Fishing with Friends: Using tabletop games to raise environmental awareness in aquariums

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ABSTRACT
We present the design and evaluation of an exhibit on the consequences of overfishing that we deployed at a local aquarium. The exhibit, *Fishing with Friends*, is a multiplayer game in which visitors compete to earn money by catching fish. As the game progresses, overzealous fishing results in damage to a simulated ocean ecosystem. Our goal is to encourage visitors to reflect on damage caused by overfishing and discuss strategies to preserve shared ocean resources. Aquariums are leading the effort to inform the general public about issues of marine sustainability. However, it is challenging to make these complex topics engaging and accessible to a diverse audiences in real-world settings. We conducted a study with 523 visitors at the aquarium to evaluate our design. Results from a questionnaire suggest that engagement with *Fishing with Friends* improved our target audience's awareness of environmental issues compared to those who were not exposed to the game. Our results also highlight challenges of using interactive tabletops displays in crowded and chaotic exhibit halls. On average, 52.6 visitors interacted with the game every hour that the exhibit was on display; this rapid flow limited engagement and presented unique design challenges that we discuss in this paper. Future work will be needed to assess longer term impacts and to compare game play to other forms of interactive and non-interactive interventions.

Categories and Subject Descriptors
H.5.2 [Information interfaces and presentation]: User Interfaces – Interaction styles;

Keywords
Games; informal learning; multi-touch tabletops; aquaria; interactive surfaces; collaboration; environmental sustainability.

1. INTRODUCTION
The world's marine ecosystems face unprecedented threats due to human activity such as overfishing, pollution, agricultural runoff, and climate change [27]. Overfishing, in particular, has led to dangerous declines in critical species, causing far-reaching economic and environmental harm. Consumer demand for threatened species coupled with widespread misconceptions have exacerbated these issues [18, 34]. Along with policy changes and enforcement of existing regulations, improved awareness on the part of the general public could encourage consumers to make more informed and sustainable choices. In this regard, informal learning institutions such as aquaria, zoos, and natural history museums have taken a leading role. Informal learning environments have been shown to be effective in engaging broad audiences with concepts related to environmental sustainability [6]. Specifically, aquariums are a leading resource of marine ecosystem education [8, 12, 35] that have had success promoting sustained pro-conservation opinions among visitor [1].

To contribute to consumer awareness, we have designed, *Fishing with Friends,* a tabletop aquarium exhibit about the detrimental impacts of overfishing. Our game is designed to illustrate the economic theory of *tragedy of the commons* [16]. This phenomenon occurs when the actions of self-interested individuals leads to the depletion of shared resources despite negative consequences to the common good. In tragedy of the commons scenarios, individuals often believe that if they don't exploit shared resources, then others will instead. The exhibit takes the form of a game in which financial incentives to encourage players to fish without limit, leading to an inevitable collapse in the game's simulated ecosystem. The goal is to encourage visitors to discuss the consequences of overfishing and devise sustainable strategies for future rounds in the game.

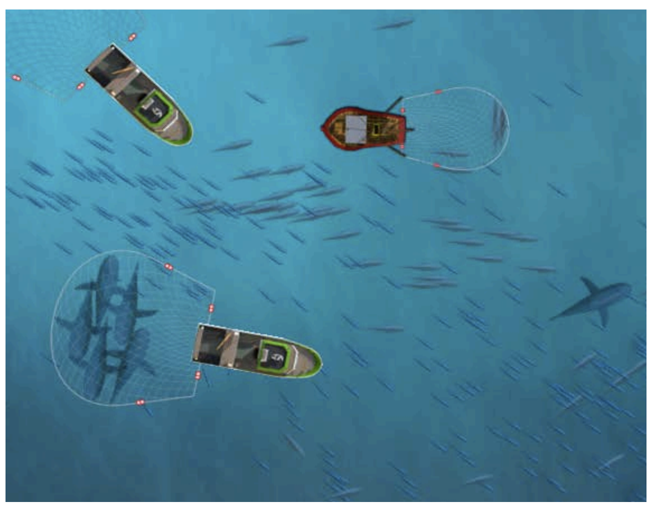

Figure 1. Screenshot of Fishing with Friends. Players use direct-touch to control the movement of boats in their fleets.

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Our design is guided by principles of *active prolonged engagement* [25], an approach to exhibit design that emphasizes in-depth, collaborative visitor interaction. This perspective acknowledges that learning in informal environments is social in nature; people visit aquariums with family, friends, and school groups [13, 20]. Therefore, it is critical to design experiences that both accommodate and are enriched by the simultaneous participation of multiple visitors [33]. Multi-touch tabletops can be used to create intuitive, walk-up-and-use experiences that encourage simultaneous interaction and provide opportunities for groups of visitors to learn together [4, 17]. However, creating effective tabletop experiences can be quite challenging, as can assessing the efficacy of tabletop-based learning experiences in the field [19, 23, 33]. For example, our field site hosts over two million visitors every year, and it is not uncommon for exhibit halls to be filled to capacity with a line of visitors out the door. Evaluating a tabletop exhibit in such a crowded environment poses new challenges that can inform the design of interactive tabletop exhibits in similar settings.

In this paper, we address the following research questions:

- Does participation in game play improve awareness and attitudes around issues of overfishing compared to traditional exhibits?
- How do groups of players engage with our simulated tragedy of the commons challenge?
- What issues do tabletop exhibits face in crowded and chaotic exhibit halls?

We conducted a two-phase study with 523 aquarium visitors to address these questions. Our target audience for this study is families with children six to fourteen years old. This has been shown to be an optimal age range for fostering pro-environmental attitudes in children [28]. The first phase involved observations of visitors as they engaged with the tabletop exhibit. Our findings from this phase raise important questions about the appropriateness of tabletops in extremely crowded and demanding public spaces. The second phase involved a more controlled study in which we invited families to play the game and then complete a questionnaire about overfishing. Results from the questionnaire suggest that gameplay can lead to improved awareness compared to visitors who were not exposed the game. We also share results from logging metrics to contribute to our understanding of in-game behavior.

