External Independent Peer Review by the Center for Independent Experts

Economic Programming Model of Time-Area Allocation

Prepared by

Independent Reviewer: Ragnar Arnason

August 4 2010

Table of Contents

Acronyms

NFMS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PIFSC	Pacific Islands Fisheries Science Center
NTVI	Northern Taiga Ventures Inc.
CIE	Center for Independent Experts
SOW	Statement of Work
TOR	Terms of reference

0. Executive summary

- This review proceeded in the normal fashion. No particular problems were encountered. The panel meeting, which took place at the facilities of PIFSC in Honolulu, was well organized and satisfactorily conducted.

- The research project under review — identifying time-area closures of the Hawaiian long-line fishery to reduce turtle interactions (deaths or severe harm) with the fishing gear at minimum cost to the commercial fishery — has been under way for close to ten years.

- A great deal of good research work, most crucially vital data collection, has been carried out during this period.

- There has also been substantial progress in terms of modeling, estimation of functional relationships and scenario analysis during the period.

- However, considering the economic values at stake — in the commercial fishery, on the one hand, and the social cost of turtle interactions, on the other hand — progress in this project has been unduly slow.

- The reasons for this slow progress are not entirely clear. Two possibilities, by no means mutually exclusive, seem to fit the available information:

  (i) The resources allocated to the project in terms of manpower and expertise seem to have been inadequate to ensure a reasonably speedy progress.

  (ii) Project progress may have been be hampered by the absence of a clear and consistent modeling framework leading to somewhat unfocussed research effort.

- The modeling framework for this project is not sufficiently well specified, at least not explicitly. No clear statement of the overall project modeling framework can be found in the research project material presented for this review. Moreover, the implicit modeling framework suggested by the research that has already been carried out is inadequate for the task at hand.

- On the positive side, most of the research already conducted fits well into what this reviewer regards as a proper modeling framework to achieve the project objectives.

- One consequence of the lack of a proper modeling framework is that the research effort so far has not dealt with two vital modeling components for indentifying economically optimal time-area closures; (i) industry response function to specific time-area closures, (ii) the economic value of turtle interactions.

- Other modeling problems have to do with a lack of proper stochastic framework to allow uncertainty and risk estimates of the modeling predictions and a maximization module to identify the best possible time-area closures.

- There are further weaknesses in the estimation procedures so far employed in the project. All modeling components have to be estimated with state-of-the art statistical procedures.

- The Hawaiian long-line fishery is economically and socially quite valuable and so are lives of the sea turtles impacted by this fishery. Therefore, the potential economic benefits of a well-founded system of time-area closures in this fishery are very substantial. Compared to this, the cost of research is miniscule. Moreover, the costs of further delays are high — every year without the best possible solution adds to the costs.

- It is therefore strongly recommended that determined steps be taken to complete this project as soon as possible. This involves essentially two items:

  (i) The preparation of a well thought out research plan.

  (ii) The addition of the necessary manpower and expertise to the project.

- Given the available data and the research already conducted, it seems reasonable that with the additions of approximately two-man years of the correct expertise, the project could be brought to a satisfactory state of practical applicability within a year.

1. Background

On 2 June 2010, I signed a contract with the Northern Taiga Ventures Inc. (NTVI) to conduct an independent external review for the Center for Independent Experts (CIE) of the time–area allocation model under development by the Pacific Islands Fisheries Science Center (PIFSC) for the Hawaiian–based pelagic longline fishery.

The main motivation for developing this time-area allocation model is the accidental capture by the this long-line fishery, which targets tunas and swordfish, of certain endangered species of sea turtles, most seriously loggerhead and leatherback turtles. Many of these captures result in turtle deaths (by drowning). The long term survival rate of the turtles that survive the experience is uncertain.

The available data show that the rate of turtle captures (generally referred to as turtle interactions) per unit effort and relative to the amount of target harvest depends on the area, the time of year and the type of long-line fishery conducted (shallow or deep sets). Given this, there is reason to believe that by the appropriate area-time closures it may be possible to achieve the double aim of keeping the number of turtle interactions within acceptable limits while minimizing the economically detrimental impacts on the commercial fishery. More generally, by the judicial use of time-area closures it may be possible to maximize the net social benefits from this fishery taking both the commercial value and the social cost of turtle mortality into account.

Given this context, I was specifically requested to address the following issues:

1. Evaluate and comment on the impact modeling approach and methodology.
2. Comment on the overall quantity and quality of data used in the model.
3. Evaluate model assumptions, estimates, and major sources of bias or uncertainty. Specifically, recommend improvements including alternative modeling approach, data sources or uses as appropriate.
4. Insert an explicit statement as to whether this model represents the best available science for estimating trade-off between reduction of sea turtle interaction and economic return to the Hawaii swordfish fishery.
5. Insert an explicit statement as to whether this model represents a viable modeling framework upon which other protected species (in addition to the sea turtle) interacting with this fishery can be added as needed in the future.
6. Provide recommendations for any further improvements given data limitations.
7. Briefly describe the panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

Further details of my obligations under this contract are set out in the Statement of Work a copy of which is found in Appendix 2 of this report.

