aquarium. Through gameplay, we hope that players become empowered to make a real world difference to help protect the North Atlantic right whale which we, as humans, have put in danger of extinction. We believe that our game and design methodology can serve as an inspiration for other organizations or individuals wanting to raise awareness of an endangered species. It is our hope that the template we described in the previous section can be applied to future video games in order to raise awareness about the various endangered species on our planet.

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## Credits

### **Player Diver**

Model and Animation by: *Adam Prueitt*

Movement Code and Implementation by: *Michael Racine & Kyle Bryant*

### **North Atlantic Right Whale**

Model, Texture, and Animation by: *Dr. Lars Howle and Adam Prueitt*

Whale Interactions and Pathing by: *Timothy Bujnevicie & Michael Racine*

### **Underwater Caustics and Camera Effects**

Caustics by: *Timothy Bujnevicie*

Camera Effects by: *Michael Racine & Timothy Bujnevicie*

### **Underwater Fish and Plant Life**

Models, Textures, and Animations by: *Patrick Petersen*

Fish Schooling and Shoaling Behaviours by: *Kyle Bryant*

### **Dynamic Ropes**

*Timothy Bujnevicie*

### **Menus and Videos**

Menu and Video Implementation by: *Michael Racine & Kyle Bryant*

Video Editing by: *Adam Prueitt*

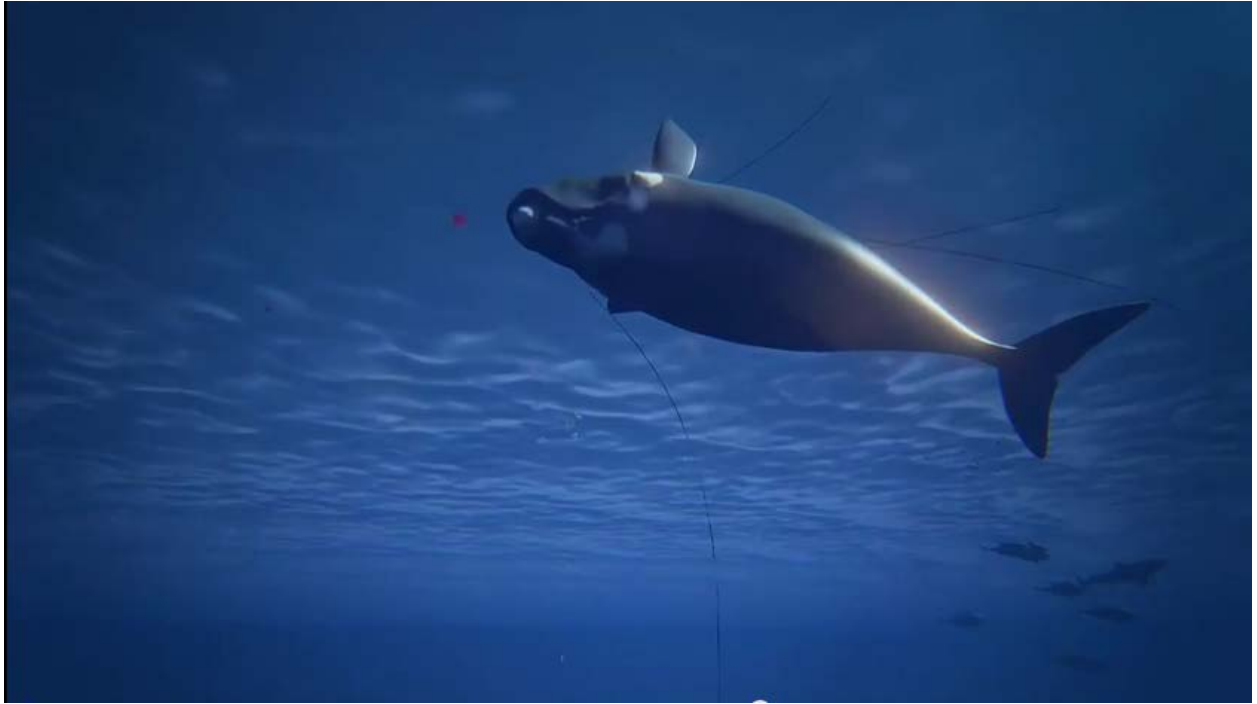
### **Game Audio**

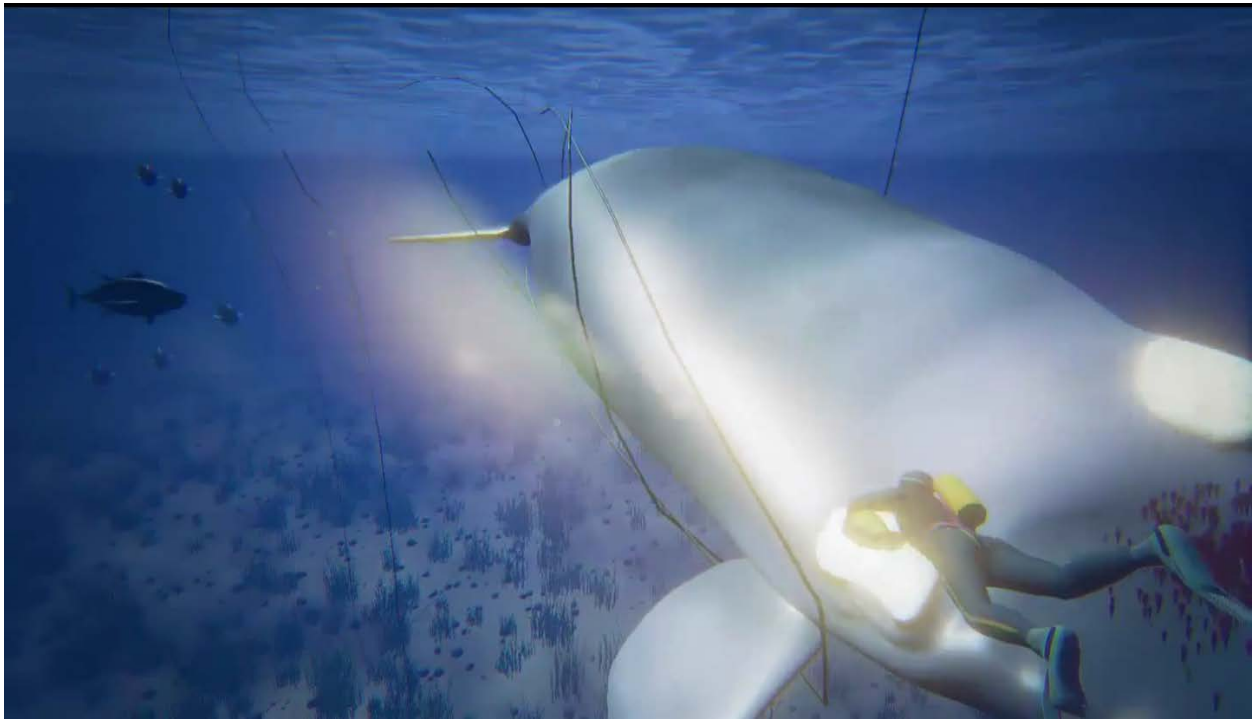
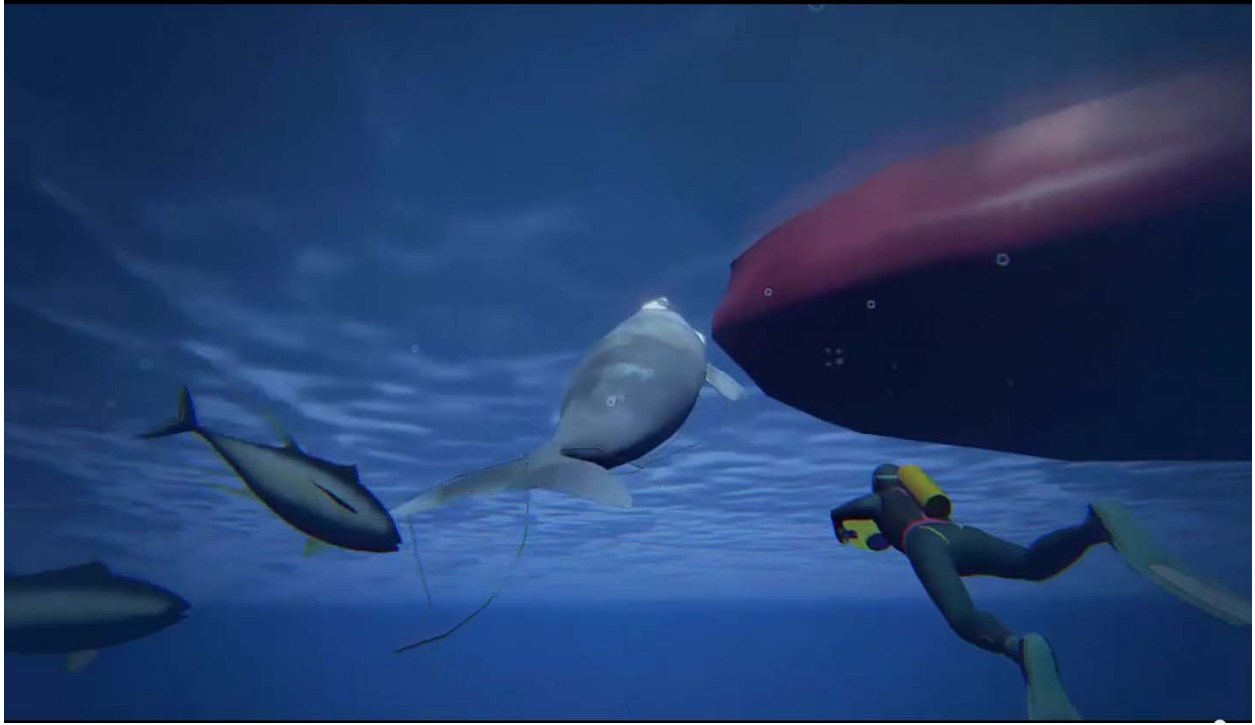
Created or Obtained by: *Adam Prueitt*

