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RESEARCH ARTICLE

Teaching fisheries bycatch: Exploring economic and behavioral drivers of bycatch through a classroom game

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Abstract

This paper presents a pedagogical exercise to explore the economics of price-based fisheries bycatch. In the exercise students experience the economic incentives that lead to bycatch due to highgrading; the discarding of low-value fish. We first discuss existing fisheries economics pedagogical activities and how our exercise is distinct. We then identify over forty economics, environmental studies, geography, management, and philosophy courses where the exercise could be played. Next, we describe the game and share results and student feedback. Finally, we provide discussion prompts and extensions to illustrate how incentives and policies can change fishing behavior to lead to sustainable fisheries.

Keywords: classroom game; economic education; economics games; fisheries bycatch; sustainable fishing; bycatch; teaching fisheries

JEL Classification Codes: A22; D21; Q22; Q57

Introduction

Bycatch are the secondary low-value fish or other aquatic animals (dolphins, turtles, etc.) which are caught/harvested when a fishing vessel is attempting to catch an economically valuable fish (Kittinger et al. 2017, Miller and Deacon 2017, Clucas 1997, Hoagland and Jin 1997, and Larson, House, and Terry 1996). The public might be aware of some high-profile bycatch issues through labels like “dolphin-safe tuna,” yet, there are many lesser-known bycatch issues related to market prices and fishery regulations related to population dynamics (Copes 1986; Anderson 1994). We focus this classroom game on price-based bycatch, also referred to as a type of highgrading where only the highest priced fish species are kept and sold on the market and the low-priced edible fish species are discarded as bycatch (Copes 1986; Anderson 1994). Typically, much bycatch is discarded, leading to significant waste. In fact, a study by Oceana found that roughly one-fifth of the total weight of commercial aquatic catches in the United States is bycatch (Keledjian et al. 2014).

Bycatch is a relevant topic for students and others to understand for a large and important reason: the world is starving, with roughly 10 percent of people being chronically undernourished (FAO 2019), and its fisheries are overharvested, with roughly one-third of fisheries being overfished in 2015 (FAO 2018). A growing world population only exacerbates these problems. Meanwhile, many commercial fisheries discard a substantial amount of their catch back into the sea. Discarded fish usually have died from oxygen deprivation when they are dumped back into the ocean by commercial fishing vessels in search of the highest-value payload. Stopping wasteful discarding of edible bycatch fish could be a key to transforming our fisheries into sustainable sources of food, while feeding the planet's most malnourished.

Many of the world's fisheries are exploited. Many popular species of fish are threatened with population collapse if an ever-increasing world population continues to pursue them beyond their ability to reproduce and to regenerate their numbers. The world's reliance on seafood is no casual matter. While many people in inland US cities or other landlocked regions of the world might consider seafood a novelty or exotic menu option, approximately three billion people in the world rely on wild-caught and farmed seafood as a primary source of protein (WWF 2021) and about 10 percent of the global population depend on fisheries for their livelihoods (FAO 2018). In fact, between 1961 and 2017, the growth rate of global food fish consumption is almost twice the growth rate of the global population (FAO 2020). From coastal developing nations to the thousands of sea-locked islands in the world's oceans and seas, cultures and civilizations, including those of advanced nations such as Japan, revolve around or depend profoundly upon sea life – and, necessarily, the health and sustainability thereof.

In this paper, we introduce a pedagogical aid by way of a classroom activity that is useful at secondary or higher levels of education as well as for the training of policy makers to highlight the economic factors guiding decision-making in a fishery and why the discarding of price-based bycatch or highgrading is prevalent.[1] We focus our activity on bycatch waste related to highgrading, the discarding of low-value fish either due to being a different species or potentially due to size or other characteristics that impact market prices (Copes 1986; Anderson 1994). Even policy makers can benefit from experiencing the simulation, in order to understand the decision-making process from the commercial fishers' point of view, thereby gaining a greater grasp of the problem to be addressed through policy initiatives. Postsecondary courses where our learning exercise may be relevant to the instructor's course objectives can include courses in resource and environmental economics, game theory, and general microeconomics courses. In Table 1, we highlight a few courses and question(s) relevant to each course's objective(s) that our activity should help the instructors meet.[2] For a full list of relevant courses, we refer the reader to Appendix III.

This list highlights some of the courses in which the game most readily adds value to the experience of students and the discourse that they and instructors can have about fisheries and bycatch within the courses' objectives. Nearly, any course which studies profit-maximizing choices, environmental policies, or environmental externalities related to food sources might find a way to incorporate our exercise to teach those and other elements of economic and environmental decision-making, but it is in the category of resource and environmental economics that our simulation is particularly relevant. For faculty of

[1]We introduce in Section 4 other ways to run the activity such that it may become a traditional experiment with students facing different treatments to understand how incentives in the mechanism drive the behavior more fully.

[2]The stated objectives are from syllabi of courses at Portland State University. We believe that many of these objectives are ubiquitous in classes such as these at any university.

Table 1. Select courses in which our exercise supports learning objectives

Course titles	Curriculum-relevant question
Contemporary Economic Issues	How do the economy and the environment complement one another, and in what ways do you see them conflicting, as highlighted by this game?
Principles of Microeconomics	What decisions does profit maximization drive, and what are the potential environmental consequences and related externalities?
Intermediate Microeconomic Theory	How does a decision maker determine quantity in order to accurately assess the point of profit maximization, when MR and MC lines meet?
Natural Resource Economics	How can the bycatch problem be addressed to minimize negative ecological impact?
Economics of Environmental Issues	What externalities, if built into the marginal cost of drawing, could influence the decision of quantity of draws?
Economics of Developing Countries	How can developing countries be incented to make environmentally sustainable choices?
Environmental Sciences	How can economics create tension with ecology? How can discarding bycatch fish contribute to environmental degradation? Can conservation measures help?
Environmental Political Theory	How would discarding edible fish be viewed in the light of sustainability? Green radicalism? Rationalism?
Issues in Public Policy	What are the challenges of implementing environmental protections against discarding bycatch?

introductory economics courses, we find this exercise very beneficial to teach profit maximization but also introduce the ways in which economics interacts with the environment; here you can introduce tragedy of the commons broadly, policy measures to correct externalities, and environmental issues, represented in this exercise by wasted bycatch.

We structure the remainder of the paper by first discussing other pedagogical exercises involving fisheries (Section "Classroom exercises to teach fisheries"), then we introduce our pedagogical exercise (Section "The bycatch teaching exercise"), we share student feedback (Section "Feedback and data from authors' classroom sessions"), and finally we end with extensions and additional treatments (Section "Discussion prompts") and a set of discussion prompts to lead discussion in the class (Section "Other treatments and their purposes").

Classroom exercises to teach fisheries

While games, simulations, and interactive learning have been shown to be effective pedagogical tools in the collegiate classroom (Nemerow 1996; Holt 1999), our proposed Fish Bycatch Game makes a unique contribution to literature by focusing on commercial fisheries bycatch. While turtles, porpoises, and other endangered species have drawn wide attention for their inadvertent catching by tuna boats, little attention has been focused on the quiet loss of biodiversity as a result of the systematic catching and discarding of bycatch of non-recreational fisheries (Halliday et al. 2001). When playing the Fish Bycatch Game, students come to understand the economic incentives that drive the catching and discarding of commercial fish species. Students experience the tension between economic necessities and rewards on the one hand and the impacts on marine life and biodiversity on the other. Participants experience the moral and ecological dilemma of wasting marine life in the pursuit of fish as a source of sustenance.

We found no other game or simulation resource for instructor use at the undergraduate collegiate level that focused on bycatch and framed the tension between economic incentives and the well-being of commercial fish populations. There are multiple classroom games that focus on common pool and natural resource management that use fisheries as the application (Giraud and Herrmann 2002; Secchi and Banerjee 2019) and multiple games and simulations that can be used to teach fisheries economics (Whitmarsh 1994; Dissanayake 2016; Cloud Institute 2019), but our game is distinct in its focus and application on price-based bycatch (highgrading) and the discussion of solutions to diversify fisheries. For completeness, we first describe the other games and pedagogical exercises focused on fisheries and highlight the differences and overlaps with our Fish Bycatch Game.

The semester-long social dilemma game (Secchi and Banerjee 2019) explores the role that economics plays in natural resource management, using fisheries as an application. Students function both independently and as part of a group, sensitizing them to the externalities of their individual decisions, as prizes are awarded both for individual as well as group performance. In this manner, the social dilemma is emphasized, and students experience an awareness that some decisions they make for the good of the group are different from the decisions they would have made strictly out of individual self-interest. Likewise, in making certain decisions in their own self-interest, they become keenly aware how their decision is negatively impacting the group. The game is framed to cause this social dilemma to be inescapable. The outcome is that students gain an awareness of externalities of their choices, the conflicts between competing economic interests, and the effects on behavior that economics and social pressures play. Our game focuses solely on economic tensions, rather than social factors, and on how students' decisions affect bycatch species. The Fish Bycatch Game we introduce is also distinct because it is designed to be played in one class period, as opposed to being a semester-long activity like the social dilemma game.