My work on this review was carried out during the period 2 June to 16 July 2010. The first part of the period was used to collect background information and study material generated by the research project and provided by the CIE. A Panel Review meeting took place at the PIFSC facilities in Honolulu, Hawaii, from 28-30 June 2010. The period after that was used to evaluate the findings and prepare this report.

2. Description of Reviewer's role in Review Activities

I took on this review task as an independent expert. According to this role I have adopted my own approach to the work and organized my own report within the parameters specified in the SOW without consulting anybody else. Similarly, I have, to the extent possible, refrained from discussing the task and its various aspects with anyone else including my fellow reviewer.

The review work was carried out during the period 2 June to 16 July 2010. It is primarily based on (i) a couple of documents generated by the PIFSC and supplied to me by the CIE (see bibliography), (ii) a number of background articles and reports that I located,(iii) presentations given by the PIFSC staff at the panel meeting in Honolulu June 28-30 and questions and discussions during that meeting and (iv) my own general knowledge of the subject. Much of the written material used for this review is listed in the bibliography.

During the panel meeting at PIFSC in Honolulu, Hawaii, from 28-30 June 2010, I had the opportunity to ask questions for clarification and discuss the various aspect of the research project with the PIFSC staff. During that meeting I received reasonably clear and satisfactory answers to all my questions. At my request a short trip to the Honolulu fishing harbor to inspect typical pelagic long-line fishing vessels was arranged. This proved helpful to better understand the nature of this fishery.

During the Panel meeting I inevitably became privy to the comments and made by my fellow reviewer. This report, however, contains exclusively my own assessments and evaluations.

In further detail, my review activities proceeded as follows:

- June 2-25. Collect and study background material including the documentation supplied by the CIE.
- June 26-July 2. Travel to and attend the panel meeting at PIFSC in Honolulu.
- June 6-16. Preparing my draft review report.

3. Summary of Findings

The Hawaiian long-line pelagic fishery constitutes a significant economic activity in Hawaii. Although somewhat variable, it usually generates between 15-20.000 metric tonnes of landings and some $50-80 million of landed value annually. Information on the number of fishermen and on-shore labor is not readily available, but it seems likely that the fishery employs a few hundred full-time fishermen equivalents and probably at least that number of people in associated upstream and downstream activities on land.

Incidental turtle (especially leatherback and loggerhead) bycatch in this fishery, especially that part of it that targets swordfish, is believed to pose a significant threat to those endangered species. A reasonably reliable economic valuation of the economic loss caused by this incidental bycatch is not available. At least, the researchers interviewed during this review were not aware of such a valuation and considerable literature search did not come up with well-founded concrete valuations.

Drawing parallels with existing valuations of other possibly endangered species (e.g. tigers, panda bears and certain species of seals and whales), however, suggests that the unit value of turtle bycatch may be quite high. It may, therefore, well be welfare enhancing to take costly measures to avoid these turtle deaths. The important point, however, is that this is not very clear at all.

Be that as it may, the administrative reality is that upper limits on turtle catches (referred to as interactions) in this fishery have been imposed and are enforced by on-board observers and other means. If these limits are hit, the entire fishery is closed forthwith. The cost of that may be very substantial

A basic question is whether there are more cost effective ways to reduce turtle interactions with less impact on the long-line fishery or, a bit more precisely, the net benefits generated by the fishery.

One possible option is to employ a system of time-area closures that achieves a certain level of protection for turtles while minimizing the cost to fishers. This is the option that has been investigated by the PIFSC for some considerable time or at least since the closure of the fishery in 2001.

It is important to realize that other options to achieve the basic aim of reducing turtle interactions at minimum cost to the fishery exist, but are not being investigated. These options include

(i) Corrective taxation
This consists of the appropriate charges or penalties being levied on each turtle/fishing gear interaction. The appropriate charges reflect the social costs (value) of each interaction, but due to imperfect enforcement might be set higher. As such, these would vary with the size of the turtle stocks and, perhaps, the accumulated catches during the year.

(ii) Turtle bycatch (interaction) quotas.
Based on an upper limit of allowable turtle interactions, individual transferable quotas for turtle interactions could be issued. In this case the quota market would set the price (economically equivalent to a tax) dependent on the total number of interactions allowed. Subsequently to the issue of these quotas, the authorities and, in principle, conservation interests could modify the actual turtle interactions by buying in a par of these quotas.

These other options have several economic advantages compared to time-area closures. Among other matters, they generate individual incentives to avoid turtle interactions by selective fishing and technological innovations.

