Mexico's 200-Mile Offshore Fishing Zone: Its Economic Impact on the U. S. Gulf of Mexico Shrimp Fishery

WADE L. GRIFFIN
and BRUCE R. BEATTIE
Department of Agricultural Economics
Texas Agricultural Experiment Station

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Wade L. Griffin
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Bruce R. Beattie

Associate Professors

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ABSTRACT

U.S. shrimp fishermen in the Gulf of Mexico have historically used fishing grounds off both the U.S. and Mexican coasts with about ten percent of their total effort being expended in Mexican waters. This ten percent, 30,600 units of effort, will no doubt be diverted to U.S. waters as a result of a complete phasing out of shrimping by the U.S. fleet in Mexican water. Assuming the U.S. portion of the Gulf is presently in open-access equilibrium, then this additional effort will yield negative rent. If it takes three years of natural attrition of effort out of the industry to regain equilibrium, then the present value of the stream of losses would be $8.6 million, given 1973 shrimp prices of $1.70 per pound. The break-even price needed to keep the U.S. fleet in open-access equilibrium at the higher effort level is $2.17 per pound. Since present shrimp prices are considerably above that level it is expected that the impact of the phasing out of shrimping in Mexican waters by the U.S. fleet will not result in a serious, detrimental economic impact on the industry.

ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. J. E. Greenfield, regional economist for the National Marine Fisheries Service for his assistance in this study. Comments of Ronald D. Lacewell and C. Richard Shumway on an earlier draft of this paper were most appreciated.

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INTRODUCTION

The United States and Mexico signed a treaty in November, 1976, concerning future U.S. shrimping activity in Mexico's portion of the Gulf of Mexico affected by the 200-mile extended jurisdiction. A three- and one-half-year phaseout period was negotiated, and all U.S. shrimp fishing within Mexico's 200-mile offshore fishing zone will be terminated by 1980.

Vessel owners and operators generally believe that this action poses serious problems for the U.S. shrimping fleet operating in the Gulf of Mexico. Vessels in the Brownsville-Port Isabel ports of Texas rely heavily on the offshore shrimp grounds of Mexico and will be forced to direct their efforts exclusively to the north and east of the Texas-Mexico border. In the past as many as 632 vessels landing shrimp in Texas have routinely fished in the Mexican portion of the Gulf. Thus the potential exists for a substantial increase in the amount of total effort expended off the Texas and Louisiana coasts. Likewise, Florida-based vessels, an average of 85 over the 1971-1974 period, have shrimped off the Yucatan Peninsula. These vessels are expected to now divert all of their effort to the shrimp grounds off the Florida, Alabama, Mississippi and Louisiana coasts.

The objective of this study is to explore the expected economic impact of the 200-mile extended jurisdiction limit by Mexico on the U.S. shrimp fleet in the Gulf of Mexico. More specifically the objectives are:

1. To estimate the average annual shrimp landings taken by U.S. fleet while shrimping in Mexican waters.

2. To estimate the expected quantity of effort that is expended in Mexican Waters by the U.S. shrimp fleet.

3. To estimate the impact of shifting the effort of the U.S. shrimp fleet from Mexican waters to U.S. waters in terms of rent loss to the fishery and break-even product prices required to achieve open-access equilibrium.

PAST U.S. SHRIMPING ACTIVITY IN THE GULF OF MEXICO

The shrimp grounds in the Gulf of Mexico considered in this study begin with area 1 off the southwestern tip of Florida and extend to area 40 just off Quintana Roo; these areas and depth zones in ten-fathom increments are shown in Figure 1. Areas 1-21, off the U.S. coast, and areas 22-40, off Mexico's coast, conform to those used by the National Marine Fisheries Service (NMFS) in collecting and reporting shrimp landings data. To give the reader an idea of the production levels of the shrimp grounds, Table 1 is a description of the Gulf of Mexico indicating where

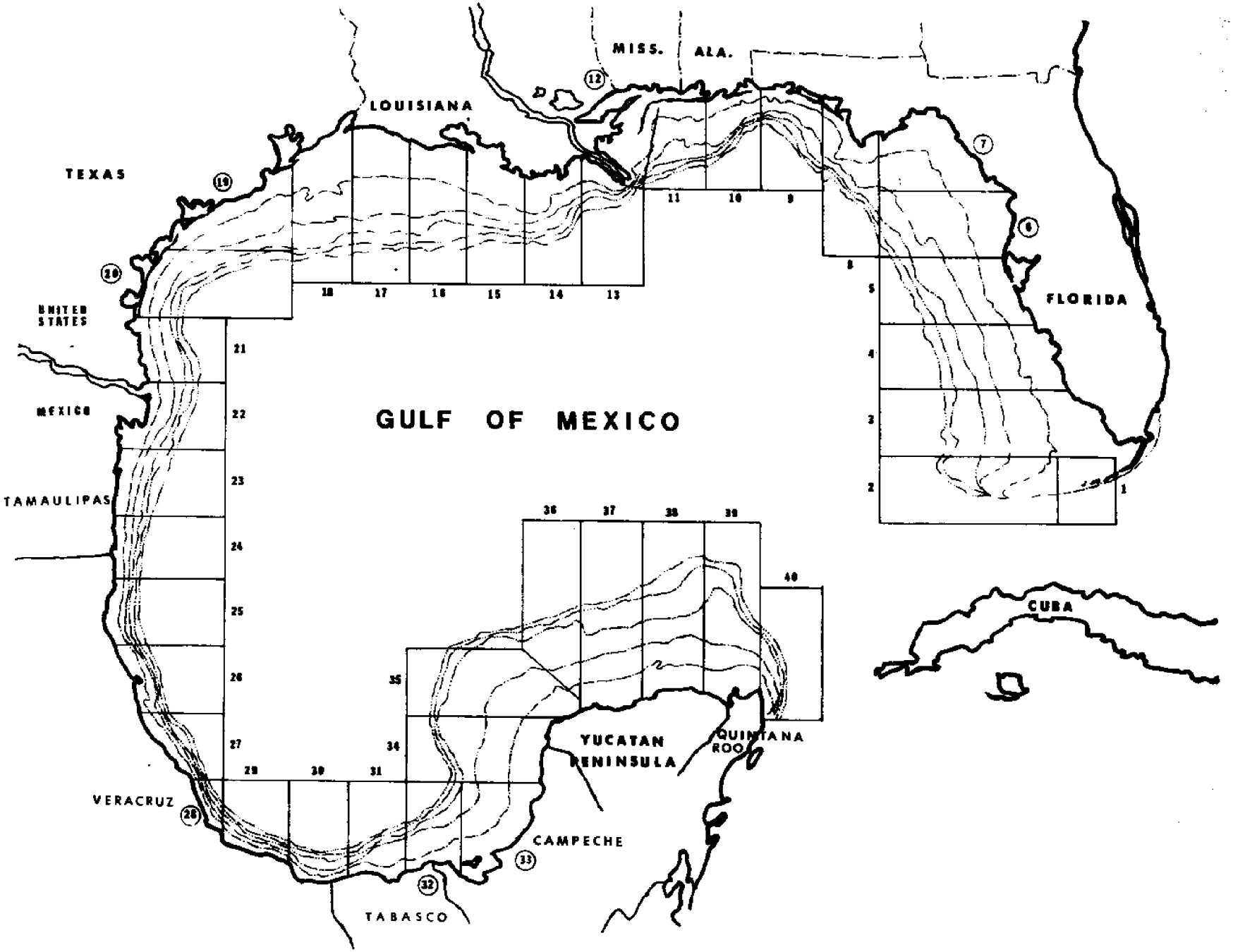

Figure 1. Gulf of Mexico Shrimp Grounds by Area and Depth

Table 1. Fishing Grounds of All Three Species by Seasons, Based on Total Pounds 1 = 500-50,000 Pounds, 2 = 50,001-100,000 Pounds, 3 = 100,001-500,000 Pounds, 4 = 500,001-1,000,000 Pounds and 5 = 1,000,001-up Pounds, Gulf of Mexico, 1963-1971.

