Tunawars and the Tragedy of the Commons

An Application of Game Theory in Introductory Courses in Political Science

Loyola College in Maryland

Tunawars Manual

Version 2.6

Ole J. Forsberg

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Preface and Purpose

The purpose of this project is to provide students with experience in relations between the states. Quite often it is difficult to understand certain International Relations theories; this simulation grounds such concepts as Realism, Liberalism, Economic Threat, and Anarchical Society in their common classroom experiences. Secondary purposes include gaining greater insight into the causes and effects of currency fluctuations on the world and the effects of unmitigated resource extraction.

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Introduction

Tunawars is a chance for you to direct your own tuna fishing fleet. In this simulation, you are given the ability to buy and sell boats, send those boats out to fish, and (hopefully) make money. As this is a competition, every group is pitted every other group to gain the most.

The simulation will continue until either 25 years have passed or until the total number of fish in the ocean drops below 500, at which time the stocks are depleted beyond recovery. Should the tuna population ever drop below 500, the simulation immediately ends. The Mediterranean Sea starts with approximately 25,000 tuna fish; the population adjusts each year for the effects of both breeding and fishing/harvesting.

A state's net worth is calculated by adding $500 per ship to the state's current cash on hand (CoH). This is then adjusted for currency exchange rates according to the buy price in the currency markets, calculated daily. The state with the highest net worth at the end of the game will be awarded 10 extra credit points each. The second place group receives 5 points extra credit, the next three places will receive 3 points. Should the tuna stocks become depleted (i.e. the population drops below 500), all groups fail in their quest and no extra credit is awarded.

The US dollar (US$, USD, or $) will be utilized as the base currency in the simulation. Thus, a state's net worth will naturally increase when the US dollar drops in value vis-à-vis that target currency, all things the same. This is not different from reality, in which the US dollar is used as the base currency for such things as most OPEC petroleum and the IMF's "Standard Drawing Rights".

The Rules

The rules are quite simple. Each state must submit four pieces of information (using the online form) to the professor **after 12:00pm** and **before 10:00pm** each night an annual plan is due. Those four pieces of information are

- The number of ships purchased (and from whom and for how much),
- The number of ships sold (and to whom and for how much),
- The number of ships to be built (purchased from the United States) for $1000, and
- The number of ships to send out to fish.

Should the professor not receive the necessary information in time, no ships will be sent out and the members of the state lose participation points for that day.

Ships can be purchased at any time from the bank[1] for the rock-bottom price of only $1,000 each. Other ship sales can be transacted between the groups. Those must be announced to the professor on the annual report of *both* states before they become finalized and usable. If there is a discrepancy between the annual reports, the deal fails to go through.

Each year, you can send ships out to fish or you can keep ships back in harbor in the dry dock. Those sent out can increase the number of fish caught for the given country.

[1] Purchasing ships from the bank, buying from the United States, and buying from the professor are equivalent actions.

Those ships kept in the dry dock incur an annual cost of $300, which covers the cost of keeping them seaworthy. There is no charge for sending the ships out to fish.

The fish population follows a split logistic population growth curve, with both a carrying capacity and a lower restoration limit.[2] Natural fluctuations in the efficiency of your fishing fleet are due to several factors, *especially* the population of the fish currently in the ocean and the annual weather conditions.

The computer calculates the important information based on the information each group provides. This information includes the number of fish caught, the price per caught fish the net profit (or loss) for each state per year, and the current population of tuna in the Mediterranean Sea. If, at any time, a group (or a consortium of groups) would like to know the current population of tuna in the ocean, that group (or consortium) can purchase that information for a mere US$10,000. This will cover the cost of the biologists hired to do the survey. The population surveys are not exact: expect no more than a 10% error between the measured population and the true population. The US$10,000 is the *total cost* for the population survey. Splitting the costs amongst the states in the consortium is appropriate.

[2] This statement is explained further in the section dedicated to population theory.

Submitting the Annual Report

Each state must submit the required information **after 12:00pm and before 10:00 pm** each night, *Monday through Friday*. This section will walk you through the process of submitting your annual report. The submission form can be located in the Tunawars section of the class website.

A glance at the home page for the Tunawars simulation will show you three areas. The first area is the brief introduction to the simulation. Above that is the listing of daily current leaders. To the left, most importantly, is the menu.