As already mentioned, the PIFSC has been engaged in investigating aspects of time-area closures of the pelagic long line fishery at least since the early 2000s. The aim of this research has been to provide modeling structure and sufficient empirical information and computational ability to allow the identification of time-area closures for this fishery that will meet the objective of keeping turtle interactions within preset bounds at a minimum cost to the fishery.

Important steps in the direction of achieving this aim have been taken. Extensive data collection has taken place producing a very impressive data bank for this fishery including both biological and economic data. Additional data continues to be generated on an on-going basis. At the same time theoretical, estimation and simulation work has taken place. Certain basic modeling aspects and an empirical prediction model of fish and turtle takes by area and time were set out in 2005 (Kobayashi and Polovina 2005). In 2009, refinements of this initial research by new empirical estimations and by adding fishery cost functions were made available (Lin and Pan 2009). Also included in this most recent report, useful scenario analyses comparing options for time-area closures has been conducted.

However, at least based on the material submitted for this review and the presentations offered at the *in situ* meetings, this research is missing certain elements that are necessary for it to achieve its basic aim in a satisfactory manner. They key missing elements are:

1. An explicit model of the situation that:
    a. Encompasses the economic essentials of the situation;
    b. Is suitable for generating policy recommendations;
    c. Provides guidance for the necessary empirical research.

2. An economic valuation of turtle interactions (deaths or serious harm due to encounter with the fishing gear). This kind of an evaluation is essential for comparison with the economic value generated by the fishery. Without measuring the costs of turtle interaction in the same units as the benefits of the commercial fishery, a sensible trade-off can not be calculated. It may be noted that this is not strictly needed if an exogenous upper bound on turtle

interactions is in place and is binding. However, that is generally not the case in the early periods of the year, even if the bound becomes binding later on.

3. A state-of-the-art robust statistical estimation of the functional relationships needed for the model. These functional relationships include:
   a. A predictive model of fish and turtle concentrations and capture rates by areas. Currently this is done by a GAM procedure which is unlikely to be the ideal procedure. Some form of a maximum likelihood procedure seems preferable;
   b. A commercial profit function for the fishery. Currently a cost function has been estimated. However, the estimation procedures are elementary and are clearly not statistically ideal;
   c. An industry response function to time-area closures. At the present no attempt at the estimation of this function has been attempted. This aspect is dealt with merely by ad hoc assumptions and scenario analysis.

4. A properly designed stochastic version of the model that:
   a. Allows the calculation of confidence intervals for the predictions (or simulations);
   b. Provides a basis for a risk analysis of the various possible options and, in due course, the identification of the optimal stochastic policy.

The first item, the lack of an explicit modeling framework, is in many respect the most fundamental and pressing problem. Without a proper modeling framework, the subsequent research is almost bound to go astray. Therefore, an outline of a model for this purpose is summarized in an appendix to this section.

This research has been going on since at least since 2001. The research is still a considerable distance away from achieving its basic aim (of being able to deliver reasonably reliable advice on time-area closures for the pelagic long-line fishery that will meet the objective of keeping turtle interactions within preset bounds at minimum cost to the fishery). Considerable values are at stake. Until the research is finished, or at least achieves a certain level of practical applicability, it cannot help in resolving the issues in the best way. Therefore, this project should be brought to a reasonable level of completion as soon as possible.

In the view of this reviewer, a key reason for this slow progress is the limited resources allocated to the project. The most serious limitations appear to be:

1. Lack of manpower. Too few people are working on the issue;
2. Lack of certain types of expertise in the project. This applies especially to expertise in (a) the type of modeling needed, (b) numerical maximization techniques and (c) statistical estimation.

It follows that to complete the project, these resources have to be made available. If that is done, it is my belief that it can be made to reach a practical application level within one year.

Short responses to the specific questions in the TOR

1. *Evaluate and comment on the impact modeling approach and methodology*.

   The fundamental modeling approach to this research is not well specified, at least not in an explicit manner. There is no clear comprehensive model presented in the material provided.

   However, it appears that the research work conducted so far is actually in good conformance with an appropriate overall modeling framework (see appendix to this section). On that basis it appears likely that the research strategy is actually based on some overall modeling approach that has not been explicitly stated.

   A major drawback in the research conducted so far is that certain key modeling components have not been dealt with at all. These include (i) the industry responses to time-area closures (and possibly other management constraints) and (ii) an evaluation of the economic value of turtle interactions.

   The overarching methodology consisting of (i) modeling, (ii) estimation and (iii) policy analysis, is fine as far as it goes. The problem lies in that detailed application of this methodology. The modeling leaves a great deal to be desired. The statistical estimation does not seem to be sufficiently state-of-the-art and the policy analysis is restricted to scenario analysis without systematic uncertainty and risk analysis, which is unsatisfactory.