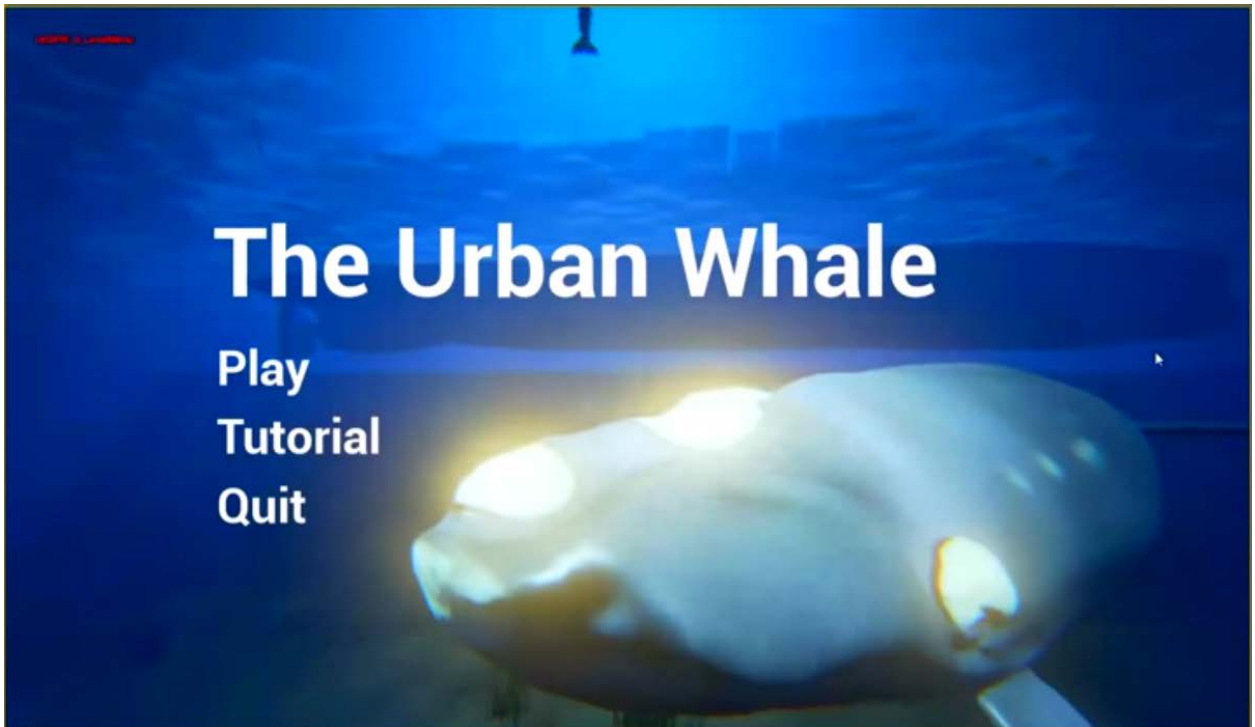
Implemented by: *Kyle Bryant*



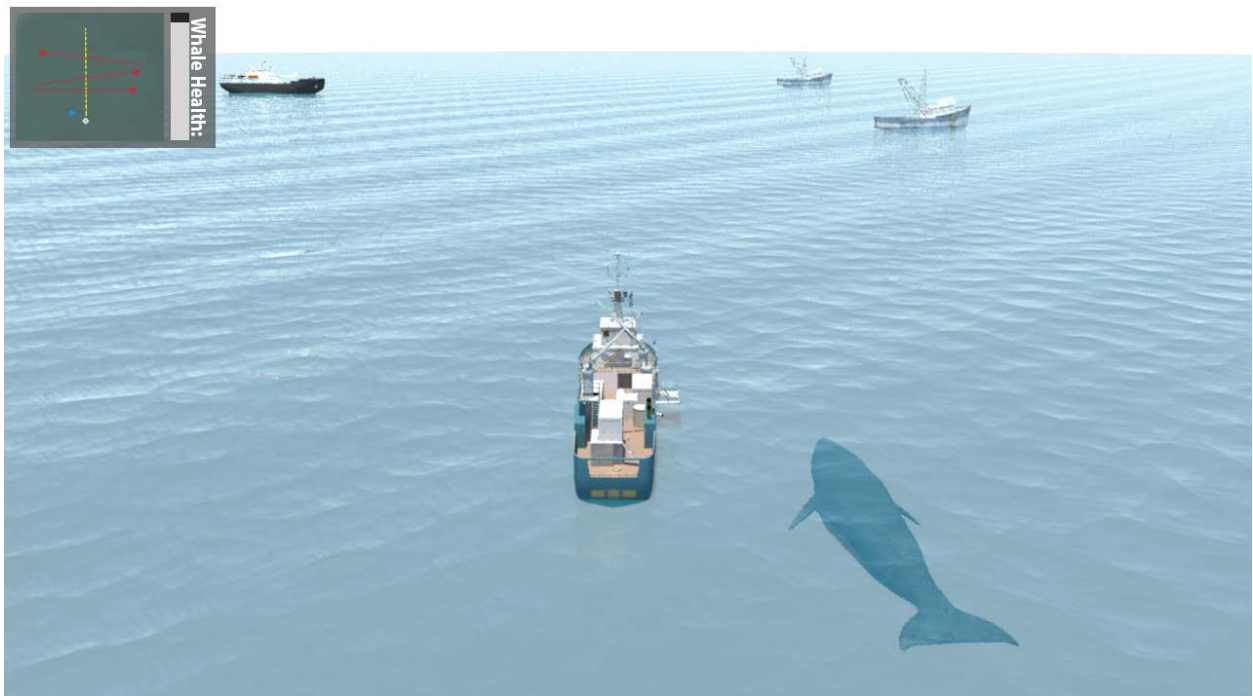