The open-access resource game (Giraud and Herrmann 2002) is designed to lead students to explore problems of open access using fisheries as an example. This game uses an in-class candy collection setup and features three rounds, each involving any one of five different scenarios, exploring a variety of policies, from unregulated open access to capital restrictions, time restrictions, and property rights, including common property and individual transferable quotas (ITQs). This game clearly demonstrates the tragedy of the commons allows students to feel the tensions between short-term exploitation and long-term optimal yields and serves as an effective on-ramp to any of a myriad of discussion topics that professors may want to have surrounding allocation of renewable resources and their management. Our game does not come close to duplicating its treatment of these topics, because our game is focused specifically on bycatch, and more specifically on the discarding that results from price-based species discrimination, or highgrading. Our game allows students to feel the tensions that lead to discarding edible fish. Our postgame discussion leads them to consider what happens to non-prime fish populations when subjected to highgrading. While the fifth scenario of Giraud and Herrmann's game features an optional alternative to explore the problem of highgrading associated with ITQs, defining highgrading as removing the largest and most valuable fish while leaving the smaller ones, our game distinguishes itself by making species-specific highgrading the central focus of all its rounds, with students tracking and tallying the number of bycatch discarded, not just the fish that are kept as "profit," as in the other game. The result is a strong sense that the economic win (from fishing and discarding to an optimum payload) came at the cost of an environmental loss to another living species. While the Giraud–Herrmann game fulfills several important purposes and focuses broadly on common pool resource management, our game fulfills a single objective in very focused detail. In particular, our game includes not only just discriminating what you catch, but also discarding bycatch.

The Cloud Institute's fishery games (Cloud Institute 2019) specifically explore profit maximization in a tit-for-tat game theory environment, where "other [virtual] player" responses are known in advance to mimic player choices. The student is given first-player advantage. The emphasis of the simulation is on overall population of a game species in a fishery. The outcome is that students learn that sustainability of a fishery is dependent on restraint from overfishing/exploitation, and that such restraint is ultimately rewarded over time with a larger harvest than would be gained by short-term exploitation that leads to collapse of the fishery population. The framing of the game makes it very likely that the uninitiated student will "overfish" and suffer a total 10-day catch that is below the benchmark. In subsequent games, she is likely to exercise early restraint in order to tease out a larger net harvest. One observation is that she is rewarded for exploiting the fishery in the final days of his/her 10-day expedition, as there is no incentive to leave an intact fish population on the tenth day. This may be intentional but seems to partially undermine the main point of the exercise. The Cloud games' emphasis on total population, their imposition of tit-for-tat opponent strategy, and their shared focus on sustainability of game/recreational fish populations within the fishery mean that both the learning outcomes and the subjective experience of the student playing the Cloud games are markedly different from those of the student playing our game. Also, our game's emphases on bycatch and related threats to biodiversity as well as the wasting of nutritious protein sources distinguish it from the Cloud games.

The spreadsheets by Whitmarsh (1994) employ computer-aided instruction (CAI) to teach fishery economics to students. The spreadsheets perform calculations, making it possible for the student to see the results and outputs from a complex economic fishery model quickly and without requiring lots of complex equations. This format enables students to conceptualize issues such as carrying capacity while ignoring the deeper mathematics. The outcome is that students gain an appreciation for what Whitmarsh terms "some of the analytical complexities of the economics of fisheries." The Fish Bycatch Game's dual emphases on economic incentives to maximize profit and an awareness of the noneconomic cost of discarded fish (which is quantified in our game) distinguish the learning outcomes and student experience of the Fish Bycatch Game from those of the CAI experience provided by the Whitmarsh spreadsheets.

The STELLA models by Dissanayake (2016) are a robust depiction of a fishery's game species populations focused on emphasizing the value of multiple cohort stock models that allow for targeted policies (by size or spatial region). Accounting for carrying capacity and being sensitive to overfishing, the models are an effective and visual portrayal of the ups and downs of a fishery's vitality, clearly depicting the impact of overfishing. The outcome is that students understand the delicate ecological balance that is a fishery, and they see that overexploitation runs contrary to maximizing total output by inducing a fish population collapse, which undermines the economic objectives of fishers. Students can clearly appreciate the role that social or governmental interventions play in keeping fishing restrained to levels that maintain sustainability of the fishery. The emphasis of the Fish Bycatch Game is on the economic incentives that drive discarding bycatch, and the resultant loss of marine life and of viable protein sources, distinguishing the Fish Bycatch Game from Dissanayake's STELLA models.

Another computer-based teaching tool is *What's the Catch?*, an interactive computer-based video game designed to engage children, hosted on the website of Fishery Solutions

Center (https://fisherysolutionscenter.edf.org/catch-share-basics/whats-catch-fishing-game). Players earn dollars to upgrade fishing gear and boats, incur fines for bycatch, and attempt to dodge storms (and collisions with other boats) to stay afloat and in business. The game is a full-featured fishing simulation that challenges the player to catch enough fish to stay in business while avoiding numerous natural, economic, and regulatory pitfalls. The outcome varies depending on length of play, because repeated financial successes are required to level up through 40 levels of play with increasing complexity and difficulty. It is holistic and is a bona fide video game played in real time. The more academic approach of the Fish Bycatch Game and its focus on student decision-making to maximize profit by controlling marginal costs (MC) against marginal revenue (MR), as well as the game's relative brevity, distinguish the Fish Bycatch Game as a collegiate pedagogical tool that supports both microeconomic and natural/resource economic course objectives without consideration of boat motor size, upgrades, inter-vessel collisions, weather conditions, and other considerations that are outside the scope of a typical environmental economics course but are central to *What's the Catch?*

Fishbanks: A Renewable Resource Management Simulation is a web-based simulation hosted by MIT Sloan School of Management. Players act as fishers seeking to maximize their net worth while competing against other players online in real time (play is synchronous). Fish stocks vary. Players buy, sell, and build vessels and carry out auctions with other players. Options explore permits and quotas. The outcome is that students gain insight into the complexity of and skillsets needed to manage a fishing enterprise profitably and fisheries sustainably. *Fishbanks* is geared toward management students and trainees and has a wider scope (i.e., business) than our game. The Fish Bycatch Game's relative simplicity, in-classroom setting, and focus on economic concepts and on bycatch distinguish the Fish Bycatch Game from MIT Sloan's *Fishbanks*.

In summary, while a variety of games, simulations, and quantitative models (Excel spreadsheets, STELLA models) exist for the purpose of exploring a variety of economic facets of fisheries and fishery management, the Fish Bycatch Game makes a unique contribution to the field of pedagogical games in its strong focus on highlighting the fisheries bycatch problem that results from raw economic incentives present in the marketplace. We focus on highgrading, a type of bycatch issue focused on discarding low-value fish (Copes 1986; Anderson 1994). Students gain a real feel for the decision-making that goes into profit maximization, and how market price differences lead to occurrences of discarding edible game fish. The postexercise discussion allows a deep exploration of both how economic incentives lead to an increase in bycatch and also how economic and behavioral approaches can lead to a solution.

Our game can also complement the fishery-related classroom games and simulations as we explore a new dimension related to price-based bycatch. We suggest playing our game after playing the fishery-related games or conducting the simulations, as we present a more focused exploration of one issue related to fisheries bycatch.

While novel and new in its approach and its focus, the Fish Bycatch Game holds tightly to established learning objectives in both microeconomics and resource economics, thus making its inclusion in the curriculum a sound pedagogical decision that brings fun, interaction, and hands-on experiential learning to the classroom while furthering learning in an engaging way that students are unlikely to forget. The extensions to the game, offered as options in the main text, explore how these incentives can be modified by (1) taxation, (2) regulation, and (3) behavioral nudges to effect positive change that benefits both the fishers and the fish populations.

The bycatch teaching exercise

Description of the exercise

Each student plays the role of the decision maker for a commercial fishing enterprise whose livelihood depends on the value of a fish harvest. There are four species of fish and they have differing market prices, with the base scenario having two high-value fish and two low-value fish.[3] The student fishes round by round; you can explain these rounds as hourly or daily effort tasks. We explain this as one throw of a net, and each fishing trip can consist of multiple net throws but each net throw (and bringing in the harvest) takes time. In each round, the student collects new fish. We explain that the finite capacity of the boat places a limit on the number of harvested fish the boat's captain can bring back to port for money. The primary choice the participating student makes is whether to continue to fish when her boat is full. If she chooses to continue fishing, she must discard some of her already-collected fish to have room to store the new catch. Simply, when the day's catch consists of a blend of high-value game fish and low-value bycatch, students must decide whether they want to discard fish of lower value in order to make room for more fish, thereby likely increasing the value of the ship's payload. As continuing to fish uses more resources (time, fuel, etc.), the student's face the trade-off of potentially higher revenues against the constant marginal cost of resources spent continuing to fish and perhaps an ethical cost of discarding edible fish.