2. *Comment on the overall quantity and quality of data used in the model*.

   A great deal of relevant data on the fishing activity, commercial harvests and turtle by-catch by time and area has been collected. These data continue to be generated on an on-going basis from logbooks and observer reports. Some very useful economic cost data have also been collected.

   The quality of these data seems generally good. The cost data is probably most suspect although there is no particular reason to doubt it. This review was not extensive enough to verify the quality of those data.

   Broadly, the overall quantity of data is good and impressive. The quality of these data also appears to be satisfactory.

   The key missing data concern the economic valuation of turtle interaction. The reason is that this information has not, so far, been identified as important for the research. There are several ways to obtain this evaluation. The most robust way is to conduct a special evaluation. This, however, is a major undertaking. A less demanding way is to use already existing evaluation research of similar endangered species to obtain estimates of the likely range of the economic loss associated with each turtle interaction.

3. Evaluate *model assumptions, estimates, and major sources of bias or uncertainty. Specifically, recommend improvements including alternative modeling approach, data sources or uses as appropriate.*

This request is dealt with at some length above and in the appendix to this section. The main modeling problem is a lack of an explicit modeling framework which identifies the key model components that need to be empirically estimated. As a result two key modeling parts are missing from the existing model components:

(i) An industry response function to management controls (time-area closures);

(ii) An evaluation of the economic value of turtle interactions.

To this, one may add that the approach of limiting the search for optimal time-area closures to scenario analysis instead of maximizing an objective function (which is readily available in the appendix to this section) is unsatisfactory. The employment of the efficient frontier is a nice idea but inadequate — e.g. there are simply too many combinations of time-area closures to make this approach workable.

Apart for the lack of data on the value of turtle interactions, there are no apparent serious data problems. The estimation of the key relationships is not particularly convincing and can almost certainly be greatly improved.

4. *Insert an explicit statement as to whether this model represents the best available science for estimating trade-off between reduction of sea turtle interaction and economic return to the Hawaii swordfish fishery.*

The model as it stands (or appears to stand) does not represent a state-of-the-art model for the specified purpose. The reasons for this conclusion are detailed above.

5. *Insert an explicit statement as to whether this model represents a viable modeling framework upon which other protected species (in addition to the sea turtle) interacting with this fishery can be added as needed in the future.*

The model as it stands cannot achieve the stated purpose of the research (identifying time-area closures for this fishery that will meet the objective of keeping turtle interactions within preset bounds at minimum cost to the fishery). The reason for this is primarily the missing modeling elements discussed above, but also the lack of a built in maximization procedure. In this sense it is not viable.

However, the model, as it stands, forms an important part of a more complete model (see appendix to this section) that can be used to achieve the objectives of the research. In this sense it is viable.

The model outlined in the appendix to this section can be extended to deal with other bycatch species in this and other fisheries.

6. *Recommendations for any further improvements given data limitations.*

The recommendations for future improvements have been outlined in some detail above and further in the appendix to this section.

To summarize, the recommendations consist of two major parts:

(1) Modeling and estimation

The modeling framework has to be improved and made explicit. The missing modeling components need to be estimated. The other estimations should be improved and statistically tested. The identification of optimal time-area closures should be on the basis of maximization of the objective function. Uncertainty should be explicitly and systematically accounted for and incorporated in the optimization procedure.

(2) Research resources

This project needs more manpower and expertise in (i) the relevant type of modeling, (ii) statistical estimation and (iii) numerical maximization techniques. Available information indicates that the benefits of a reasonably efficient time-area closures is counted in millions of US$ annually (Li and Pan 2009). It is therefore worth a substantial investment expense to accomplish this.

7. *Brief description of panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.*

There is not much to say about this. The panel review proceeded fairly normally. Only one of the main researchers, Dr. Pan, was present and she did a very good job of explaining the research and respond to panel questions. The organization of the panel meeting was good and the time allocated sufficient. As expected much of the discussion concerned the modeling framework and the data.

Appendix to section 3

An outline of a model for determining optimal time-area restrictions

The following outlines a model of the type that is needed to deal with the basic task of selecting optimal time-area closures.

(i) Time-area modeling

The required model is concerned with time and areas. This can be modeled in a continuous fashion. Indeed, that would be most convenient from a mathematical perspective. However, due to various practical considerations, it is probably more helpful to proceed in terms of discrete time and area measures.

As a first order approximation to optimal time-area allocations, it is sufficient to consider one year. This implicitly assumes given biological stocks, companies and fleets. To the extent that these stock variables are thought to be important — and they surely play a role — the model needs to be extended to multiple years.

The year is divided into months (or other convenient units). The months are referred to by the index t, t=1,2, ...T, where, if the time measure is months, T=12.