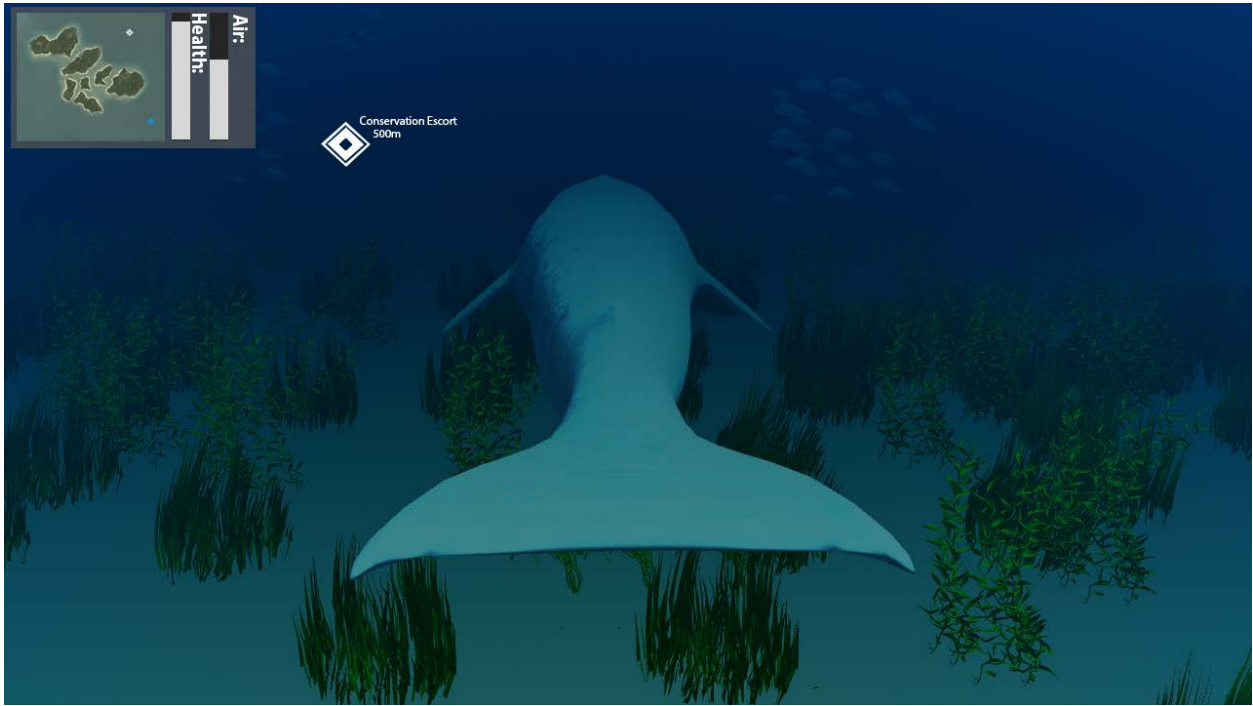
**Appendix A: Screenshots of *The Urban Whale* Prototype**







