FISH 6.0: Manual & Program

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Brief Introduction

FISH 6.0 is an online microworld exercise designed by University of Victoria professor Dr Robert Gifford and programmed by Dr Jorge Aranda for studying the resource management decision-making of individuals and small groups. The latest version of FISH, implemented in late 2023, was produced in collaboration with Drs Johannes Koomen, Rebecca Koomen, Bryony Buck, and PhD Candidate Mr Richardt Hansen.

FISH 6.0 is especially useful for conducting studies that examine situations often called commons dilemmas, resource dilemmas, or social dilemmas. These situations focus on valuable, limited, common-pool resources in which individuals make decisions whether to cooperate (harvest little, resulting in modest short-term gain but long-term conservation of the resource) or defect (harvest a large amount, resulting in large short-term gains but endangering or even extinguishing the common resource (Gifford & Gifford, 2000)). FISH 6.0 can be run with either all human fishers, or both human and computer-simulated fishers in both in-person sessions or entirely online remote sessions. For a brief description of how a typical FISH 6.0 session proceeds, see "How to Fish" on page 6. This manual was authored by Mr Richardt Hansen as an update to the manual for FISH 4.0 (Gifford & Aranda, 2013).

Access to FISH 6.0

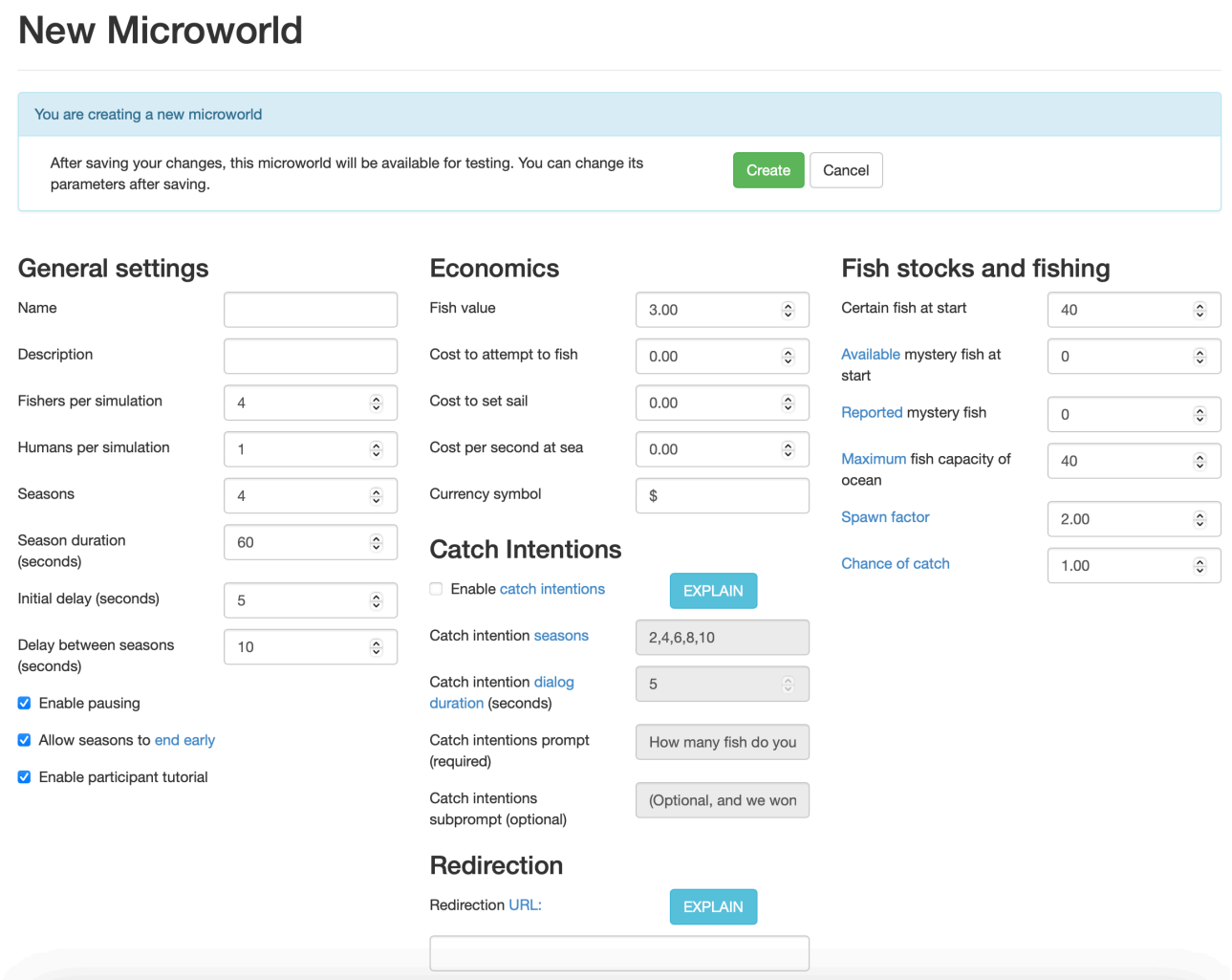
Access to the FISH 6.0 program is available by request to Dr Robert Gifford, at no charge. To request access, contact him at rdgifford@gmail.com.

FISH 6.0 Quick-Start Instructions

Below are simple instructions for running FISH 6.0 on an internet browser.