Note, however, that there is no modeling reason to have all the time periods of equal length. For instance, it might be a good idea to have finer time grids during the most "crucial" periods (e.g. the first two months of each year.

The area in question is divided into a finite number of blocks. As for the time units, it is important to realize that from a modeling perspective, these blocks can basically be of any size or shape. However, in what follows, we will talk about them as squares. We refer to these squares by the index a, a=1,2,...A, where A is the total number of blocks (squares). Thus, $a(t)$ refers to location a at time t.

In what follows, we will find it convenient to talk about the set **A** as the set of all possible locations.

Note, that for modeling consistency, one (or more) of the locations in the list of locations must be must be the port (or ports).

According to Kobayashi and Polovina (2005), the total fishing area is 0-45°N and 140-180°W. Thus, for 1x1° squares (approx. 60 by 60 nautical miles), A=1800. For 2x2° squares (approx. 120 by 120 nautical miles), A=450. Neither number would be a cause for numerical computational concern.

(ii) Stocks of fish and turtles

Let $x(a,t)$ be the stock of commercial fish in area a at time t. Note x can be a vector of different species. It seems reasonable that at least x contains swordfish and tunas separately.

Let $y(a,t)$ be the stock of turtles in area a at time t. As the commercial species, y can be a vector of turtle species. It could even include other by-catch species. Given the available description of the situation (see bibliography), it seems reasonable that the vector y should have three dimensions representing leatherheads, loggerheads and other sea turtles.

Note that the dimensionality of the vectors, x and y may be further increased to account for age and/or size classes of the species in question.

(iii) Commercial profits (benefits)

Given the description of the situation, it seems reasonable to define commercial profits as profits per unit of effort, effort being defined as number of sets (of long-line).

Let commercial profits per unit effort in area a at time t be defined as

(1) $$\pi(a,t) = \pi(x(a,t), a, s, p) - \overline{\pi},$$

where, for reasons that will become apparent, fixed costs, $\overline{\pi}$, are specifically accounted for. The location a appears separately to reflect the distance of area a to the landing port (usually Honolulu). The index s refers to the type of set and the vector p refers to exogenous variables such as prices, the capital being applied and so. Note that the particular fishing vessel or its characteristics may be included in the vector p.

Note, as already mentioned it is very important for modeling consistency to include the port as one of the location. So, for staying in ports there would be some profits, possibly equal to $\overline{\pi}$.

A slightly more advanced version of the profit function is:

(2) $$\pi(a,t) = \pi(x(a,t), a, a_0, s, p) - \overline{\pi}$$

where a_0 is the location of the fishing vessel at the end of the last period. : note that this leads inevitably to a space dynamic optimization.

Note that (1) and (2) implicitly include a harvesting function, i.e. a function that maps fish stocks, type of set and effort (number of sets) into profits. They, of course, also implicity include a cost function such as the one estimated in (Li and Pan 2009).

(iv) Turtle interactions (capture)

Define the harvest of turtles per unit effort (long line set) as

(3) $h(a,t) = H(y(a,t), s, \phi)$,

where ϕ represents vector pertinent vessel characteristics and selectivity measures. Note that (3) defines a vector of these functions, one element for each species of turtle.

(v) Valuation of turtle interactions

Merely counting the number of turtle interactions is not satisfactory from a social decision making view. The benefits of commercial fishing have to be compared to the costs of turtle interactions. Such a comparison can only be made by measuring both in the same units. Since, commercial benefits are traditionally measured in monetary unity, it seems natural to measure turtle interactions in the same units. This is generally referred to as valuation in the natural resource and environmental literature (Hanley et al. 1997).

A general expression for the valuation of turtle capture in area *a* at time *t* is:

(4) $-\Psi(h(a,t), t, y)$,

where *y* represents the total stock of the turtle species in question and *t* is supposed to reflect the possible changes of this evaluation over the year. The negative sign is merely for the convenience that this value (representing interactions and not conservation) is negative.

In simple cases, this valuation might be fully represented by a unit price multiplied by the harvest:

$$-\Psi(h(a,t), t, y) = -\eta(t, y) \cdot h(a,t),$$

where $\eta(t, y)$ is the unit price of turtle interaction. Remember, this price is a vector having the same dimension as the $h(a,t)$.

(vi) Time-area restrictions

Time-area restrictions can be modeled with a binary variable $R(a,t)$ defined as:

$$R(a,t) = \begin{cases} 1 \text{ (no restrictions)} \\ 0 \text{ (closed)} \end{cases}$$

So $R(a,t)$ =1 means that area *a* is open at time *t* and $R(a,t)$ =0 that it is closed.

(vii) Commercial behavior and fishers' behavior

Fishers presumably want to maximize their expected benefits. These benefits were above talked about as profits. In a more general modeling, they can be any benefits and the profit function any objective or benefit function they seek to maximize.

