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ICMRD Working Paper #14

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INTERNATIONAL CENTER FOR
MARINE RESOURCE DEVELOPMENT
126 WOODWARD HALL UNIVERSITY OF RHODE ISLAND
KINGSTON, RI 02881 USA

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by

Luis Guillermo Lepiz
Escuela de Economía Agrícola
Universidad de Costa Rica

and

Jon G. Sutinen
Department of Resource Economics
University of Rhode Island

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ABSTRACT

This paper examines enforcement and surveillance operations for the Pacific tuna fishery in the extended economic zone (EEZ) of Costa Rica. A zero-one integer programming model is used to optimize the allocation of sea patrol vessels and assess the cost of a surveillance program. Results suggest that a surveillance and enforcement program for Costa Rica should place special attention on the fishing activities along the EEZ boundaries with Panama and Colombia. The program should be dynamic and adaptive, accounting for seasonal and sub-seasonal changes in the fishery. Under the assumption of unilateral enforcement of a tuna policy for Costa Rica, the program is likely to cost nearly 50 percent of the income from user fees estimated to be in the range of U.S.$2 to $2.5 million under current conditions in the fishery.

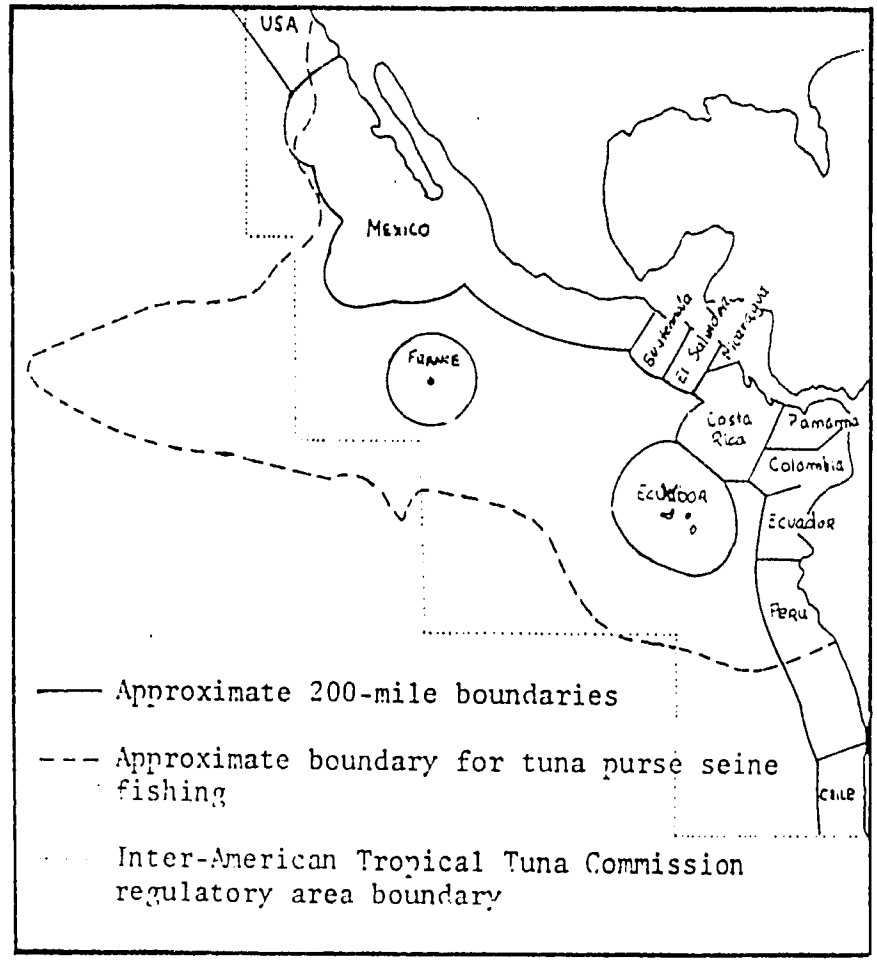
1. Introduction

How an international management system for tuna in the eastern tropical Pacific (ETP) (see Figure 1) should be established in order to avoid biological and economic waste is not clear. Several studies have stressed the need for such a system and have proposed specific programs for management of the fishery.[1] However, study of surveillance and enforcement operations as part of a managment program has been neglected, despite the fact that enforcement is recognized as essential for a stable and rational tuna management system in the area. As an attempt to fill this gap, we develop in this paper a model to evaluate enforcement and surveillance operations for the tuna fishery in the Costa Rican extended economic zone (EEZ).

Surveillance and enforcement operations are critical to the success of any system of fisheries management (Miles, 1981), and they acquire ever more importance in an international context. Suspicion among coastal state officials that the terms of a management arrangement are being violated by other participants could have destructive long run consequences for the management system (Munro, 1983). Experience in the ETP shows that some of the Latin-American coastal states would quickly raise questions if they felt that something was wrong with the distribution of catches, rents etc., among participants in the fishery.[2]

In addition, any enforcement operations in the area will be conditioned by the characteristics of the fishery and each country's claims to it. Unilateral enforcement operations by the Latin-American coastal states in the ETP have been strictly related to the

Figure 1. The Eastern Tropical Pacific Tuna Fishery



Source: Keen (1983).

claims of property rights over tuna and sovereignty over the seas. Therefore, it is unlikely that any enforcement system, carried out by an international enforcement agency in the 200-mile zones would be readily accepted by the involved coastal states. International enforcement would clearly raise questions of sovereignty over the 200 mile exclusive economic zones, perhaps adding conflicts to an already politically unhealthy fishery regime.