2. RELATED WORK

Multi-touch tabletops have been shown to have unique affordances for collaborative learning [4, 14, 31]. However, only a handful of studies have been conducted on the use of tabletops in museums, zoos, and aquariums [3, 7, 19, 21, 23]. Furthermore, these studies largely lack quantitative measures of learning outcomes. Horn et al. [21] studied a tabletop puzzle game on the topic of evolution in a natural history museum. Antle et al. [3] deployed a collaborative game on sustainable development at the 2010 Winter Olympics. Hinrichs & Carpendale [19] and Hornecker [23] investigate pre-existing tabletop based exhibits in an aquarium and natural history museum respectively. Their findings highlight the difficulty of designing effective tabletop learning experiences for informal environments, but also suggest that multi-touch tabletop games can be engaging for groups of visitors. These studies are primarily observational and have motivated our efforts to include measures of learning and attitudinal shifts in this study.

In more recent work, researchers analyzed pairs of children interacting with a zoomable Tree of Life exhibit in a natural history museum and found significant short-term learning outcomes compared to a baseline condition [22]. Analysis of video recordings of this exhibit suggests that several different patterns of interaction could lead to learning outcomes [10]. These findings suggest that it is worth investigating whether tabletop exhibits can lead to quantifiable outcomes in informal learning settings.

2.1 Collaborative Learning and Tabletops

Large interactive displays have affordances that support collaborative learning [11, 31]. For example, users can monitor one another's actions and communicate verbally or nonverbally to establish shared understanding. Large tabletops attract visitors from a distance and allow for people to congregate around all sides of the display [32]. Distributing roles across users can encourage discussion and problem solving [5, 30]. These affordances, while attractive to designers, can also lead to conflict, interference, and confusion rather than collaboration and learning [2, 24]. For example, simultaneous input from groups of visitors introduces the potential for unwelcome intrusions, requiring more attention and coordination on the part of users compared to other forms of input [7, 23]. As tabletops become more prevalent in informal environments, there is a need to evaluate their effectiveness and understand factors that contribute to audience engagement and learning.

2.2 Games for Learning

Games can be effective vehicles for learning [15]. Games have many characteristics that help motivate players to engage complex concepts. For example, games can distribute challenges to allow new players to develop and refine skills over time. Additionally, role-playing in game play can help players become immersed in the experience and encourage self-motivated play [15]. Simulation games are well suited for encouraging playful engagement with current issues for younger audiences, while making complex topics more accessible [3].

Educational game designers often struggle to find the right balance between educational material and fluid gameplay [29]. In an effort to avoid this shortcoming, our game features limited instruction and expository educational content. We prompt players to explore the limitations of the simulation through role-play. Although the game design encourages overfishing in the short term, the only way to win is to adopt a sustainable strategy in which players collaborate with one another to keep the ecosystem balanced.

Figure 2. Concept sketches of game design.

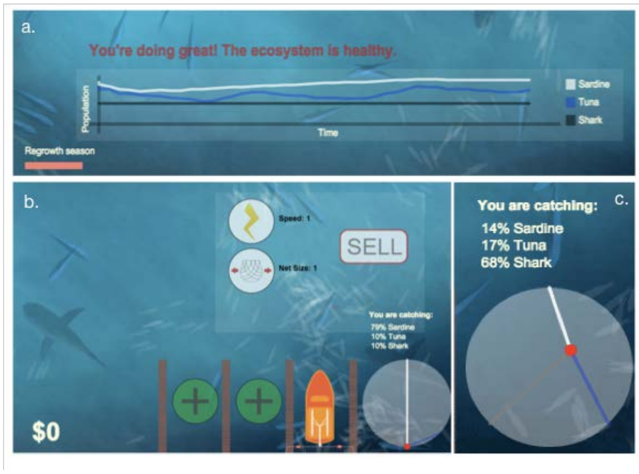

Figure 3. Early Iteration (a) Population graph was replaced with badges, (b) Buying and selling boats phase was removed, (c) Fish type selector was replaced with specific boat types

3. GAME DESIGN

Fishing with Friends is a multi-player game that aquarium visitors play on a 46-inch 3M tabletop display. We sought to use game play to engage visitors in a tragedy of the commons scenario as a way to raise awareness and knowledge about overfishing. The game does not include formal instructions or a statement of goals, and we avoided prompting a specific game strategy so as to allow for a more self-directed experience. Participants are expected to make inferences about the goal of the game as they play.

Our design was inspired by other tragedy of the commons exhibits such as Text Fish at the San Francisco Exploratorium and existing game-based exhibits such as *Futura* and *Build-a-Tree* [3, 21]. The final design is the result of a yearlong iterative design process consisting of multiple iterations of paper prototypes and computer demos. Substantial changes were made to accommodate the constraints of our field site, such as limiting total game time and simplifying the game mechanics. For example, in early prototypes we used interactive graphical representations to depict population health over time and to allow players to select the types of fish to catch (see Figure 3). However, pilot studies with our target audience revealed that these representations were confusing and hindered gameplay. Given the flow and attention span of aquarium visitors, we removed an entire phase (selling boats) for more rapid game play.

In the game visitors control one of four boats on the screen (prompted by an arrow that says "Drag boats to catch fish"). Fishermen can team up to form a fleet of two boats. Fleets are differentiated by color and location on the screen. Fishermen choose a single species of fish to pursue during a given season. The ocean ecosystem consists of sharks, tuna, and sardines. At the end of each season the fleet's catches are tallied to determine profits earned. The two fleets are faced with the goal of maximizing financial profit from one season to the next for five seasons. This challenges players with a scenario similar to that of modern commercial fishermen—balancing the incentive to increase profits in the short term with the need to preserve natural resources in the long term. These kinds of role-playing elements have been shown to foster a deeper understanding of complex issues similar to overfishing [15].

To highlight the consequences of their actions in real time, players see how catching fish changes the health of the ecosystem throughout the game. The health of the ecosystem is measured by the change in population of species relative to the starting population. Fish populations are directly affected by player behavior (catching fish removes them from the population). Populations also fluctuate with inter-species dependencies designed to simulate predator-prey relationships in the marine food webs. We consulted science advisors at the aquarium to ensure reasonable level of accuracy for our representation.