Formally, at each time (here modeling time) fishers seek to solve the following problem:

(I) $$\max_{a\in A, s\in 1,2} \pi(a,t) = \pi(x(a,t), s, a_0, p)\cdot R(a,t) - \bar{\pi}$$

So, they select a location from the total available set of locations, and the type of long-line set form the two that, apparently, are available. This they do on the basis of (expected) concentrations of fish, exogenous variables, p, and, at least in general, their current location.

Note that this feature (i.e. current location) in the profit function leads to an inherently dynamic problem for the fishers. They will, in principle have to plan their fishing operations for the year on the basis of their expectations of fish locations and the pattern of closures. As a first modeling step, it seems reasonable to ignore this complication

Note that the fixed costs, $\bar{\pi}$, will not affect fishers choice. However, if may induce them to go fishing, even when total profits are negative.

Note further that if closures are in place some $R(a,t)$=0, and effectively enforced, the fisheries will not choose to go to these areas.

Since, presumably, the fishing vessels always operate at maximum effort, once they have selected a and s, their effort units are defined (by choice of a and s and their current location, a_0). If not, effort will have to be included as a choice variable.

Solving maximization problem (I) leads first of all to area choices by the fleet. Note that due to different initial locations, different expectations and pure randomness, this will normally not lead to all the fleet congregating on one area.

Solving maximization problem (I) also leads to the number of effort units in each area. Let us refer to this as

(5) $$e(x(a,t), a, a_0, p, R(t); s).$$

This equation, which may be referred to as the fishers' behavioral function, is crucial to the modeling. It gives the effort units of type s in each area at each time as a function of the fish availability, the current location relative to the location a, exogenous variables and the complete <u>vector</u> of restrictions.

Note that problem (I) is relatively easy to solve, even if it is done for each fishing vessel separately. The numerical algorithm merely has to calculate the expected profits for every location and then for every boat pass over all possible locations and pick the one with the highest profits. For standard desktop computers this would only take a few seconds at most.

(viii) The social problem: Optimal time area closures

The social problem is to select the optimal area closures at each point of time. For this purpose define the social benefit function per unit effort for each area at any given time as:

$$B(a,t;R) = (\pi(x(a,t),a,a_0,p;R(t)) - \Psi(h(a,t)),$$

where, it will be recalled, $\Psi(h(a,t)$ is the valuation of turtle interactions and $R(t)$ is the vector of closures.

At this stage, it is useful to consider two variants of the basic problem.

Variant 1

The first and simpler variant is when the objective is merely to identify the socially optimal time area closures. In that case, the authorities only need to close areas with negative expected social benefits. That problem can be written in a very simple way as:

$$\text{(II)} \qquad \underset{R(a,t),\forall a,t}{max} \sum_{a}^{A} B(a,t;R(t)) \cdot R(a,t).$$

Solving this problem yields the appropriate time area closures for each single area at all times.

Note that to solve this problem, we do not really need to know how fishers respond to the restrictions. Closing all areas where fishing can be socially harmful, given their current location, renders it unnecessary to know where they will go. Neither do we need to know the effort that is going to be exerted in each area. This is because of our assumption that harvests of all species depends linearly on the effort. This assumption may or may not be sufficiently realistic. The shorter the time interval, the more realistic it will probably be.

Variant 2

The second variant is where the actual number of turtle interactions is important. This is for instance the case where an upper limit on turtle interactions has been set and is binding or when the social cost of turtle interactions depends on the number that has already been caught. The first case is the current latter administrative reality. The latter case may well be a better description of reality than assuming a fixed unit cost. Thus, this variant of the basic problem, variant 2, may well be the more realistic of the two.

In this case the social problem may be written (in a slightly simplified form) as:

(III) $$\max_{R(a,t),\forall a,t} \sum_{t=1}^{T}\sum_{a=1}^{A} B(a,t;R(t))\cdot e(x(a,t),a,a_0,s,p;R(t))\cdot R(a,t)$$

$$Subject\ to \sum_{t=1}^{T}\sum_{a=1}^{A} h(a,t)\cdot e(x(a,t),a,a_0,s,p,R(t)) \le \bar{h}$$

Note that if the constraint is not binding (and a constant valuation of turtles applies each time period), problem (III) is reduced to problem (II) which is much simpler.

The simplification is that (III) does not represent all the fishing boats and their location. If that were explicitly accounted for (III) would be written:

(III’) $$\max_{R(a,t),\forall a,t} \sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{k=1}^{K} B(a,t;R(t))\cdot e(x(a,t),a,a_0(k),s,p;R(t);k)\cdot R(a,t)$$

$$Subject\ to \sum_{t=1}^{T}\sum_{a=1}^{A}\sum_{k=1}^{K} h(a,t)\cdot e(x(a,t),a,a_0(k),s,p,R(t);k) \le \bar{h}$$

The numerical requirements for solving problems (III) and (III’) are substantial, but appear quite feasible. Note that the endogenous optimization, i.e. solving the optimal response of fishers to closures, increases the numerical demands very substantially. A good strategy would be to solve the simpler problem (II) first and then go to (III) and do (III’) last.