We have parameterized the game such that each fishing round brings in three fish, and each participant's boat can hold three rounds of fish (nine fish, in total). Thus, after the third round, decisions involve creating waste via discarding bycatch of economically less-valuable fish and attempting to increase the boat's profit. Every round that a student continues to fish will create three more discarded fish in addition to requiring her to pay the associated marginal monetary cost for her ongoing fishing. Net profit for the student when she finishes is the value of the nine kept fish less fixed and variable costs seen in Equation 1 below:

$$\begin{aligned}\text{Earnings} = \text{Value of Final Catch} - \text{Fixed Expedition Cost}\\ -(\text{Variable Cost} * \text{Number of Draws})\end{aligned} \tag{1}$$

The following section discusses how we implemented the game in a classroom and offers advice for those who wish to do so.[4] This supplements the Instructor's Guide, provided in Appendix I, which contains a detailed explanation of running the game for a group, including a presentation for after the game that can be used as it is or modified according to your needs. Appendix II provides instructions and game sheets for players.

[3]We have typically used prices of \$6, \$5, \$4, and \$3. At the same time, one of the extensions that we propose, varying the differences between high-value and low-value fish species, can be incorporated directly into the first version of the game by changing the prices to \$7, \$6, \$3, and \$2 or even \$8, \$6, \$2, and \$1. More details are discussed in the next section.

[4]If practicable, we suggest that you pay one or more participants an amount of money proportional to their earnings. This makes the game's incentives real for the players. Since payouts rarely exceeded \$25, we found it feasible to pay two players: One randomly selected student who agreed to participate in the full physical game in the front of the room, and a second randomly selected student from those who played the paper version in their seats. This second paid participating student is selected after play was concluded. In both cases, the real dollar payout matches the net profit from the player's play of the game. (In earlier iterations, we paid ¼ of game profits, with real money payouts topping out at \$5.)

Implementation of the game in the classroom

This section provides a detailed explanation of how to prepare for and conduct the game, but Appendix I provides the Instructor's Guide to run the game in bullet point format for quick reference. We suggest you plan the game to take a single 50-minute class period or about 50 minutes out of a longer class period. In a class period longer than 50 minutes, the postgame discussion is easily extendable to be more inclusive and address all relevant course learning objectives.[5]

You might consider directing students to relevant readings before the class session in which you perform this interactive demonstration. Studies on fishery bycatch are numerous, as are studies emphasizing the catastrophic results of fishery exploitation and chronic overfishing. Students not only see the tragedy of the commons on full display but also gain an appreciation for the delicate nature of ecosystems and the startling degree to which the world's food supply is in jeopardy. For a discussion that focuses on bycatch, Lewison et al. (2014), Wallace et al. (2010) and (2013), Shester and Micheli (2011), Finkbeiner et al. (2011), and Read, Drinker, and Northridge (2006) provide a broad overview as well as specific case studies. For a discussion on solutions and economic drivers, Miller and Deacon (2017), Chan and Pan (2016), Holland (2010), Segerson (2010), Len and Squires (2017), Kirby and Ward (2014), Pascoe et al. (2010), and Larson, House, and Terry (1996) present a broad range of economically based solutions. Recent journal articles or blog posts connected to the subject can help engage students in deeper understanding and prime them for the in-class simulation provided by the game. We also recommend showing one or both of the short videos listed on the Instructor's Guide that illustrate how consumer demand for high-value species and differential price lead to price-based bycatch discarding.

Before running this simulation in class, it is imperative to choose which mechanism to use for the students' catches (their "draws") and to identify the fish species they caught. The Appendix depicts the four-sided dice method we used in our trials, which were available cheaply online, but free online random number generators are also very easy to access on a computer or on the students' phones.

Distribute the instructions and recording sheet (found in Appendix II) to students in advance and ask them to read both before class begins.[6] Though we developed the game to have a maximum of eight draws, you can limit the number of draws to six or seven to ensure timely completion of the game without compromising the overall results (there is no value in increasing the upper limit, however). Many students will choose to stop fishing after five rounds, and few, if any, will persist beyond six, but the high upper limit of eight practically ensures that students conclude fishing by choice rather than by the exercise's terminal round forcing them to do so. In the base version of the game, the other parameters of the game should remain fixed unless the instructor wishes to run the suggested alternative forms of the activity outlined in Section "Feedback and data from authors' classroom sessions." The detailed game play discussion and the results we present are for the base version of the game. As noted previously, it is possible to directly start with the varying price treatment; in our more recent use of the game, we now start with this treatment.

[5]Students completing the game seem particularly receptive to economic theory that explains their experience. Professors may find that their teaching is optimized, as students are primed for learning. This is further discussed in Section 3.

[6]If starting with the varying price difference treatment, use the recording sheets in Appendix II-B and Appendix II-C. Ensure that high-price and low-price treatments are distributed roughly equally among the students.

Begin by handing out recording sheets at the beginning of the session. Explain that during the game, as the activity progresses, students individually record their results on their recording sheets to document the simulation. This setup ensures that the instructor has time to run the full exercise and gives the students more ownership of the outcomes. It is helpful to build curiosity about the outcome and for students to understand that the game is not a competition between students so that they do not feel incentivized to cheat on that basis. Terms such as *simulation* or *exercise* may be less likely to incite overzealous competitiveness than repeated use of the word game in describing the activity.

Randomly select one student to play the game in front of the classroom, if desired. In each of our classroom sessions, we did so. For each draw, that student drew three physical, colored nylon fish from an opaque container (which held 20 of each of 4 colors of nylon fish) to make their selections, while students at their desks simultaneously rolled their set of three dice to generate their "draw." Having the one student up front served two purposes. First, it helped other students to see how the game was working with actual draws of physical, tactile items (multicolored nylon fish). Secondly, this setup allows the instructor to ensure that the pace of the game moves smoothly, as all the students with dice are watching and participating with the one student up front, ensuring everyone is going at the same pace. The students at their desks can see how to fill out their decision sheets correctly by watching someone else do it in real time.

Introduce the game and clearly post how payoffs are calculated (Equation (1)) and the labeled Price List that specifies the value paid *to* the participating students at the end of their fishing expedition based on their kept fish.[7] Also, display (project or write on the board) a table that shows the correlations between the dice numbers rolled and the color of fish being drawn as a result.[8] Distribute the dice or otherwise ensure students have access to the randomization method you have chosen.

Explain that the entire class will roll their dice simultaneously and that the game proceeds in a synchronized fashion. Encourage students to ask questions during the game to ensure that there is no confusion and that the students record all their choices correctly. Emphasize that players will record their rolls and their subsequent decisions on the game result sheets. They will record their draw and discard outcomes as the instructor shows those of the chosen student up in the front of the room. In this way, all students will understand via watching and explanation how to complete their sheets and will stay synchronized with the instructor.

From the discussion of payments, costs, and revenues, students should understand the objective of the game is profit maximization and that maximizing profit is the criteria they should use in making their decisions during the game. Emphasize to the students that the commercial fisher's livelihood depends on fishing[9]. As one of our colleagues graphically

[7]If the varying price difference treatment is being implemented, then only put the prices in the student's worksheet (and not on the board or screen as the fish prices would depend on the treatments that the students are in).

[8]For example: 1 to orange, 2 to green, 3 to blue, and 4 to purple.

[9]We want to highlight the importance of emphasizing the profit-maximizing motive as students play the game. In general experiment settings, and to quote a reviewer who inquired on this aspect, "inculcating the profit-maximizing objective would be a very strange approach for most experiments in economics." At the same time in this game, unlike with experiments in experimental economics research, we do not provide incentives based on participants decisions. Therefore, participants could easily and costlessly choose to not discard any fish. Therefore, we recommend highlighting and emphasizing the profit motives to way to help the student players adopt to the mindset of a commercial fisherperson who often will not have the luxury of abandoning the profit motive.

Further, the behaviors that flow from this objective comprise the learning experience, as well as the framed this point with regard to another classroom pedagogical exercise, "If they don't bring in a sufficient income, there will be starving children who will cry all night long."

Once an overall understanding has been achieved, and students are clear about (1) the payoffs listed on the Price List, (2) that their fixed cost for the day's fishing expedition is \$10 and their per-draw variable cost is \$3 for every draw from the first draw, and (3) that they should proceed synchronously with your directions, you are ready to orchestrate the first draw.

Commence with the first draw. The student up front will blindly draw three fish from the container, while students at their desks will roll their three dice. Have students record the three fish that their draw yielded by writing in the white boxes beside DRAW 1 the first letter of each color of fish drawn.[10]

Proceed with the second draw and repeat the recordkeeping; then the third.

After the third draw, and after every subsequent draw, they will make a decision. Their choice will be whether to quit fishing (for the day) or to continue to draw again, at the cost of \$3 per draw. After the third draw, many students will elect a fourth draw. Those who do will face a decision of which three fish to discard after they catch the three new fish. They will record their discard decision on the game sheet. Then, those who are still fishing will again decide whether to quit fishing or draw again. For each round, it is important to ensure that all students are moving simultaneously to avoid confusion, only when the whole class has made decisions about the current round should the students who are still fishing then roll their dice for their next draw. Every draw after the third draw repeats these two decicions; after the draw they decide which fish to discard and then they decide to quit fishing or continue fishing. This process repeats until all students finish fishing or the game reaches the terminal round.