Once you receive an e-mail with the links to the program, begin by clicking on the FISH 6.0 Administration link. You will be asked to log in with a User ID, which will also be provided to you. Enter this ID and click "Login".

To create your first simulation, click on "New Microworld". You will then be directed to the following screen, where a variety of parameters such as the number of fishers, the cost per fish, the number of fish, and many others can be modified.



Preparation text

This text is shown to all participants before starting the simulation

FISH simulates fishing in an ocean. You and the other fishers are the only fishers in this ocean. All the fishers see the same ocean that you do. At the beginning, the number of fish will be displayed on the screen. However, sometimes there is some uncertainty about the number of fish. In those cases, "mystery fish" will be shown on the screen as well, and the number is displayed as a certain range, not as an absolute number. Once the simulation begins, you and the other fishers may catch as many of these fish as you like. Once you have taken as many fish as you want, you return to port with your catches, and the first season ends. Then the fish spawn for the next season, if any are left to spawn (if no fish are left, they cannot spawn). For every fish left at the end of one season, two fish will be available to be caught in the next season. However, because the ocean can support only so many fish, the total number of fish will never exceed the original number of fish. Fishing can go on this way for many seasons, but all fishing permanently ceases any time that all the fish are caught.

You can make money fishing. You will be paid $3 for every fish you catch. (For now, this is "play" money... but please treat it as if it were real money.)

Your job is to consider all these factors, and the other fishers, and make your own decisions about how to fish. Fish however you wish.

End (by time) text

This text is shown if the simulation ends because all seasons have passed

Seasons come and seasons go, but for now we are done.

End (by depletion) text

This text is shown if the simulation ends because the fish have been depleted

All the fish are now gone.

Information display

- [x] Show all fishers
- [x] Show their names
- [x] Show their status
- [x] Show their number of fish caught
- [x] Show their balance
- [ ] Disable profit columns
- [ ] Warn when overfishing

Bot behaviour

Name	Greed	Trend	Greed Spread	Predictability	Probability of action	Maximum casts per second
Dolphin	0.50	Stable	0.20	Erratic	0.80	3
Shark	0.50	Stable	0.20	Erratic	0.80	3
Octopus	0.50	Stable	0.20	Erratic	0.80	3
	☑ Uniform	☑ Uniform	☑ Uniform	☑ Uniform	☑ Uniform	☑ Uniform

Status Table Behaviour

Static Behaviour

- (•) Current user on top
- ( ) Current user in middle
- ( ) Current user on bottom

You are creating a new microworld

After saving your changes, this microworld will be available for testing. You can change its parameters after saving.

Create Cancel

Creating and Testing a Microworld

The first step on this screen is to enter a name into the "Name" text box. This name will help you keep track of your experimental simulations. For instance, a suitable name for the microworld could be your project/study name.

The next step is to enter a description in the "Description" text box. This description will help you keep track of different versions of a microworld. For instance, if you manipulate certain variables such as number of fishers or fish in the ocean. A description that helps you immediately identify the specific version of the microworld – or any other description that suits your need – would be a suitable description.

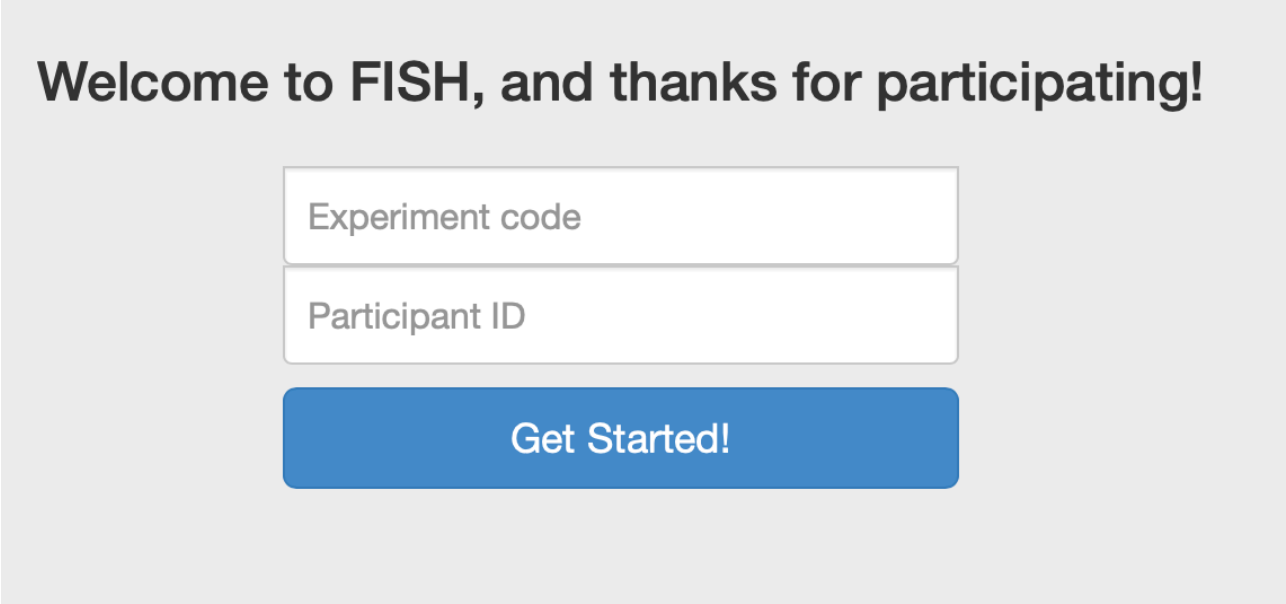
Importantly, participants **will not** be able to see the name of the microworld **nor** the description, so feel free to write anything that makes sense to you and your project.

