

# Preliminary Method for Estimating Marine Fisheries Enforcement Requirements

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## Introduction

The Fishery Conservation and Management Act of 1976 (FCMA) and other Federal laws related to marine resources have placed new enforcement requirements on the U.S. Coast Guard, the National Marine Fisheries Service (NMFS), and State conservation agencies that have entered into cooperative enforcement agreements with the Federal agencies. Among other things, the FCMA established the U.S. Fishery Conservation Zone (FCZ) and Regional Fishery Management Councils to prepare Fishery Management Plans (FMP's). At present, approximately 76 FMP's have been identified by the Regional Councils for implementation during the next few years. Most of these plans are for domestic fisheries which have historically been managed by the individual coastal states.

One of the immediate problems facing the enforcement agencies is the development of standard systems to estimate requirements and/or allocate available resources to ensure compliance with the many regulations. The

*ABSTRACT—Standard methods are needed for estimating requirements and allocating limited resources to meet enforcement demands created by the Fishery Conservation and Management Act of 1976 and other Federal laws related to marine mammals and endangered species. The methods presented here were developed for use in the Southeast Region of the National Marine Fisheries Service. They are proposed as a first step toward the development of a more complex system. Estimates are based on the vessel population of the fishery, the fishing area, and the length of coastline fronting the fishery and/or connecting fishing ports. They include sea patrols, shore inspections, investigations, and general support.*

initial system should be as simple as possible but accommodate the main numerical variables (e.g., vessel populations, lengths of shoreline fronting the fisheries, fishing areas, etc.) and allow for inclusion of other quantitative variables as experience indicates. The preliminary methods described here were developed by the Law Enforcement Division of the Southeast Region, NMFS, to estimate the enforcement needs of the region. Other systems to measure enforcement efficiency, effectiveness, and quality similar to those proposed by Hirsch and Riccio (1974) will be necessary to evaluate programs and verify the initial enforcement allocations.

## Regulatory Mechanism

Traditional and accepted regulatory mechanisms to prevent the depletion of marine resources have been discussed by many authors (Christy and Scott, 1965; Robinson and Rollins, 1971; and others). Controls are essentially related to fishing gear and fishing effort and may include restrictions on the type and size of gear, materials used in the construction of gear, areas and times of fishing, size or condition of species taken, and the allowable catch. Other types of regulations are related to licenses, permits, and reporting procedures such as those currently required of foreign vessels fishing in the FCZ.

In estimating the requirements for fisheries scheduled for regulations, the planner may have limited information on the kinds of regulations that will eventually be promulgated. Planners will, however, have relatively good in-

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formation on the vessel population of the fishery, the size of the fishing area, the length of the coastline fronting the fishery and/or connecting the major fishing ports, the number of ports and fish processing facilities, and the fishing season. Preliminary enforcement plans must therefore be based on available data.

## Regulatory Modes

Certain fishery regulations can be enforced primarily at the dock and others must be enforced at sea. The enforcement modes used will therefore depend on the regulations. Those that can generally be enforced at the dock include catch quotas, size and condition limits, permit and reporting requirements, and some fishing gear restrictions (Fig. 1). Regulations that must be enforced at sea from patrol vessels and aircraft are those pertaining to closed areas, seasons, and some gear restrictions. Certain gear and possession regulations can only be enforced by boardings at sea from patrol vessels (Fig. 2).

Preliminary enforcement estimates should address three modes: 1) Primarily shore-side enforcement (80 percent shore and 20 percent sea); 2) balanced shore and sea enforcement (50 percent shore and 50 percent sea); and 3) primarily at-sea enforcement (80 percent sea and 20 percent shore) to allow for the various types of possible regulations. Regular enforcement duties must also be supported by special investigative techniques to ensure compliance with any regulatory mechanism.

## Methods

The proposed methods for estimating enforcement requirements are based on one possible enforcement contact (boarding and inspection at sea or at the dock) with each vessel in the fishery during the fishing season or fishing year. One enforcement contact a season or year is believed to be a reasonable level of effort in newly regulated fisheries of the southeastern United States. The vessel population is thus the primary factor in preliminary enforcement estimates. Other variables considered are the fishing area and the length of the coast fronting the fishery. The

length of the fishing season is used to prorate the required enforcement activities on a monthly basis.