The iterative process of the game, along with the steps for each round in order, is outlined in Table 2.

Finally, ask students to prepare their recording sheets to be collected. Direct students to fill in their final haul in the nine boxes provided and to sum the value of the resultant catch. Collect game materials and lead the debrief and discussion or instruct the students how to prepare to have a discussion in the next class session.

A quick and easy alternate framing of the game to highlight the importance of price differences on bycatch outcomes can be achieved by distributing varying sets of prices for the potential fish species. With a large enough class, this will highlight the differences in bycatch rates as a function of the price variation. Instructors can include a discussion about methods to reduce bycatch by diversifying fisheries. Section "Economics and policy variations" discusses this treatment in detail. Next, we present the data and student feedback from the base version of the game.

Feedback and data from authors' classroom sessions

An analysis of the students decisions

In this section, we present data on our most recent and refined version of the game, described above. We report observations from playing the game in a game theory class

tensions, decisions, and increasingly stark awareness of the negative environmental impacts of short-run profit-maximizing behaviors. This sets the stage for postgame discussion that illuminates students to the environmental-economic win-win of fisheries management, quotas, tradable property rights, etc., and the concepts of sustainable yield, long-run maximum yield, and tragedy of the commons.

[10]For example, "BPG" would be written by a student who drew one blue, one purple, and one green fish. "OGO" would be recorded by a student who drew one green and two orange fish. The order in which students list these fish is unimportant.

Table 2. Round-by-round actions of students

	DRAW
Step 1	Roll Dice (or other method) to Determine which Fish are Harvested
Step 2	Record These Fish
Step 3	If Round < 3, Go to Step 1 for Next Round If Round $= 3$, Go to Step 6 If Round > 3, Go to Step 4
	DISCARD
Step 4	Choose Three of Twelve Available Fish to Discard
Step 5	Record Discarded Fish
	DECIDE
Step 6	Decision: Quit or Continue If Continue Fishing, Proceed to Step 1 If Stopping Fishing, Activity Ends for Student

at a regional state university in spring 2019. We have 26 observations from 26 respondents. The data are both qualitative and quantitative. It is important to include each so that we can see what students chose to do (quantitative) but also understand why they did it and what they learned/took away from being engaged in this activity (qualitative).

We start by introducing the quantitative data. Many of the students engaged in what seems like profit-maximizing behavior. This outcome is not surprising given that many fishing companies behave in this manner and that it is the outcome standard economic theory suggests. In the tables and figures below, we display this data in an easy-to-process format.

First, we present the Total Revenue and Total Cost (Figure 1), the Marginal Revenue and Marginal Cost (Figure 2) and the Count of Marginal Revenue by Round (Figure 3). The first two figures should be familiar to anyone who has taught the classic fisheries economics section in an environmental or resource economics course. Even with just 26 observations from this session, we find that in general total revenue increases with fishing effort (number of rounds) and the marginal revenue decreases, supporting that the use of the game complements teaching the basic fisheries model. Furthermore, Figure 1 and Figure 2 indicate that based on the specified parameters, the maximum economic yield would be at four draws, and Figure 2 indicates that the net marginal revenue becomes negative from the fifth round for the fishery in aggregate.

It is important to note that Figures 1 and 2 show aggregate outcomes for the class (fishery) as a whole. We use Figure 3 to present the individual decisions focused on the marginal revenue for each player for every round in which they decide to engage in a draw. Figure 3 indicates three outcomes; first, the marginal revenue of an added round of fishing is high for the initial rounds. Second, for rounds after round three, when each player's boat becomes filled to capacity, the marginal revenue starts decreasing. This is because for the marginal revenue to increase, the player must draw at least one fish that has a higher price than the nine fish in the boat, and the probability of this decreases as the number of rounds increases. Third, it is also important to note to the students that since the marginal cost per draw is \$3, any marginal revenue not exceeding \$3 results in zero or negative marginal

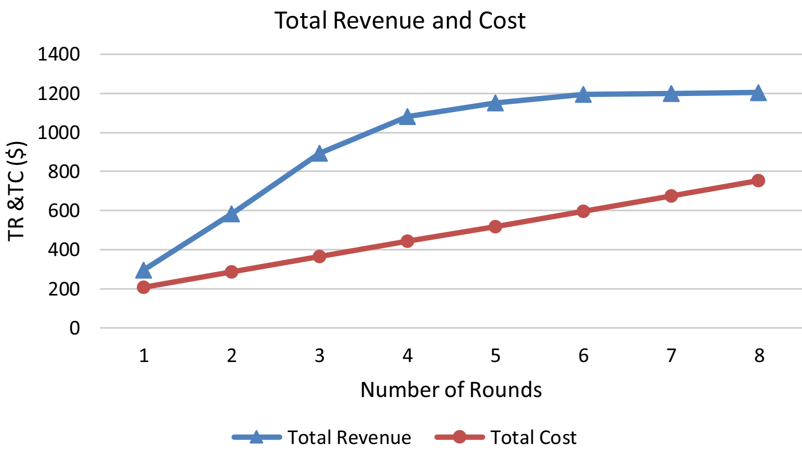

Figure 1. Total cost and total revenue.

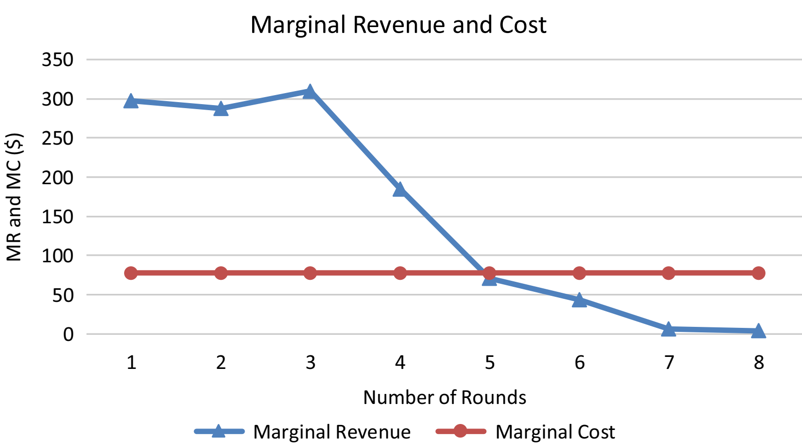

Figure 2. Marginal cost and marginal revenue.

profit. In this instance of play, we see that in a total of nine draws (three in round five, one in round six, one in round seven, and four in round eight), players lost money.

Now that we have shown that the game complements the classic fishery models, we turn to study the outcomes of these fishery decisions on bycatch. Figures 4, 5, and 6 show the stock of accumulated harvest (the fish kept in the players' boats) by round, the discarded fish each round, and the accumulated discarded fish by round, respectively. The values for each of the four fish species are shown separately in each graph.

Figure 4 shows that as the rounds progress, the accumulated harvest of the high-value fish, blue and purple fish, increases, while the accumulated total of the low-value fish, orange and green, decreases. In particular, the harvested stock of the orange fish, which has the lowest value, drops towards zero rapidly, as this is the fish that players are most likely to discard. We see this illustrated in Figures 5 and 6, where the orange fish that were

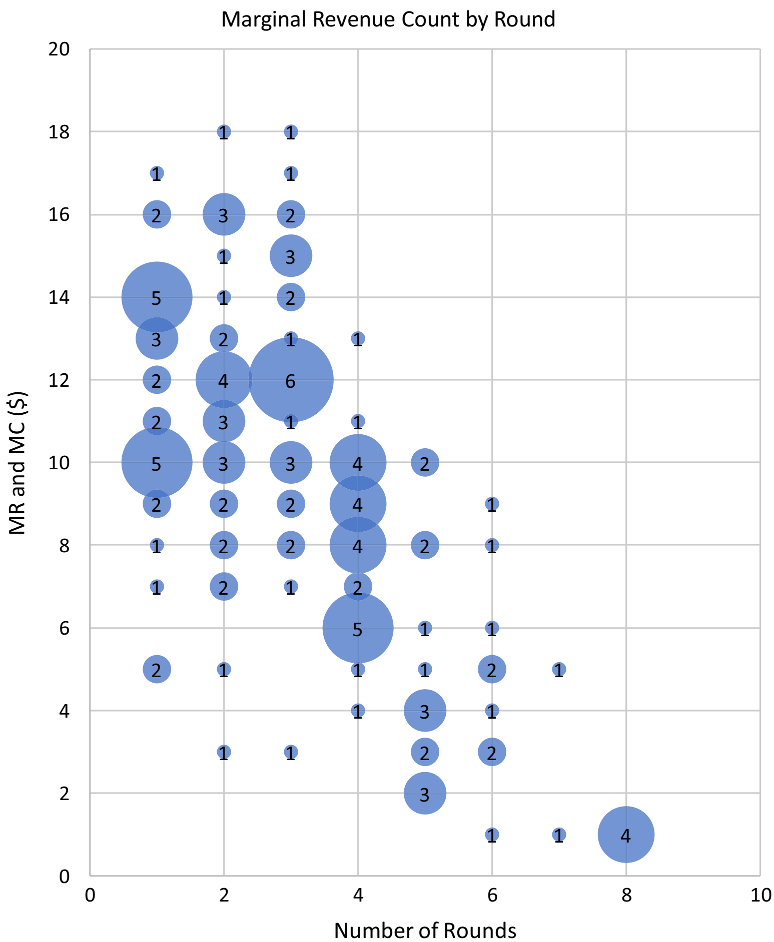

Figure 3. Marginal revenue count by round.

caught in the early rounds are rapidly discarded from round four onward. We also see that the blue and purple fish are rarely discarded, and that discards of the blue fish only happen in the very late rounds.