(ix) Extensions

The above basic model can be extended is several ways:

(1) It is possible that the concentrations of fish in each area alters significantly during the time period as a function of the number of vessels going to the area. Allowing for this stock effect would greatly complicate the model and the calculations. Rather than to model this explicitly, a superior strategy might be to reduce the length of the time periods;
(2) From a practical perspective it seems a good idea to first work out an ex ante time-area closure plan and then update it as more information becomes available. Of course, keeping the fishing costs in mind, the updating can not be too frequent;
(3) All of the above modeling and the estimated functional relationships involved are subject to uncertainty. Hence the proper maximization approach is stochastic maximization, possibly utilizing certain principles of stochastic decision theory.

These extensions are pretty straight-forward. They, however, add substantially to the numerical requirements.

4. Conclusions and recommendations

Impressive research has already taken place. The quality of this research is quite acceptable. The collection of data is impressive. It appears that, apart from missing information on turtle valuation, the existing data are adequate for the needs of the project.

However, apparently due to the absence of an explicitly stated modeling framework, this research has not been sufficiently focused. In particular it has not dealt at all with certain vital modeling elements which are necessary for the task at hand. There are other less fundamental weaknesses in the research. As a result, this research, in spite of having been ongoing for close to a decade, is still some way from reaching it objective (of providing well-based advice on time-area closures for the long-line fishery).

At the same time the values at stake in terms of (a) suboptimal fishery closures and (b) unnecessary turtle mortality are quite substantial.

On this basis it is recommended that determined steps be taken to complete this project as soon as possible. This involves essentially two things:

1. The preparation of a well thought-out research plan;
2. The addition of the necessary manpower and expertise to the project.

Item 1. is necessary to (a) maximize the likelihood to a successful research and (b) render the research as time and cost effective as possible.

Regarding item 2. the following amplifications can be offered:

- Two additional experts to the current research team are needed for and extended period of time (6-12 months); a practical econometrician and a numerical maximization specialist;
- This might be complemented with some short term expert consultation;
- The task would be to complete an empirically well-founded and theoretically consistent operational time-area selection model;
- A reasonable time to complete this task with the above additional manpower over one calendar year.

Appendix 1
Bibliography

Materials provided for review

Kobayashi, Donald R. and Jeffrey J. Polovina. 2005. Evaluation of Time-area Closures to Reduce Incidental Sea Turtle Take in the Hawaii-based Longline Fishery: Generalized Additive Model (GAM) Development and Retrospective Examination. NOAA Technical Memorandum NMFS-PIFSC-4. March 2005.

Li, Shichao and Minling Pan. 2009. Fishing Opportunities under the Sea turtle Interaction Caps—A Spatial Bio-economic Model for the Hawaii-based Longline Swordfish Fishery. A working paper.

Presentations during the meeting

Minling Pan. 2010. Baseline Economic Information of the Hawaii longline Fisheries. Power point presentation. Pacific Islands Fisheries Science Center. CIE Review. Jun 28-29, 2010.

Minling Pan and Shichao Li. 2010. Evaluation of Fishing Opportunities under the Sea Turtle Interaction Caps -- A decision support model for the Hawaii swordfish fisheries management. Pacific Islands Fisheries Science Center. CIE Review. Jun 28-29, 2010.

Other useful background material

Bartram P., J. Kaneko and K. Kucey-Nakamura. 2010. Sea turtle bycatch to fish catch ratios for differentiating Hawaii longline-caught seafood products. *Marine Policy* 34:145-9.

Beverly S, Chapman L. 2007. Interactions between Sea Turtles and Pelagic Longline Fisheries. Third regular session, Scientific Committee, Western and Central Pacific Fisheries Commission (WCPFC), Honolulu; 13–24 August 2007.

Chakravorty, U. and K. Nemoto. 2001. Modelling the Effects of Areas Closure and Tax Policies: A Spatial-Temporal Model of the Hawaii Longline Fishery. *Marine Resource Economics* 15:179-204

Curtis R. and R. L. Hicks. 2000. The Cost of Sea Turtle Preservation: The Case of Hawaii's Pelagic Longliners. *American Journal of Agricultural Economics* 82: 1191-91.

Curtis, R., 1998. The welfare effects of reducing sea turtle interactions: an application to the Hawaii longline fishery. (Dissertation project with the University of Maryland, Dept. of Agricultural and Resource Economics.).