Suggestions have been made that one of the alternatives to the enforcement of an international tuna management system in the ETP is to allow coastal states to individually control their own exclusive economic zones (EEZs) (Broadhead in Flagg et al., 1979), or to have an integrated system by which coastal states provide enforcement throughout the entire ETP (Keen, 1983). The latter proposal is not clear about how the enforcement system would be integrated, and one is left to assume that each state will take care of its own EEZ with a general coordination of activities among neighboring countries. In any case, each state must develop the ability to enforce regulations in its own zone must be developed.

2. The Jurisdictional Issue

On the political side, Costa Rican claims over the 200-mile zone cannot be separated from the regional context. According to Luna (1972), the eastern Pacific Latin American countries (EPLAC) have long been in the middle of the present ocean rights revolution. In June of 1947, Chile was the first country of the world to assert national sovereignty out to 200 miles. This action was followed by Peru in August of the same year. In July of 1948, Costa Rica asserted sovereignty over its continental shelf and established a 200-mile zone for the management and protection of the living and non-living marine

resources of those waters. By 1952, El Salvador, Ecuador and Honduras had claimed special rights over the 200-mile zone; and the 200-mile doctrine had important multilateral support in the so called Declaration of Santiago in which Chile, Ecuador and Peru asserted their sovereignty and jurisdiction over their 200-mile zones. Since 1955 Costa Rica has adhered to the Declaration of Santiago, although in 1948 it claimed only special jurisdiction over fisheries in the 200-mile zone rather than sovereignty as claimed in the Declaration of Santiago.

In spite of the historical importance of these countries in advancing the now accepted 200-mile doctrine, there are still conflicting interests at stake with respect to the property or ownership rights to the tuna resources in their waters. The U.S., which has the largest tuna fleet in the ETP, does not recognize ownership over the highly migratory species of tuna. However, while countries such as the U.S. do not formally recognize "property" rights of the coastal nations to migratory species of tuna, they seem to recognize a kind of "liability" right over the tuna resources by the coastal state.[3] Liability rights over tuna resources are implicit in the arrangements that the U.S. recently signed with countries in the western Pacific and in the so-called "Eastern Pacific Tuna Agreement" signed in April, 1983, with four Central American countries, including Costa Rica.[4] The important point here is that under either of these "liability" or "property" right regimes the coastal state has the right to obtain revenue from the tuna resources in its waters.

3. The Fishery

About 10 percent of the total landings of tuna in the ETP have been yellowfin and skipjack from the 560,000 square kilometers of Costa

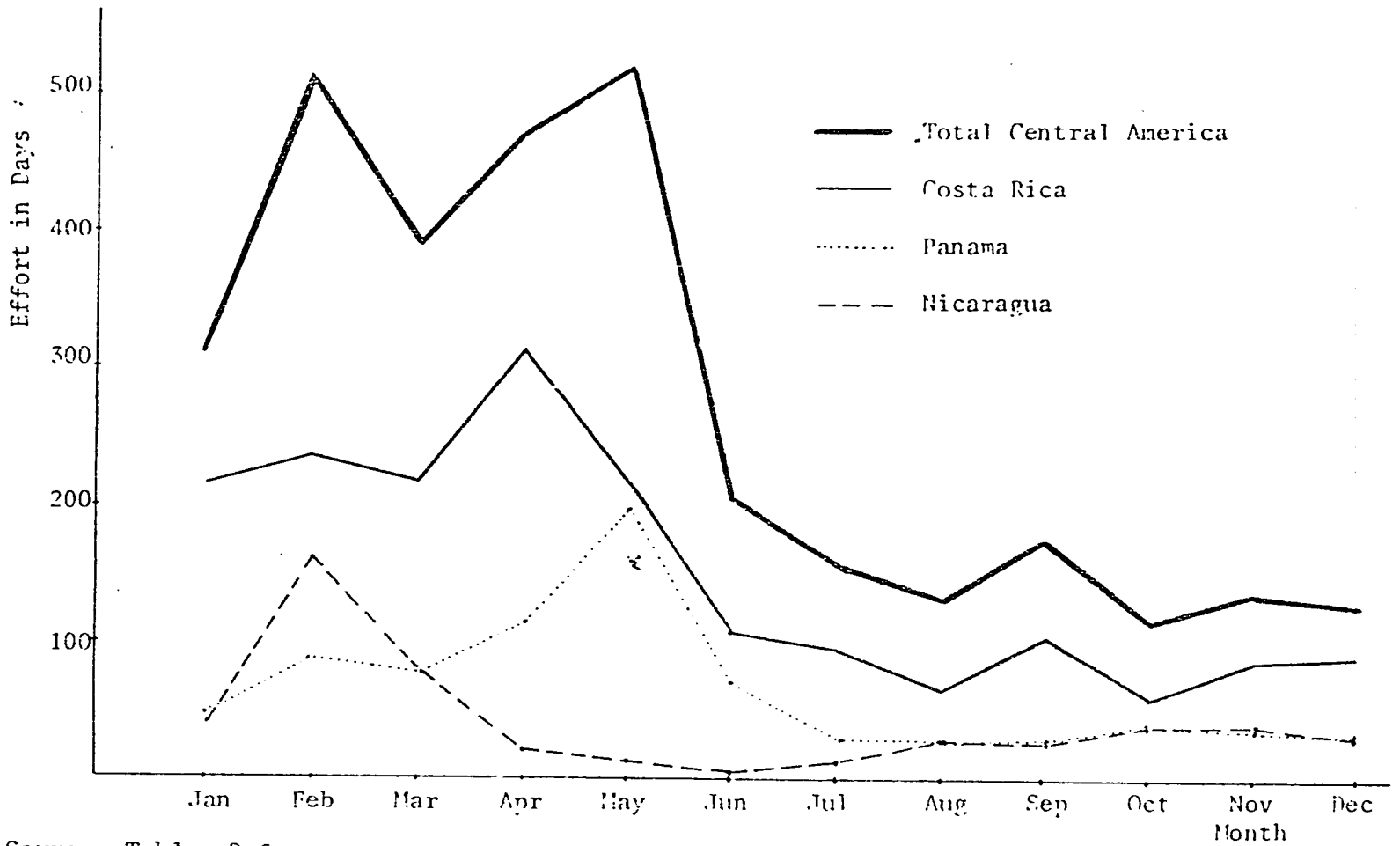
Rica's EEZ, an area ten times the size of the country. Definition of the tuna stocks of the region is not very precise. It is believed that there is one yellowfin stock whose habitat is mostly within the 200 mile boundaries from Mexico to Ecuador. This stock is believed to have a moderate exchange with another stock located in the area outside the 200-mile zones. Migrations of this first stock are mostly north and south within the 200-mile boundaries. Skipjack stocks are less well defined and it is believed that they migrate across the entire Pacific, spending only a few months in the eastern Pacific (Joseph, 1979).