The Tunawars Menu

This subsection describes the purpose of each of the seven links on the left menu. Note: You must be logged into the system to access the important areas of the simulation.

Home:	Returns you to the home page for the simulation.
Current Status:	Takes you to the current status of the simulation and the position of your state within the simulation.
Annual Report:	Takes you to the page allowing you to send in your annual reports. This is only available if you are logged in to the system.
Course Home:	Takes you back to the home page for your class.
Change Class:	Takes you to the main page for the Tunawars simulation and allows you to change the class under consideration. While this may not seem important, it allows you to search through what other classes have done and allows you to learn from their actions—both good and bad.

In addition, along the top of the photograph, there are four icons. The icons represent four important links:

- 学 This is the Japanese character for 'study,' and it will return you to the course website.

- This is the link to the state listings for the simulation. Here, you can determine which fellow student represents which state. Furthermore, if you have logged into the system, the student name links to their email address.

- This icon links to this manual.

- This key icon will take you to place to log into the system. If you have already logged into the system, this icon will be replaced with your state's flag.

The Annual Report

Clicking on the 'Annual Report' link will take you to the Annual Report Submission page. You are now at the "Annual Report Submission Form" page. Your name and position are listed to the right of the flag of your state. If you (or any members of your group) have already submitted an annual report, summaries of those submissions are listed below the area identifying you and your state. The last submission of the year is the only one that counts. So, if you wish to change your report, you can do so at any time before the due time.

Below the identification area (and the previous submissions, if any) is the submission form (Figure 1). Your name and proper email address are already filled in for you. There are spaces for you to provide the necessary information for your annual report. The ‘Any Comments’ field is provided so that you can further explain your report if necessary. This will come in handy should you make multiple sales and purchases in a single year.

Once you have filled in all of the necessary spaces, click on the “Send Annual Report” button. Your information will be submitted to the simulation, and you will be taken to an acknowledgement page. An email will be sent to you summarizing the information you submitted. Once you are taken to the acknowledgement page, you have successfully submitted your annual report. Congratulations!

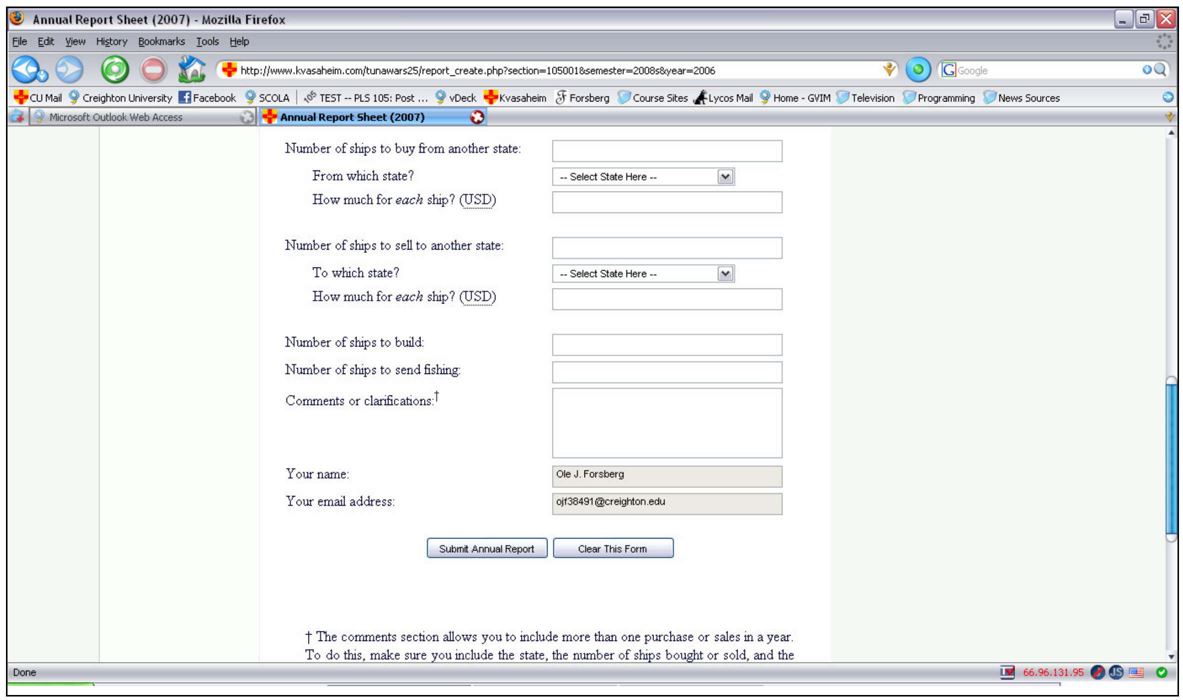

Figure 1: Annual Report Submission Form (bottom)

Bankruptcy

Besides the catastrophic depletion of the tuna population, the other way your state can have difficulties in the simulation is through bankruptcy. In this simulation, there are two types of bankruptcy.