## Appendix B: Initial Screen Mockups





## Appendix C: Art Asset Gallery

**Mako Shark**



**Basking Shark**



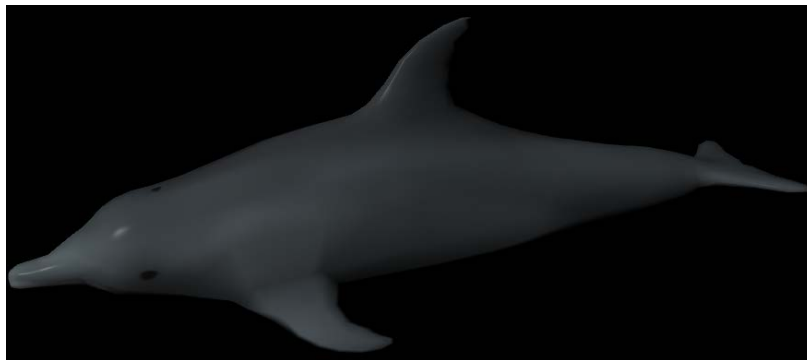
**White Shark**



**Loggerhead Sea Turtle**



**Bottlenose Dolphin**



**Bluefin Tuna**



**Yellowfin Tuna**



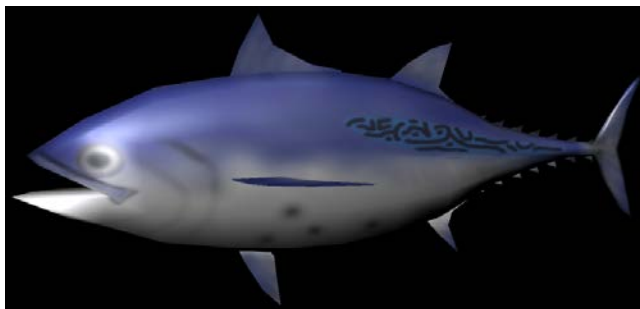
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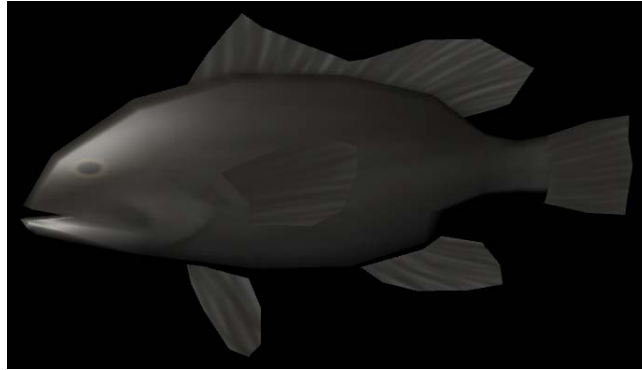
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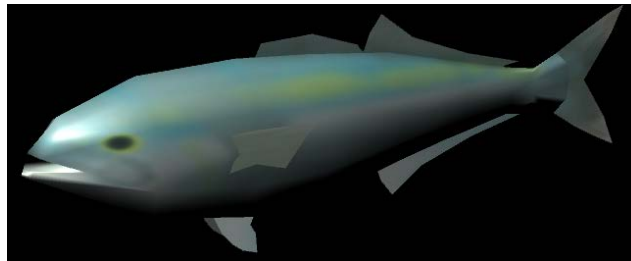
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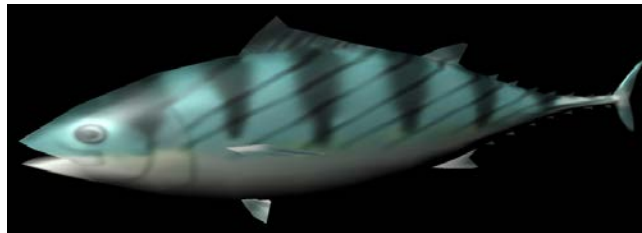
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**Blue Fish**