3.1 Game Play

The game itself is structured into three phases (Figures 1 and 4) that repeat over five rounds. Each phase is timed and players are allowed to proceed to the next round if the ecosystem remains intact. In the *fishing phase* (25 seconds), players touch and drag to direct a species-specific fishing vessel (e.g. a shark boat) to

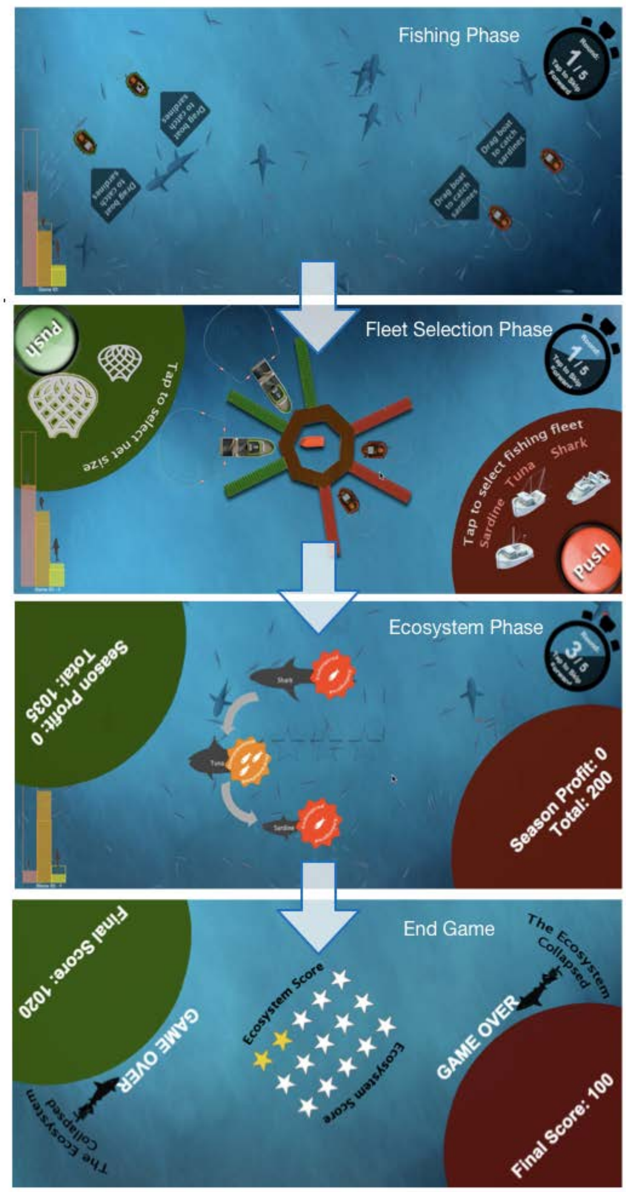

Figure 4. Phases of game play

harvest fish by dragging boats around the screen as their nets fill. This phase is the longest motivates players to act in self-interest by providing financial rewards and visually filling nets with fish. The game is intended to encourage overfishing while also leaving time for players to recover in later rounds or during replay.

In the second phase, the *ecosystem reflection phase* (10 seconds), players receive scores and badges illustrating the impact of their actions on the simulated ocean ecosystem. The two fleets receive badges as a group for the health of each species (overpopulated, healthy, endangered, and extinct; See Figure 4). They also receive up to 3 stars for maintaining healthy populations of species (one star for each "healthy" badge received). Players are shown the cumulative and current season profits for their individual fleet. This phase is designed to highlight the tension between the competing motives of personal profit and ecosystem health. For example, overfishing results in increased profit in the short-term but leads to extinction in the ecosystem; not fishing results in no profit but can lead to overpopulation in the ecosystem. Players must find the right balance to maintain a healthy ecosystem.

Finally, in the *fleet selection* phase (15 seconds), players make decisions about what kind of fish to pursue by selecting a boat type and net size. This provides players an opportunity to react to the ecosystem status report and discuss their goals for the next round in the game.

The game ends after five rounds, or when a species goes extinct. At the end of the game, players are presented with a summary screen showing total profits earned for each fleet and the ecosystem stewardship stars (up to 15), which are tallied to determine the score. A full game lasts approximately four minutes.

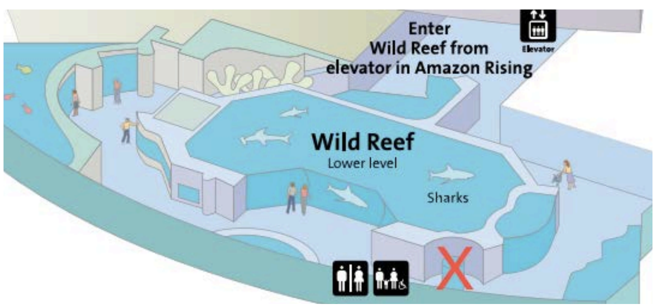

Figure 5. Location (indicated by red X) and set up of Fishing with Friends at the aquarium

Table 1. Adult participant demographic data

Age	20s 1.5%	30s 27.3%	40s 51.5%	50+ 19.7%
Ethnicity	White: 71.2%	African American: 6.1%	Asian: 15.2%	Hispanic: 7.5%
Education	High School: 1.5%	Some College: 10.6%	College Graduate 57.6%	Grad School: 30.3%
Income	25-99: 30.2%	100-200: 25.8%	200+: 12.1%	N/A: 31.8%

The intention is for visitors to play two to three rounds (round = 50 seconds) that result in overfishing and collapse of the virtual ecosystem, only earning a small amount of money and very few stars overall. Once the ecosystem has failed, the game encourages players to try again in the hopes that they will adopt a more sustainable approach. The quick nature of game play is intended to encourage guests to experiment with different approaches and ideas with a reasonable investment of time.

4. METHODS

This study took place at a local aquarium in a Wild Reef Exhibit (see Figure 5) appearing on the floor for 10 days over the course of one month. The Wild Reef is the main shark exhibit at the aquarium; Fishing with Friends was located immediately after the shark viewing area surrounded by traditional non-interactive exhibit material such as informational photographs and text based posters about sustainability and marine life. Although this area of the aquarium is crowded, the exhibit material is the most contextually relevant to our design. Observations and questionnaire data were gathered in two phases: 1) observations only and 2) questionnaire (consisting of two conditions: questionnaire only and game play followed by questionnaire).