Figure 2 shows that the seasonality of the regional tuna fishery is relatively well defined. Higher concentrations of effort are made in the first semester of the year. In the second semester there is substantial reduction of fishing effort. The variations in effort are directly related to changes in abundance or availability of tuna during the year. In general, this seasonality of the fishery holds throughout the Central American area. The hydrobiological conditions of the Costa Rican EEZ (currents, nutritients, temperature, etc.) present a relatively well defined pattern which allows prediction of patterns of concentration in the fishery. However, substantial changes from year to year and season to season make uncertain the exact amount and location over time of the concentrations. Therefore, the indicated concentrations of fishing activity in the zone should be understood as averages with considerable variation, rather than as amounts highly likely to arise on a regular basis.

4. Surveillance and Enforcement Operations

The main purpose of surveillance and enforcement is to provide a credible deterrent to the violation of regulations or laws (Clough,

FIGURE 2. Annual Distribution of Effort for Selected Countries in Central America. 1978-82 Period



Source: Table B.6

1980). The purpose is not only to prevent unauthorized foreign fishing, but also to ensure the observance of agreed measures for both nationals and foreigners (Jennings, 1980). Additional roles include providing information about fishing effort, catches, etc. Such information is needed for negotiating new or revised agreements, for deciding on national policies, and for strategic and tactical decisions about enforcement. In order to carry out such responsibilities, enforcement operations should include several support functions such as the coordination, planning, data processing and retrieval, case review for trials and hearings, and clerical support (Fuss et al., 1980).

There are four main fishing surveillance-enforcement modes: 1) air patrols; 2) sea patrols; 3) special observers on fishing vessels; and 4) inspections in harbors (Clough, 1980; FAO, 1981). The enforcement modes used depend on the resources available, the nature of the regulations and the characteristics of the fishery.

In the case of Costa Rica, where tuna vessels rarely stop at Costa Rican ports, unilateral enforcement may be entirely at sea. The use of observers on fishing vessels could be an alternative solution in the case of a regional program for the entire ETP. However, it is not likely to be a cost-effective mode of enforcement for the individual coastal state. For example, if Costa Rica hired 50 observers at a cost of U.S. $30 thousand per year each, salaries alone would reach U.S.$1.5 million. Moreover, this alternative is not sufficient in itself but complementary to other enforcement modes.

For purposes of this study we assume that any national program would include both air and sea patrols. The prime function of air patrols is to establish a strategic picture of the fishing activity

(Derham, 1981). Air patrols provide tactical information for patrol vessels, plus data on fishing fleet movements and indirectly on fish migrations (Clough, 1980). Where surveillance over a considerable area is required, the use of air patrols is essential (FAO, 1981). Air patrols are especially advantageous in the initial stages of a regulatory program where they can be used to locate fishing vessel concentrations for sea patrols (Fuss et al., 1980). However, while the advantages of the air patrols are clear, they are not by themselves sufficient to produce a credible level of deterrence. Air patrols have to be considered as a supplement to sea patrols (Fuss et al., 1980; Allain, 1982; FAO, 1981).

Sea patrols by surface vessels are the principal means of deterring violations by maintaining presence on the fishing grounds and by conducting inspections of fishing vessels at sea (Derham, 1981). Fishing vessels are boarded to verify the use of legal gear, to inspect catches and check previous radio reports and logbooks. Additional tasks of sea patrols are to provide information for fisheries intelligence and assistance to vessels in distress. In summary, air and sea patrols are highly complementary in the surveillance and enforcement task.

5. Fisheries Enforcement Economics

In addition to the physical enforcement modes, a fisheries surveillance and enforcement policy should consider additional factors, such as the relationship of the penalty fee to the level of surveillance (Andersen and Sutinen, 1982a; Clough, 1980). A fisherman's decision (under the assumption of rational behavior) whether or not to commit a violation depends on whether he expects to lose more by breaking the law than by following it (May, 1981; Clough;

1980; Andersen and Sutinen, 1982a). Enforcement costs are therefore affected by the fisherman's loss or penalty fee structure. For a given catch rate target, an increase in the marginal penalty fee will permit lower enforcement costs, ceteris parabis (Andersen and Sutinen, 1982a, 1982b).