After giving a name and description to your microworld, you can change any number of parameters now or scroll down to create the microworld by pressing "Create". Creating the microworld will enable it for testing; you will still be able to change all parameters after creating the ocean, including its name and description.

Once the microworld is created, you will see it appear in the "Microworlds being tested" dashboard on the home screen. You will notice an "Experiment Code" in the middle column. Your participant(s) will need this experiment code to enter the microworld you created. Each microworld you create will have a unique experiment code.

Participants will also need a Participant ID to enter the microworld. Note, any participant ID will grant the participant access and will be visible to all other human participants taking part. More information on how to automatically assign participants a Participant ID in section "Running a FISH Experiment Online".

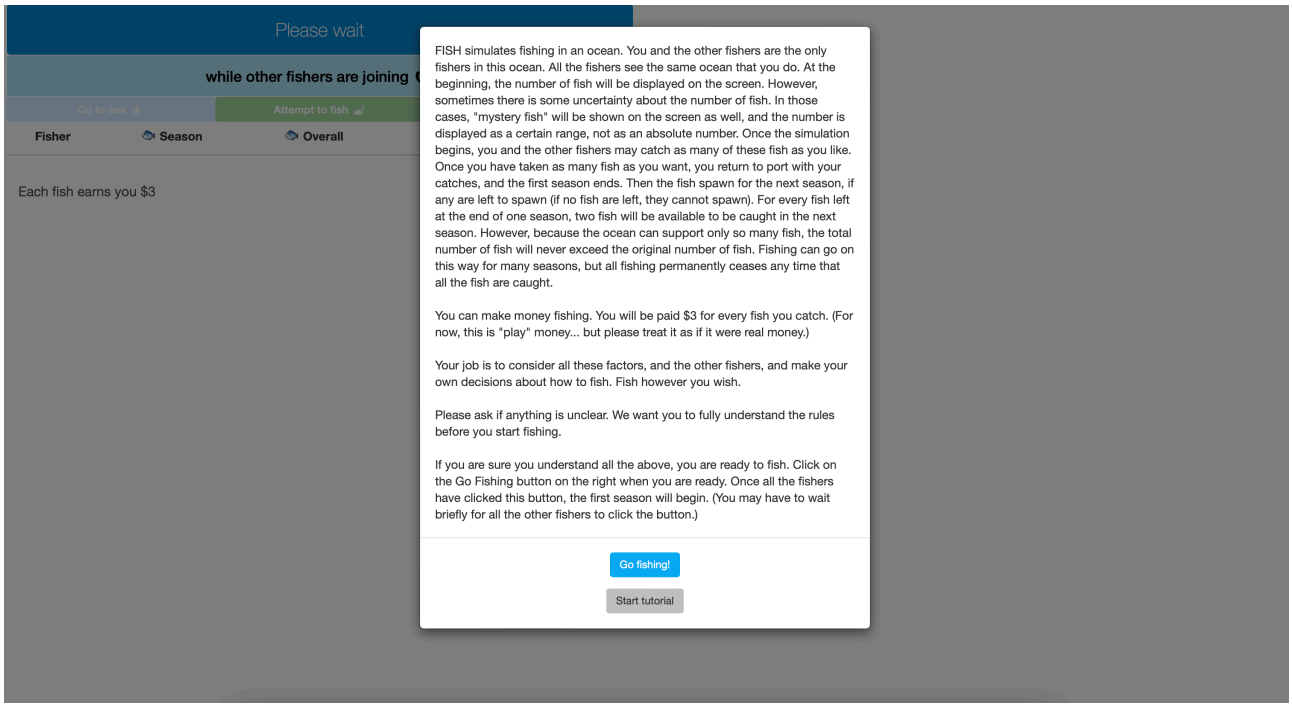
Participants about to enter your microworld will see the following screen:



To enter the microworld, the participant must enter the experiment code for your microworld and their Participant ID (unless automatically assigned).

Participant View

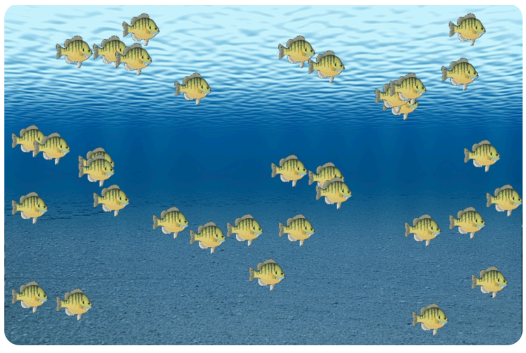
When entering the microworld, participants will see the following instruction screen (you can customise the instructions to suit your study – more on this later).



How to Fish

After reading the instructions, participants get two options: "Go fishing!" or "Start tutorial". Clicking the "Start tutorial" will give the participant step-by-step instructions for how each game interface feature works. It is highly recommended for participants to complete this (but cannot be forced).