**Bonito**

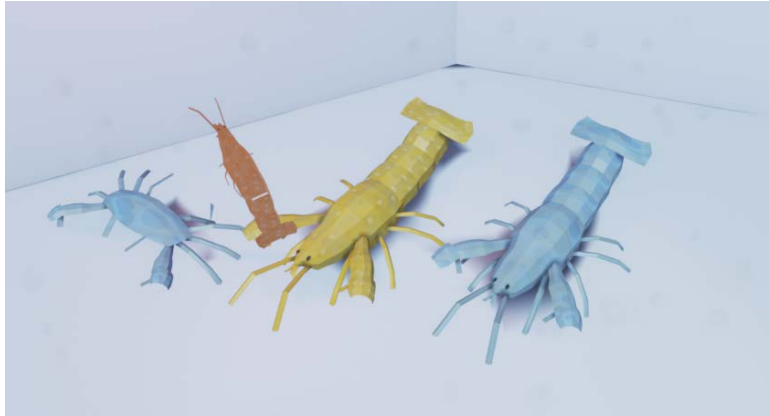


**Summer Flounder**

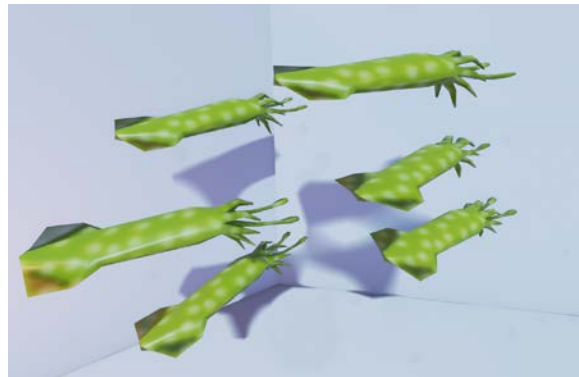




## Crustaceans



## Squid



## Sunfish



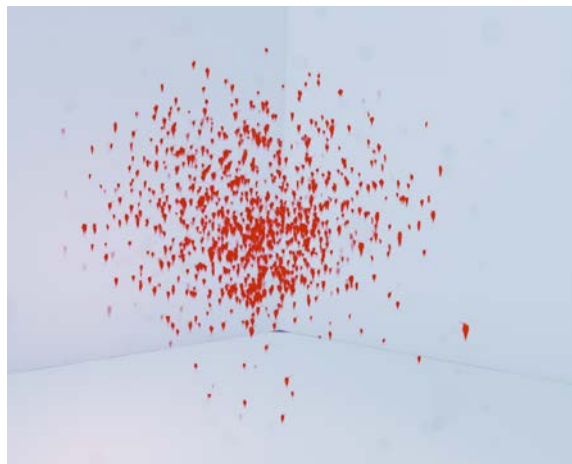
**Porpoise**



**North Atlantic Right Whale**



**Zooplankton Swarm**



## Diver



## Appendix D: Tech Features Tracking Sheet

Milestone	Importance	Status
Controllers		
Player Controller	High	Complete
Boat Controller	High	Complete
Whale Controller	Deprecated	Incomplete
Mechanics		
Attractors	High	Complete
Deterrents	Deprecated	Incomplete
Whale spline following	Deprecated	Complete
Rope/net/trawl line entanglement	High	Complete
Ship strike (PG version)	High	Complete
Radioing	Deprecated	Incomplete
Boat/whale view toggle	Deprecated	Incomplete
Rope/fishing net removal	Deprecated	Incomplete
Environmental		
Realistic water	Medium	Complete
Underwater Caustics	High	Complete
Level chunks	Deprecated	Incomplete
Art Integration	High	Complete
Urban 'skyline'	Low	Incomplete
NPC Generation	Medium	Complete
- Marine wildlife	Medium	Complete
Asset Generation	Medium	Complete
- Marine plantlife	Medium	Complete
NPC AI		
Whale AI	High	Complete
Oil Tanker/Cargo Ship AI	Medium	Complete
Marine Life AI	Medium	Complete

Physics		
Above Water Physics	Depreciated	Complete
Underwater Physics	Medium	Complete
- Movement physics	High	Complete
- Rope/net/trawl line physics	High	Complete
User Interface		
Health Gauge (whale)	Depreciated	Incomplete
Oxygen Gauge (whale)	Depreciated	Incomplete
Minimap	Depreciated	Incomplete
- Ship location	Depreciated	Incomplete
- Whale location	Depreciated	Incomplete
- Obstacle location (ropes, nets)	Depreciated	Incomplete
- Ship paths	Depreciated	Incomplete
Waypoint Markers	Depreciated	Incomplete
- Load level for 'whale level'	Depreciated	Incomplete

## Appendix E: Screenshots of Referenced Games

### Screenshots From:

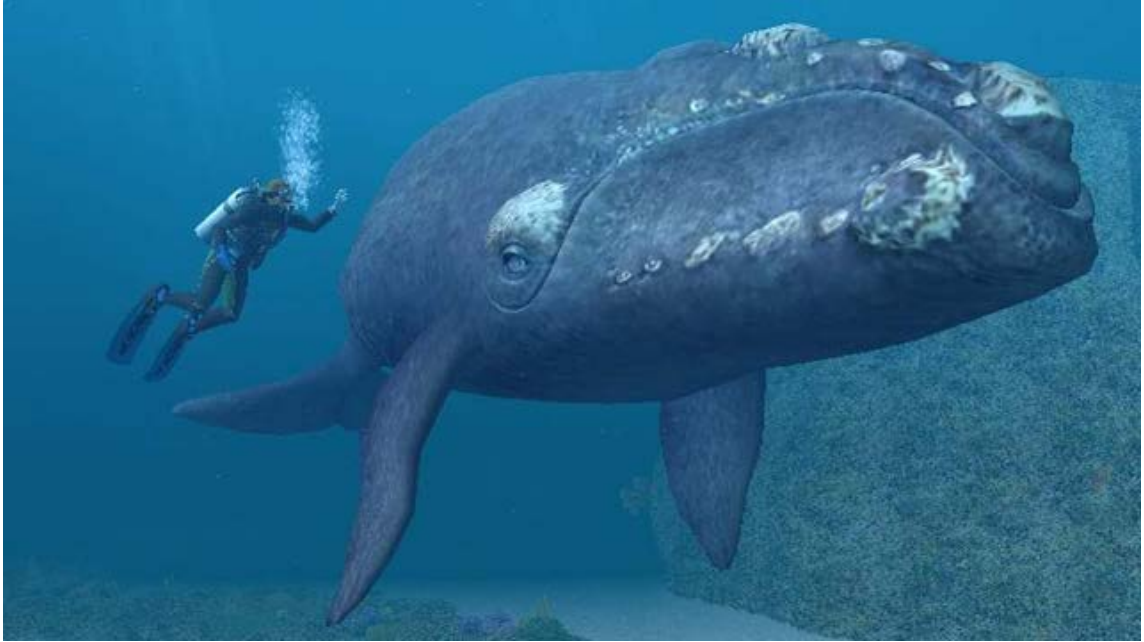
- *Jaws Unleashed* (2006)