	Depth in fathoms	Florida									Ala.	Miss.	Louisiana						Texas				Mexico																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Season 1 (May,Jun,Jul)	Inshore							2	3	2	4	5	5	5	5	5	3		3	4	3	2																			
	1-10	1	1	1	3	2	2	3	3	1	1	5	3	4	4	5	5	4	4	4	3	1	1	1	1								1	1	1							
	11-20	1	5	1	1	2	3	1	2	1	1	5	1	3	4	3	3	4	5	5	5	5	3	1	1	1	1				1		2	4	3							
	21-30		1	1							1	3		2	2	3	3	3	3	3	3	3		3	2	1	1	1	1		1		1	2	3	1		1				
	31-40											1		1	1	1	1	1	1	1	1	1		1	2	1	1	1			1		1		1							
	41-50											3		1	1		1	1	1																							
Season 2 (Aug,Sep,Oct)	Inshore					1		3	2	1	3	3	5	5	5	3		3	5	5	3																				
	1-10	1	1	1	1		1	1	3			4	3	5	3	5	5	5	5	5	3	1	1											1								
	11-20	1	5	2	1	1	1	1	1		1	5	1	3	4	3	3	4	5	5	5	5	3	1	1								1	3	3							
	21-30											4		3	3	3	2	3	3	5	5	5	3	3	3	1	1	1					1	1	2	1						
	31-40											3		3	1	1	1	1	1	1	3	3	2	3	3	1	1	1							1							
	41-50											1		1				1		1	1	1																			
Season 3 (Nov,Dec,Jan)	Inshore					1		2	1	1	3	2	4	4	5	3		3	3	3	1																				
	1-10	1	2	1	3			2	3		1	4	3	5	4	5	4	4	3	4	2	2	1	1										1	1							
	11-20	1	5	3	1	1		1	1		1	3	1	3	2	3	2	1	1	4	3	3	1	1	1		1		1				1	4	3	1			1			
	21-30		3	1	1							3		3	3	2	2	3	3	4	4	4	3	3	3	1	2	1	1		1		1	2	3	1						
	31-40		1									3		2	1	2	1	2	1	3	2	4	1	2	3	2	2	1	1	1			1		1							
	41-50											1		1	1		1	1	1	1	1	1				1																
Season 4 (Feb,Mar,Apr)	Inshore	1				1		1	2	1	1	1	1	1	1	1			1	1	1																				
	1-10	1	1	1	3	1	1	3	1		1	1	1	3	2	3	3	3	3	3	1	1	1	1		1								1	1							
	11-20	1	5	3	1	1	1	1	1		1	4		1	1	3	2	1	1	3	1	2	1	1	1	1	1	1	1				1	5	4	1	1	1				
	21-30		3	1	1							3		2	3	2	3	3	1	3	3	3	3	3	3	1	2	2	1		1	1	2	3	3	4	1	1			
	31-40		1									2		3	2	3	3	3	1	1	1	1	1	1	3	1	3	1	1	1	1	1	1	1	1	1					
	41-50											1		1	1	1	1	1	1	1	1							1	1					1							

Source: Griffin, Cross and Ryan, 1974.

and in what quantities U.S. Gulf shrimpers harvest shrimp. The columns represent areas and the rows represent depths. The greatest landings are taken from Mississippi, Louisiana, and Texas coasts. However, it can be seen that an important quantity of shrimp comes from two basic areas in Mexican waters, areas 22-30 and areas 31-40. Starting in 1962, data on catch, value and effort are aggregated for areas 1-21, areas 22-40 and for the two areas within Mexican waters, 22-30 and 31-40. The data reported in this study are for vessels which are five gross tons or larger and are registered with the U.S. Coast Guard[1] (U.S. Department of Commerce, 1973).

TRENDS IN SHRIMP DATA

Catch

Catch harvested from the Gulf of Mexico by U.S. shrimpers is shown in Table 2 for years 1962 through 1974 and for the five-year average 1970-1974. This data is also shown in Figure 2. Catch by vessels increased for the whole Gulf from approximately 90 to 100 million pounds of heads-off shrimp from 1962 to 1974. Catch in 1962, 1973 and 1974 was low but statistical results indicate that this is correlated with high river discharge (Griffin, Lacewell and Nichols). The average catch for the last five years (1970-1974) was 94.6 million pounds.

Shrimp landed from U.S. waters increased from approximately 75 to 90 million pounds with the average being 85.0 million for the last five years. Therefore, landing from U.S. waters increased slightly faster than landings from the total Gulf.

Landings from Mexican waters have decreased from around 18 to 10 million pounds with the average for the last five years being 9.6 million pounds. The decrease in landings came from regions 31-40 off the Yucatan Peninsula where catch dropped from 12 million pounds to 4 million pounds as is illustrated in Figure 2. Landings from areas 22-30 remained fairly constant at 5 to 6 million pounds. During 1970-1974, 90 percent of U.S. shrimp landings came from U.S. waters and 10 percent from Mexican waters. Within the last five years almost two-thirds of the landings from Mexican waters came from areas 22-30 on the Texas side of the Gulf.

Value of Catch

Total value of catch has increased dramatically over the 13-year period with the exception of 1974 (Table 3 and Figure 3). Where catch increased approximately 10 million pounds (11 percent) for the entire Gulf over the 13-year period, value increased over $80 million (160

[1]Unregistered vessels are generally the smaller bay boats and are not included in this study.

Table 2. Total Shrimp Catch Harvested by Vessels From the Gulf of Mexico by Areas.

Year	Areas				
	Total Gulf	U.S.	Total	Mexico	
	1-40	1-21	22-40	22-30	31-40
	Million Pounds				
1962	64.6	45.5	19.1	5.9	13.9
1963	91.1	77.1	14.0	3.3	10.7
1964	88.5	71.1	17.4	5.2	12.3
1965	96.5	80.2	16.3	5.0	11.4
1966	88.5	78.4	10.1	6.1	4.1
1967	109.7	99.7	10.0	5.0	5.0
1968	98.1	83.7	14.4	8.1	6.3
1969	90.8	82.5	8.3	4.1	4.2
1970	105.3	96.2	9.1	5.2	3.9
1971	100.4	91.4	9.1	6.3	2.7
1972	106.1	94.4	11.7	8.3	3.4
1973	81.2	71.1	10.1	5.7	4.4
1974	80.0	71.8	8.2	4.8	3.4
1970-1974 Average	94.6	85.0	9.6	6.1	3.6
Percent	100.0	89.9	10.1	6.4	3.7