4.1 Participants

In this study we had a total of 166 recruited visitor groups (523 individuals). For the purposes of this study, a group contained at least one adult and one child between the ages of 6 to 16 years old. There were no significant differences between ethnicity, education, age, gender, and income across the two conditions. Demographic data for participants in the questionnaire phase are provided in Table 1.

Observation Phase

In the observation phase, we observed 100 non-recruited social groups (consisting of 277 individuals) who interacted with the game over the course of two days. The social groups consisted of 171 children (104 boys and 67 girls) and 106 adults (46 males and 60 females); the average estimated child age was 8.3 (SD = 3). The average group size was 2.8. To avoid interfering with natural engagement and flow of groups we did not collect questionnaire data during this phase. Additionally, due to the inability to restrict traffic through the space we did not video record visitors.

Questionnaire Phase

In the questionnaire phase, we recruited a total of 66 social groups (consisting of 246 individuals). For the questionnaire-only condition we recruited 45 groups of adults and children to participate. The exhibit was not present during this condition. These groups consisted of 165 individuals (86 children and 79 adults) the average child age was 9.5 (SD = 2.3). The average group size was 3.75. In the game play followed by questionnaire condition, we recruited 21 groups of children and adults to participate in at least one full round of game play followed by the questionnaire. Eight groups played two or more full games and 13 groups played one full game. These groups consisted of 81 individuals (47 children and 34 adults); the average child age was 9.8 (SD = 2.3). The average group size was 3.85.

4.2 Game Logging Metrics

Game play data was logged automatically by the exhibit. In total, we collected logs from 130 game plays. Game plays were only recorded if participants played at least one full round (holding time and behaviors of participants who did not compete a full round were captured in the observation phase). Results from game logs, which included both recruited and non-recruited participants, should be viewed as approximations because we did not eliminate repeated plays and changing / overlapping groups. Game logs recorded the following metrics for each round:

- Time (per round and overall)
- Healthy Ecosystem Stars Earned (per round and overall)
- Number of Fish in Population (by species)
- Boat Type per Team (shark, tuna, or sardine)
- Net Size per Team (large or small)
- Team Profit (per round and overall)
- Number of Fish Caught per Team (by species)
- Win/Loss (win = completing 5 rounds without causing a species to become extinct, loss = species extinction)

4.3 Questionnaire

To evaluate the effectiveness of our game for improving awareness, we developed a questionnaire for our target audience consisting of 14 questions on a 5-point Likert scale. Questions addressed attitudes and misconceptions. The questions were developed through multiple brainstorming sessions with stakeholders at the field site and revised to address four themes: *human impact, I can make a difference, economic trade-offs*, and *importance to protect the ocean,* with 3-4 questions per theme. For example, the prompt: "it is possible for people to fish too much and damage ocean ecosystems" fits within *human impact*; the prompt: "we shouldn't restrict fishing so fishermen can make money" fits in the *economic trade-offs* theme; the prompt: "I would change what I eat if it would help protect ocean ecosystems" fits within the *I can make a difference theme*; and the prompt: "ocean life is important for human survival and livelihood" fits within the *importance to protect* theme. Additionally, we included two open-ended questions about population dynamics. The *top-predator* question asked what would happen if sharks were removed from the ecosystem, the *mid-predator/prey* question asked what would happen if tuna were removed from the ecosystem. Adults received a written questionnaire that included a demographic survey (including age their child), five questions on conservation awareness (e.g. "I try to eat sustainably caught seafood"), and two open-ended questions on their rationale for visiting the aquarium and frequency with which they visit informal learning environments.

4.4 Procedure

In the observation phase, the game was set up in the Wild Reef exhibit near the shark habitat. Visitors who approached were told that we were testing a new exhibit and that they could use it as they would with any other exhibit at the aquarium. Observations were done in real time, and visitors were informed that they would be observed if they chose to participate. The researcher noted social interactions between players, such as collaborating, rule enforcing, explaining, insights, attitudes, and team dynamics (i.e. adults playing with or against children). Researchers also recorded time spent engaging with the game, gender, and estimates for the age and sex of each visitor who chose to participate.

In the questionnaire phase, we collected data in two conditions: without the game present (questionnaire only condition) and with the game present (game play followed by questionnaire condition). For both conditions, groups were recruited randomly as they walked past the area designated for the installation (see Figure 5). A researcher approached groups and invited them to participate in a research study that would inform the design of a potential exhibit. After playing the game, parents completed a written questionnaire, while a researcher administered the verbal questionnaire to children. When a participant expressed uncertainty, we recorded a neutral response. Visitors were informed that their participation was voluntary and that they would not receive payment for their participation.

In the *questionnaire only* condition, groups were invited to participate in the questionnaire without any gameplay. While in the *game play followed by questionnaire* condition, groups were invited to interact with the game for at least one full round and were welcome to play as many times as they liked. Following game play, groups participated in the questionnaire. Questionnaire results and corresponding game play(s) were paired for analysis. Researchers recorded field notes in real time while groups interacted with the game. The field notes included quotes from participants specifically focusing on utterances indicating reflection, intention, and strategy. Quotes from participants are labeled with age and sex.