The level of surveillance effort desired is also affected by the stock size. According to Andersen and Sutinen (1982a), increases in the stock size require greater enforcement costs to control illegal catch at a given level. in this sense, as pointed out by Miles (1981), one of the major problems in tuna surveillance is that the stocks fluctuate considerably. Assuming a constant level of enforcement effort, an increase in the tuna stock size will obviously attract a more intensive illegal fishing activity to the fishery. Therefore, to sustain a given level of deterrence requires a higher level of enforcement. On the other hand, years of small stocks would not require a high level of enforcement since the same level of deterrence may be reached with reduced surveillance and enforcement activities. Therefore, since the penalty fee is established by legislation and is relatively slow to change, the level of enforcement effort for tuna regulations must be dynamic and adapt to changing conditions in the fishery.

Another issue in fisheries enforcement economics concerns a efficiency. The question is how much enforcement effort should be applied to the fishery, and also how this effort should be allocated spatially. Obviously, without an efficient allocation of effort the resulting deterrence will be less than if effort were appropriately allocated to strategic areas. Where the fishery covers vast ocean areas with only a few fishing vessels to be monitored, the task of

managing an enforcement program is complex and potentially very costly. Mathematical allocation models are well-suited for resolving many of the issues presented by the fisheries enforcement problem. The following section addresses the particular issue of efficiency by creating a linear programming model for the allocation of patrol vessel effort to tuna fishing ares in the 200-mile zone of Costa Rica.

6. Linear Programming Formulation

The mathematical model recognizes that enforcement by patrol vessels depends upon the number of sightings of or encounters with fishing vessels, and that these are a function of the path of the patrol boat, the time at sea and the distribution and density of fishing vessels. Further, the model considers costs of achieving any level of encounters given the constraints on patrol vessels' operating range and time. The integer linear programming algorithm is capable of incorporating the aforementioned relationships. By defining the surveillance area with nodes and arcs betweem nodes (see Figure 3) the objective is reached by determining the path which minimizes the sum of costs along the directed arcs of the path. A directed arc is defined as a line segment with an arrow to show the direction of travel between two nodes. Nodes are defined for one degree square areas in the Costa Rican EEZ.

A modification of the linear programming traveling salesman (TS) problem has been developed for present purposes.[5] The modified model improves the standard TS problem by not requiring all nodes be visited. It allows the model to select particular nodes and create a path among them.

In brief, the problem is to minimize

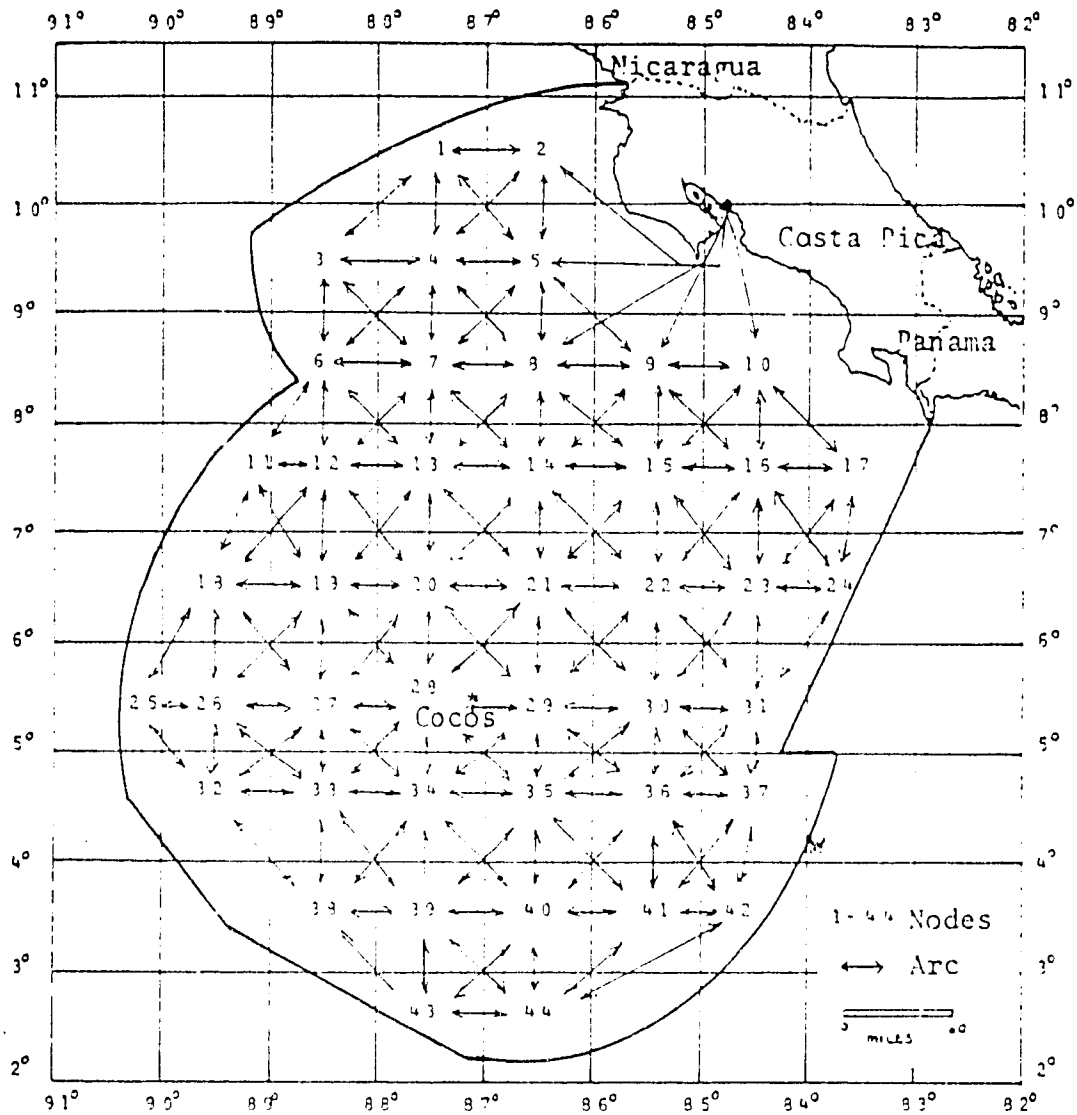


Figure 3. Nodes and Arcs in 1° squares for the Patrol Vessel Surveillance of the Costa Rica's Exclusive Economic Zone (EEZ) in the Pacific Ocean.