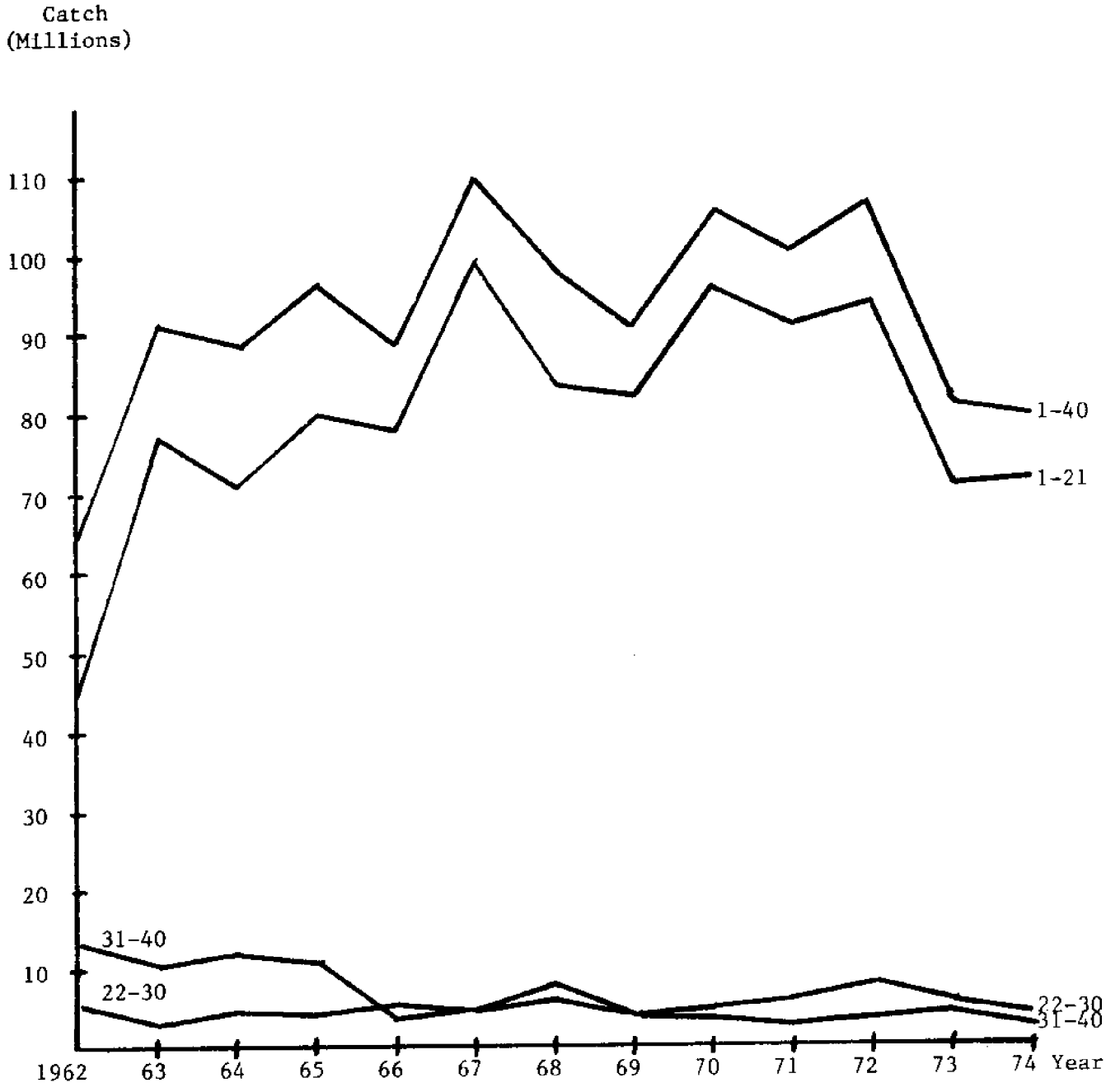

Figure 2. Total Shrimp Catch Harvested by Vessels from the Gulf of Mexico by Areas.

Table 3. Total Value of Shrimp Catch Harvested by Vessels from the Gulf of Mexico by Areas.

Year	Areas				
	Total Gulf	U.S.	Total	Mexico	
	1-40	1-21	22-40	22-30	31-40
	- - - - - - - - - - - -Million Dollars - - - - - - - - - - - -				
1962	49.1	33.4	15.7	5.0	10.7
1963	51.8	41.5	10.2	2.5	7.7
1964	52.2	40.8	11.4	3.9	7.5
1965	60.8	49.2	11.7	3.7	8.0
1966	71.1	61.9	9.1	5.6	3.5
1967	77.7	68.6	9.1	4.6	4.5
1968	82.4	68.4	13.9	8.0	5.9
1969	83.2	74.3	8.9	4.5	4.4
1970	90.6	81.5	9.1	4.9	4.2
1971	112.3	100.8	11.5	8.3	3.1
1972	136.2	120.1	16.0	11.6	4.4
1973	137.4	118.6	18.8	11.1	7.7
1974	10	96.9	12.4	8.1	4.3
1970-1974 Average	117.2	103.6	13.6	8.8	4.7
Percent	100.0	88.4	11.5	7.5	4.0

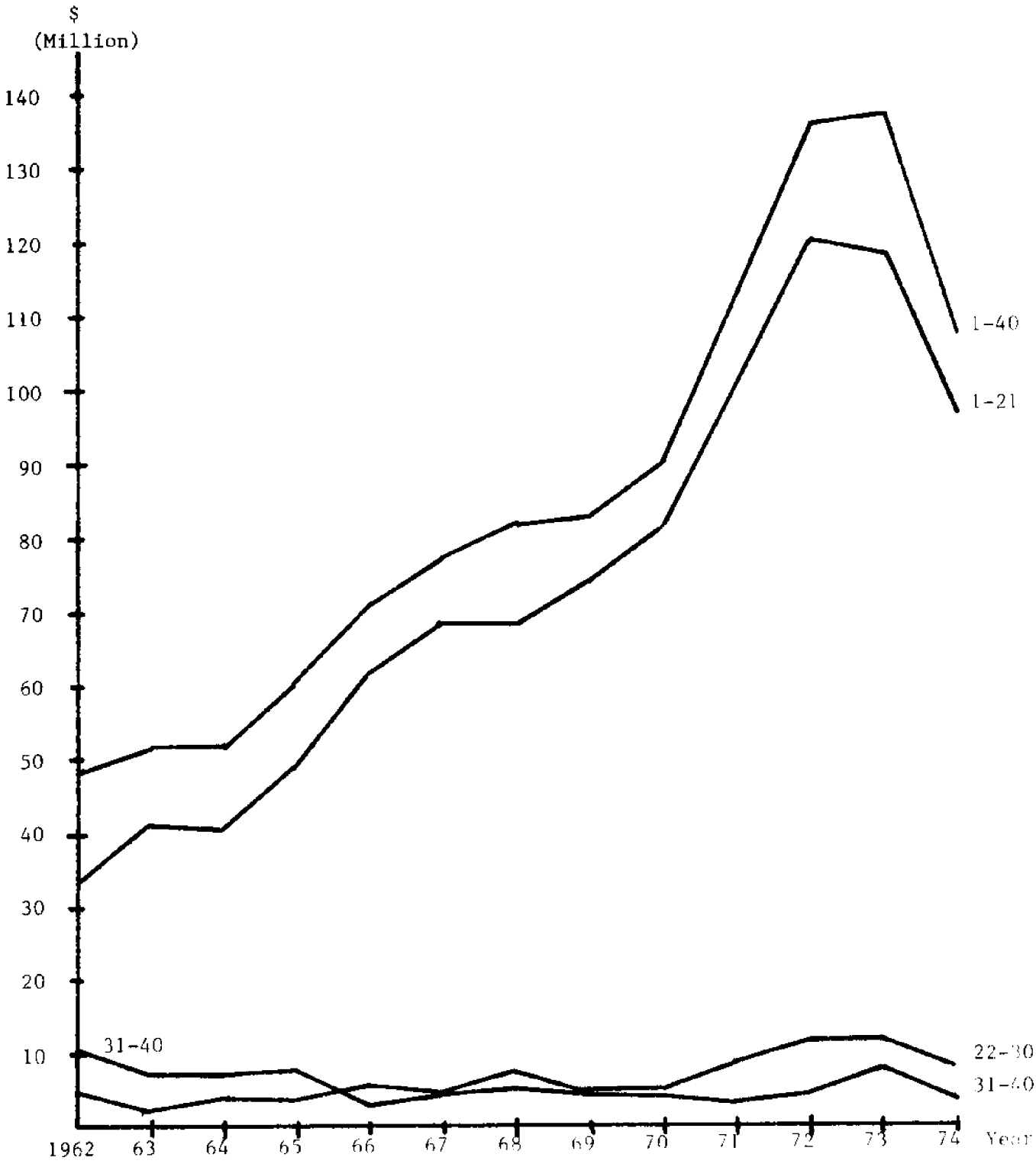

Figure 3. Total Value of Shrimp Catch Harvested by Vessels from the Gulf of Mexico by Areas.

percent). Total value of catch from Mexican waters (areas 22-40) remained fairly constant at $13 million. Areas 22-30 have become relatively more valuable to Gulf shrimpers in the U.S. than areas 31-40. While Mexican vessels have begun in recent years to fish in U.S. water, their catch and associated value is negligible.

Days Fished

Days fished in the entire Gulf increased from approximately 130,000 to 155,000 days between 1962 and 1974 (Table 4 and Figure 4). Days fished in U.S. waters increased more than proportionately from approximately 90,000 to 140,000 days, as the Gulf shrimpers shifted their efforts from Mexican waters to U.S. waters. The most noticeable shift was between 1965 and 1966 when days fished dropped from around 30,000 to 17,000 days in areas 31-40 of Mexican waters. Days fished in areas 22-30 of Mexican waters remained nearly constant at about 10,000 days for the 13-year period.