Our purpose including these results in the paper is to highlight (1) that the structure of the game and the resulting decision-making simulated the classic fisheries models taught in undergraduate and graduate classes and (2) that the game clearly illustrates the occurrences of bycatch and how the relative market prices of fish drive bycatch outcomes, especially discarding. Next, we discuss the student feedback on the game and how the game helped achieve specific learning outcomes.

A discussion of learning outcomes and student feedback

Now we turn to the qualitative discussion – that is, what did students say they were doing and why did they behave the way that they did in this game. We report observations from

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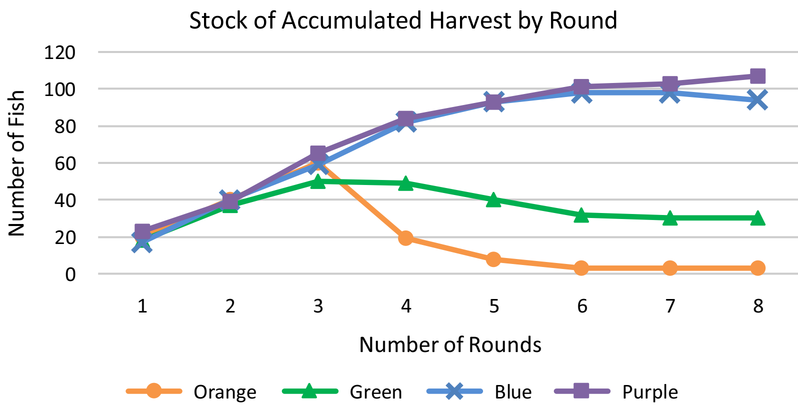

Figure 4. Stock of accumulated harvest by round.

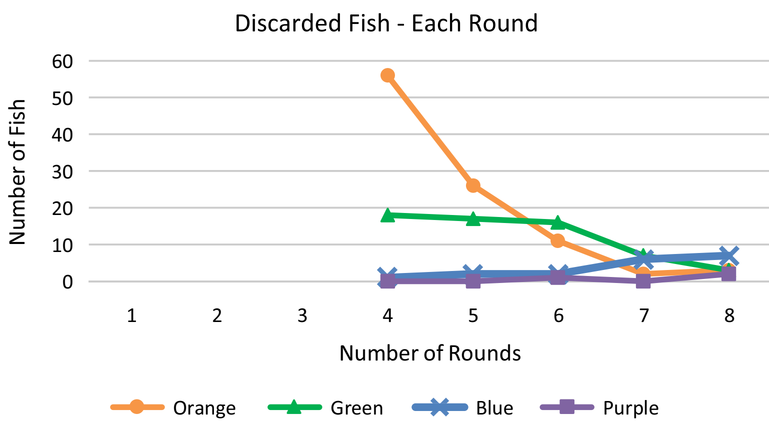

Figure 5. Discarded fish in each round.

playing the game in a game theory class at a regional state university in spring 2019. We conducted an informal postgame feedback where the students were given a short one-page survey on the game and the learning outcomes. All of the 26 students in class on the day we conducted the game participated and filled out their feedback forms.

We first summarize how playing the game contributed to participants' learning about eight important concepts relevant to the game. Specifically, we asked "*Did you understand how each of these concepts was incorporated into the game and discussion? Please choose the appropriate option (strongly agree to strongly disagree) for each concept*. The results are summarized in Table 3. A majority of participants agreed that these concepts were reflected in their experience with the game, and some of the topics (such as economic incentives, undervalued fish, and market prices and catch decisions) had even stronger recognition with more than 90% of participants choosing Strongly Agree or Agree for these concepts.

Some concepts, specifically common pool resources and fisheries diversification, had a lower number of participants selecting Strongly Agree and Agree. This finding is not

Table 3. Participant recognition of topics in the game

Economics and fisheries concepts	Percentage
Marginal cost and benefit	88.46%
Total cost and benefit	92.31%
Economic incentives	92.31%
Common pool resources	73.08%
Undervalued (or trash fish)	96.15%
Bycatch	84.62%
Market prices and catch decisions	96.15%
Fisheries diversification.	57.69%

Note: Cells contain percentages of responses to the question, "Did you understand how each of these concepts was incorporated into the game?" that were "Strongly agree" or "Agree" for the named topic.

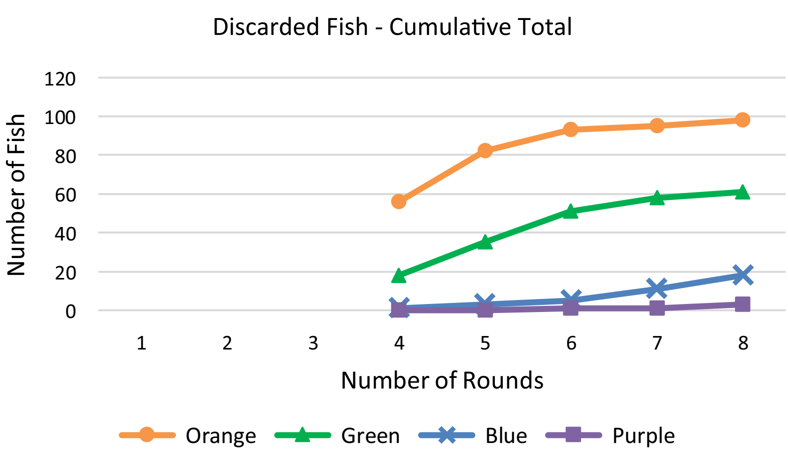

Figure 6. Cumulative total of discarded fish by round.

surprising as these concepts are key discussion items that follow the activity, but we conducted the survey prior to the discussion to elicit feedback on the game itself. Further, we played the game in a game theory class, and as such, we did not hold a detailed discussion of these concepts.

The feedback form also elicited answers to open-ended questions about the game. When asked "What were the main takeaways and lessons from the game and the discussion/presentation?" 61% (16) of respondents discussed how economic incentives contribute to discarding bycatch in fisheries, 42% (11) discussed environmental and ethical aspects of fisheries bycatch, and 19% (5) identified or discussed the optimal stopping point to maximize returns.

The participants also clearly identified the motivations that lead to discarding of low-value fish. When asked "Which fish, if any, did you know that you would not keep as soon as you caught them?" 91% of the respondents stated that they would discard the orange fish (which are the fish with the lowest value). Further, among participants who

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discarded fish, 83% mentioned maximizing profit or increasing their profit in response to the question "Did you discard fish in any round? If so, what motivated you to discard the fish?"

The qualitative feedback we received demonstrates that the students responded to the game and that the game was effective in highlighting how economic incentives and decision-making drive issues related to bycatch, including discarding edible fish. The feedback shows that students understood their mission to maximize profit and had carried it out in a rational manner. The resulting marginal revenue and marginal profit curves closely resembled those appearing in a microeconomics textbook. The students had actually made decisions that mirrored this familiar pattern. In the postgame presentation, they were able to see these graphs (compiled from an earlier class trial) and relate their actual decision-making practices to this fundamental microeconomic theory, bringing the theory to life. The feedback also indicates that the game was illustrative in showing the extent and magnitude of bycatch-related issues. Next, we introduce a series of discussion prompts that can be used to explore solutions and to enhance the learning outcomes of playing the game. We follow this with a discussion of possible treatments and extensions.

Discussion prompts

We suggest that the postgame discussion touch on the learning objectives achieved in the students' experience of the game, then extend learning to encompass potential solutions to the occurrence of bycatch and its discarding, engaging students' creativity and input in offering solutions. Following the discussion, students will be primed to learn in subsequent lessons about possible market-based interventions to reduce bycatch, including Pigouvian taxes, tradable permits, command and control regulation(s), and behavioral nudges. Having "lived" the experience of weighing economic incentives and making decisions, students are more likely to be engaged and able to actively process the incentives, having had a relatable first-hand experience as a decision maker.

Time permitting is possible to extend the above discussion to explore the efficacy of different market-based instruments to reduce bycatch and its discarding. A few suggested readings are Miller and Deacon (2017) and Lent and Squires (2017) for an overview of regulation versus market instruments, Mukherjee and Segerson (2011) and Chan and Pan (2016) for a discussion of the regulatory approaches to protect sea turtles, Singh and Weninger (2015) for a model of a cap-and-trade bycatch avoidance policy, and Larson, House, and Terry (1996) for an illustration of efficient quotas using a linear-programming framework.