Curtis, R.., 1998. Spatial allocation of effort: a discrete choice model of short run supply response in the Hawaii longline fishery. (Dissertation project with the University of Maryland, Dept. of Agricultural and Resource Economics.)

Hamilton, Marcia S., 1996. Hawaii longline vessel economics. *Marine Resource Economics*. 11(2): 137-140.

Hanley, N., J.F. Shogren and B. White. 1997. *Environmental Economics in Theory and Practice*. Macmillan Text in Economics. Macmillan Press.

Lewison, R, S. Freeman and L. Crowder. 2004. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecology Letters 7: 221–231.

National Marine Fisheries Service (NMFS). 2000. Fisheries off West Coast States and in the Western Pacific; Western Pacific Pelagic Fisheries; Hawaii-based Pelagic Longline Area Closure. *Federal Register* 65: 1991–96.. US Dept. of Commerce. Washington DC.

Pan, M., P. Leung and S.Pooley. 2001. Decision Support Model for Fisheries Management in Hawaii: A Multilevel and Multiobjective Programming Approach. *North American Journal of Fisheries Management*. 21: 293-309.

Appendix 2
Statement of Work for Dr. Ragnar Arnason

External Independent Peer Review by the Center for Independent Experts

Economic Programming Model of Time-Area Allocation

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.com.

Project Description: PIFSC has developed several fisheries oceanography models of time-area distribution of swordfish and loggerhead turtles relative to management of the Hawaii longline fishery. Based on these models, the PIFSC economics program has developed models that estimate the economic trade-offs of various time-area closure options. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Two CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of fisheries economics, especially with experience in spatial-temporal economic models in support of fisheries management and decision making. Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Honolulu, Hawaii during 5-7 May 2010.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the

NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/sponsor.html).

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate in a panel review meeting in Honolulu, Hawaii during 28-30 June 2010.
3) During 28-30 June 2010 in Honolulu, Hawaii as specified herein, conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 16 July 2010, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

17 May 2010	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
24 May 2010	NMFS Project Contact sends the CIE Reviewers the pre-review documents
28-30 June 2010	Each reviewer participates and conducts an independent peer review during the panel review meeting
16 July 2010	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
30 July 2010	CIE submits CIE independent peer review reports to the COTR
6 August 2010	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,
(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Key Personnel:

William Michaels, Contracting Officer's Technical Representative (COTR)
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-713-2363 ext 136

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
10600 SW 131st Court, Miami, FL 33186
shivlanim@bellsouth.net Phone: 305-383-4229

Minling Pan, Economist (NMFS Project Contact)
NMFS Pacific Islands Science Center, 1601 Kapiolani Blvd. Suite 1110, Honolulu, HI 96814
Minling.pan@noaa.gov Phone: 808-944-2190

Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Economic Programming Model of Time-Area Allocation

1. Evaluate and comment on the impact modeling approach and methodology.
2. Comment on the overall quantity and quality of data used in the model.
3. Evaluate model assumptions, estimates, and major sources of bias or uncertainty. Specifically, recommend improvements including alternative modeling approach, data sources or uses as appropriate.
4. Insert an explicit statement as to whether this model represents the best available science for estimating trade-off between reduction of sea turtle interaction and economic return to the Hawaii swordfish fishery.
5. Insert an explicit statement as to whether this model represents a viable modeling framework upon which other protected species (in addition to the sea turtle) interacting with this fishery can be added as needed in the future.
6. Recommendations for any further improvements given data limitations.
7. Brief description of panel review proceedings highlighting pertinent discussions, issues, effectiveness, and recommendations.

Annex 3: Tentative Agenda

Economic Programming Model of Time-Area Allocation

University of Hawaii at Manoa
East-West conference center
1777 East-West Road
Honolulu, Hawaii 96848

28-30 June 2010

Point of contact for reviewer security & check-in: Dr. Minling Pan

Day 1 June 28, 2010

9:00 Introduction
10:00 Research background
11:00 Data used in the model

12:00 BREAK

1:00 Cost function and economic return estimation
2:00 Sea turtle interaction estimation
3:00 Model structure
4:30 Other issues and general discussion

Day 2 June 29, 2010

9:00 Recap yesterday
10:00 Simulation design and model applications
11:00 Model results

12:00 Break

1:00 Other issues and general discussion
2:00 Summary
3:00 Adjourn

Day 3 June 30, 2010

Report writing and final session for questions

Appendix 3
Panel Membership

Jon Conrad. Professor, Charles H. Dyson School of Applied Economics and Management. Cornell University.
Ragnar Arnason. Professor, Department of Economics, University of Iceland

At the panel meeting in Honolulu, the above met with the following employees of the PIFSC:

Sam Pooley, Science Center Director
Minlin Pan, a member of the economics research team working *inter alia* on the research project under review.
Sarah Malloy, Management Analyst officer