Effort

The U.S. Gulf of Mexico shrimp fleet is a heterogenous group of vessels. In addition the composition of this group of vessels is changing over time as older less powerful vessels have been replaced with more powerful vessels causing the average power that the vessels exert in a day fished to increase (Griffin, Cross and Nichols). Consequently, to arrive at an acceptable measure of fishing effort over time, it is necessary to establish an index of relative vessel fishing power (effort index) to standardize days fished.[2] Standardized days fished or effort is calculated as the effort index times days fished.

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[2]Effort index is defined as the ratio of catch per unit of fishing time of a vessel to that of a standard vessel, fishing on the same density of fish on the same type of ground. The value for the effort index for each vessel was calculated by Griffin, Cross, Lacewell and Nichols (1973) as follows:

$$EI_i = \frac{(HP)_i^{.1385} \; (LFR)_i^{.4064}}{(38)^{.1385} \; (14.6)^{.4064}}$$

where EI_i = effort index for vessel i

$(HP)_i$ = horsepower for vessel i

$(LFR)_i$ = sum of the lengths of the footropes measured in yards for vessel i

38 = average horsepower of the smallest class of vessels operating in the Gulf from 1962-1971

14.6 = average net size measured in yards of footrope used by the smallest class of vessels for the same period.

Table 4. Total Days Fished by Vessels in the Gulf of Mexico by Areas.

Year	Areas				
	Total Gulf 1-40	U.S. 1-21	Total 22-40	Mexico 22-30	Mexico 31-40
	- - - - - - - - - - - - - - - - Thousands - - - - - - - - - - - - - - - -				
1962	126.6	88.6	38.0	11.5	26.5
1963	139.3	113.0	26.3	5.9	20.4
1964	145.4	114.4	31.0	8.9	22.1
1965	141.7	113.8	27.9	7.8	20.1
1966	131.3	113.8	17.5	10.3	7.2
1967	130.7	116.1	14.6	7.1	7.5
1968	144.5	121.5	23.0	11.8	11.1
1969	164.7	147.8	16.8	9.2	7.6
1970	150.2	134.7	15.5	7.7	7.8
1971	151.9	137.0	14.8	10.5	4.3
1972	163.6	146.8	16.8	12.3	4.5
1973	157.8	140.1	17.7	10.5	7.2
1974	147.6	132.6	15.0	10.3	4.7
1970-1974 Average	154.2	138.2	16.0	10.3	5.7
Percent	100.0	89.6	10.4	6.7	3.7

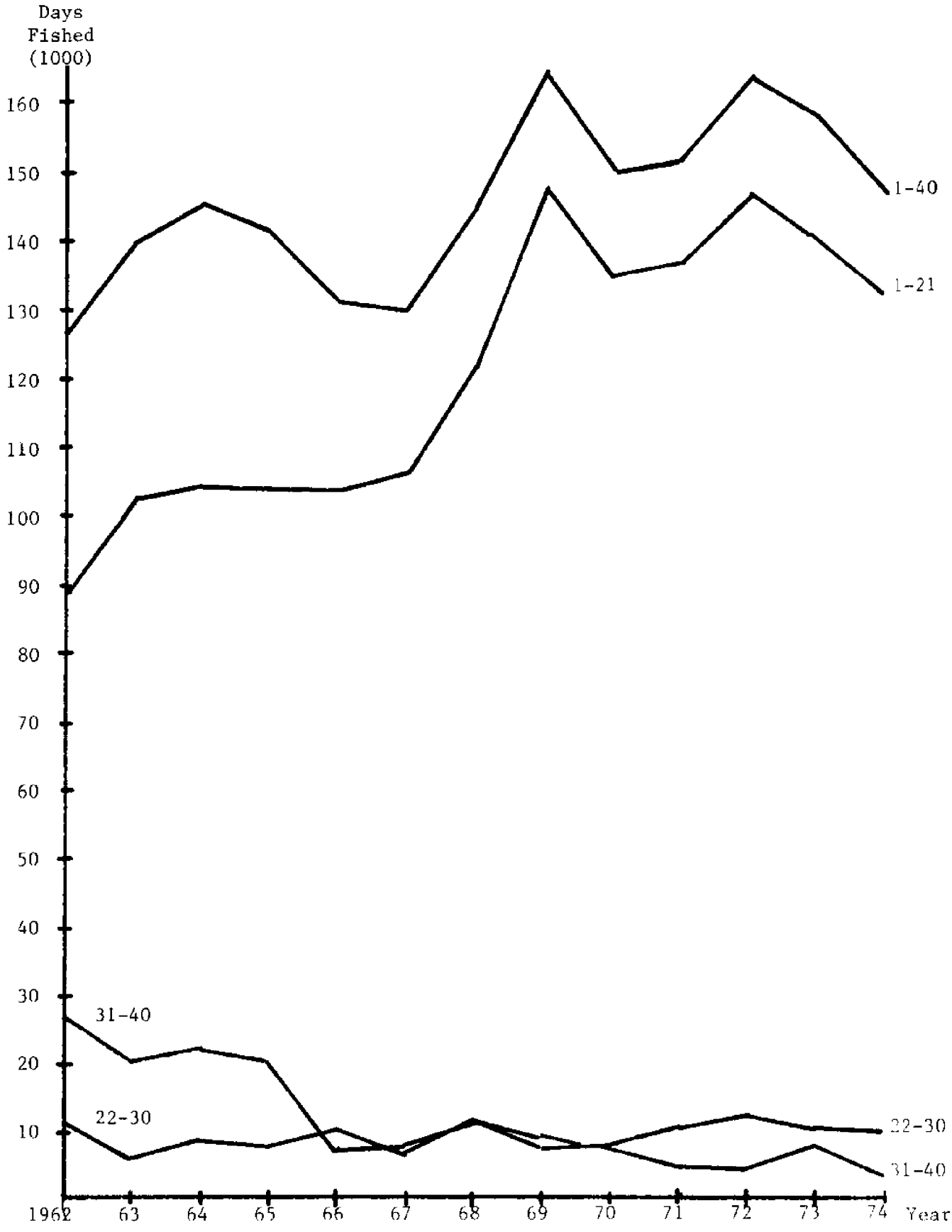

Figure 4. Total Days Fished by Vessels in the Gulf of Mexico by Areas.

Table 5 and Figure 5 show the trend in effort over the 13-year period. While days fished had increased approximately 25,000 days (20%) from 1962 to 1974, actual effort expended on the Gulf shrimp resource increased by approximately 60,000 units (30%), i.e., from 230,000 to 300,000 units. In areas 22-30 of Mexican waters effort increased only slightly from 18,000 to 20,000 units; in areas 31-40 effort decreased from 40,000 to 10,000 units.

Slightly more than 10 percent of the total effort in the Gulf shrimp fishery was expended in Mexican water during the 1970-1974 period (Table 5). This 10 percent, 30,600 units of effort, is the amount which will have to be absorbed as a result of a complete phasing out of shrimping by the U.S. fleet in Mexican waters.

Number of Vessels

The total number of vessels harvesting shrimp in areas 1-40 increased from approximately 2600 to 3300 by 1968 and has remained relatively constant since then (Table 6 and Figure 6). Vessel equivalents, calculated based on the percentage of effort exerted in each of the different areas of the Gulf for each year, are also reported in Table 6 and Figure 6. Vessel equivalents is a measure of the number of vessels it would take to harvest the shrimp taken in an area assuming all vessels were average size vessels. The number of vessel equivalents in areas 1-21 has increased from approximately 2000 to 3000 vessels. Areas 22-30 has remained constant around 225 vessels equivalents and in areas 31-40 vessel equivalents have declined from approximately 400 to 100 vessels.