### At-Sea Enforcement

Patrol vessel requirements are based on the assumption that a unit can accomplish an average of six vessel boardings during a 12-hour day and visually search 600 square miles of ocean. Six hours are allowed for boardings and 6 hours for searching at an average speed of 10 knots with an effective visual observation range of 5 miles on each side of the patrol track. For each hour steamed at 10 knots the patrol vessel will roughly cover 100 square miles. The average patrol day selected is the median from the probable combinations of boarding and search time shown in Table 1.

The patrol vessel's track will be affected by fishing vessel density in the area searched as shown in Figure 3. A vessel density equal to or greater than 1 vessel per 100 square miles ( $\geq 0.01$  vessel per square mile) will probably require the patrol vessel to deviate considerably from track and reduce the area searched. Under such conditions, patrol vessel requirements will be a function of the number of vessels only and area need not be considered. When fishing vessel density is less than one vessel per 100 square miles ( $< 0.01$  vessel per square mile) patrol vessel requirements will be a function of area as well as number of vessels.

Estimates of vessel density (*VD*) can be obtained by dividing the vessel population (*VP*) of the fishery adjusted for

**Table 1.—Probable combinations of at-sea boardings and areas searched during a 12-hour patrol vessel day (5-mile visual search range each side of track).**

Vessels boarded (1 h/boarding)	Hours searched (speed 10 knots)	Area searched (square miles)
0	12	1,200
1	11	1,100
2	10	1,000
3	9	900
4	8	800
5	7	700
6	6	600
7	5	500
8	4	400
9	3	300
10	2	200
11	1	100
12	0	0

<sup>1</sup>Median.



Figure 1.—State officer inspects catch at dock for compliance with regulations. Florida Marine Patrol photograph.



Figure 2.—Coast Guard unit boarding fishing vessel during general enforcement patrol. U.S. Coast Guard photograph.

the enforcement mode (*EM*) (percent at-sea enforcement) by the fishing area (*FA*):

$$VD = \frac{VP \times EM}{FA} \quad (1)$$

If the quotient is equal to or greater than 0.01 vessel per square mile ( $\geq 1$  vessel per 100 square miles), estimates of patrol days required (*PDR*) may be obtained by dividing the vessel population adjusted for the enforcement mode by six probable boardings a day (the median of probable boarding in an average patrol day):

$$PDR = \frac{VP \times EM}{6} \quad (2)$$

If the quotient of Equation (1) is less than 0.01 ( $< 1$  vessel per 100 square miles), *PDR* estimates may be derived by dividing the adjusted vessel population by 12 possible boardings a day (days required for boardings) and the fishing area by 1,200 possible square miles searched per day (days required for search) and adding the quotients:

$$PDR = \frac{VP \times EM}{12} + \frac{FA}{1,200} \quad (3)$$

Equations (1), (2), and (3) can be combined into a single equation (4) based on the average patrol vessel day (six probable boardings and 600 square miles searched with a ratio of one boarding to 100 square miles) that will eliminate the vessel density calculations. To estimate the patrol days required, divide the adjusted vessel population by six probable boardings per day and the fishing area in excess of 100 times the adjusted vessel population by 1,200 square miles (maximum area searched with no boardings) and add the quotients. Do not use negative numbers in the second part of the equation (excess fishing area) as they will cancel out any additional patrol days required. The recommended equation is:

$$PDR = \frac{VP \times EM}{6} + \frac{FA - [100 \times (VP \times EM)]}{1,200} \quad (4)$$