Map Source: Instituto Geografico Nacional, Costa Rica
Estimated Boundaries, Non-Official

$$(1) \quad Z = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} (C_{ij}X_{ij}) + C_i Y_i \right)$$

subject to:

the coverage level condition

$$(2) \quad \sum_{i=1}^{n} a_i Y_i \geq b;$$

the limited range condition

$$(3) \quad \sum_{i=1}^{n} \left(\sum_{j=1}^{n} (d_{ij}X_{ij}) + d_i Y_i \right) \leq g;$$

the open loop (or leaving port) condition

$$(4) \quad Y_p = 1;$$

feasible departures

$$(5) \quad -Y_i + \sum_{\substack{j=1 \\ i \neq j}}^{n} X_{ij} = 0, \qquad \text{for } i = 1,2,\ldots,n;$$

feasible arrivals conditions

$$(6) \quad -Y_j + \sum_{\substack{i=1 \\ i \neq j}}^{n} X_{ji} = 0, \qquad \text{for } j = 1,2,\ldots,n;$$

loop conditions (to rule out sub-tours)

$$(7) \quad \sum_{m=1}^{k} \{X_{ij}^{m} \mid X_{ij}^{m} \text{ is the m-th transit path on a k-node sub-tour}\} \leq k-1$$

$$\sum_{m=1}^{k} \{X_{ji}^{m} \mid X_{ji}^{m} \text{ is the m-th transit path on a k-node sub-tour}\} \leq k-1$$

$$\text{for } m = 1,2,\ldots,k \quad k \geq 2$$

where:

Z = total costs,

n = number of nodes,

X_{ij} = transit path defined from node i to node j,

Y_i = zero-one positive integer decision variable representing a transit node,

C_i = non-transit operating costs at node i,

C_{ij} = total transit cost from node i to node j,

a_i = concentration of fishing vessels coefficient at node i,

b = number representing the coverage level target,

d_{ij} = number of miles implicit in the transit from node i to node j,

d_i = number of miles associated with the deviations from patrol track (d_{ij}) caused by fishing vessel density,

g = maximum range of operation for patrol boat, in miles,

Y_p = node representing the port operating base,

m = any integer variable (X_{ij}) that participates in a subtour which is not admissible,

k = number of integer variables (X_{ij}) representing an inadmissible subtour.

Equation (1) represents the general form of the objective function, where n equals the number of nodes. The cost associated with traveling along the arcs X_{ij} is represented by C_{ij}. Coefficient C_i allows for the non-transit costs associated with the deviations from the patrol track caused by fishing vessel density or related factors.[6]

Condition (2) represents the sighting priorities and desired coverage level. Coefficient a_i represents the probabilities of sighting a fishing vessel in the ith area, number of fishing days or any other coefficient that relates the fleet location and pattern of

effort. The g and a_i values vary by season. In the present case effort data in days were obtained from the IATTC. In an on-going program, these coefficients would be up-dated regularly from data provided by air patrols and other intelligence services of the system.

Condition (3) is the constraint on the range, or distance, a patrol vessel can cover as limited by its fuel capacity. It considers the number of miles (hours, or gallons of fuel) implicit in the transit from one node to another. Coefficient d_i allows for the deviations from the patrol track caused by fishing vessel density.

Equality (4) represents the leaving port condition. Since the patrol begins in port, in this condition this node is equal to one. By virtue of conditions (5) and (6), a loop is opened which guarantees the "return" to port. Since the decision variable Y_i equals one (or two in the case where we want to visit the same node twice) if the tour includes the "visit" to node i, it requires an arrival at that node by any arc X_{ij}. This works as a chain which begins and ends in port.

A set of inequalities (7) are added to rule out integer solutions which are not admissible. These are known as sub-tours or loop conditions and are well documented in the LP traveling salesman literature.[7] The first inequality rules out sub-tours in the ij direction and the second inequality rules out sub-tours in the ji, or reverse, direction. To prevent a sub-tour among k nodes, k-1 constraints are required and, to prevent all k-node sub-tours from occurring among the n nodes, ${}_nC_k(k-1)!$ constraints are required.

7. Results

The model was run for several sets of conditions. The grid pattern of monthly average fishing effort (in days) was used to obtain

a path which outlines a general surveillance strategy.[8] Additional runs were made simulating different conditions. Average data for the months of February, May, August, and November were used for such purposes.

Numerical results from the model are displayed in Table 1, which shows that the average value of the objective function ranges from U.S. $10,728 to $11,324. Mileage values ranged from 900 to 950 nautical miles respectively.[9]

The duration of each trip is estimated to be from 7.5 to 8 days, based on the assumption that each patrol vessel has a 12-hour day of visual search and an average surveillance speed of 10 knots. The expected number of sightings or encounters varies from a low of 1.2 fishing vessels per trip for the average conditions of August to a high of 5 fishing vessels per trip for the most favorable average conditions of May. The anticipated number of sightings per trip for the total average conditions is 2.8 fishing vessels.[10]

The paths for the aforementioned cases are shown in Figures 4 and 5. These results suggest that sea surveillance in the Costa Rican EEZ should be mainly in the east-central part of the 200-mile zone. The average path (shown in Figure 4) shows that the main zone of attention should be from 86 degrees longitude to 4 degrees latitude with some emphasis along the Panamanian and Colombian boundaries. From the results shown in panels A, C, and D of Figure 5 it can be inferred that this area presents the highest and most stable pattern of concentration throughout the year. These findings are also consistent with the pattern of the monthly distributions of effort.