Clicking the "Go fishing!" button begins the microworld and, after a delay determined by you, the first fishing season begins. The participant will see the following screen:



All participant choices are made using the three buttons "**Go to sea**", "**Attempt to fish**" and "**Pause**". To begin fishing, the participants must click on the "Go to sea" button. You will notice this changes the anchor (representing being at port) to a globe (representing being at sea). Once at sea, the participant can catch fish by clicking the "Attempt to fish" button. If, for any reason, the participant wants to pause the fishing season, they should click the "Pause" button (if enabled by you the

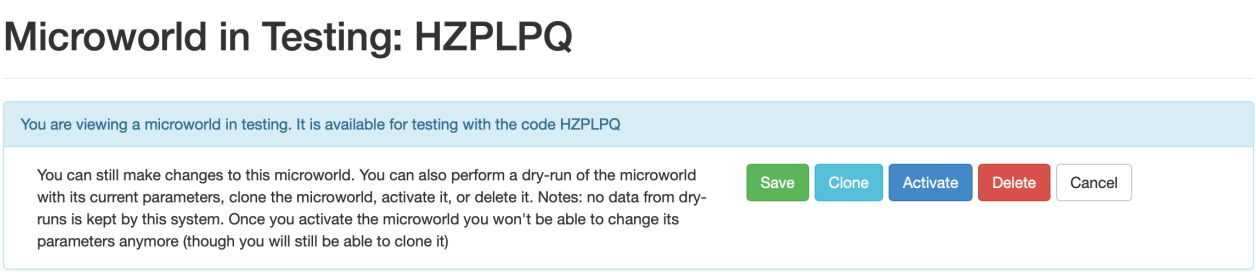
experimenter). When a fisher decides to stop fishing, they click the "Return to port" button. Participants can only fish when at sea.

Each fishing season ends when all the fishers in the ocean have returned to port or when all the fish have been harvested. You can also have a time-based season exclusively. That is, you can force the simulation to run through its full time, even though all fishers may have returned to port. When the season ends, the fishers wait for the remaining fish (if any) to spawn in order to begin the next fishing season. The session can go on for multiple seasons. The maximum number of seasons is set by you in the "General Settings" page.

Please note that it may be helpful to explain to participants that catching fish can only be done by pressing the "attempt to fish" button, and not by clicking directly on the fish in the right-hand side ocean.

Changing Parameters in a Microworld Being Tested

You can return to change parameters in any microworld in the "Microworlds being tested" dashboard. Importantly, no data is saved for microworlds in the testing stage. Once your microworld is fully set-up to your particular needs, you must activate the microworld BEFORE starting to collect data. Only activated microworlds will save participant data. You can activate your microworld by pressing the blue "Activate" button as in the image below. Just saving the microworld will keep it in the testing stage and will not activate it. Once activated, you can no longer change any parameters in a microworld. But you can clone an activated microworld, thus allowing you to change parameters as needed.



FISH 6.0's Features & Parameters

FISH 6.0 is a fully interactive environment. That is, individuals entering each simulation interact with one another simultaneously and in real-time in such a way that when a fisher takes a fish from the ocean, those fish disappear from the screens of the other fishers in the same ocean.

Many different scenarios are possible with FISH 6.0 by varying the parameters in the "General Settings", "Economics", "Catch Intentions", "Fish stocks and fishing" dashboards

General Settings

- **Name**: The name of your microworld will only be visible to you and helps you to organise your microworld(s) (e.g., by project or study).

- **Description**: The description of your microworld further allows you to add context to the microworld, for instance if it is part of a larger study manipulating different parameters. The description is also only visible to you.
- **Fishers per simulation**: The total number of human AND computer fishers in the ocean.
- **Human fishers per simulation**: The total number of human fishers in the ocean.
- **Seasons**: The maximum number of playable seasons in your microworld. The simulation will terminate at the end of your specified maximum number of seasons.
- **Season duration (seconds)**: The maximum duration of a season in seconds.
- **Initial delay (seconds)**: The delay in seconds that will pass between when all fishers in the simulation have pressed the "Go fishing!" button and the first season beginning.
- **Delay between seasons (seconds)**: The delay in seconds that will pass between the end of one season and the beginning of the next, at which time fish spawn.
- **Enable pausing**: If enabled, fishers will be able to pause the fishing season at any time.
- **Allow seasons to end early**: If enabled, seasons will end early if all fishers in the ocean return to port at least once, and when all fishers are inactive for three seconds, before the end of the season duration. If disabled, seasons will last the full season duration regardless of whether all fishers have returned to port or if the ocean is depleted.
- **Enable participant tutorial**: If enabled, participants have the option to start a tutorial of the game interface before entering the microworld. This is optional but highly recommended.

Economics

- **Fish value**: The fish value represents the monetary value of each fish caught.
- **Cost to attempt to fish**: The cost paid by the fisher for each attempt made to catch a fish.
- **Cost to set sail**: The cost paid by the fisher for each time they set sail and go to sea.
- **Cost per second at sea**: The cost paid by the fisher for each second at sea.
- **Currency symbol**: The currency symbol of the other four economics parameters.

Fish stocks and fishing

- **Certain fish at start**: The initial size of the fish stock in the ocean (the limit is several hundred) indicates the number of fish that will be available at the beginning of the first season of the simulation.
- **Available mystery fish at start**: The available mystery fish at start indicated the real number of mystery fish that fishers can catch. Participants will not be able to see these in the "Available fish" counter nor in the ocean.
- **Reported mystery fish**: The reported mystery fish is the number of mystery fish that the fishers are told could potentially exist in the ocean. This can be any number greater than, less than, or equal to the available mystery fish set above.
- **Maximum fish capacity of the ocean**: The number of fish in the ocean can never exceed this amount. Must be equal to or higher than the sum of certain fish at start and availably mystery fish at start.
- **Spawn factor**: The regeneration rate of the fish stock (a multiplier; that is, if set to 2, the fish remaining at the end of one season doubles for the beginning of the next season). The default spawn factor is set to 2.0; this means that if 20 fish remain at the end of a season, they will spawn by a factor of 2.0 and thus 2 * 20 = 40 fish will be available for the following season. If the spawn factor was 3.0, 60 fish would be available for the following season. However,

the total number of fish can never exceed the maximum fish capacity of the ocean. This is for ecological validity (oceans can only support so many fish).