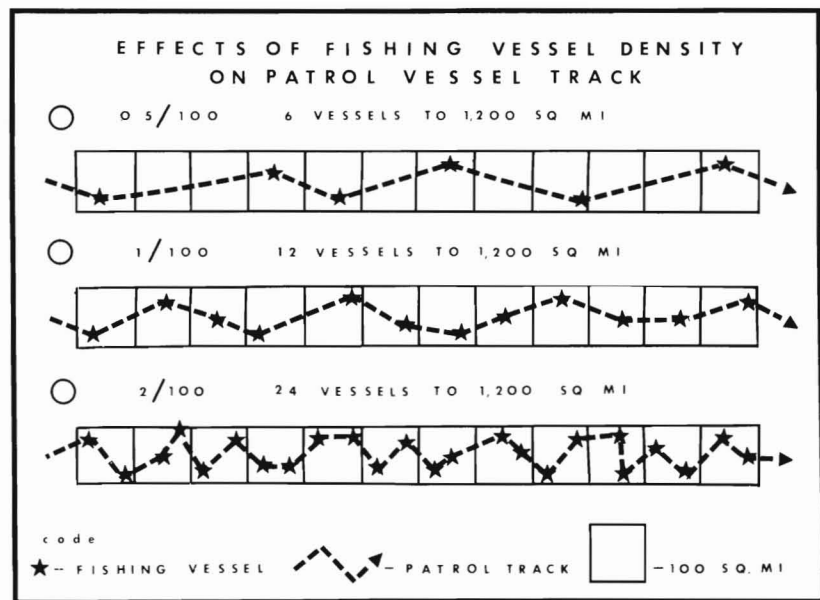


Figure 3.—Methods of estimating sea patrol requirements must allow for deviations from patrol track caused by vessel density.

To estimate the patrol days required (or desired) for each month of the fishing season divide the total number of patrol days needed to accomplish the necessary boardings at sea by the number of months in the fishing season.

Staff years of enforcement officer (enforcement specialist in addition to patrol vessel complement) effort required for sea patrols was explained in a previous joint study by the U.S. Coast Guard and the National Marine Fisheries Service to estimate the enforcement requirements for extended jurisdiction under FCMA<sup>1</sup>. The study was directed entirely toward estimating the requirements to ensure compliance by foreign vessels with FCMA regulations in the FCZ. Enforcement officer

<sup>1</sup>For a complete report, see Knapp, R. J., and M. M. Pallozzi. 1977. Initial joint NMFS/CG program for enforcement of fishery regulations under extended jurisdiction. Unpubl. rep., 145 p. National Marine Fisheries Service, Law Enforcement Division, Washington, D.C.

requirements were based on the assumption that one officer would be necessary for each 60 days of patrol. There is no reason to change this assumption and it is applied here. The total days derived from the patrol days required equation is divided by 60 to determine officer staff years.

Patrol aircraft requirements are considered as a supplement to patrol vessel requirements. In initial regulatory programs patrol aircraft should be used to locate fishing vessel concentrations for surface patrols and for independent patrols over closed areas and/or during closed seasons to identify violators. Aircraft patrols are remote from the fishermen and therefore do not have the impact of surface patrols with boardings and inspections. They do, however, greatly facilitate the efficiency of surface patrols and should be used for that purpose as much as possible. A reasonable estimate of required aircraft patrol hours is 1 hour for each patrol vessel day to assist the surface patrols in locating target vessels. Enforcement officer requirements for aircraft patrols are included in the estimates for vessel patrols.

## Shore-Side Enforcement

Fishing vessel inspection requirements are based on the assumption that a single enforcement inspector can accomplish three vessel inspections during an average 8-hour day and search 30 baseline miles of coast. Two hours of each day are allowed for reports and miscellaneous (including inspections of fish processing facilities), 3 hours for vessel inspections, and 3 hours for searching at a rate of 10 miles per hour. The search rate is limited to 10 miles of coast per hour to allow for traffic, coastline deviations in bays and coves, difficult access roads to vessel landings, and fishing schedules. The ratio of vessel inspections to miles of coastline searched in an average inspection day is 1:10. The average inspection day selected is the median from the probable combinations of inspection and search time shown in Table 2.

The inspection vehicle track and search rate are affected by fishing vessel density but not in the same way as patrol vessel track deviations (such as those described in the sea patrol estimates). Vessels may well be concentrated in a few ports and the inspection track (coastline) is relatively fixed. The probability, however, of locating the desired vessels in a particular port on a given day seems remote due to fishing schedules. The greater the number of vessels to be located (more vessels per given coastline) would compound the problem. Given a vessel density equal to or greater than one vessel per 10 miles of coastline ( $\geq 0.1$  vessel per mile) the inspection day requirements will be primarily a function of the number of vessels to be inspected adjusted for the enforcement mode (percent shore-side

enforcement) and the length of coastline need not be considered. When fishing vessel density is less than one vessel per 10 miles ( $< 0.1$  vessel per mile), inspection day requirements will be a function of length of coastline as well as number of vessels.