A second important sub-zone for surveillance is the area known as Guardian Bank (delineated by the path in panel B, Figure 5), located

TABLE 1.

Objective Function, Mileage, Trip Duration and Estimated Number of Sightings for Alternative Cases

Case	Objective Function	Mileage	Trip Duration in Days*	Expected Number of Sightings**
Total Average	$11,153	935	7.5 - 8	2.8
Average February	$11,277	946	7.5 - 8	3.0
Average May	$11,324	950	7.5 - 8	3.8
Average August	$10,728	900	7.5 - 8	1.2
Average November	$11,074	929	7.5 - 8	1.7

* For calculations the surveillance trip is assumed to be of 7 effective days.

** Assumes 12-hour day of visual search and average speed of 10 knots.

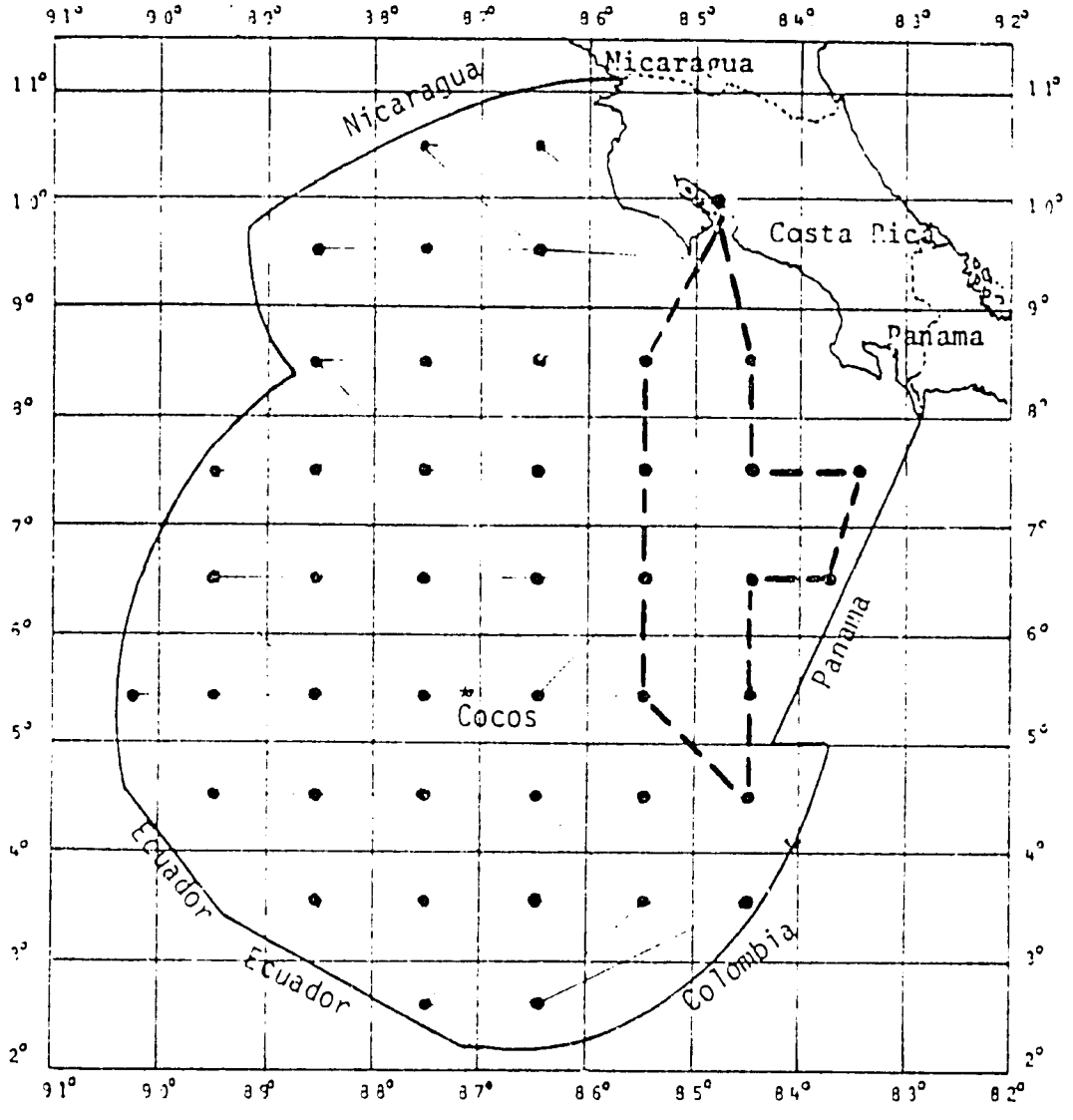
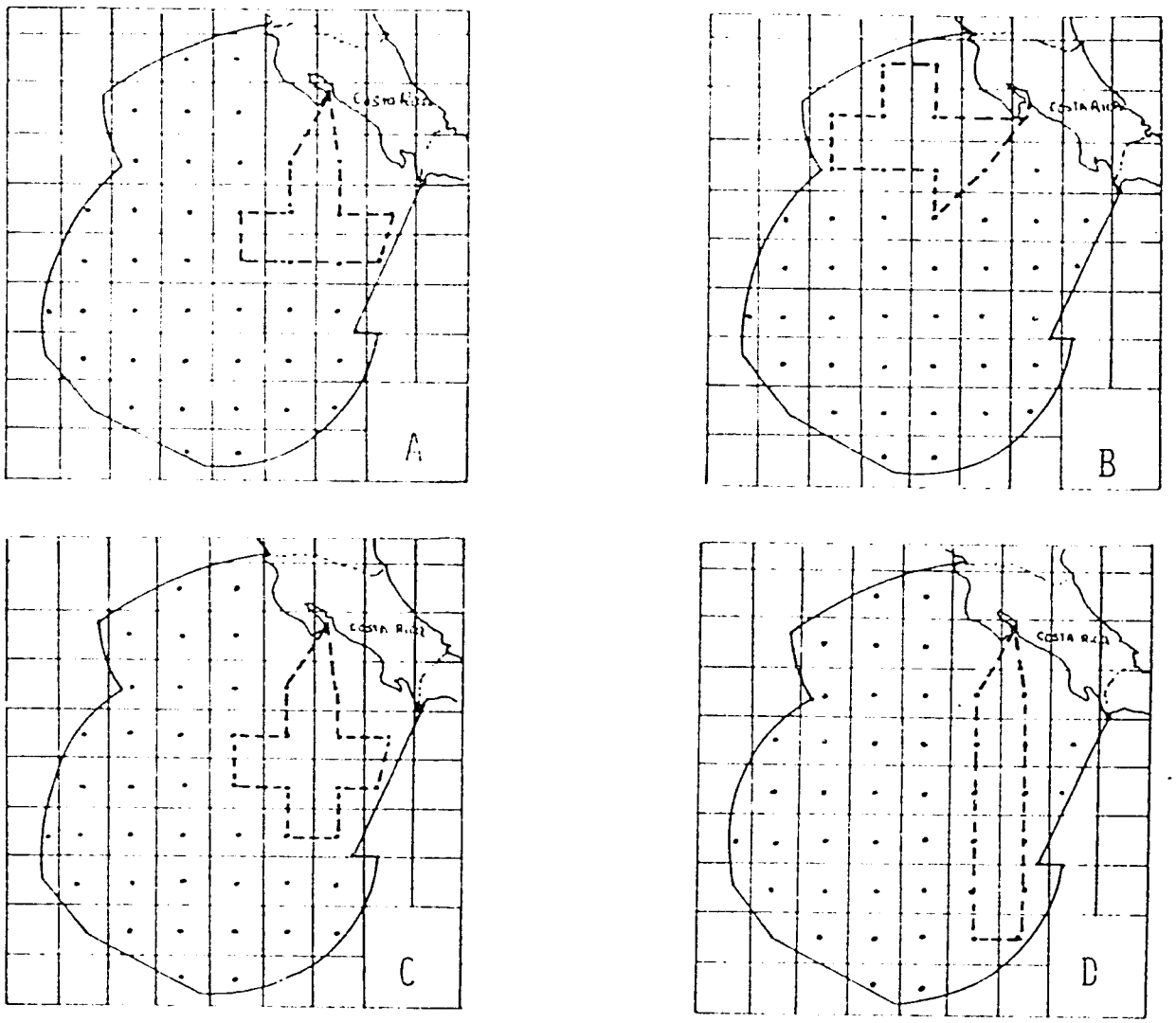