4.5 Data Analysis

Questions were grouped together by theme: *human impact* (Cronbach's α = .673), *I can make a difference* (α = .694), *economic trade-offs* (α = .503), and *importance to protect the ocean* (α = .138). Due to the low reliability score for our *importance to protect* scale, we broke this into individual questions. We did not see significant results for any of these individual questions. We also eliminated two questions from analysis due to high levels of visitor uncertainty about the meaning of the questions. Two researchers independently coded responses to all open-ended questions achieving an agreement rate of 97.8% (Cohen's kappa = 0.927). Responses were given a score for depth of understanding on a 5-point scale. Points were assigned for stating any of the following: effects of overfishing, indirect causal relationships, multiple effects, temporal delay, and explanations describing causal relationships. For example, the response "without tuna sardines would become overpopulated and the sharks would become endangered because they would have no food" would receive three points, one for stating an effect (overpopulation), one for multiple effects (overpopulation and

Table 2. Mean Scores for Question Themes and Significance for Effect of Condition

Theme	Questionnaire Only *n = 45*	Post Game *n = 21*	Significance
Economic Trade-offs	3.40 SD = 0.81	3.92 SD = 0.88	p = 0.021
I Can Make a Difference	3.91 SD = 1.10	4.47 SD = 0.48	p = 0.027
Human Impact	3.89 SD = 1.21	4.21 SD = 1.31	p = 0.329
Important to Protect	4.84 SD = 0.37	4.95 SD = 0.22	p = 0.146
Important for Survival	4.31 SD = 1.01	4.05 SD = 1.28	p = 0.412
Can Impact my Life	4.42 SD = 1.30	4.33 SD = 0.73	p = 0.061

endangered), and one for explanation (lack of food). Scores ranged from 0-4, and the mode was 1 point for both questions.

5. RESULTS

In this section, we measure changes in awareness through results from our questionnaire and evaluate visitor engagement levels via measures of holding time. We also present an analysis of game behavior and strategies derived from observations and log data.

5.1 Changes in Awareness

To evaluate whether or not the game could raise children's awareness of topics related to overfishing we examined results from our questionnaire. We used a 2x2 design with two factors age (young: 6-9, old: 9-16) and condition (participated in game play or not). Table 2 shows the mean scores for the two conditions. We ran a two-way ANOVA on condition and age.

There was a significant main effect of condition for the "*I can make a difference*" theme ($F(1,66) = 5.098$, $p = 0.027$), with children who played the game performing better than those who did not. There was no effect of age and no interaction effect.

For the *Economic Trade-offs* theme there was a significant effect of condition ($F(1, 66) = 4.43$, $p = 0.021$) and of age ($F(1, 66) = 4.430$, $p = 0.039$), with game participants and older children performing best. There was no interaction effect. The questions within these themes directly related to actions in the game. Participants had full control of their fishing fleet and their actions directly changed the health of the synthetic ecosystem. This may have contributed to participants feeling more empowered in their ability to make a difference in the health of the oceans. Additionally, the relationship between fish and money is explicit in the game and may have highlighted issues of economic trade-offs, prompting them to confront these trade-offs in a simulated environment.

For the *Human Impact* theme there was a significant effect of age only, with older children out performing younger ($F(1, 66) = 11.3$, $p = 0.001$). However, within the game play condition, we did see a significant effect of condition ($F(1, 38) = 6.04$, $p = .0186$) for participants who played two full games (mean = 4.87, N = 8) compared to those who only played one full game (mean = 3.8, N = 13). This could suggest that prolonged game play contributes to increased awareness. Specifically, when players decide to replay the game they can explore new strategies that may enhance their understanding of the consequences of their actions. Reflection and evaluation of their in-game actions might contribute to better understanding of how different fishing practices could impact the health of the ocean. However, it is also possible that these participants were more aware (and interested in playing) to begin with, thus accounting for this result.

There were no effects of condition for the remaining questions; however, there was an effect of age for "*health of the oceans can impact my life*" ($F(1, 66) = 4.223$, $p = 0.044$) with older children agreeing more strongly than younger.

5.2 Open-Ended Questions

For the open response questions we ran a two-way ANOVA on condition and age. For the top-predator questions, there was a significant effect of age ($F(1, 53) = 4.21$, $p = 0.045$) with older children performing better (means = 1.2, .75) However, there was no effect of a condition and no interaction effect. For the mid-predator/prey question there was a significant effect of age ($F(1, 51) = 7.22$, $p = 0.009$, means = 1.44, 1.00) with no effect of condition and no interaction. Although the game exposed participants to population dynamics, we did not explicitly define this concept for participants. It is not surprising that older children provided more elaborate answers, possibly because they had been exposed to similar topics in school.

5.3 Holding Time

To evaluate engagement with tabletops in crowded environments we measured the length of interaction for every participant. The overall average holding time, the duration of engagement with the game, for observed visitors was 1 minute and 22 seconds. This is consistent with findings from other informal learning environments such as science museums [25]. Additionally, for guests who completed at least the first round of the game, average play time was 3 minutes and 48 seconds, which is consistent with holding times that are considered *prolonged* for museums [25].

The recruited participants in the game play condition averaged a holding time of 5 minutes and 46 seconds. Although average holding times for this study are consistent with previous studies in informal environments, our observations suggest that conditions unique to our field site also influenced holding time. The aquarium is one of the most well attended attractions in the area, and it was

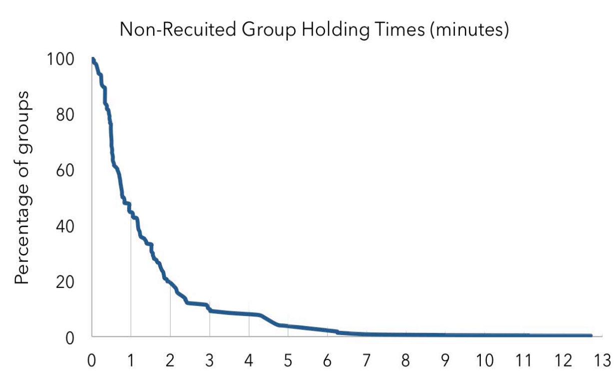

Figure 6. Holding Time for Non-Recruited Participants

Table 3. Game success for all participants who played at least the first round.

	Win	Loss	Did Not Finish
% of Participants	43%	32%	25%
Average Rounds	4	2	3
Average Time	4:22	2:58	3:38

difficult to limit game interaction to one family at a time. In many cases families left the game because another group started to play.

Of the 100 groups observed, 60% of groups left after the first reflection phase. As shown in Figure 6, there is a clear drop at about the 1-minute point when most groups reached the reflection phase. Our observations suggest that this drop off was largely due to groups thinking the game had ended at the first reflection phase. The lack of interactive elements in the reflection phase did not seem effective enough to maintain visitor attention. Additionally, there is a drop off at around 3 minutes, which is the average ending time for plays that ended in a loss (see Table 3). Sustained attention can be seen between 3 and 4 minutes followed by a steady drop at about 4 and half minutes when the game ended (see Figure 6).