An estimate of vessel density ( $VD'$ ) (vessels/mile) can be obtained by dividing the vessel population of the fishery adjusted for the enforcement mode ( $EM'$ ) (percent shore enforcement) by the baseline miles of coast ( $CL$ ) fronting the fishery or connecting fishing ports:

$$VD' = \frac{VP \times EM'}{CL} \quad (5)$$

If the quotient ( $VD'$ ) is equal to or greater than 0.1 vessel per coastline mile (one vessel per 10 miles), estimates of inspection days required ( $IDR$ ) may be obtained by dividing the vessel population adjusted for the enforcement mode by three probable inspections a day (the median of probable inspections in an average inspection day):

$$IDR = \frac{VP \times EM'}{3} \quad (6)$$

If  $VD'$  is less than 0.1 ( $< 1$  vessel per 10 miles),  $IDR$  estimates may be calculated by dividing the adjusted vessel population by six possible inspections a day (days required for inspections) and the length of coastline by 60 possible miles searched per day (days required for search) and adding the quotients:

$$IDR = \frac{VP \times EM'}{6} + \frac{CL}{60} \quad (7)$$

As with sea patrol estimates, Equations (5), (6), and (7) can be combined into a single equation based on the average inspection day (three probable inspections and 30 miles searched with a ratio of one inspection per 10 miles) that will eliminate the vessel density calculations. To estimate the inspection days required, divide the adjusted vessel population by three probable boardings a day and the coastline in excess of 10 times the adjusted vessel population by

60 miles (maximum miles searched with no inspections) and add the quotients. Do not use negative numbers in the second part of the equation (excess coastline) as they will cancel out any additional inspection days required. The recommended equation is:

$$IDR = \frac{VP \times EM}{3} + \frac{CL - [10 \times (VP \times EM)]}{60} \quad (8)$$

To estimate the inspection days required (or desired) for each month of the fishing season divide the total number of inspection days needed to accomplish the necessary inspections by the number of months in the fishing season.

For estimates of staff years of effort required for inspections we may assume that one inspector will be available for approximately 220 working days a year (allowing for weekends, holidays, and annual/sick leave). To estimate inspector years required for shore-side enforcement the total inspection days derived should be divided by 220.

## Investigations

Patrol and inspection functions will identify areas of high violation potential and provide leads that will require in-depth investigations of individuals believed to be violating regulations intentionally. These efforts should be conducted by enforcement agents trained in after-the-fact investigative techniques and equipped with the necessary tools. Quantitative factors will not be available to the enforcement planner in making preliminary estimates of investigative requirements. Such estimates can be based on requirements for sea patrols and shore-side inspections for each fishery. Past experience (NMFS Southeast Region) with domestic marine mammal and endangered species enforcement programs indicates that investigative requirements are about 30 percent of the total staff years necessary for overt patrols and inspections.

Table 2.—Probable combinations of shore-side vessel inspections and coastline searched during an 8-hour inspection day (allowing 2 hours for reports and miscellaneous).

Vessels inspected (1 h/inspection)	Hours searched (10 miles/hour)	Coastline searched (baseline miles)
0	6	60
1	5	50
2	4	40
3	3	30
4	2	20
5	1	10
6	0	0

<sup>1</sup>Median.

## Support

As used here, support functions include the coordination of enforcement activities (patrol, inspection, and investigative), the development of plans, data processing and retrieval, review of violation case reports for trials and hearings, and clerical support. These are necessary to ensure efficiency, effectiveness, and quality of coordinated enforcement activities. Past experience with foreign and domestic fishery enforcement programs indicates that support requirements are about 10 percent of the total staff years necessary for patrols, inspections, and investigations.