FIGURE 4. Path for the Total Monthly Average Conditions 1978 - 1982 Period.

FIGURE 5. Paths for the Average Conditions of February (A), May (B), August (C) and November (D). 1978-1982.



along parallel 7 degrees north and meridian 86 west and along the northwest boundary of the EEZ. This zone presents relatively high concentrations of fishing activity at certain times of the year.

The results also suggest that surveillance should be conducted on a relatively concentrated basis. Surveillance trips along huge open sub-areas of the EEZ are not prescribed. For example, if the area near the Nicaraguan boundary is to be patrolled, surveillance should concentrate along the Nicaraguan boundary to the north and to the central part of the EEZ, avoiding the southern section of the EEZ. As seen in panels A and B in Figure 5, higher fishing density is likely to reduce the length of the surveillance trip, as is shown for the higher density month of February in relation to low density August conditions.

8. Discussion

The results above should be used as a guide to surveillance strategy rather than as a fixed and unchangeable strategy. Patrol paths should be set on a dynamic rather than on a static basis. That is, the paths should be adapted to the peculiar features of the fishery at any time as dictated by weather and hydrobiological conditions. In addition, if the surveillance paths are fixed, fishermen would learn to avoid encounters with the patrol vessel. The use of aircraft for surveillance will be necessary under present conditions. Aircraft provide the information necessary for the determining strategic sea patrol paths, such as the ones proposed in this paper.

An administrative enforcement-intelligence office must work constantly to coordinate activities and analyze data received from the surveillance and enforcement operations. Under the assumption that

radio reporting of fishing activities will be required of the fishing vessels in the EEZ, the office should have computer facilities to process the data received. The complex task of enforcement and management can benefit from the use of models, such as the one used here, to help managers in the decision process for selecting short-term strategies of surveillance.

Given the seasonality of the fishery, surveillance and enforcement effort should be applied more intensively in the first semester of the year. This means more aircraft and sea patrols in the first semester and fewer patrols in the second semester. In the first semester the program can be accomplished with three sea patrols per month by the existing 105 ft. patrol vessel and in the second semester with 1.5 trips per month. The sea patrols can be complemented with two chartered aircraft trips per patrol vessel trip, which will account for a total of 42 flying hours a month in the first semester and 21 hours in the second semester. Annual operating costs of such a program would be approximately U.S. $540,000. In addition, fixed costs (depreciation, administrative personnel, patrol crews) are assumed to equal operating costs for a total cost of approximately U.S. $1.08 million per year.