Table 3 shows the average time it took visitors to complete the game (win or lose), and the average time for those who did not complete the game. The table contains a subset of participants for both conditions who played at least one round to depict average holding time for the groups considered to be engaged. We categorize a win as completing five rounds without causing a species to become extinct. Play time was shorter for games that ended in a loss because players did not have the opportunity to play as many rounds as a full game.

We designed the game to progress rapidly from one phase to the next to accommodate the flow of visitors through the aquarium. Naturalistic observations indicated that an average of 52.6 visitors interacted with the game every hour. Most participants who completed the first round engaged with the game to completion (75% resulted in either a win scenario or lose scenario). The 25% of the groups that did not finish the entire game completed on average 3 rounds or 3 minutes of game play.

5.4 In-Game Participant Behavior

Participants in our study were encouraged to experiment with different fishing strategies. Illustrating the effects of overfishing and allowing players to reflect on their behavior may have contributed to increased awareness. A third of the participants (see Table 3) overfished species to extinction, thus losing the first game. Many groups verbally expressed a connection between their fishing behavior and species extinction.

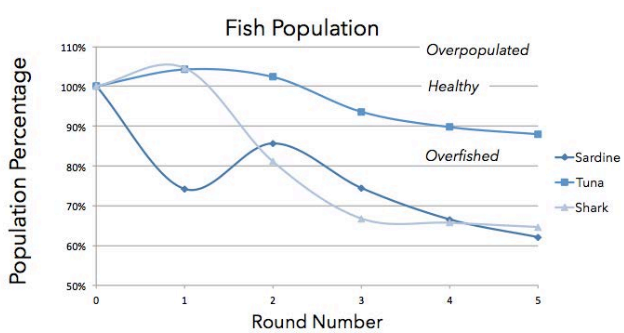

Figure 7. Change in fish population for all game plays.

Table 4. Boat selections of recruited participants for each round (round 1 default starts with sardines).

	Round 1	Round 2	Round 3	Round 4	Round 5
Sardine	100.00%	48.33%	56.67%	38.33%	38.33%
Tuna	0.00%	23.33%	23.33%	25.00%	26.67%
Shark	0.00%	28.33%	13.33%	26.67%	18.33%
Loss	0.00%	0.00%	6.67%	10.00%	16.67%

“We made the sharks extinct” M10

“Where did the sharks go?” M11 “I have more sharks” F12 “Oh that’s where all the sharks went” M11

In all of these cases sharks were the species driven to extinction. The reaction to sharks was one of the most pronounced behaviors we observed and captured in game logs. Participants tended to fish sharks more aggressively in the game and discuss their attitudes towards sharks.

Table 4 highlights the difference in fishing behavior with sharks compared to other species. It is important to keep in mind that the game starts with a sardine boats, and visitors must make a decision to switch to a different kind of boat after the end of the first round.

Preference for sardine boats decreased over successive rounds as players figured out how to change boats. The selection of tuna boats remained steady throughout the game. In contrast, the selection of shark boats fluctuated.

The game logs were paired with questionnaire results for participants in the game play condition. Within this subset, 38% of plays ended due to extinction of sharks. Despite this rate, both parents (mean = 4.69) and children (mean = 4.97) strongly endorsed the statement that it is important to protect ocean life in the questionnaire. This suggests that although players expressed interest in protecting ocean life, the game environment allowed them to experiment the simulated ecosystem.

Across all conditions, when players had the opportunity to choose a boat type at the end of the first round, 44.74% did not change boats and stayed with sardines, 19.74% chose to fish tuna, and 35.53% chose sharks. Our field notes of participant conversation suggest that visitors were the most enthusiastic about fishing for sharks compared to other species.

“I wanna catch sharks” F11

This could be a reflection of the general population’s negative perception of sharks as dangerous killers, or it could be an effect of sharks being the largest fish displayed in the game. Although, the monetary value of each fish was not represented in the game, participants may have associated the size of the sharks to a higher market value, thus suggesting that players might have targeted sharks to increase team profit. Figure 7 shows the recorded changes in the composition of the ecosystem over the course of a full game. The sardine population declines rapidly after the first round because all of the players are initially assigned sardine-specific fishing boats. The sardine population is somewhat stable for the remaining rounds, while the shark population experiences a decline after the second round when players have the first opportunity to choose different boats (see round 2 in Figure 7). The tuna population remains steady throughout the gameplay. After losing the game, participants often engaged in unprompted reflection on why they lost.

"I think the point of the game is to teach you that you shouldn't keep fishing till its gone" M9

All participants who won the game changed their boat type within 1-2 rounds after receiving an endangered badge.

"We didn't catch the wrong fish" M40

Of the 21 recruited families in the game play condition, 7 groups played the game twice, and 6 of those 7 groups performed better the second time they played. As mentioned in the questionnaire results, participants who played more than one full game had significantly increased awareness compared to participants who only played once.

5.5 Game Strategies

We were careful to limit the amount of instruction and explicit goals present in *Fishing with Friends* as we wanted visitors to explore their own strategies and discuss the purpose of the game. Our field notes revealed several different visitor strategies. The most prominent was to catch as many fish as possible. Both children and adults adopted the catch everything approach.

"you have to get all the fish" F12

"You gotta net'em go!" M40

In contrast, participants who adopted a more sustainable approach often had to explain their reasoning to other members of their family. This often occurred after participants received an *endangered* badge for one of the species in the ecosystem.

"If you select the big net you have to be careful" M40

"Big is best" M9 "No we don't want to catch too many" M10

The *endangered* badge shown in the reflection phase was a critical moment in the game to encourage strategy change. Ideally participants would recognize the warning and take action (i.e. change their type of fishing boat or fishing strategy).

Table 5 shows how often each species became endangered and how participants responded to warnings that a population was endangered. Participant responses to endangerment warnings differed by species. Participants adjusted their fishing behavior about half the time in response to tuna or sardine endangerment. In contrast, only 26% adjusted their behavior when sharks became endangered, contributing to the frequency of shark extinctions.