- **Chance of catch**: The probability that each cast (attempt to fish) will be successful. This number is a decimal, with 0 meaning each cast is never successful, and 1 meaning that each cast is always successful.

Example for Certain & Mystery Fish

If there are 40 certain fish in the ocean, 10 available mystery fish, and 20 potential mystery fish, participants would be told there are "between 40 and 60 fish". In reality, there are exactly 50 fish.

Catch Intentions

- **Enable catch intentions**: Before the start of some seasons, prompt human fishers to indicate and broadcast the number of fish they intend to catch. Computerised fishers will broadcast a random number.
- **Catch intention seasons**: Comma-separated list of season numbers, 2 or higher, when to prompt human fishers to indicate their intent.
- **Catch intention dialogue duration (seconds)**: The number of seconds at the beginning of the delay between seasons during which human fishers are prompted to indicate their intent.
- **Catch intentions prompt (required)**: Required catch intentions prompt/instructions for human fishers.
- **Catch intentions subprompt (optional)**: Optional sub-prompt, for catch intentions for human fishers.

Redirection

- **Redirection URL**: If your microworld is part of a larger study, you can redirect the fisher to another platform; for instance, SONA or Gorilla.sc. See the EXPLAIN button and "Running a FISH Experiment Online" for how this works.

Messages for Participants

Toward the bottom of the screen, you will see the **"Preparation text**", "**End (by time) text**", and "**End (by depletion) text**". Each of these texts can be changed by simply clicking on the text box and typing a new message. Currently, the program is available in English, Chinese (Simplified and Traditional), French, German, Korean, Portuguese, and Spanish.

The **"Preparation text**" is seen by participants before the first season. The "**End (by time) text**" is seen at the very end of the simulation if and only if fishers did not deplete the ocean and the simulation ended when time ran out. The "**End (by depletion) text**" is seen by participants if all fish are harvested in any season, including the last season.

Information Display

Under the "Information Display" section, you can decide what information each fisher will be able to view about the other fishers. You can choose

- **Show all fishers**: whether all fishers will be able to see the other fishers in the ocean.
- **Show their names**: whether all fishers will be able to see the names of the other fishers.
- **Show their status**: whether the status (location) of the other fishers (at port or at sea) will be visible to all fishers.
- **Show their number of caught fish**: whether all fishers will be able to see the number of caught fish they themselves and all other fishers have caught.
- **Show their balance**: whether all fishers will be able to see the balance (that is, profit earned by catching fish) for themselves and all other fishers.
- **Disable profit columns**: This gives you the option to disable all profit columns (seasonal and total profits) throughout the simulation.
- **Warn when overfishing**: whether all fishers will receive a warning when overfishing occur.

Status Table Behaviour

Under the "Status Table Behaviour" section, you can decide how the status table appear to the fishers in your microworld.

Static Behaviour: By default, the status table is static, that is, not changing throughout the simulation, with the following three options for how participants are positioned in the table.

- **Current user on top**: All fishers will always see themselves at the top of the table.
- **Current user in middle**: All fishers will see themselves in the middle of the table.
- **Current user on bottom**: All fishers will see themselves at the bottom of the table.

Dynamic Behaviour: If the status table is set to dynamic, the participant position in the table will change based on your chosen parameter of the following options.

- **Descending by fish caught this season**: The fisher position is based on the number of fish caught in the current season, with the fisher catching the most fish on the top.
- **Descending by fish caught overall**: The fisher position is based on the number of fish caught across all seasons up to this point, with the fisher catching the most fish on the top.
- **Descending by $ this season**: The fisher position is based on the profit earned by catching fish in the current season, with the fisher earning the highest profit on top.
- **Descending by $ overall**: The fisher position is based on the profit earned by catching fish across all seasons up to this point, with the fisher earning the highest profit on top.

Bot behaviour

In FISH 6.0, you have the option to let human participants interact with a number of computerised fishers (called "Bots"), whose behaviour can be manipulated in several ways.

- **Name**: You can choose the name(s) of all Bots in your microworld. By default, these are animal names, but can be changed to whichever is most suitable for your project. Neutral names are recommended (e.g., Player 2, Player 3, …) to avoid names becoming a confounding variable.