The first type occurs when the state's cash on hand (CoH) drops below zero. When this happens, there are two results. First, that state is no longer able to purchase ships. Second, should a state's cash on hand remain below zero for *three consecutive years*, the United States will auction off their ships in an attempt to increase their cash reserves to a non-negative number. If the auction fails to achieve this all-important result, the state is dismissed from the simulation.

The second, and more important, type of bankruptcy occurs when the state's *net worth* drops below zero. Should this ever happen, that state is *immediately* dismissed from the simulation, and those ships permanently removed from play.

Dismissed states can *never* rejoin the simulation.

Currency

Currency values fluctuate. During the last year, the value of the US dollar has dropped significantly against most other currencies. One major effect of this devaluation is that non-US manufactured goods become more expensive in the United States and US-manufactured goods become less expensive outside the United States.

In the simulation, currency value fluctuations affect the true net worth of the state and the costs of ships and dry-docking. If the value of your currency drops, it will cost you more to buy ships and your net worth will drop. All currencies are calculated from the 'ask' exchange rates vis-à-vis the US dollar as of 10:00pm on calculation day.

My source of currency exchange rates is ICCFX. There is nothing inherently good about this source; it is convenient. They provide the currency ticker on the Tunawars site, and they provide the important currencies to me easily. The URL I use is

http://www.iccfx.com/curtable.php?tocompare=ALL,DZD,BAM,HRK,EGP,EUR,ISK,LBP,LYD,MDL,MAD,NOK,ILS,CSD,SEK,SYP,TWD,TND,TRY,UAH&tosearch=USD

Population Theory

This section explores the dynamics of (tuna) populations in the simulation (and in real life). Populations change based on two competing factors: birth rate and death rate.

Birth Rate

The birth rate is directly proportional to the density of tuna fish in the ocean. This is simply a manifestation of mating being predicated on contact. Tuna fish are sexual entities; as such, they cannot reproduce on their own. Small populations in large regions have a small chance of bumping into each other enough to procreate. Large populations in small areas have a much higher probability of meeting up at the right time to mate.

There is a theoretical lower limit to possible population growth. This is the point where the density is too low for reproduction to offset natural deaths. When this level is reached, the population begins to die off with no hope for return. In this simulation, that critical lower population is 500 fish.

Death Rate

The second aspect of population growth is the death rate. There are two factors that affect mortality: natural lifespan and food depletion. The first is a constant that depends on the species itself. The second depends on the population density.

The Bluefin Tuna (*Thunnus thynnus*) has a lifespan of approximately 15–30 years. Assuming a natural lifespan of 30 years means that 3% of the tuna population dies from old age annually. Assuming a lifespan of 15 years means that 7% of the population dies from old age annually.

The second factor is that there needs to be sufficient levels of food and other nutrients for the fish to be able to survive. When the fish population gets too high—beyond what is termed the “Carrying Capacity” of the area—the fish begin to naturally die off from effects of low nutrition.

Both of these factors combine to create a rather complicated population plot (see Figure 7). This plot may be called a split-logistic population curve. A normal logistic curve has a single fixed-point asymptotically stable population (the carrying capacity)