With the payment conditions specified in the Eastern Pacific Tuna Agreement and assuming 75 percent compliance, revenue in the near future is estimated to be approximately U.S. $2.25 million per year.[12] Revenue net of enforcement costs, therefore, is expected to equal about U.S.$1.17 million per year. Under the conditions assumed here, the cost of enforcement is almost 50 percent of the total rents likely to come from the fishery.

Christy (1979) asserts that the goal of coastal states with

extended jurisdictions should be to maximize fishery resource rents over time. The only way that the Costa Rican government has to maximize resource rents is to join a regional management system for the fishery. With reduced fishing effort over time the fishery will ultimately tend to yield increased total resource rents, thus increasing the rent for Costa Rica. As properly stated by Joseph (1977), biological overfishing and overcapitalization can be avoided only if a management system covers the entire fishery. Of course, complete management coverage is possible only with some sort of international management system in the region.

9. Conclusions

The results from this study suggest that a surveillance and enforcement program for Costa Rica should place special attention on the east-central part of the EEZ and along the Panamanian and Colombian boundaries. The results also suggest that, in general, the expected number of sightings is low. Therefore, without a timely flow of information on the pattern of fishing effort any enforcement program is likely to be ineffective. The results also suggest that patrol vessel activities should be relatively concentrated in selective sub-zones rather than spread throughout vast areas of the ocean. The characteristics of the fishery also dictate the need for a flexible surveillance program that responds quickly to changes in effort patterns. Even a modest surveillance and enforcement program, such as the one suggested here, is expected to be relatively expensive and the revenues generated by the Eastern Pacific Tuna Agreement are not expected to be large. Costa Rica obviously will be better off in the long run by integrating its fishery management program with an overall regional management program.

Acknowledgements

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FOOTNOTES

[1]Three major proposals have been made by Joseph (1977), King (1979) and Keen (1983). Tuna management is especially difficult due to the extensive migratory character of the tuna stocks, which move from one EEZ to another and from outside and inside the EEZs. Therefore, it has been concluded that the problem of open access to the resource cannot be solved by a single coastal state in a unilateral action. The problem must be solved by all the states participating in the fishery through an international management system.

[2]This point is related to past problems in the IATTC. After several years of claiming larger shares of the overall quota, Mexico and Costa Rica left the IATTC in 1978 and 1979 respectively.

[3]In general terms, the definition of rights in the fishery is not clear. Some ambiguity results from the use of the terms of property and ownership rights for tuna in the fishery. In the context of this paper we use the term property right as the one defined by Bromley (1978) and Calabresi (1972) where "property rule entitlement" for individual B is the one where individual A may not take actions which interfere with individual B without the latter's consent. Under the definition of "liability" right for party B, party A may proceed over party B, but, party B must be compensated.

[4]The "Eastern Pacific Tuna Agreement" is an interim agreement signed in San Jose, Costa Rica in April 1983, by representatives of Costa Rica, Panama and the U.S. Salvador and Honduras signed the agreement a few months later. The terms imposed are that tuna ships from the five countries will pay $60 per each net registered ton and be granted one year licenses. According to Fishing News International (1983), a similar agreement has been signed recently in the South Pacific by the U.S., Micronesia, Kiribati and Palau.

[5]The traveling salesman problem is a well known zero-one integer programming model. Under the regular approach a traveling salesman visits n cities and returns to his starting point. He desires to minimize his total travel cost. This classic problem does not allow for choosing the cities, they are given. The modification allows for a discriminatory selection of "cities" (nodes in this case). Further information on the modified and classic model is given in Dantzig (1963) and Budnick et al. (1977).

[6]The need for deviations from the track has been pointed out by Fuss et al. (1980). The patrol vessel arc will be affected by fishing vessel density in the area searched, since it will have to deviate to establish contact, verify identity or board and inspect.

[7]The loop or sub-tour conditions are discussed in Dantzig (1963) and Budnick et al. (1977).

[8]Data used for this purpose was non-standardized monthly fishing effort in days, provided by the IATTC.

[9]The values of the objective function only account for the fuel consumption of a 105 ft. patrol vessel belonging to the Marine Surveillance Department of the Republic of Costa Rica. It is assumed here that other non-included operational costs (food, maintenance, etc.) are proportionally related to the consumption of fuel. Values of fuel under the Costa Rica conditions are estimated to be 75% of the total patrol vessel operating costs. Costs for crews, depreciation, etc., are assumed fixed.

[10]Once the maximum value of coefficient "b" in condition (2) was obtained from the model solution, the number of sightings was estimated using the following formula:

$$PS = (ED \times A30)NS$$

where

PS = number of tuna purse-seiners sighted per surveillance operation trip

ED = Total one degree square monthly fishing effort days obtained from the model solution

A = Percentage of one degree square area likely to be visually searched

NS = Number of effective patrol surveillance days at sea.

[11]Patrol vessel operating costs of U.S. $14,325 per trip are assumed for this purpose. A chartered twin-engine, turbo-powered, 7-hour range, fixed wing aircraft at a cost of $400 per hour is also assumed.

[12]Vessels operating in the waters of Costa Rica each year would have a total carrying capacity of 75,000 tons on the average. The estimated revenues are calculated using a charge of U.S. $33 per net registered ton (NRT) of vessel, where NRT and carrying capacity are assumed closely correlated. The $33 charge is the share Costa Rica would obtain of a potential $60 charge per NRT currently under consideration by Central American countries.

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