### Single Fishery Estimates

A hypothetical gillnet fishery is shown in Figure 4. We can estimate sea enforcement requirements from the factors given:  $VP=720$  and  $FA=30,000$ . Using Equation (4) and an at-sea enforcement mode of 20 percent, we find:

$$\frac{720 \times 0.20}{6} + \frac{30,000 - [100 \times (720 \times 0.20)]}{1,200} = 37 \text{ PDR.}$$

Again, using Equation (4) with an at-sea enforcement mode of 50 percent, we find:

$$\frac{720 \times 0.50}{6} + \frac{30,000 - [100 \times (720 \times 0.50)]}{1,200} = 60 \text{ PDR.}$$

Finally, calculating *PDR* with an 80 percent at-sea enforcement mode, we get:

$$\frac{720 \times 0.80}{6} + \frac{30,000 - [100 \times (720 \times 0.80)]}{1,200} = 96 \text{ PDR.}$$

In the 20 percent enforcement mode, the fishing area (30,000 square miles) is greater than 100 times the vessel population adjusted for the enforcement mode. Therefore 13 additional patrol days are required to cover the area. In the 50 percent and 80 percent enforcement modes the fishing area is less than 100 times the adjusted vessel populations and no additional patrol days are required.

Using Equation (8), we can also estimate the shore-side enforcement requirements for the hypothetical gillnet fishery from the factors given ( $VP=720$ ,  $CL=300$ , and  $EM=20$  percent):

$$\frac{720 \times 0.20}{3} + \frac{300 - [10 \times (720 \times 0.20)]}{60} = 48 \text{ IDR.}$$

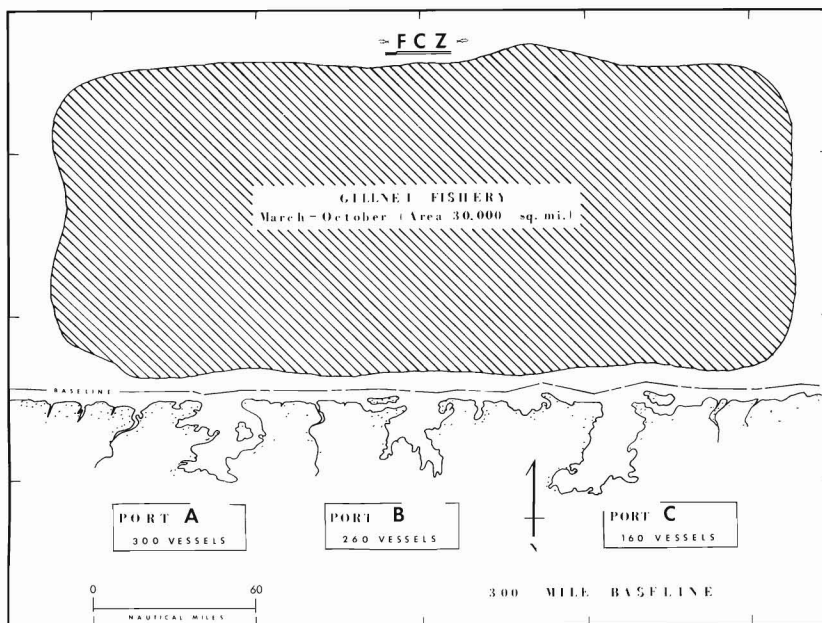


Figure 4.—A hypothetical gillnet fishery scheduled for regulation.

In this example the coastline is less than 10 times the adjusted vessel population and no additional inspection days are required to cover the coast. The remainder of the calculations for shore-side enforcement, investigations (30 percent), support (10 percent), and total staff years required are shown in Table 3.

### Multiple Fishery Estimates

When the coastline and/or fishing areas are common to two or more fisheries the estimated enforcement requirements may be calculated from the combined fishing areas and the common coastline. This may eliminate additional patrol vessel days required to cover fishing areas that exceed 100 times the adjusted vessel population and inspection days required to cover coastlines that are greater than 10 times the adjusted vessel population.

Hypothetical purse seine and trawl fisheries with a common coastline and partly common fishing areas are shown in Figure 5. Using an enforcement

**Table 3.—Summary of enforcement estimates for the hypothetical gillnet fishery shown in Figure 4.**

Sea Patrols					
Enf. mode <sup>1</sup>	Vessel population	Percent enf.	Boardings required	Patrol days	Officers required
I	720	80	576	96	1.6
II	720	50	360	60	1.0
III	720	20	144	37	0.6
Shore Inspections					
Enf. mode	Vessel population	Percent enf.	Inspections required	Inspection days	Inspectors required
I	720	20	144	48	0.2
II	720	50	360	120	0.6
III	720	80	576	192	0.9
Investigations					
Enf. mode	Sea officers	Shore inspectors	Total sea/shore	Agents required	
I	1.6	0.2	1.8	0.6	
II	1.0	0.6	1.6	0.5	
III	0.6	0.9	1.5	0.5	
Support and total					
Enf. mode	Field enf. required	Support required	Total staff years		
I	2.4	0.2	2.6		
II	2.1	0.2	2.3		
III	2.0	0.2	2.2		