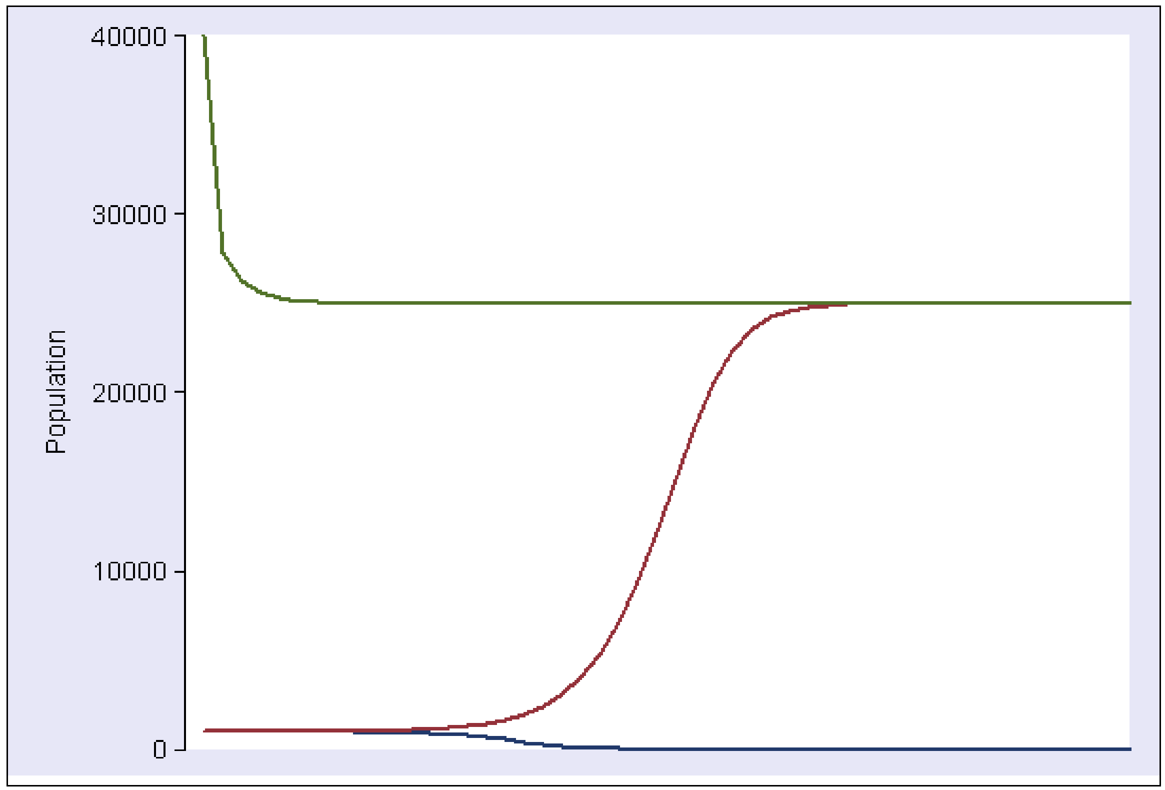

Figure 7: Split Logistic Population Graph

and a single fixed-point non-stable population (usually zero). This equation models a population that will always approach the carrying capacity as long as there is a non-zero population. However, in reality, there is a lower bound, beyond which populations cannot rebound. This lower bound is called the lower support population.

A split-logistic equation addresses this fact; it changes the zero-point to a fixed-point asymptotically stable population level and adds a single fixed-point non-stable population at the lower support population. The effect is that populations below the lower support limit naturally decay to zero, while those above it will approach the carrying capacity of the region.

The closed form equation of the standard logistic formula is simply:

$$x(t) = \frac{1}{1 + \left(\frac{1}{x_0} - 1 \right) e^{-rt}}$$

Here, t is the time elapsed, x_0 is the initial population, and r is the Malthusian parameter, which determines how quickly the population changes. This equation is not as helpful as it may appear. The important parameters, while present in the equation, are hidden. Additionally, while this equation gives the population at any future (or past) time, given the two parameters, it does not easily allow for shocks to the system (like fish harvesting).

To make the logistic equation more helpful for our needs, we can rewrite it in its differential form (after a little Calculus):

$$\frac{dN}{dt} = \frac{rN(K - N)}{K}$$

Here, N is the current population, r is the Malthusian parameter, and K is the carrying capacity of the region. The left-hand side of the equation represents the instantaneous change in population. There are but two parameters: carrying capacity and the Malthusian parameter. One thing to notice about the equation is that there is only one non-trivial point[3] where the population is stable, and that is where the current population (N) equals the carrying capacity (K). Any perturbations of the population around K results in the population eventually returning to K.