In a microeconomics or game theory course, you might begin by examining the economic tensions (marginal revenue vs. marginal cost) experienced by the students in their effort to maximize profit. Students should be able to fully appreciate your point that profit is maximized when marginal revenue equals marginal cost.

Second, to explore the environmental side of the game, turn the discussion to the issue of fisheries bycatch. Explain the meaning of this term, and that bycatch is often referred to as "trash fish" (and perhaps emphasize how unfortunate it is that this term has been attached to living things). Asking students what economic incentives drove the decision to discard the bycatch fish species can lead to a very fruitful discussion.

Next, it may be instructive to introduce the following facts: (1) that up to 22 percent of commercial catches may be bycatch (Smith, citing Oceana); (2) a billion people rely on seafood as their primary source of protein (Marine Stewardship Council 2015); (3) nearly a billion people are starving (WHO 2018); and (4) the world's fisheries are overfished. Most people are surprised to learn that so-called trash fish are, in many cases, both nutritious and tasty. You might discuss efforts to increase consumer acceptance of bycatch species (we include several examples herein, some by chefs). Also, is this waste of food tonnage something that governments (i.e., fishery managers) should address in order to ease world hunger?

If a reduction of bycatch and its discarding is found to be beneficial to fish and human populations, then (a) fishery management practices could be prescribed that would reduce bycatch and its discarding, (b) public awareness campaigns could be launched to create markets for bycatch species, and (c) the commercial uses of bycatch fish could be encouraged or subsidized, such as use as production inputs for cat food, fertilizer (Pavlis 2014) – fish fertilizer is about 2% nitrogen, standard for organic fertilizers; microbes in the soil digest fish oil and convert it to nitrate and phosphate for crops and plants – and other products, including farmed fish feed (Edwards, Tuan and Allan 2004) and collagen for pharmaceutical and biomedical applications (Muralidharan, et al. 2013).

Numerous public awareness campaigns exist, and other can be conceived, to promote demand for bycatch species. Once consumers become acquainted with bycatch species, and try them, they are more likely to have an openness to purchasing those species subsequently (Witkin, Dissanayake, and McClenachan 2015). Further, engaging fisher communities more closely with the fishery supply chain all the way to the consumer and using socially sustainable seafood labels like "Fair Trade Tuna" can incentivize commercial fishers to explore solutions to reduce bycatch (Jaffry et al. 2016; McClenachan Dissanayake, and Chen 2016; Kittinger et al. 2017).

A National Geographic article states, "Conscientious chefs who cheered the farm-to-table and eat-local movements are turning their attention seaward. They're experimenting with bycatch, sea creatures and fish unintentionally brought in along with desired species. Also called trash fish or wasted catch, bycatch may account for up to 22 percent of commercial catches in the U.S., says a 2014 report from the nonprofit Oceana. Improved fishing practices may lessen the problem. Meanwhile, restaurateurs and home cooks are putting bycatch species on the menu: dogfish tacos or blowfish tenders, anyone?" (Smith 2015). In Sarasota, Florida, the annual Sarasota Trash Fish Dinner, renamed in 2017 Sustainable Seafood Dinner, brings together 11 award-winning chefs and their staff to create a "delicious opportunity" for the public to get to know "tasty, healthy species of fish that consumers aren't hearing about" (Indigenous Sarasota 2016).

Finally, the ethics of discarding bycatch can be discussed. While animal rights movements and diets focused on vegetarian and vegan options are gaining popularity, many people who maintain omnivorous diets believe that it is justifiable to take animals' lives for the purpose of food, but that killing an animal and not eating it is not ethically justifiable. Against that backdrop, discarding bycatch raises this ethical question: How does one justify the discarding of bycatch, when thousands of wholesome, delicious, and otherwise healthy bycatch species are killed and dumped back into the ocean, based not on human survival, but only on consumer preferences and market prices?

Next, we introduce a set of treatments that can be played with the game to expand the learning outcomes and pedagogical goals.

Other treatments and their purposes

Rather than using this pedagogical exercise strictly to demonstrate the problems surrounding bycatch and to discuss solutions, we invite instructors to expand upon the base form of this exercise to include different treatments highlighting the factors that drive or could mitigate these outcomes. Below, we outline a few modifications and what they represent to the baseline game covered in Section "Classroom exercises to teach fisheries." We discuss what these changes mean to expected behavior of the students playing the game. As the instructor, you might choose to run some of our suggested variations alongside the baseline activity outlined earlier in the text, if time permits. Doing it this way and then showing the difference in behavior, we believe, will be a highly effective pedagogical method to highlight the way that certain mechanisms influence behavior. This understanding is important when holding classroom discussion and considering potential policies on this and related issues. We organize these additional treatments into two different categories: Economics/Policy Variations and Ecological Variations.

Economics and policy variations

Historically, environmental policy employs three approaches: quantity control (direct regulation), taxes/fees to influence the costs/benefits from actions, and behavioral approaches meant to "nudge" decision makers toward targeted outcomes, with the latter being a much newer policy approach. For theoretical approaches of quantity and price regulation in fisheries, we suggest you view Weitzman (2002), Jensen and Vestergaard (2003), and Hansen (2008). Below, we introduce possible modifications to our learning activity that addresses each of these approaches that policy makers employ.

Varying price difference treatment and increasing the consumer willingess to pay (WTP) for low-value fish

Consider using a version of the game with a narrower price spread (where the prices of the four fish species are closer together). This outcome would happen if policy makers tried to increase the economic value of the "trash fish," raising their demand and potentially lowering that of the substitute fish a bit (see Kittinger et al. 2017, McClenachan Dissanayake, and Chen 2016 and Witkin, Dissanayake, and McClenachan 2015, Jaffry et al. 2016 for a discussion on consumer responses to sustainability in fisheries). When this occurs, their prices are driven toward one another. Playing a treatment with a tighter price distribution will result in a lesser number of rounds of fishing and a smaller amount of discarded bycatch.

Attempts to achieve this outcome are seen in costal restaurants where chefs prepare meals using these lesser known (and less appreciated), but otherwise nutritional fish (Chefs Collaborative 2017). This approach is an example of a "nudging" style of policy (Witkin, Dissanayake, and McClenachan 2015; Jaffry et al. 2016). Once such fish become more well known both by chefs and consumers, demand for them rises, as does their economic value to fishing companies, thereby decreasing the amount of bycatch discarded.

We explored this treatment in two classes during winter 2020, an Economics of Sustainability class in the university's economics department and a Conservation Biology class in the biology department. The pooled results are shown in Table 4.

Table 4. Summary of draws and discards from price treatments

	Price distribution	# of respondents	Average number of drawsMean (standard deviation)	Average number of discards Mean (standard deviation)
Treatment 1	$6, $5, $4, $3	11	4.81 (0.75)	1.81 (0.75)
Treatment 2	$7, $6, $3, $2	12	5.91(1.83)	2.91(1.83)

It is important to note that this is not a statistical analysis, but it highlights that gathering the total responses quickly in class allows illustrating how price differences impact bycatch. This can then lead to a discussion about mechanisms to improve prices of low-value fish. We supplemented this discussion by having the students read/present a subset of the papers mentioned above.

Strong restrictions on number of casts (Rounds)

A simple and direct approach to control bycatch is to limit directly the number of hours or days that a vessel can fish. In our proposed design, this would be putting a binding cap on the number of rounds that is much less than eight in the original proposal. (Eight was intended to be nonbinding, while ensuring the game would end.) We would suggest this value be four or five rounds based on the observed data from our own sessions. Here, the class should discard fewer fish when compared to the baseline case. The instructor could even run this variation, the baseline, and another treatment listed next in parallel in a large enough classroom (or if she has the time, to run multiple activities in sequence). This extension also helps highlight important aspects that price and quantity controls can both work to accomplish the same outcomes.

Higher marginal costs for fishing

Price controls/fees are a second policy technique that administrators and regulators may use to control bycatch. Thus, an easy change that instructors can make to the baseline activity is to increase the variable cost of fishing. This change represents a third party such as government office imposing a fee for fishing. That is, the standard (capital and labor) economic costs have not changed, but the new group/treatment that has marginal cost have higher costs due to some fee they owe the government/fishery management. Students pay the fee on a per hour/use basis regardless of the value of the harvested fish. Of course, basic economic theory will show that as the cost is higher, there should be less fishing overall.

This setup means that their marginal cost now has two (still constant per use) sources. The standard economic cost of labor and equipment in addition to the usage fees/taxes. In the two treatments, the higher cost treatment would result in a lower number of fishing rounds and thus lower bycatch. In this very simple modification, the instructor illustrates another role that a third party may have at mitigating the problem. Further, it could tie into discussions on issues like Pigouvian taxes. By having students assigned to each of the treatments (baseline, quantity control, and prices/fees), the class can discuss their experiences with the mechanisms and thoughtful discussion about fish and other natural resources/public goods management should emerge.