Distribution of Landings from Mexican Water

Landing data for the period 1970 to 1974 indicate that more than 99 percent of the catch from Mexican waters was landed in Florida and Texas (Table 7). For the five Gulf States an average of 85.0 million pounds (90 percent) of the shrimp landed during the 1970-1974 period came from U.S. waters whereas 9.5 million pounds (10 percent) came from Mexican waters. Eighty-nine percent of Florida's landing (and revenue) came from U.S. waters and 11 percent from Mexican waters. Texas is somewhat more dependent on Mexican waters since 17 percent of its landings and 19 percent of its revenue comes from Mexican waters.

Most of the catch taken from Mexican water and brought to Texas is landed in the ports of Brownsville and Port Isabel. For these two ports, located across the Rio Grande River from Mexico, 58 percent of the landing comes from U.S. waters and 42 percent from Mexican waters. Thus, vessels operating out of Brownsville and Port Isabel are currently very dependent on Mexican waters.

Table 8 shows the number of Florida and Texas vessels that will be directly affected by the 200-mile extended jurisdiction by

Table 5. Total Effort Expended by Vessels in the Gulf of Mexico by Areas.

Year	Areas				
	Total Gulf 1-40	U.S. 1-21	Total 22-40	Mexico 22-30	Mexico 31-40
	-Thousand Units-				
1962	205.7	144.1	61.7	19.0	7.42
1963	225.5	181.9	43.6	9.9	33.7
1964	238.0	186.4	51.6	14.8	36.8
1965	234.2	187.6	46.6	13.0	33.6
1966	220.3	190.3	29.8	17.5	12.4
1967	235.0	201.8	33.2	19.4	13.8
1968	260.6	218.2	42.4	21.5	20.8
1969	305.4	273.6	31.8	16.9	14.8
1970	277.4	249.1	28.3	13.9	14.4
1971	287.9	259.0	28.9	20.2	8.7
1972	315.4	282.6	32.8	23.9	9.1
1973	304.4	269.7	34.7	20.3	14.4
1974	271.9	243.6	28.3	19.9	8.4
1970-1974 Average	291.4	260.8	30.6	19.6	11.0
Percent	100.0	89.5	10.5	6.7	3.8

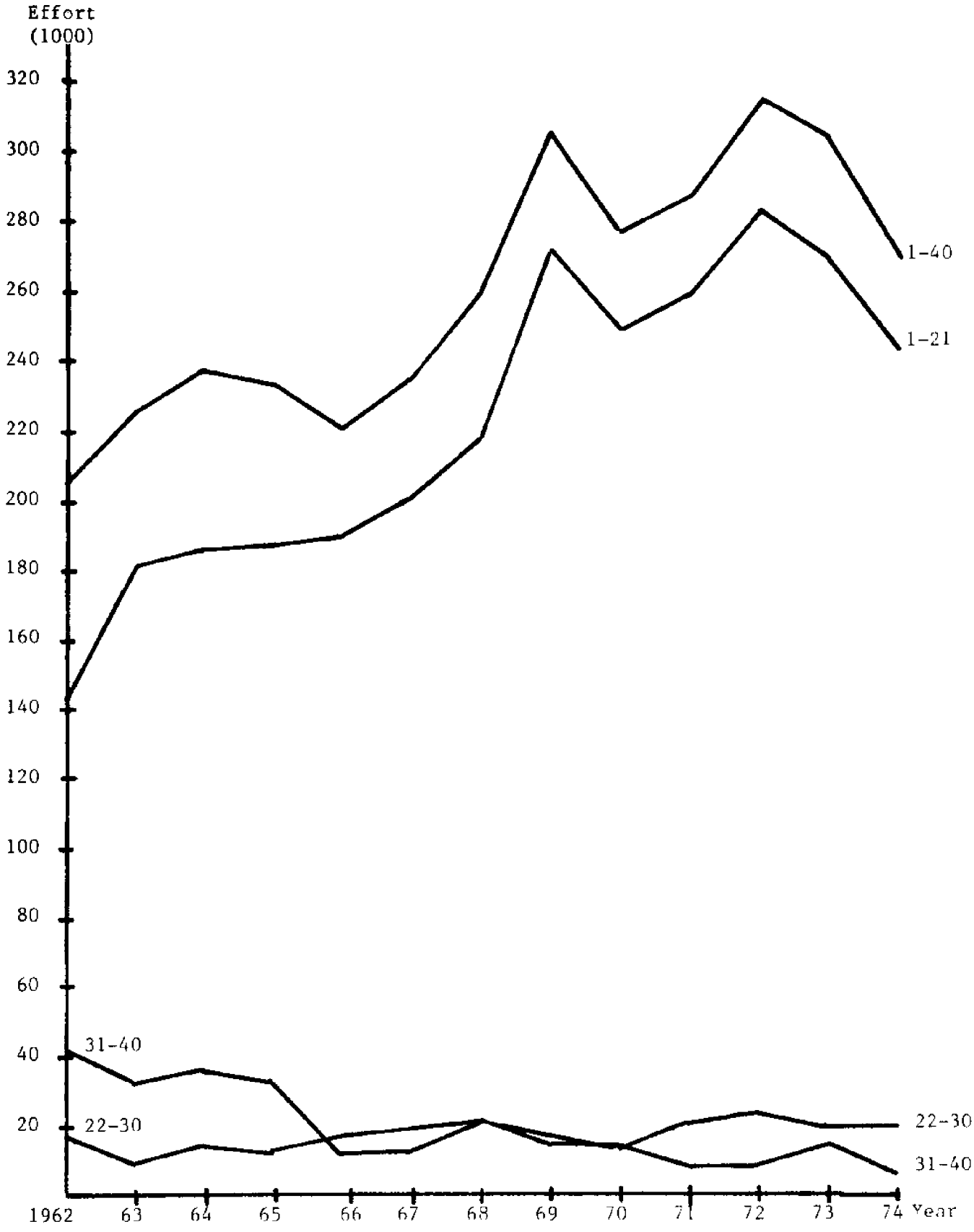

Figure 5. Total Effort Expended by Vessels in the Gulf of Mexico by Areas.

Table 6. Total Number of Vessels and Vessel Equivalents* Harvesting Shrimp in the Gulf of Mexico by Areas.

Year	Vessels	Vessel Equivalents in Areas			
		U.S.	Total	Mexico	
		1-21	22-40	22-30	31-40
1962	2542	1781	762	232	530
1963	2653	2140	513	116	396
1964	2795	2189	606	174	432
1965	2804	2246	558	153	405
1966	2924	2529	396	232	165
1967	3098	2660	438	256	181
1968	3346	2802	544	276	268
1969	3362	3012	350	185	164
1970	3298	2962	336	164	172
1971	3282	2953	329	230	99
1972	3345	2997	348	251	97
1973	3453	3059	394	225	169
1974	3247	2930	317	236	79
1970-1974 Average	3325	2976	349	223	156
Percent	100.0	89.5	10.5	6.7	3.8

* Calculated based on effort.