Real populations, and our tuna populations, have *two* non-trivial stable points: the carrying capacity (K) and the lower support limit (L). Employing the lower support limit to the above equation (and some algebra), results in the difference equation for the split logistic curve:

$$\frac{dN}{dt} = \frac{rN(N-L)(K-N)}{(K-L)^2}$$

Here r, K, and N represent the same as before, and L represents the lower support limit of the region—the population at which the fish cannot reproduce enough to overcome the natural death rate.

It is this last equation that I use to determine the increase/decrease in the tuna population from one year to the next. The actual formula I use is

$$P_{t+1} = P_t - C + \frac{rN(N-L)(K-N)}{(K-L)^2}$$

Here, P_{t+1} represents the new population, P_t is the previous population, C is the number of tuna caught that year, and N is the population at the end of the year ($P_t - C$). In other

[3] In this context, 'non-trivial' means non-zero. The zero population is trivially stable, as there is no sex.

words, this approximation assumes you catch all fish at the beginning of the year and all fish spontaneously mate at the end of that year.

Grading in the Simulation

This simulation carries three grades to it. The first is straight participation. The second is the daily journal you keep regarding the Tunawars simulation. The third is the Tunawars Analysis paper. The third is graded according to the paper description found on the course website.

Your Participation

Participation for this simulation is graded based on the number of annual reports you submit properly as a percent of the total number of reports that should be submitted, which is 25—one for each year of the simulation. As the total participation grade is 50 points, each annual report is worth two points.

This has two major consequences. The first is that each group member (in multi-member groups) gets the same number of participation points as every other member of that group, regardless of how many annual reports that individual member submits. You may want to investigate ‘free-riding’ and the problems associated with it.

The second consequence is that if your state *is not able* to submit the annual report, you will not receive the two points for that year. This means that if your state goes bankrupt, it can earn no more participation points for the remainder of the simulation. It also means that if the fish population drops below 500, *no group* earns additional participation points, which could lead to everyone failing the simulation.

As an example, consider the class which depleted the tuna stocks in 9 years. Each member of the class earned no more than 18 participation points out of the 50 possible, which is a 36%. Additionally, several states failed to submit annual reports on most of those years. They received even fewer participation points.

You will want to consider both of these carefully when designing your strategy. Participation pressure also colors the efficacy of treaties if you are not careful. Issues of fairness become confused with issues of justice and success: Is it fair that a state with 30 ships be forced to dock half of them like a state with two? Or, is it more important to hold back equal numbers of ships? Compromise built the United States; will it build your new world fishing order?

No one said this was going to be easy, only that this really simulates the issues our world leaders face every morning they get out of bed. Should we negotiate with North Korea? Should we give them fuel oil to keep them from going nuclear? Is it fair to the nicer states that need the energy supplies just as much as North Korea? Is it fair that North Korea may not be in this situation had they utilized their resources differently? What is fair? Is fairness even a relevant concept in the system of states?

Daily Journal

During the Tunawars Simulation, each student is required to keep an annual journal. This journal needs to contain both relevant information about the state of your fleet and your thoughts about strategy. It needs to be completed each simulation year. I will collect all of the journals within a week of simulation completion.

Necessary Information

For each simulation year, you need to include the following information in an easy-to-read format: Name; State; Current Year; Current rank; Annual profit from last year; Starting funds for this year (Current cash-on-hand); Total number of ships owned; Total number of ships you will send out this year; Price of fish; Number of fish caught; Total number of ships everyone sent out last year; USD value of one of your currency; The change from last year; Your current strategy; How well you think your strategy is working; Your new strategy, if you are going to change; and Your reflections on how this simulation applies to the current topic in class.

While you may order this information however you wish (as long as it is easy to read), there is an example of a possible format online at:

http://oforsber.kvasaheim.com/courses/pls105/docs/twjournal.pdf

Some Suggestions

- Keep current on the journal. Waiting until the last moment to complete it will be quite obvious to me.
- Almost all of the information can be found on the Tunawars simulation site's "Current Status" page for each year.
- The necessary currency information can be located in a variety of places, such as Yahoo!, XE, and Forex. Make sure that you use the number of US$ that can be purchased by one of your currency.
- Make sure you use appropriate currency symbols in your journal. If there is a single symbol, like the € or the ₤, you may use it. If not, you will need to use the appropriate international abbreviation for it (SEK, NOK, BB$, etc.). Note that quite a few states use the $ as their currency symbol. In those cases, the correct symbol is their two-letter abbreviation followed by the $, thus BB$, CA$, US$.
- Type it. Nothing hand written is allowed on it.
- Do *not* print out this journal. I will give you directions on what to do with it when the simulation completes.