- **Greed**: You can choose the Bots greediness within a range of 0 and 1, where 0 causes them to take no fish, 0.5 causes them to take fish at an exactly sustainable rate, and 1 causes them to take every fish possible. Greed can be kept constant/uniform across Bots, or can be varied for all Bots or for individual Bots.
- **Trend**: Bots greediness can be kept stable across time or can be increased or decreased with time.
- **Greed Spread**: You can choose a greed range for your Bots, either constant/uniform across Bots or varied for various Bots. The greed spread will center around your chosen greediness for any given Bot and can range between 0 to 2*Greed. For instance, a greed of 0.5 and a greed spread of 0.2 will result in a low season greed score of 0.4 and a high season greed score of 0.6 centered around an average greed of 0.5.
- **Predictability**: You can choose the Bots' behaviour to be erratic or regular. Erratic Bots behave non-deterministically (they may or may not act at any given time during the simulation and thus appear more life-like, but they may behave non-optimally.
- **Probability of action**: If Bots are set to behave erratically, the predictability of action, a decimal between 0 and 1, is the likelihood that the Bot will act. The lower the probability, the more the Bots will appear to hesitate.
- **Maximum casts per second**: If Bots are set to behave erratically, you can choose the maximum number of fish a Bot will attempt to catch in any given second, assuming the Bot acts in that second. If Bots are set to behave regularly, you can choose the maximum number of fish a Bot will attempt to catch in every second, until they fulfil their quota.

Suggestions for Using FISH 6.0 in Research

Run a Practice Session

It is a good idea to allow fishers to engage in a practice session at the beginning of their participation. The practice session need only be two or three seasons long so that fishers can see how the program works and how the fishing conditions change from one season to the next. You want their choices to reflect their values, not their learning about how FISH 6.0 works.

To create different experimental conditions, enter the values you desire for the various parameters and simply click "Create".

Running a FISH Experiment Online

Running entirely remote and online experiments has become much more popular in recent years with the emergence of online recruitment platforms such as MTurk and Prolific. However, this posed challenges when utilising FISH in an experiment chain, which, in part, this newest version aimed to overcome.

Transparently sending your participants into FISH

Often, your FISH experiment will be part of a chain, where your participants start with some activity (e.g., survey) on Platform A, then do your FISH experiment, followed by some more activity on Platform B (or back to Platform A). For instance, if recruiting participants from online recruitment platforms such as MTurk or Prolific, you will want to send participants from there into FISH without needing them to log in to FISH in the usual form-based, manual way. And you want participants to

automatically be redirected back to the recruitment platform when they complete your FISH experiment for them to complete the rest of your experiment and get paid.

This can be accomplished by providing Platform A the standard FISH URL augmented with 2 query parameters:

expid: the ID of the FISH experiment.

partid: the ID of the FISH experiment.

For instance, provide Platform A the following FISH URL (of cause, instead of '225' you may be able to use Platform A's mechanism to put in that platform's participant ID:
http://www.fishsim.org:8080/?expid=XWDJ6X&partid=225

Transparently sending your participants onward from FISH

Your experiment design (the "microworld") can include a Redirection URL, which FISH will use to send participants to another web site after completing your experiment. (This happens when participants click the OK button on the pop-up window announcing the completion of the experiment.)

Before executing this, FISH will perform variable substitution on the URL using any query parameters that were passed in when FISH started. Two additional variables are also available for substitution:

fishTotal: The total number of fish caught by the participant.

profitTotal: The total earnings of the participant.

For instance, you could put the following in the Redirection URL textbox:

https://www.payme.com/?subject=${partid}&catch=${fishTotal}&earned=${profitTotal}

Transparently sending your participants from FISH back to the previous platform

If Platform B is actually the same as Platform A (i.e., you want to send the participant from Platform A to FISH and then back to Platform A after completing your FISH experiment), you can get Platform A to provide one or more other query parameters. These may include a completion code that can be used on the way back to inform Platform A that the participant has completed FISH and is ready to move on. This should be used to enable participants to continue on that platform where they left off upon completion of the FISH experiment. FISH will capture those query parameters when it starts, which you can include in the Redirection URL using variable substitution.

An example going from Gorilla.sc to FISH and back to Gorilla.sc

In this example, assume we have a participant in Gorilla (experiment design software for behavioural scientists) whose participant id is MYPID, and your FISH experiment id is FISHEX.

Step One: In Gorilla, create a Redirect Node and configure it as follows:

- **URL**: Set this to: http://www.fishsim.org:8080/?exp=FISHEX
- **Append Public ID**: Name this public id: **partid**

- Completion dropdown menu: Select ‘Completion Token’

When Gorilla’s participant reaches this Node in the Gorilla Experiment, Gorilla expands the URL as

http://www.fishsim.org:8080/?expid=FISHEX&partid=MYPID&completion_token=A7B8C9

and sends the participant to this FISH page. FISH will immediately start the game with experiment ID FISHEX and participant id MYPID, while remembering the “completion_token” value for later use.

Step Two: In FISH, in your experiment’s microworld parameters, set the Redirection URL to:

https://research.sc/participant/login/resume/${completion_token}.

When your FISH participant completes the game and clicks the OK button, FISH expands the Redirection URL (using the completion_token query parameter from the start URL) as