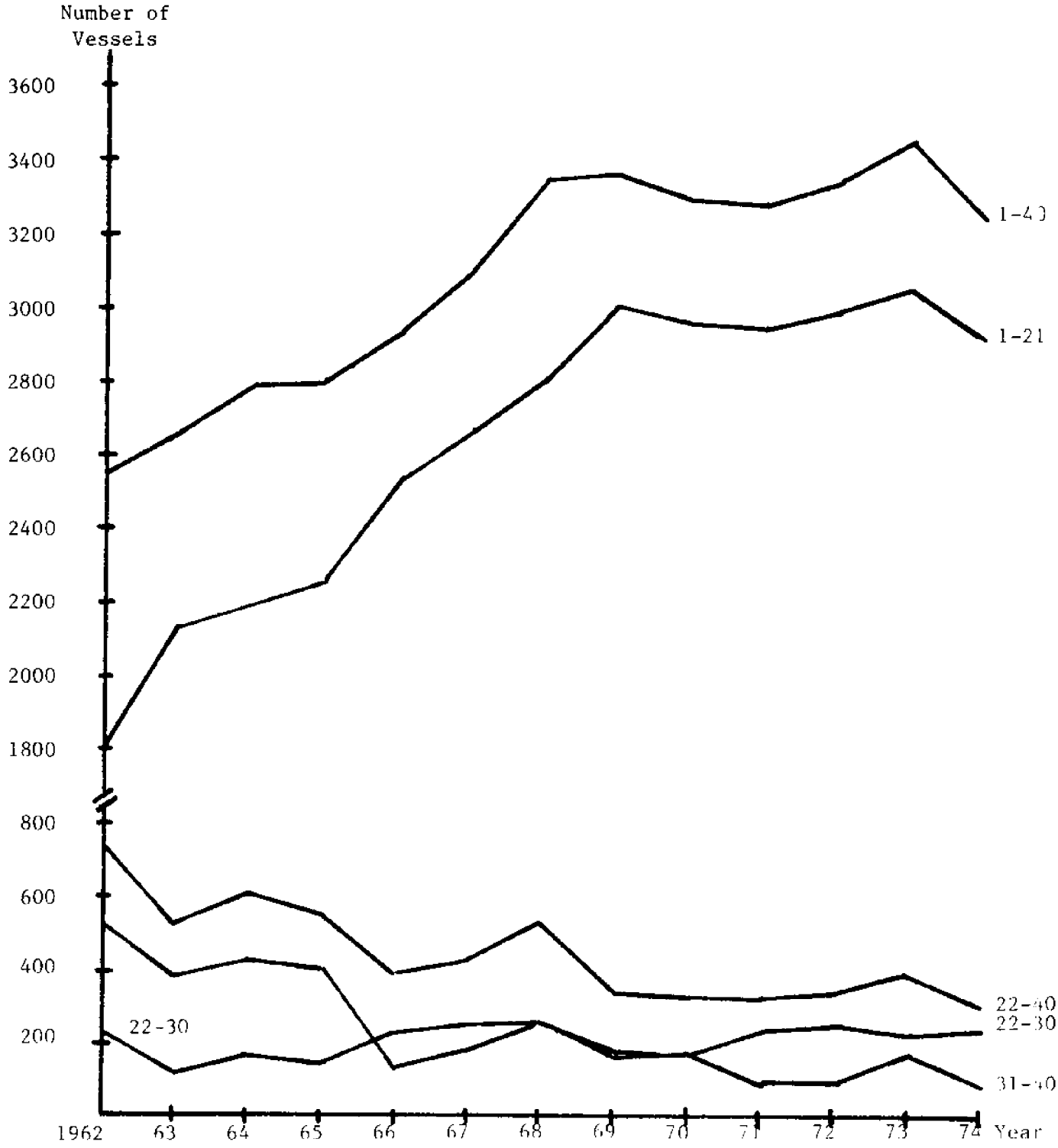

Figure 6. Total Number of Vessels and Vessel Equivalents Harvesting Shrimp in the Gulf of Mexico by Areas.

Table 7. Total Pounds and Value (and Percentages) of Shrimp Landed in the Five Gulf States, Florida, Texas and Brownsville/Port Isabel by Areas of the Gulf of Mexico, Average over the Five Years, 1970-1974.

Area	Five Gulf States		Florida		Texas		Brownsville & Port Isabel	
	Pounds (mil)	Dollars (mil)	Pounds (mil)	Dollars (mil)	Pounds (mil)	Dollars (mil)	Pounds (mil)	Dollars (mil)
U.S.:								
1-21	85.0	103.6	13.5	15.1	38.2	49.5	9.9	12.6
	(90)	(89)	(89)	(89)	(83)	(81)	(58)	(54)
Mexico:								
22-30	6.0	8.7	*	*	*	*	*	*
	(6)	(7)			(13)	(15)	(34)	(47)
31-40	3.6	4.7	1.7	1.9	1.9	2.8	1.4	2.1
	(4)	(4)	(11)	(11)	(4)	(5)	(8)	(9)
Total Gulf:								
1-40	94.5	117.0	15.2	16.9	46.0	59.1	17.3	23.3
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)

*Less than 100,000

Table 8. Number of Vessels from Texas and Florida Fishing in the Gulf of Mexico by Areas, 1971-1974.

	Texas				Florida			
	Areas				Areas			
Year	Total* 22-40	22-30	31-38	39-40	Total* 22-40	22-30	31-38	39-40
1971	570	460	158	78	75	4	11	72
1972	632	528	193	74	90	0	7	86
1973	615	480	323	53	96	0	14	86
1974	444	393	153	30	79	1	5	77
Average	565	465	207	59	85	1	9	80

*Total is not equal to sum of separate areas because some vessels fished in more than one area.

Mexico.[3] The average number of Texas vessels that fished in Mexican waters for the period 1971-1974 was 565; for Florida the average was 85. Of the 565 Texas vessels, 464 fished in areas 22-30, 207 fished in areas 31-38 and 59 fished in areas 39-40. The Florida vessels are more dependent on areas 39-40 where 80 of the 85 vessels fished. Only 9 of the Florida vessels fished in areas 31-38 and only one fished in areas 22-30.

ECONOMIC CONSEQUENCE OF EXTENDED JURISDICTION

Slightly more than 10 percent, 30,600 units, of the total effort expended by U.S. shrimpers on the Gulf shrimp fishery was in Mexican water during the 1970-1974 period. For purposes of this paper it is assumed that when Mexico's extended jurisdiction goes into full effect in 1980, these 30,600 units of effort (E_m in Figure 7 will be diverted to U.S. waters. Assuming that the U.S. Gulf of Mexico fishery is currently in open-access equilibrium at E_u (Figure 7) where total value product (TVP) equals total cost (TC), we should expect a temporary disruption of that equilibrium to E_t.

[3]Vessels were classified as Florida or Texas vessels based on where they made the most number of landings. For example, a vessel making 10 landings in Florida, 1 in Louisiana and 5 in Texas, was classified as a Florida vessel.

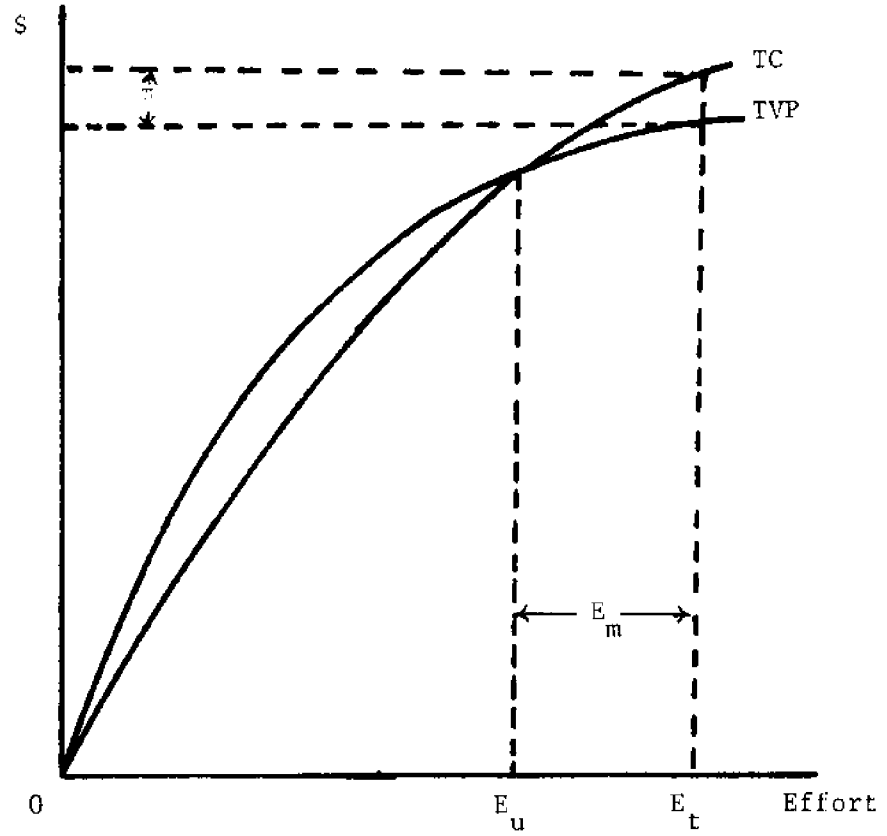

Figure 7. Hypothetical Curves Showing Industry Equilibrium in an Open-Access Fishery

Since rent is zero at equilibrium in an open-access common property resource (Gordon), rent (π) will be temporarily negative due to the excess effort. The efficiency cost of this excess effort is given by the present value of the stream of negative rent over the period of time it takes to shift E_m units of effort out of the fishery and return to equilibrium. To estimate this cost we consider first the impact on the yield function

Impact on Yield Function

In most fisheries, the yield function is affected by both stock and crowding externalities. While the Gulf of Mexico shrimp fishery is characterized by crowding externalities, stock externalities is not a problem since shrimp is an annual crop.[4] That is, fishing effort does

[4] See Griffin, Lacewell and Nichols for a more detailed discussion.

not affect the recruitment stock relationship as effort increases with catch approaching some annual maximum yield (Schaefer).