- *Endless Ocean 2* (2007)



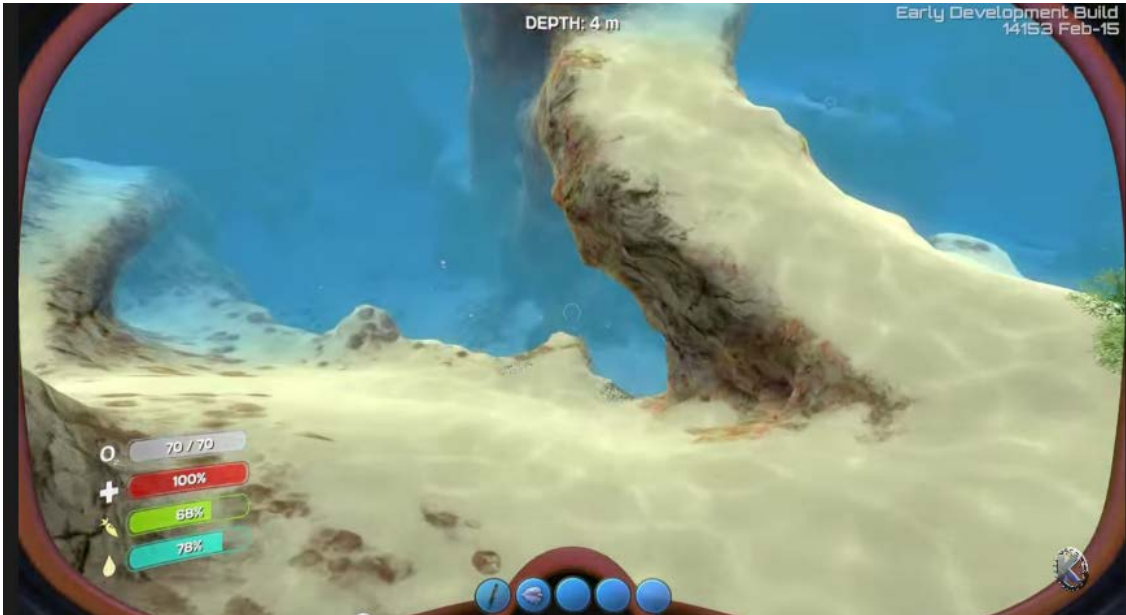




- *Wolf Quest* (2008)



- *Subnautica* (In Development)





## Appendix F: List of Software Used

- Unreal Engine 4 ([www.unrealengine.com](http://www.unrealengine.com))



- Autodesk Maya & 3DS Max ([www.autodesk.com](http://www.autodesk.com))



- Adobe Photoshop ([www.adobe.com](http://www.adobe.com))



- Microsoft Visual Studio 2015 ([www.visualstudio.com](http://www.visualstudio.com))



## Appendix G: Bugs, Issues, and Recommendations

### Prototype

#### **Known Bug #1: Level 2 will not finish sometimes**

Estimated Work Hours: 1

Priority: High

- Sometimes, Level 2 will not end because:
  - The user has a low-end machine that extends the duration of the level, causing the whale to surface before reaching the “finish” zooplankton.
  - The user has moved zooplankton to extend the duration of the level, causing the whale to surface before reaching the “finish” zooplankton
- Solution:
  - Edit the “Surfacing Time” variable in level 2 to be infinity, or the highest float value the engine will allow. This will ensure the whale never surfaces during level 2

#### **Known Issue #2: The whale “snaps” towards zooplankton during level 2**

Estimated Work Hours: 3-5

Priority: High

- During level 2, the whale does not correctly interpolate between rotations, creating a “snapping” motion. This breaks realism and looks ridiculous.
- Solution: Edit code for whale in level 2 to correctly linear interpolate between two rotations, creating the “smooth” transitions seen in the tutorial and level 1