Ecological variations

Altering the probabilities of catching each species

Instead of removing one of the fish completely from the pool, you may instead make one or two of the fish much harder to catch to reflect decreasing stock sizes on high-value fish. This can be accomplished simply by using six-sided dice instead of four-sided dice. To model situations where you would expect fishers to create large amounts of discarded bycatch, we suggest the following assignment values for each six-sided die: $1 Orange Fish (1 or 2), $3 Green Fish (3 or 4), $5 Blue Fish (5), and $6 Purple Fish (6). Note, now the two best-value fish are jointly only caught one-third of the time, and this represents a scenario where the high-value fish stocks have been depleted.

When this treatment is implemented, we predict that the number of draws and the amount of bycatch will increase (the low catch probability for fish species with low stock levels (which typically are the high-value fish) will lead to fewer high-value fish being caught. This will incentivize the players to keep fishing/drawing to increase the number of high-value fish in their final catch).

Adding a trigger mechanism and altering the number of fish species available to catch

The game can be easily modified to account for potential fish stock collapses by removing one of the types of fish available for students to catch. This does require changing the game play so that the students will report their catches in every round/draw (as opposed to merely turning in the recording sheet at the end of the play). By asking students to turn in or submit catch information at the end of every round, the instructor can create a trigger mechanism where the highest-value fish species suffers a stock collapse once predetermined number of fish has been caught (equal to say, 2 x the number of players x 3, to correspond to a situation where the high-value fish consists of 66% of the catch before any discards happen). When this number has been reached in any subsequent draw, the high-value fish will be eliminated from the fishery. If you have used the four-sided dice method of determining random draws, this fishery collapse can be implemented by asking students to reroll a particular die if the highest-value fish is returned for any die in a roll. If the students were using an online dice roller, this can be easily implemented by asking the students to select a virtual dice with three sides. Using six-sided dice, pairs of numbers will be associated with each of the remaining three fish species.

Conclusion

Given the stress of climate change on fish populations, increased harvesting of fish, and the reliance of much of the world's population on fish, it is imperative to understand issues surrounding fisheries. Bycatch is one of major issues in commercial fishing. Secondary and tertiary species of fish are being killed, while fishers harvest more economically profitable fish. Such excess harvesting harms the health of the fishery. We create a classroom exercise to help students and others to understand more fully why, even when we know such a problem exists, fishing vessels still often engage in behavior that leads to discarding edible fish.

This activity is a way to engage students in issues of profit-maximizing behavior on its own but also extends to allow discussion of tragedy of the commons and regulation. Further, the exercise caters to deeper discussions about how economics and the environment or ecological welfare are tied together. In classes where discussion about the role of government in the management of resources is a central theme, the variations discussed to the main game can be particularly useful.

We share our experience playing the game and summarize quantitative and qualitative feedback on the students' performance, how the game complements the standard models used to teach fisheries, and the students' views of the game. We hope you are able to use this game in your classroom not only to discuss fisheries management and bycatch but also to create an active, engaging, and memorable classroom experience for your students.

Data availability statement. The data that support the findings of this study are available from the corresponding author, SD, upon reasonable request.

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Appendix I. Instructor's Guide

Preparation

- Choose a randomization method (e.g., four-sided dice; six-sided dice; online random number generator)
- Distribute Student Game Instructions (Appendix II) and assigned readings, if any
- Prepare Price List and number-to-color correlation
- Prepare physical game, if applicable (for use with model student at front of room)
- Prepare postgame presentation and discussion
- Load up the two videos on price-based bycatch
  - Why Eating Trash Fish is Good for Eaters, Fishermen, and Ocean Fish (https://www.youtube.com/watch?v=OHL8a1QiCng)
  - Why eating "trash" fish is good for fishermen & sustainability/UNC-TV Science (https://www.youtube.com/watch?v=7x7eseNxTWM)

Setup

- Display Price List and number-to-color correlation
  - If starting with
- Distribute Student Game sheets to record results
- Distribute dice, if applicable, or post website for randomization
- Explain real money payouts
- Explain that this is a noncompetitive game to be played synchronously
- Randomly select a student and ask if they want to play up front as the model student
- Explain basic game parameters: three fish per draw; nine fish capacity; revenue and costs (fixed and marginal costs)

Play

- Draw three fish and record the first letters in the white boxes for the corresponding draw
- Discard three fish by recording the first letters in the shaded boxes AND by drawing a large X through the white boxes containing the discarded fish (applies to fourth and subsequent draws)
- Decide whether to continue fishing or quit fishing. The choice to quit fishing is designated by drawing a line to cross out the next (i.e., fist unused) white row of boxes
- A choice to continue fishing leads to repeating all the steps above
- The game is limited to a maximum of eight draws

Conclusion

- Ask students to tally their catch of nine fish and perform calculations on sheets, turn them in
- Conduct postgame presentation on the problem of bycatch waste
- Lead postgame discussion
- Distribute and collect postgame survey or feedback, if any

Appendix II-A: Student's Instruction Sheet – Base Treatment

You will be participating in a simulation of a day at sea, making decisions on behalf of a commercial fishing enterprise. The goal of the day's expedition is to maximize your net return or the profit you will make.

In each round of fishing, you will draw three fish from the sea into your commercial fishing vessel. You decide how many rounds to fish. Each draw costs $3. The fixed cost for the day's expedition is $10.

Your revenue depends on the fish aboard your vessel at the end of your fishing day. There are four colors of fish: purple, blue, green, and orange. Each purple fish is worth $6, blue $5, green $3, and orange $1.

The capacity of the fishing vessel is represented by nine fish. After three draws, your total costs will be $19, and your boat will be full.

You must now decide whether to continue fishing or stop fishing. Your decision will be based on your analysis of the fish you have collected. Is it likely to be profitable to continue fishing? The cost is $3, but it could improve the value of your payload.

If you decide to continue fishing, you will first draw an additional three fish. Your draw is random, and each fish is equally likely to be purple, blue, green, or orange. After drawing, you'll have 12 fish and you'll need to discard 3 fish of your choice to get back to your vessel's capacity of 9 fish.

Again, you'll consider the particular mix of fish you have aboard, and you'll decide whether you think profit will be maximized if you quit fishing or if you pay yet another $3 to draw again, subsequently discarding three fish.

The process of deciding, drawing, and discarding is repeated until you decide to quit fishing or you have reached the day's maximum limit of eight draws.

Once you've finished fishing, you'll add up the value of the nine fish you have aboard, subtract your fixed expedition cost of $10 and your variable cost of $3 per draw, and determine your profit for the day's fishing.

You'll also tally the number of fish you discarded.

While we understand that some students would not be inclined to fish in real life, we ask that you participate in this simulation with a mind to maximizing game profit in order to gain a firsthand understanding of what drives behaviors in a commercial fishing enterprise.

Once the game is done, we will evaluate the results and discuss causes and solutions.

Fish Bycatch Game

Date:	Game #	Sex	Age	Do you fish?	Vegan/veg?	Willing to participate?
	2	**M F X**				

Draw 1:	
Draw 2:	
Draw 3:	
Draw 4:	
Discard	
Draw 5:	
Discard	
Draw 6:	
Discard	
Draw 7:	
Discard:	
Draw 8:	
Discard	

Final haul of fish:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

	Purple (@$6)	Blue (@$5)	Green (@$3)	Orange (@$1)	Total
Count					
Value ($)					

Total Revenue: ____ Total Cost $3 per draw x ____ draws + $10 = $____ Profit: $______
Total Count of Fish Drawn: ____ Total Count of Fish Discarded: ____ Ratio: Disc/Drawn ___%

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Appendix II-B: Student's Instruction Sheet – Low-Price Treatment

You will be participating in a simulation of a day at sea, making decisions on behalf of a commercial fishing enterprise. The goal of the day's expedition is to maximize your net return or the profit you will make.

In each round of fishing, you will draw three fish from the sea into your commercial fishing vessel. You decide how many rounds to fish. Each draw costs $3. The fixed cost for the day's expedition is $10.

Your revenue depends on the fish aboard your vessel at the end of your fishing day. There are four colors of fish: purple, blue, green, and orange. Each purple fish is worth $6, blue $5, green $4, and orange $3.

The capacity of the fishing vessel is represented by nine fish. After three draws, your total costs will be $19, and your boat will be full.

You must now decide whether to continue fishing or stop fishing. Your decision will be based on your analysis of the fish you have collected. Is it likely to be profitable to continue fishing? The cost is $3, but it could improve the value of your payload.

If you decide to continue fishing, you will first draw an additional three fish. Your draw is random, and each fish is equally likely to be purple, blue, green, or orange. After drawing, you'll have 12 fish and you'll need to discard 3 fish of your choice to get back to your vessel's capacity of nine fish.

Again, you'll consider the particular mix of fish you have aboard, and you'll decide whether you think profit will be maximized if you quit fishing or if you pay yet another $3 to draw again, subsequently discarding three fish.

The process of deciding, drawing, and discarding is repeated until you decide to quit fishing or you have reached the day's maximum limit of eight draws.

Once you've finished fishing, you'll add up the value of the nine fish you have aboard, subtract your fixed expedition cost of $10 and your variable cost of $3 per draw, and determine your profit for the day's fishing.

You'll also tally the number of fish you discarded.