<sup>1</sup>Enforcement modes: I—80 percent sea, 20 percent shore; II—50 percent sea, 50 percent shore; III—80 percent shore, 20 percent sea.

mode of 50 percent sea and 50 percent shore with the factors given for both fisheries, a comparison can be made of the enforcement requirements calculated for the individual fisheries and for the two fisheries combined. At-sea enforcement requirements can be estimated from the factors given: For Fishery X,  $VP=30$  and  $FA=63,000$  square miles; for Fishery Y,  $VP=1,200$  and  $FA=56,000$  square miles; and for Fisheries X and Y,  $VP=1,230$  and  $FA=95,500$  (fishing areas for X and Y combined minus the common area, 23,500 square miles).

For Fishery X, using Equation (4), we find:

$$\frac{30 \times 0.50}{6} + \frac{63,000 - [100 \times (30 \times 0.50)]}{1,200} = 53.8 \text{ PDR.}$$

For Fishery Y, we find:

$$\frac{1,200 \times 0.50}{6} + \frac{56,000 - [100 \times (1,200 \times 0.50)]}{1,200} = 100.0 \text{ PDR.}$$

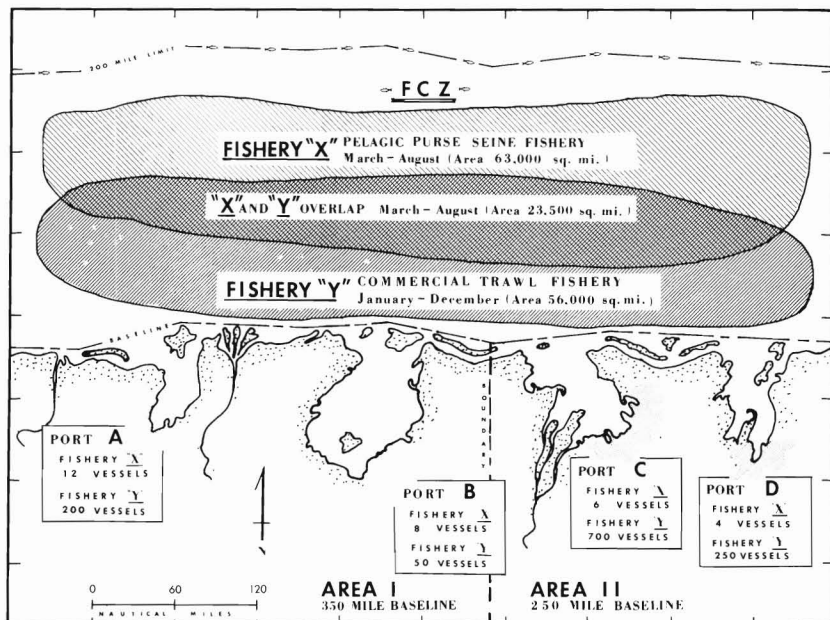


Figure 5.—Hypothetical purse seine and trawl fisheries scheduled for regulation.

For Fisheries X and Y, we find:

$$\frac{1,230 \times 0.50}{6} + \frac{95,500 - [100 \times (1,230 \times 0.50)]}{1,200} = 130.8 \text{ PDR.}$$

In this example, the patrol vessel day requirements calculated for the combined fisheries are 23 less than the total calculated independently for the two fisheries to accomplish the same mission. The remainder of the enforcement estimate calculations for the two fisheries are given in Table 4. Note that a total of 5.1 staff years is indicated by separate calculations whereas 4.4 staff years are identified by joint calculations. Enforcement requirements for fisheries with common (or partly common) fishing areas and/or common coastlines should therefore be calculated jointly.