#### **Known Issue #3: Words appear off screen during videos**

Estimated Work Hours: See “*Replace Placeholder Videos*” recommendation

Priority: High

- Subtitles for the prototype's end of level videos will sometimes be cut off screen, this is caused by the aspect ratio that the player uses on their computer.
- Solution: See *"Replace Placeholder Videos" Recommendation*

#### **Known Issue #4: Menu options are often unresponsive**

Estimated Work Hours: 5+

Priority: Medium

- The menu items require the player to double click on the letters, often frustrating the players, as they believe the menu options to be unresponsive to input.
- Solution: Create box inputs for each menu item the mouse can select, and require only one mouse click, rather than two. Highlight each menu item when the mouse scrolls over them.

#### **Known Issue #5: Hard/Impossible to dive after surfacing**

Estimated Work Hours: 5+

Priority: Medium

- When the player swims to the surface of the water, there is currently no easy way to dive back down. This often traps the player on the surface of the water.
- Solution: Create a "dive" button that will automatically force the player underwater. Consider using "spacebar" for this function, in addition to its current use for looking at whale.

#### **Known Issue #6: Fish exhibit odd behaviors**

Estimated Work Hours: 3-5 (See *"Overhaul Fish Spawning" recommendation*)

Priority: Low

- Some of the fish currently have settings that will create odd behaviors on some levels, while perfectly natural behaviors on others.
- Solution: Go through each fish and edit settings, ensuring realism of behaviors after edits.

### **Known Bug #7: Whale upcalls can be heard during cut scenes**

Estimated Work Hours: 1-5

Priority: Low

- During cut scenes, a whale upcall can be heard every so often that is not a part of the video
- Solution: Find the root cause of the upcalls during cut scenes and remove them

## **Recommendations for Final Game**

### **Recommendation #1: Playtest with a large audience**

Estimated Work Hours: 40+

Objective: Empathy, Education, and Entertainment

Priority: High

- Create a survey, playtest with a large audience, and record answers
- Multiple rounds of playtesting may be necessary

### **Recommendation #2: Replace placeholder videos**

Estimated Work Hours: 40+

Objective: Education, Empathy

Priority: High

- Use NEAq footage and research to create more inspiring cut scenes between each level
- Remove first video, replace with statistics
- Fade into and out of each video
- (Optional) Create an end level screen that tells the player how well they did

### **Recommendation #3: Overhaul surface environment**

Estimated Work Hours: 200+

Objective: Entertainment, Education

Priority: High

- Use Community ocean UE4 project to add a dynamic, buoyant ocean surface
- Add buoyancy to buoys connected to trap lines
- Implement boat spawning and collision system

**Recommendation #4: Add foliage and more ropes**

Estimated Work Hours: 10+

Objective: Entertainment, Education

Priority: Medium

- Use existing 3D foliage models to populate underwater environment
- Add additional trap lines around the entire map to increase realism

**Recommendation #5: Additional levels**

Estimated Work Hours: 100++

Objective: Entertainment, Education

Priority: Medium

- Create additional levels, adhering to the inverse difficulty specification
- Consider introducing new obstacles that convey more educational content

**Recommendation #6: Overhaul fish spawning**

Estimated Work Hours: 50+

Objective: Entertainment, Education

Priority: Medium

- Overhaul fish spawning, removing the current “FishManager” and replacing it with Fish Nodes that specify species and number, to give the level designer more freedom over how many, and what type of fish are in each level.

**Recommendation #7: Extend Ocean**

Estimated Work Hours: 100+

Objective: Entertainment

Priority: Low

- Create the effect of a larger ocean from the player's point of view

### **Recommendation #8: Adding/Improving art assets**

Estimated Work Hours: 100+

Objective: Entertainment

Priority: Low

- Create additional art assets and improve existing ones

## **Future Development Options**

### **Option #1: Recruit UE4 Developers**

- Pros: A team of developers with UE4 experience will be able to develop quickly
- Cons: Cost of recruitment, Time to learn existing code, No knowledge of Right Whales, Need development environment

### **Option #2: Utilize WPI's MQP and IQP Teams**

- Pros: No cost, unlimited resource for playtesting and development
- Cons: Limited time to learn system, a lot of re-learning between teams, slow development time

### **Option #3: Hire Members of Our MQP Team Part-Time/Full-Time**

- Pros: Knowledge of system, Quick development time, Knowledge of Whales
- Cons: Only some members available for employment, Need a development environment

## Appendix H: List of Controls

<b>Keyboard Control</b>	<b>Use</b>
"W", "UP-ARROW"	Swim Forwards
"S", "DOWN-ARROW"	Slow Down
"E"	Pick Up/Drop zooplankton swarm
"Mouse"	Look Around