While we understand that some students would not be inclined to fish in real life, we ask that you participate in this simulation with a mind to maximize game profit in order to gain a firsthand understanding of what drives behaviors in a commercial fishing enterprise.

Once the game is done, we will evaluate the results and discuss causes and solutions.

Fish Bycatch Game

Date:	Game #	Sex	Age	Do you fish?	Vegan/veg?	Willing to participate?
	2	**M F X**				

Draw 1:	
Draw 2:	
Draw 3:	
Draw 4:	
Discard	
Draw 5:	
Discard	
Draw 6:	
Discard	
Draw 7:	
Discard:	
Draw 8:	
Discard	

Final haul of fish:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

	Purple (@$6)	Blue (@$5)	Green (@$4)	Orange (@$3)	Total
Count					
Value ($)					

Total Revenue: ____ Total Cost $3 per draw x ____ draws + $10 = $____ Profit: $______
Total Count of Fish Drawn: ____ Total Count of Fish Discarded: ____ Ratio: Disc/Drawn ___%

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Appendix II-C: Student's instruction sheet – High-Price treatment

You will be participating in a simulation of a day at sea, making decisions on behalf of a commercial fishing enterprise. The goal of the day's expedition is to maximize your net return or the profit you will make.

In each round of fishing, you will draw three fish from the sea into your commercial fishing vessel. You decide how many rounds to fish. Each draw costs $3. The fixed cost for the day's expedition is $10.

Your revenue depends on the fish aboard your vessel at the end of your fishing day. There are four colors of fish: Purple, Blue, Green, and Orange. Each purple fish is worth $8, blue $7, green $2, and orange $1.

The capacity of the fishing vessel is represented by nine fish. After three draws, your total costs will be $19, and your boat will be full.

You must now decide whether to continue fishing or stop fishing. Your decision will be based on your analysis of the fish you have collected. Is it likely to be profitable to continue fishing? The cost is $3, but it could improve the value of your payload.

If you decide to continue fishing, you will first draw an additional three fish. Your draw is random, and each fish is equally likely to be purple, blue, green, or orange. After drawing, you'll have twelve fish and you'll need to discard three fish of your choice to get back to your vessel's capacity of nine fish.

Again, you'll consider the particular mix of fish you have aboard, and you'll decide whether you think profit will be maximized if you quit fishing or if you pay yet another $3 to draw again, subsequently discarding three fish.

The process of deciding, drawing, and discarding is repeated until you decide to quit fishing or you have reached the day's maximum limit of eight draws.

Once you've finished fishing, you'll add up the value of the nine fish you have aboard, subtract your fixed expedition cost of $10 and your variable cost of $3 per draw, and determine your profit for the day's fishing.

You'll also tally the number of fish you discarded.

While we understand that some students would not be inclined to fish in real life, we ask that you participate in this simulation with a mind to maximizing game profit in order to gain a firsthand understanding of what drives behaviors in a commercial fishing enterprise.

Once the game is done, we will evaluate the results and discuss causes and solutions.

Fish Bycatch Game

Date:	Game #	Sex	Age	Do you fish?	Vegan/veg?	Willing to participate?
		M F X				

Draw 1:	
Draw 2:	
Draw 3:	
Draw 4:	
Discard	
Draw 5:	
Discard	
Draw 6:	
Discard	
Draw 7:	
Discard:	
Draw 8:	
Discard	

Final haul of fish:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

	Purple (@$8)	Blue (@$7)	Green (@$2)	Orange (@$1)	Total
Count					
Value ($)					

Total Revenue: ____ Total Cost $3 per draw x ____ draws + $10 = $____ Profit: $______
Total Count of Fish Drawn: ____ Total Count of Fish Discarded: ____ Ratio: Disc/Drawn ___%

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Appendix III: Courses and course-relevant discussion question(s).

Table A.1. Where the game/experiment supports course objectives

Economics courses	Curriculum-relevant questions
Contemporary Economic Issues	How do the economy and the environment complement one another, and in what ways do you see them conflicting, as highlighted by this game?
Principles of Microeconomics	What decisions does profit maximization drive, and what are the potential environmental consequences and related externalities?
Intermediate Microeconomic Theory	How does a decision maker determine quantity in order to accurately assess the point of profit maximization, when MR and MC lines meet?
Fundamentals of Game Theory	Can you describe an optimum strategy to maximize your payoff in this game?
Economics of Environmental Issues	What externalities, if built into the marginal cost of drawing, could influence the decision of quantity of draws?
Economics of Developing Countries	How can developing countries be incentivized to make environmentally sustainable choices?
Introduction to Mathematical Economics	Could a model of utility maximization be developed to demonstrate to policy makers that a subsidy to reduce discarding bycatch fish could lead to socially superior outcomes?
Microeconomic Theory with Calculus	How could the rate of change of marginal revenue per draw be modeled?
Economics of Industrial Organization	How would you explain the decision-making process modeled here within vessels in the commercial fishing industry?
Economics of Regulation	How can government regulation influence performance in this market to reduce discarding bycatch fish?
Resource and Environmental Economics	What are the negative externalities to discarding bycatch fish?
Advanced Environmental Economics	How can the bycatch problem be addressed to minimize negative ecological impact?
Advanced Natural Resource Economics	How can the bycatch problem be addressed to minimize negative ecological impact?
Business Environmental Management Economics	Analyze policy options to foster environmental management for a public good, fisheries, in order to achieve sustainability.
Taxation and Income Policies	What would be the expected behavioral and social outcome impact of a policy imposing a tax on each draw? Who would bear this tax (incidence)?
Energy Economics	If electrical rates were increased to fund fishery remediation, what would be the economic effect?

(*Continued*)

Table A.1. (*Continued*)

Economics courses	Curriculum-relevant questions
International Trade Theory and Policy	What happens when certain countries adopt ecologically sensitive policies as it relates to public goods in international waters?
Global Environmental Economics	What global environmental problem is identified by this experiment?
Economics of Green Power	In what ways do green policies overlap to promote both green energy production and fishery health? What are the parallels between dams and the discarding of bycatch fish?
East Asian Economic Development	How significant a role do East Asian countries play in sustainable fishery management?
Mathematical Economics	Could a model of utility maximization be developed to demonstrate to policy makers that a subsidy to reduce the discarding of bycatch fish could lead to socially superior outcome?
Economics of Sustainability: Theory and Practice	What sorts of regulation could support the sustainability of fisheries?
Cost–Benefit Analysis	How would you model closing a fishery for one year to allow fish stocks to replenish and determine the return on investment (ROI) on such a decision?
Advanced Microeconomics II	How does microeconomic theory drive the choices? Is it socially optimum? Were the choices modeled in the experiment rational?
Environmental studies courses	**Curriculum-relevant questions**
Environmental Sciences I	How can economics create tension with ecology?
Environmental Sciences II	How does the discarding of bycatch fish contribute to environmental degradation? Can conservation measures help?
Applied Environmental Studies: Policy Consideration	To what extent might regulations and laws be able to address the bycatch problem?
Environmental Systems II	What is the human impact of discarding bycatch fish on aquatic ecological processes?
Fish Ecology and Conservation	What issue or problem does this experiment demonstrate that impacts fish conservation?
Ecology and Management of Bio-Invasions	In what ways might discarding bycatch fish actually be used to support the battle against invasive aquatic species that threaten the health of native fish species? How can fishing behaviors that support sustainability be incented?
Geography courses	**Curriculum-relevant questions**
Environment and Society: Global Perspectives	In what ways have humans modified their environment as demonstrated in this experiment?
Resource Management	What resource management issues arise from this demonstration/experiment?

(*Continued*)

Table A.1. (*Continued*)

Geography courses	Curriculum-relevant questions
World Population and Food Supply	What world food supply issues are exemplified?
Environmental Issues and Action	What should be advocated?
Resource Management Topics	What policies might result from a sustainable approach to development of natural resource policy?
Business and management courses	**Curriculum-relevant questions**
Sustainability Metrics in Business	How would you prioritize your fishing firm's environmental performance in relation to its business practices in the area of discarding bycatch fish?
Product Design and Stewardship for Sustainable Enterprises	How can waste be minimized for sustainable stewardship of ocean fisheries resources?
Current Issues in Environmental Policy Natural Resource/Water Policy & Admin Fish & Wildlife Policy and Administration	What measures should policy makers consider in order to reduce both the occurrence and the discarding of bycatch?
Philosophy courses	**Curriculum-relevant questions**
Environmental Ethics	What environmental ethic is adequate to address the issue of discarding bycatch fish in commercial fishing?
Philosophy of International Law	How could international law mitigate the bycatch problem?
Food Ethics	How is the moral status of animals relevant here?
Plato/Aristotle/Kant	How can reason and morality conflict? Is the rational decision maker a moral decision maker?
Empiricism	Does the experience of a simulation affect what we are then able to think or learn?
Philosophy of Sustainability	Do you believe that discarding bycatch fish is environmentally sustainable? Economically? Socially?
Environmental Political Theory	How would discarding bycatch fish be viewed in the light of sustainability? Green radicalism? Rationalism?

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