**Table 4.—Summary of enforcement estimates for the hypothetical purse seine and trawl fisheries shown in Figure 5. Enforcement mode: 50 percent shore and 50 percent sea.**

Sea Patrols				
Fishery	Vessel pop.	Boardings required	Patrol days	Officers required
X	30	15	54	0.9
Y	1,200	600	100	1.7
X-Y	1,230	615	131	2.2
Shore Inspections				
Fishery	Vessel pop.	Inspections required	Inspection days	Inspector required
X	30	15	12	0.1
Y	1,200	600	200	0.9
X-Y	1,230	615	205	0.9
Investigations				
Fishery	Sea officers	Shore inspectors	Total sea/shore	Agents required
X	0.9	0.1	1.0	0.3
Y	1.7	0.9	2.6	0.8
X-Y	2.2	0.9	3.1	0.9
Support and total				
Fishery	Field enf. required	Support required	Total staff years	
X	1.3	0.1	1.4	
Y	3.4	0.3	3.7	
X-Y	4.0	0.4	4.4	(Total X & Y)

### Area Enforcement Estimates

Shore enforcement requirements for political or arbitrary divisions of coastline fronting a fishery or fisheries as shown in Figure 5 may be calculated independently. Areas I and II could represent two coastal states that have entered into agreements with the Federal government to enforce FCMA regulations within their boundaries under Fishery Management Plans (FMP's) for the hypothetical purse seine and trawl fisheries. Using Equation (8) for inspection days required with an enforcement mode of 50 percent shore and 50 percent sea and the factors given for each area, we can estimate the respective requirements for Fisheries X and Y for each area as follows: For Area I,

$$\frac{270 \times 0.50}{3} + \frac{350 - [10 \times (270 \times 0.50)]}{60} = 45 \text{ IDR.}$$

and for Area II,

$$\frac{960 \times 0.50}{3} + \frac{250 - [10 \times (960 \times 0.50)]}{60} = 160 \text{ IDR.}$$

### Discussion

A standard quantitative method to estimate enforcement requirements for FMP's and other marine resource management or protection programs is essential to the equitable allocation of limited resources; both Federal and State. Without a basic system allocation, decisions are subjective. The system proposed here is for initial enforcement estimates in the Southeast Region of NMFS. If estimates for three enforcement modes covering primarily sea and shore enforcement and a combination of both are calculated, the mode ultimately selected will probably be covered. Experience with enforcement of regulations in individual fisheries should identify additional variables that can be inserted in formulas for revised estimates.

The methods for estimates proposed are based on one enforcement contact per season or year with each vessel in the fishery or combinations of fisheries. A management decision, however, can be made to increase or decrease the desired contacts per season or year and the equations will still apply by simply adjusting the vessel population for the desired contacts (e.g., double for two contacts a season or year or divide by two for contacts every two seasons or years) before adjusting the population for the enforcement mode. In initial estimates the proposed standard of one contact a year appears reasonable for fisheries of the southeastern United

States and is therefore recommended until experience indicates otherwise.

The developers of regulations for management plans should consider the enforcement modes (sea, shore, or combinations) that will be required for compliance and the relative cost. Regulations that can be enforced at dockside are certainly cheaper to enforce than those that must be enforced at sea. If at-sea regulations are mandatory, the ratio of vessels in the fishery to the fishing area is an important consideration. For fisheries with few vessels and a large fishing area (such as the example used for the purse seine fishery), a 50 percent sea mode may require an effort equal to 100 percent sea enforcement to cover the fishing area. In such cases planners should attempt to write regulations that can be enforced entirely at sea

and eliminate shore-side enforcement. The same applies when shore-side regulations are imperative. For fisheries with few vessels and an extensive coastline, a 50 percent shore-side enforcement mode may require the same effort as a 100 percent mode and at-sea regulations should be eliminated if possible.

Enforcement cost estimates can also be derived from the proposed equations by applying known dollar values to staff years of effort, vessel days, aircraft hours, and vehicle miles required for each fishery or combinations of fisheries. Further, the methods proposed can be used to prorate available enforcement dollars and personnel to meet minimum enforcement requirements for multiple fisheries. If "X" number of fisheries are to be regulated with "Y" enforcement resources, the staff years of effort required for individual fisheries can be converted to percentages of the total requirements for all fisheries and then applied to the available resources. Standardization of methods for making enforcement estimates is thus a prerequisite to developing a rational law enforcement resource allocation system.

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