Shrimp spawn offshore and the larvae move inshore to the estuaries, become juveniles and then move offshore to grow to maturity. The natural environment in the estuaries has a significant effect on annual shrimp production. High river discharge during the period that shrimp are in their nursery grounds reduces the water temperature and salinity, causing a reduction in population and, in turn, catch. Therefore, the Mississippi River discharge, D, during the months that shrimp are in their nursery grounds, is included as an explanatory variable in the yield function serving as a proxy for total river discharge into the Gulf.

The following yield relationship was hypothesized:

$$(1) \qquad Y = \beta_c D^{\beta_2} [1 - \beta_1^{E}] + \mu$$

where Y is yield or catch, $\beta_c D^{\beta_2}$ is the maximum yield the function approaches for a given level of river discharge, D, β_1 indicates the ratio by which marginal productivity of effort, E, declines (Heady and Dillon, pp. 86-88), and μ is an error term.

Equation (1) was estimated using an iterative regression procedure[5] and time series data for the period 1962-1974.[6] The resulting equation was

$$(2) \qquad Y = 6593\ D^{-0.60134}\ (1 - .995701^{E})$$

where Y (catch or yield) is in million pounds, D (Mississippi River discharge) is in cubic feet per second, and E (effort) is in thousand units. All estimated coefficients were significant at the 1% level; R^2 was 78.5; the Durbin-Watson statistic was 2.25. The simple correlation coefficient between catch and effort was 0.64 and between catch and discharge was -0.63.

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[5]Because the function can not be transformed to a linear form the equation estimated was $Y = \beta_c D^{\beta_2} [1 - \beta_1^{E}]^{\alpha} + \mu$. Theoretically, $\alpha = 1$; therefore, β_1 was solved for through an iterative procedure such that α approached unity.

[6]The catch-effort data used to estimate this relationship was developed from individual vessel records collected by the National Marine Fisheries Service for the period 1962 to 1974 (U.S. Department of Commerce, 1962-1974). Catch is total pounds (heads-off) landed by all vessels in the Gulf of Mexico and total effort is measured by days fished standardized by the relative fishing power of the individual vessels (see footnote 2). River discharge is that reported by the U.S. Army Corps of Engineers for the Mississippi River, which was taken as a proxy for total U.S. river discharge into the Gulf.

Setting average daily river discharge at its mean value, the maximum yield for U.S. vessels in the Gulf shrimp fishery was estimated to be 128.7 million pounds annually (see Figure 8, upper panel). Assuming the equilibrium level of effort for the U.S. portion of the Gulf of Mexico to be 260,800 units (1970-1974 average), the associated equilibrium yield or catch is 87.8 million pounds. With an anticipated increase in effort diverted from Mexican waters, the new effort level will be 291,400 with a shrimp yield of 91.9 million pounds.

Impact on Total Value Product and Cost

The expected impact of an additional 30,600 units of effort on total value product (TVP), cost (TC), and rent (π) is also depicted in Figure 8 (lower panel). The total value product function is based on an assumed product price of $1.70 per pound (or $1,700,000 per million pounds) the approximate price received in 1973 for shrimp landed at U.S. ports in the Gulf.

The nonlinear cost function assumes that certain costs are proportional to catch rather than effort. That is,

$$(3) \qquad TC = C_y + C_e$$

where C_y denotes costs proportional to catch and C_e is costs proportional to effort. Cost proportional to catch is given by

$$(4) \qquad C_y = r_1PY + r_2r_1PY + r_3\ (1-r_1)\ Y$$

where r_1PY is crew share and is calculated as the percent received by the crew (r_1) of total revenue PY (P is product price per million pounds); r_2r_1PY is payroll taxes and is calculated as the unit cost of payroll tax (r_2) times crew share; and $r_3\ (1-r_1)Y$ is packing charges and is calculated as the unit cost of packing times vessels owners share of the catch $(1-r_1)Y$. For the U.S. Gulf shrimp fleet crew share is generally 35 percent of landings (catch); payroll taxes are approximately 7 percent of crew share; and packing and handling charges are about 8 cents per pound (or $80,000 per million pounds landed) of vessel owner's share of landings. Substituting these values into (4) and simplifying, gives

$$(4a) \qquad C_y = (.3745P + 52{,}000)Y$$

Cost proportional to effort includes variable costs such as fuel, ice, repair and maintenance, nets and supplies, and fixed costs such as depreciation, insurance, overhead, interest, and "normal profit" representing the opportunity cost of owner's equity capital and his management. Thus, cost proportional to effort is