https://research.sc/participant/login/resume/A7B8C9

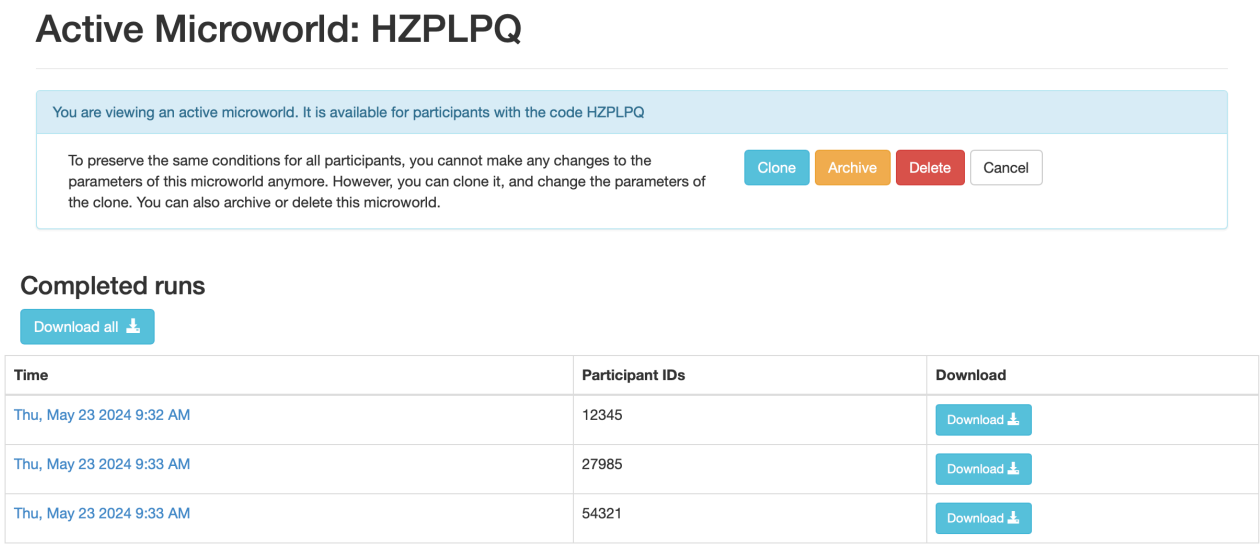
and sends the participant on to this Gorilla page. Gorilla will then let the participant proceed to the next Node in the Gorilla experiment.

Output Files

FISH automatically collects, aggregates, and stores information about each fisher’s harvesting behaviour in each season. It also automatically computes four different cooperation formulae that measure both harvest restraint and harvest efficiency at both the individual and group levels for each season and over all seasons (cf. Hine & Gifford, 1996 and the next section of this manual). From this information, rates of defection (harvesting a large amount, resulting in large short-term gain but endangering or even extinguishing the common resource) and cooperation (harvesting little, resulting in modest short-term gain but long-term conservation of the resource) can be determined. This is the information (dependent variables) that researchers use to analyse the individual or group behaviour of participants during the session.

Saving the Output from FISH 6.0 Sessions

To save the output from a microworld, click on the microworld in either the “Active Microworlds” or the “Archived Microworlds” dashboard to open it. Then you will see a screen similar to the following.



Here, you have the option to download the data from each individual simulation or download all data into a single file. All data will be saved as a CSV file in long format.

Transferring the Output into a Statistical Package for Analysis

The output is organised so that the individual data for each fisher, as well as the group data of each separate ocean are easily displayed. The numbers produced in the output file can be transferred into statistical packages such as SPSS, R, or Excel for statistical analysis.

The output comes pre-formatted so that it can be directly transferred to many statistical packages which accept CSV files, such as SPSS, R, and Excel. However, depending on your preferred programme, you may need to clean the dataset to satisfy the specific requirements of your programme.

Note that data are produced for each season separately. This is useful for examining behaviour during each season or identifying behavioural patterns across seasons. However, an average across all seasons for individual or group data may be calculated by hand or in the statistical package in order to examine behaviour patterns across all seasons for the entire session. FISH 6.0 does not do this automatically.

Depending on your statistical approach, you may want the data to appear in wide-form rather than long-form. This can be achieved with a few lines of code in R as shown below.

```r

# Open Required Packages
library(readr)
library(tidyverse)


# Open FISH Data Frame
dataFISH <- read_csv("dataFISH.csv")
View(dataFISH)

# We will rename column names for convenience
dataFISH <- dataFISH $>$
  rename("RunID" = "Run ID",
         "PID" = "Fisher",
         "FishStart" = "Fish at Start",
         "FishEnd" = "Fish at End",
         "FishPlanned" = "Fish Planned",
         "FishTaken" = "Fish Taken",
         "IR" = "Individual Restraint",
         "GR" = "Group Restraint",
         "IE" = "Individual Efficiency",
         "GE" = "Group Efficiency")

# If you have Bots in your microworld, you can easily filter them out by keeping
# only human fishers.
dataFISH <- filter(dataFish, Type == "human")

# You can also get rid of columns that do not provide useful information
# -> Removing Type, Greed, and GreedSpread.
names(dataFISH)
dataFISH <- select(dataFISH, -Type, -Greed, -GreedSpread)

# Now we convert the default long-data to wide-data
dataFISH_Wide <- dataFISH %>%
  pivot_wider(
    id_cols = c(PID, RunID),
    names_from = Season,
    values_from = c(FishStart, FishEnd, FishPlanned, FishTaken, Profit, IR, GR, IE, GE),
    names_glue = "{.value}{Season}"
  )

# Should you have multiple datafiles from different microworlds (e.g., dataFISH1
# and DataFISH2), you can use the above code for each and then combine the
# files with the following code.

dataFISH_Full <-  bind_rows(dataFISH1, dataFISH2)
```

The Cooperation Formulae for FISH 6.0

Cooperation may be measured for each individual fisher, or for the group. It may also be measured in terms of harvest restraint in an absolute sense (i.e., X fish taken), or in the context of current stock size, that is efficiency (also known as conservationism or sustainability, i.e., X fish taken when Y fish were available). This implies four different measures of cooperation as follows.