Our field notes suggest that when adults were actively engaged in game play or attentively observing, they often prompted reflective questions and contributed to strategy development.

"Why are you trying to catch sharks?" F45 "because I want to" F9

"Oh... I don't think we were supposed to catch all the sharks" F30

Unfortunately, adults did not always participate in game play as much as we expected. This could have been because the table was installed at kids' height, about 24-inches off the ground. At this height it was approachable and inviting for younger children but

Table 5. Game behavior for participants when they encountered an endangered status, broken down by species.

	Sardine Endangered	Tuna Endangered	Sharks Endangered
# of occurrences	39	37	65
% of teams that altered behavior	55%	49%	26%

slightly inaccessible for adults (unless they knelt on the floor). Additionally, our observations revealed that many adults had a negative association with playing games and engaging with technology at the aquarium, often discouraged children from trying the exhibit. Similar findings have been seen at a natural history museum and art museum [9, 21], suggesting that technology-based exhibits need to include elements that adults deem appropriate for the space.

"If you are too focused on the video game you are going to miss stuff" F20

The team structure within *Fishing with Friends* (represented by different colors and opposite corners of the display) was designed to support competition or cooperation with mixed-aged groups. Families typically ignored this design feature and played collaboratively. The lack of competition did not change strategies within the game. Rather than forming teams, players were individually motivated to catch fish, which still resulted in overfishing outcomes. Children were often the first to approach with parents initially just watching.

For families with younger children, scores were often not the main motivator and typically did not drive competition. However, older kids were much more likely to pay attention to the numeric scores, suggesting that multiple motivators such as team scores, stars, and badges will increase the appeal for different age groups.

6. DESIGN IMPLICATIONS & FUTURE WORK

Informal learning environments are difficult to design for, and each institution presents its own unique set of challenges. Our field site is very crowded and has many highly stimulating attractions such as large habitats and dolphin shows. Families at the aquarium often move through exhibits quickly. When asked for their reason for visiting the aquarium, only two of the 66 families who participated in our questionnaire mentioned 'learning' as a goal of their visit. Common responses focused on entertainment or tourism instead. That said, even though our exhibit was appealing to children, many parents were not supportive of video games in this environment, suggesting that education was at least a somewhat important motivator for visiting the aquarium. Providing additional roles for adults in game based exhibits such as topics to facilitate discussion with their children may help improve engagement and approval.

The use of a large multi-touch display seemed attractive and inviting for many children who chose to interact with our game. Indeed, the sheer size of the monitor made it difficult to confine interactions to one family. This problem was exacerbated by the large number of visitor groups at the aquarium; on average, 52.6 visitors per hour interacted with the game while we were observing, leading to many occasions members of one group would insert themselves into another group's game. This suggests that large display sizes, while inviting, may not necessarily be the best approach for achieving sustained uninterrupted attention in crowded informal learning environments. Additionally, continuous game play (instead of a structure based on levels or rounds) might provide more fluid support for players entering and leaving at different points in the game. As mentioned, many groups stopped playing after the first round believing that the game was over; a continuous style of play may avoid this situation while supporting more prolonged engagement and spontaneous interaction. Along these lines, we found it necessary to simplify and shorten the game considerably from our initial designs to make the game more approachable and entertaining for children of different ages. We also relied on simple cues such as on screen timers, colored badges, and stars to keep the round times short but informative without having to add formal instructions.

Additionally, we found the use of recognizable marine species to be both positive and negative. On the one hand, the use of well-known fish (sharks, tuna, and sardines) seemed to make the game more accessible because visitors could rely on prior knowledge about how these organisms might interact in a marine ecosystem. On the other hand, the public's apparent negative perception of sharks may have contributed to exaggerated game strategies in which the sharks were hunted to extinction. Replacing sharks with a positively perceived but equally charismatic species that faces similar threats, might drastically change participants' game strategies and outcomes.

In the future we hope to offer take-home print materials and a downloadable version of the game for personal devices. We would like to understand longer-term outcomes on consumer behavior, perhaps through repeated game play on personal devices. We would also like to compare game play to other typical focused interventions used in places like museums, zoos, and aquaria.

7. CONCLUSION

In this study we designed and evaluated a game-based exhibit about the consequences of overfishing. Our results show that interacting with our tabletop game can improve awareness along with traditional aquarium experiences such as live animal shows, docents, pictures, and text-based information. In our study, brief interactions led to short-term attitudinal shifts further contributing to the argument that tabletops can support group learning in informal settings. Additionally, our results suggest that a game-based learning activity can encourage playful and exploratory engagement. However, we further emphasize the point that informal learning environments are not one-size-fits-all. Unique constraints of the environment should be considered. Future work will be necessary to understand longer-term effects and to compare game play to other education interventions.