Tunawars Analysis Paper

The Tunawars Debriefing represents a chance for you to share the lessons you learned from the Tunawars activity. In a well-organized essay, and pulling in class material from the semester, what lessons did the Tunawars simulation teach?

This short paper (~4 pages) will be graded on how well you use class topics and explain them using the examples of the Tunawars activity. Do not forget to properly cite and reference your sources. I would hate to fail anyone on this assignment. Follow the outline in writing your paper.

Frequently Asked Questions

As with most simulations, the description rarely covers all possible questions. This means the rules are complex, there is room for creativity, or there are subtle aspects to the simulation that you need to consider. To solidify the rules even more, here is a list of some of the more frequently asked questions regarding aspects of the Tunawars simulation.

- **Ok, I just want to be sure I am correct—we start out with 5 ships and 10,000 dollars.**

  Yes.

- **I tried to calculate the cash on hand manually, but I am coming up with different numbers than you have. What is wrong?**

  Remember that ships are counted as $500 in calculating your state's net worth, *regardless of how much you actually paid for it*. Thus, had you paid $750 for a ship, you will have immediately *reduced* your net worth by $250. Had you paid only $100 for the same ship, you would have immediately increased your net worth by $400.

  One year, there was a state who sold all their ships to make things easier, but they sold the ships at too low of a price each. The unintended result was their immediate and permanent bankruptcy.

- **About the ships we buy from you, when are they done being built?**

The United States is a fast ship builder. In fact, they are like McDonalds in that respect—a whole bunch, ready-made, and sitting around. You order a ship from us, and it is ready to send out *the same* year. So, if you now have 10 ships and you build 4 more, you are responsible for dealing with 14 ships *this* year. This is an important point.

- **What determines how many tuna we catch?**

There are two types of determinants: predictable and stochastic (random). The predictable determinants are the total number of ships sent out, the number of ships your state sends out, and the number of fish in the ocean.

The two stochastic determinants are the annual weather and the efficiency of your crew. The weather values range from 0.500 (really bad weather) to 1.500 (really efficacious weather). The crew efficiency values range between 0 (completely incompetent crew) to 100 (completely competent crew).

Each of the four determinants acts as a *multiplier to the actual tuna catch* for the year. Thus, a weather value of 0.500 indicates you caught half of the tuna you would have caught had the weather been average (1.000), all other things being equal.

Future editions of this simulation will allow you to invest in crew training, thus increasing the efficiency of your ships. Until that time, however, the crew efficiency values increase and decrease randomly (and slightly).

- **If two teams each send 10 ships, then do both catch the same, or how does that work?**

  That is correct. Only the total number of fish caught in the year is calculated. Those fish are equally split those amongst the ships sent out. Thus, were 500 tuna caught in a year in which 10 ships were sent out, each ship would catch 50 tuna fish.

- **If we all send out the same number of ships every day and catch the same number of tuna every day for the entire time of this project then essentially we all would finish first and we all then would share the 10 extra-credit points and everyone benefits and no one suffers or loses or comes up short.**

  Yes, Comrade Marx, this is absolutely true, except for the fluctuating exchange rates and the states who decide to defect on the last year. If you notice, those states who pursue identical fishing strategies and who are members of a monetary union (like most, but not all, of the European Union states) will place identically in the standings. However, not every state in this simulation is a part of the Eurozone.

- **Are there any fees for sending a ship out?**

  No, fees are charged only for docking them.

- **The price for a fish population survey is rather steep. Can several countries share the cost?**

  Yes, as long as all of the countries involved are *explicit* about their willingness to be involved and *explicit* about the amount of money they wish to be charged for the population survey. I will give the fish population information only to those countries who are members of the consortium. The fees are usually divided evenly among the

states involved; however, this does not have to be the case. As long as a total of $10,000 is spent towards the fish survey, the states can divide the cost as they see fit.

- **How do we know how many ships to send or buy? If we send too many—we can deplete the supply, but not enough and we do not catch as many tuna as other states.**

  Good question.

- **Ok, should we get together with other groups and come up with restrictions on what we can catch?**

  Should you? Beats me.

- **Can you give us any suggestions?**

  Do not forget to send in those annual reports.