IR: Individual Restraint

IR ranges from 1 (if this harvester was totally restrained, i.e., took no fish) to 0 (if this harvester took 1/Nth of the entire pool), to 1 – N (a negative number, if this harvester took 100% of the pool), where N is the number of fishers. If this harvester has a score of 0, and all others did the same, the pool was exhausted and all harvesters had equal harvests; the fishers are thinking only of the present, with no thought of conservation. Scores less than 0 indicate very little restraint – this harvester was taking enough fish to rapidly deplete the pool by themselves. The lowest possible score depends on the

number of fishers in the ocean, because the formula reduces to 1–N when the fisher takes all the fish to themselves. IR says nothing directly about sustainability, but a sustainable harvest pattern will receive a score between 0 and 1, depending on the spawning rate. IR is also the proportion of fish that would be left in the pool if all harvesters acted exactly as this one did. Overall, IR scores from 1 down to 0 represent the range from preservationism to conservationism, and negative scores represent degrees of defection or greed. See the full formula below and Gifford & Hine (1997) for more information.

$$IR = \frac{\frac{S}{N} - T_1}{\frac{S}{N}} = \frac{S - T_1 N}{S}$$

Where:

- S = Stock available at the start of the trial.
- N = Number of harvesters in the group.
- T_1 = Stock taken by the individual harvester.

GR: Group Restraint

GR ranges from 1 (no harvester in the group took any fish) down to 0 (if the harvesters as a group extinguished the resource by taking 1/N of the fish each). No restraint is 0, up to full restraint, which is 1. GR cannot fall below 0, because if it takes 1/N across all fishers, no fish are left. GR is calculated by the following formula.

$$GR = \frac{S - T_G}{S}$$

Where:

- S = Stock size at the beginning of the trial.
- T_G = Amount taken by the group as a whole.

IE: Individual Efficiency (No-Danger & In-Danger Forms)

Efficiency (both individual and group) is computed in one of two ways, depending on whether the stock (in any given season) was endangered or not (see also Hine & Gifford, 1996 for details). Please note that the formula for IE_{ND} is incorrect in the Gifford & Hine (1997) publication; however, the formula is correct within the FISH 6.0 program and calculations done based from the programme are correct. The correct formula is provided in this manual.

IE_{ND} (individual efficiency no-danger) is the value for an individual fisher when the resource could regenerate to its original level, with enough harvester restraint, that is, OSS (Original Stock Size) is less than or equal to R * S, where R is the regeneration rate, and S is the initial stock size at the beginning of the current season. Perfect efficiency or sustainability (i.e., the harvester took just enough fish so that, once spawning occurs, the resource would regenerate to its original size – ignoring what other harvesters do) receives a score of 1. Scores above 1 mean that the harvester took less than the most efficient amount (i.e., the fisher were following a preservationist strategy rather than an efficiency or sustainability strategy, which could be called inefficient: not taking fish that would have been replenished naturally). Scores below 1 indicate the other kind of inefficiency –

taking too much of the resource so that the fish will be unable to regenerate to their original level when spawning occurs. A score of 0 means that the harvester took 1/Nth of the whole existing pool after a respawn, far too much for the pool to regenerate in the next round. Scores below 0 indicate even greater inefficiency or greed. The formula for IE_{ND} is as follows.

$$IE_{ND} = \frac{(S - T_1 N) * R}{OSS}$$

Where:

- S = Stock size at the beginning of the trial.
- R = Regeneration Rate
- N = Number of harvesters in the group.
- OSS = Original Stock Size
- T_1 = Stock taken by the individual harvester.

IE_D (individual efficiency in-danger) is the value for an individual fisher when the resource cannot regenerate to its original level even if all harvesters take nothing. That is, the original stock size (OSS) is greater than the regeneration rate times the initial stock size (R * S). The ideal harvest when the stock is in danger is no fish, so as to build up the stock to its original level. IE_D ranges from 1 (full restraint, that is, no fish taken) to negative numbers, exactly like IR does. Indeed, the formula is the same as for IR, as seen below.

$$IE_D = \frac{\frac{S}{N} - T_1}{\frac{S}{N}} = \frac{S - T_1 N}{S}$$

Where:

- S = Stock available at the start of the trial.
- N = Number of harvesters in the group.
- T_1 = Stock taken by the individual harvester.

GE: Group Efficiency (No-Danger & In-Danger Forms)

GE_{ND} (group efficiency no-danger) scores will be 1 when the group as a whole harvest exactly enough to allow full resource regeneration, no more and no less; thus, perfect efficiency. Scores greater than 1 indicate group harvesting that reflects preservationism or underharvesting. More of the resource could have been taken and full regeneration would still occur. Scores smaller than 1 indicate some greed-based inefficiency at the group level; a score of 0 indicate the group exhausted the resource, leaving none to regenerate for the next season. The formula is as follows.

$$GE_{ND} = \frac{R(S - T_G)}{OSS}$$

Where:

- R = Regeneration rate
- S = Stock available at the start of the trial.

- T_G = Amount taken by the group as a whole.
- OSS = Original Stock Size

GE_D (group efficiency in-danger) can range from 1, when the group engages in maximum restraint (i.e., takes none of the resource) to 0, when the group takes all the resource. The formula is as follows.

$$GE_D = \frac{S - T_G}{S}$$

Questions or Comments

Questions or comments about the program's concept and design should be directed to Dr Robert Gifford (at rdgifford@gmail.com). Questions about the software implementation and usage should be directed to Dr Jorge Aranda (at jorge.aranda@cuevano.ca).

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