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9. REFERENCES

1. Adelman, L.M., Falk, J.H., and James, S. (2000). Impact of National Aquarium in Baltimore on visitors' conservation attitudes, behavior, and knowledge. *Curator: The Museum Journal, 43*(1), 33-61.
2. Allen, S., & Gutwill, J. (2004). Designing with multiple interactives: Five common pitfalls. *Curator: The Museum Journal*, *47*(2), 199-212.
3. Antle, A.N., Bevans, A., Tanenbaum, J., Seaborn, K. and Wang, S. (2011). Futura: Design for collaborative learning and game play on a multi-touch digital tabletop. In *Proc. Tangibles, Embodied and Embedded Interaction (TEI'11)*, 93-100. ACM Press.
4. Antle, A.N. and Wise, A.F. (2013). Getting down to details: Using learning theory to inform tangibles research and design for children. *Interacting with Computers, 25*(1), 1-20.
5. Antle, A.N., Wise, A.F., Hall, A., Nowroozi, S., Tan, P., Warren, J., Eckersley, R., & Fan, M. (2013). Youtopia: a collaborative, tangible, multi-touch, sustainability learning activity. In *Proc. Interaction Design and Children (IDC'12)*, 565-568. ACM Press.
6. Ballantyne, R. & Packer, J. (2005). Promoting environmentally sustainable attitudes and behavior through free-choice learning experiences: what is the state of the game? *Environmental Education Research 1*(3)*,* 281-295.
7. Block, F., Hammerman, J., Horn, M., Spiegel, A., Christiansen, J., Phillips, B., Diamond, J., Evans, E.M., Shen, C. (2015). Fluid Grouping: Quantifying group engagement around interactive tabletop exhibits in the wild. In *CHI 2015*.
8. Cainey, J., Bowker, R., Humphrey, L., & Murray, N. (2012). Assessing informal learning in an aquarium using pre- and post-visit drawings. *Educational Research and Evaluation*, *18*(3), 265-281.
9. Cosley, D., Lewenstein, J., Herman, A., Holloway, J., Baxter, J., Nomura, S., & Gay, G. (2008). ArtLinks: fostering social awareness and reflection in museums. In *Proc. CHI'08,* 403-412. ACM Press.
10. Davis, P., Horn, M.S., Block, F., Phillips, B., Evans, E.M., Diamond, J., Shen, C. (2015). "Whoa! We're going deep in the trees!": Patterns of collaboration around an interactive information visualization exhibit. *International Journal of Computer-Supported Collaborative Learning*, 10, 53-76.
11. Dillenbourg P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.) *Collaborative-learning: Cognitive and Computational Approaches*. (pp.1-19). Oxford: Elsevier.
12. Falk, J.H., & Adelman, L.M. (2003). Investigating the impact of prior knowledge and interest on aquarium visitor learning. *J. Research in Science Teaching, 40*(2), 163-176.
13. Falk, J.H. and Dierking, L.D. (2000). *Learning from museums: Visitor experiences and the making of meaning.* AltaMira.
14. Fleck, R., Rogers, Y., Yuill, N., Marshall, P., Carr, A., Rick, J., & Bonnett, V. (2009). Actions speak loudly with words: unpacking collaboration around the table. In *Proc. Interactive Tabletops and Surfaces*, 189-196. ACM.
15. Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-learning*, *2*(1), 5-16.

16. Hardin, G. (1968). The tragedy of the commons. *Science, 162*(3859), 1243-1248.

17. Heath, C., vom Lehn, D., Osborne, J. (2005). Interaction and interactives: collaboration and participation with computer-based exhibits. *Public Understanding of Science 14*, Sage.

18. Hilborn, R., & Hilborn, U. (2012). *Overfishing: What everyone needs to know*. Oxford University Press.

19. Hinrichs, U., & Carpendale, S. (2011). Gestures in the wild: studying multi-touch gesture sequences on interactive tabletop exhibits. In *Proc. CHI'11*, 3023-3032. ACM Press.

20. Hope, T., Nakamura, Y., Takahashi, T., Nobayashi, A., Fukuoka, S., Hamasaki, M., & Nishimura, T. (2009). Familial collaborations in a museum. *Proc. CHI'09*, 1963-1972. ACM.

21. Horn, M., Atrash Leong, Z., Block, F., Diamond, J., Evans, E. M., Phillips, B., & Shen, C. (2012). Of BATs and APEs: an interactive tabletop game for natural history museums. In *Proc. CHI'12,* 2059-2068. ACM.

22. Horn, M., Phillips, B., Evans, E.M., Block, F., Diamond, J., Shen, C. (2015). Visualizing the tree of life: Learning around an interactive visualization of biological data in museums. *National Association for Research in Science Teaching Annual International Conference (NARST 2015)*.

23. Hornecker, E., Marshall, P., Dalton, N. S., & Rogers, Y. (2008). Collaboration and interference: awareness with mice or touch input. In *Proc. CSCW'08*, 167-176. ACM.

24. Hornecker, E. (2008). I don't understand it either, but it is cool—Visitor interaction with a multi-touch table in a museum. In *Proc. IEEE Tabletop'08,* 113-120. ACM.

25. Humphrey, T. and Gutwill, J. (2005). Fostering active prolonged engagement: The art of creating APE exhibits. *San Francisco, CA: The Exploratorium*

26. Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S. & Davies, M. (2011). Rethinking 'multi-user': an in-the-wild study of how groups approach a walk-up-and-use tabletop interface. In *Proc. CHI'11*, 3033-3042. ACM Press.

27. McCauley, D. J., Pinsky, M. L., Palumbi, S. R., Estes, J. A., Joyce, F. H., & Warner, R. R. (2015). Marine defaunation: Animal loss in the global ocean. *Science*, *347*(6219), 1255641.

28. Mckenzie-Mohr, D. and Smith, W. (1999). *Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing*. New Society Publishers.

29. Linehan, C., Kirman, B., Lawson, S., & Chan, G. (2011). Practical, appropriate, empirically-validated guidelines for designing educational games. *Proc. CHI'11,* 1979-1988. ACM.

30. Piper, A. M., Friedman, W., & Hollan, J. D. (2012). Setting the stage for embodied activity: scientific discussion around a multitouch tabletop display. *International Journal of Learning Technology 7*(1), 58-78

31. Rick, J., Marshall, P., & Yuill, N. (2011). Beyond one-size-fits-all: how interactive tabletops support collaborative learning. In *Proc. IDC'11*, 109-117. ACM.

32. Ryall, K., Ringel Morris, M., Everitt, K., Forlines, C., Shen, C. (2006). Experiences With and Observations of Direct-Touch Tables. In *Proc. IEEE Tabletop'06*, 89-96. ACM.

33. Snibbe, S. and Raffle, H. (2009). Social immersive media: Pursuing best practices for multi-user interactive camera/projector exhibits. *In Proc. CHI'09,* 1447-1456. ACM.

34. Verbeke, W., Vanhonacker, F., Sioen, I., Van Camp, J., & De Henauw, S. (2007). Perceived importance of sustainability and ethics related to fish: A consumer behavior perspective. *AMBIO: A Journal of the Human Environment*, *36*(7), 580-585.

35. Wyles, K. J., Pahl, S., White, M., Morris, S., Cracknell, D., & Thompson, R. C. (2013). Towards a Marine Mindset: Visiting an Aquarium Can Improve Attitudes and Intentions Regarding Marine Sustainability. *Visitor Studies*, *16*(1), 95-110.