$$(5) \qquad C_e = rE$$

where r is the unit cost of effort and E is total effort exerted on the

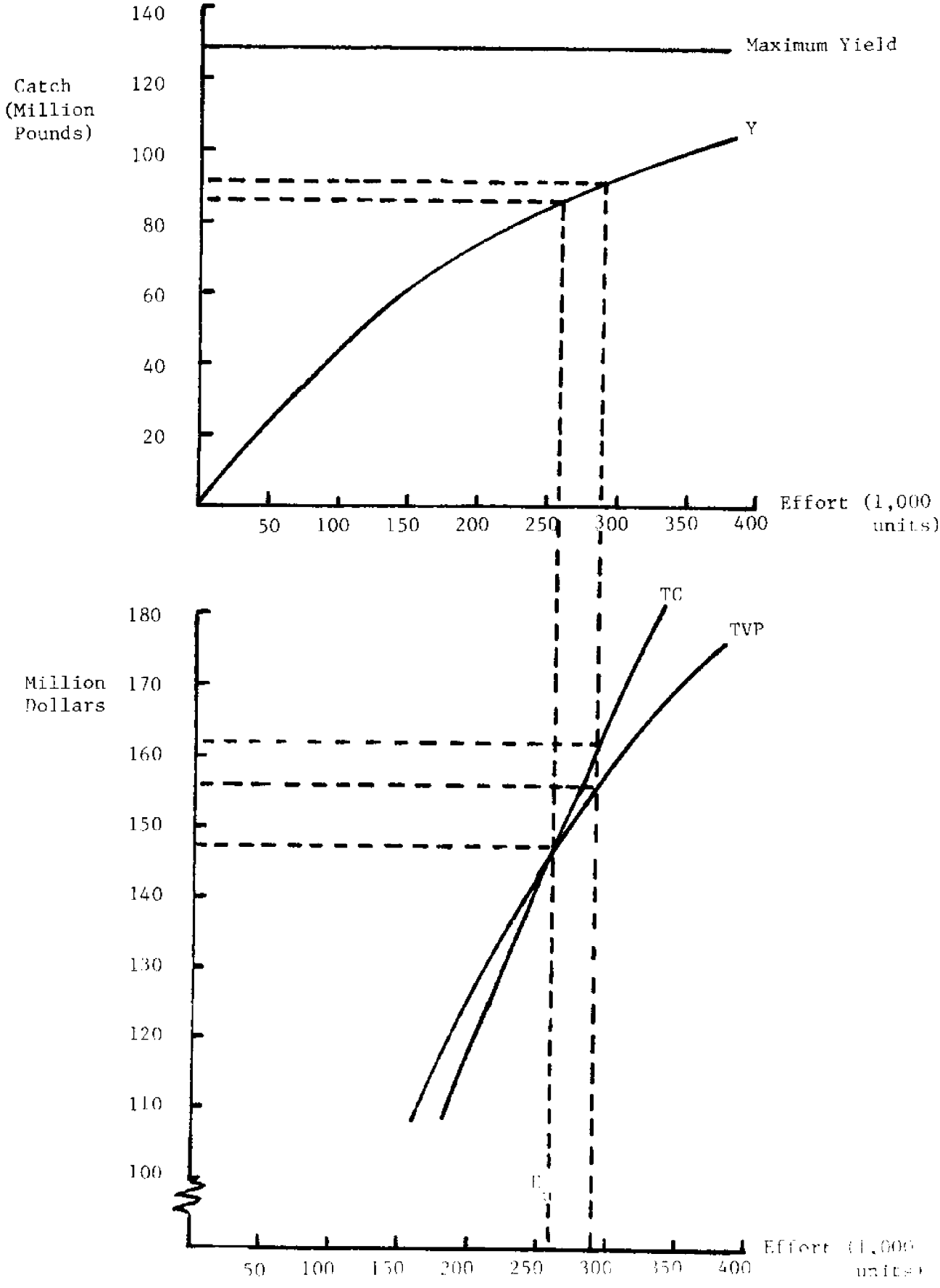

Figure 8. Estimated Yield Function (Y), Total Value Product (TVP) and Total Cost (TC) Assuming $1.70 per Pound of Shrimp Landed and Equilibrium Effort (E_0) at 260,800 Units.

fishery. Since equilibrium conditions are assumed such that TVP = TC and effort (E_u = 260.8 thousand), catch (Y = 86.6 million pounds) and price (P = $1.7 million) are known, then r, the cost per unit of effort, can be calculated by substituting equations (4a) and (5) into equation (3) and setting equal to TVP; i.e.,

(6) $PY = (.3745P + 52{,}000)Y + rE$

Substituting in for E, Y and P yields a cost per thousand units of effort (r) of $335,824.

Now total cost can be expressed as

(3a) $TC = (.3745P + 52{,}000)Y + 335{,}824E$

Substituting in for Y from the yield function (equation 2), costs may be expressed as a function of effort, the product price and river discharge:

(3b) $TC = (.3745P + 52{,}000)\ 6593D^{-0.60134}\ (1.0-.995701^{E}) + 335{,}824E$

Setting mean river discharge at 696 and product price at $1.7 million, equation (3b) may be expressed exclusively of a function of effort:

(3c) $TC = 88{,}655{,}766\ (1.0 - .995701^{E}) + 335{,}824E$

which is the equation plotted in Figure 8 (lower panel).

Present Value of Negative Rent Stream

When the 30,600 units of effort presently exerted in Mexican waters are diverted to U.S. waters the industry will temporarily incur negative rents. The expected increase in effort (E_m = 30,600) will result in an increase in TVP from $147.6 million to $156.4 million and in TC from $147.6 million to $161.4 million (Figure 8, lower panel). At 291,400 units of effort, rent accruing to the fishery would be a negative $5.1 million per year.

Since the industry is no longer in equilibrium it will move toward the equilibrium effort level of 260,800 units if cost-price relationships do not change. The magnitude of the real cost to the industry is the annual stream of net loss over that period of time until equilibrium is reached. Table 9 shows the present value of the stream of losses for alternative adjustment periods, and prices per pound of shrimp landed assuming a 10 percent discount rate. Adjustment is assumed to take place in equal increments of effort each year until equilibrium is reestablished (i.e., at 260,800 units of effort).

At a price of $1.70 per pound of shrimp landed[7], a discount rate of 10 percent and a 3-year adjustment period, the present value of the stream of net losses would be $8.6 million. Assuming the same price and discount

[7] If it is assumed that Mexico will harvest the shrimp in their waters and export them to U.S., then any change in shrimp prices will be negligible.

rate but 5 years to adjust the net present value of the stream of losses would be $12.1 million. Obviously, the longer the adjustment period, the larger the loss.

A $1.70 per pound was the average shrimp price received in 1973. Both price and cost have increased since then. The average price received is now closer to $2.50 per pound. Also presented in Table 9 are estimates of the present value of the negative rent stream assuming alternative shrimp prices. Since a change in product price shifts TVP and thus the equilibrium effort level, the estimates presented assume that cost of production shifted simultaneously so that the same (260,800) equilibrium effort level was maintained. Given this assumption, the present value of the stream of losses would be $12.8 million assuming $2.50 shrimp price and 3 years to adjust. At the same shrimp price but assuming a 5-year adjustment period, the present value of the loss stream would be $18.0 million.

Break-even Shrimp Prices at Alternative Equilibrium Effort Levels

The above is based on the assumption that shrimp price and costs of production increase in a manner such that the same (original) equilibrium effort level is maintained. If the price of shrimp increases relatively faster than the cost of harvesting shrimp, equilibrium effort will increase beyond the originally assumed 260,800 units for the U.S. waters. Given alternative effort, yield and unit cost proportional to effort levels, the price that shrimpers must receive to ensure zero rent (open access equilibrium) can be calculated. These prices are presented in Table 10 for five alternative equilibrium effort and five unit cost proportional to effort levels. That is, the table shows the price that must be received by given level of effort and unit cost proportional to effort assuming catch equal to expected yield based on the production function in equation (2).

At a unit cost of $243 (1973 level)[8] and effort level of 260,000 units (assumed equilibrium effort level in U.S. water) the average shrimp price would have to be $1.25 per pound for zero rent to be achieved. (The break-even price is $1.25 rather than $1.70, the actual 1973 price, because in 1973 the 260,000 units of effort yielded less than the expected catch due to higher than normal river discharge). However, since the unit cost proportional to effort has increased 60 percent since 1973 ($243 to $389 in 1975), an average shrimp price of $1.95 is required to achieve open access

[8] An adjustment must be made in the cost proportional to effort to solve for the $243 price unit of effort. Cost started to rise and profits went from positive, in the first part of 1973, to negative in the latter part of 1973. Total cost for the industry in 1973 was, on the average, zero, to ten percent less than total revenue. Assuming total cost was five percent less than total revenue and since landings were based on the estimated production function (Figure 8), the unit cost proportional to effort should be adjusted by subtracting the cost proportional to catch from 95 percent of the value of shrimp landed in 1973 [($118.6) .95-$47.1 = 65.6] and dividing by effort exerted in U.S. waters in 1973, [$65.6/269.8 = $243] to yield an estimate of unit cost proportional to effort of $243.

Table 9. Present Value of U.S. Cost Due to Mexico's Extended Jurisdiction in the Gulf of Mexico for Alternative Adjustment Periods and Product Prices (Assuming Equilibrium Effort at 260,800 Units and a Ten Percent Discount Rate.)

Years to Adjust	Ex-Vessel Price Per Pound			
	$1.70	$2.00	$2.50	$3.00
	Million Dollars			
1	4.6	5.5	6.9	8.3
3	8.6	10.1	12.8	15.4
5	12.1	14.3	18.0	21.8
7	15.2	18.0	22.7	27.4

equilibrium at 260,800 units of effort.[9] If costs in 1966 are 70 percent above the 1973 level (i.e., $413) the break-even shrimp price is $2.06 per pound.

When the U.S. effort expended in Mexican waters is diverted to U.S. waters (implying approximately 290,000 units of effort exerted in U.S. waters), the achievement of open access equilibrium without a reduction in effort would require a price of $2.17 per pound of shrimp landed. Recently the average ex-vessel shrimp price received has exceeded this amount so the adjustment process appears (for the moment) not to be a major concern. Also the three and one-half year phaseout will help buffer shrimpers from an abrupt adjustment. Only if shrimp prices should fall (as indeed they could) or production costs rise disproportionately to product price, would the adjustment costs be substantial.

CONCLUSIONS

Since the latter part of 1973 the shrimp industry has experienced considerable ex-vessel price variation and rapidly increasing cost. Commercial fishing for shrimp in the Gulf was slightly better than a marginal economic activity in 1973. Cost and return data for 1974 and 1975 indicate substantial economic losses in 1974 and the first half of 1975. Profits were again made in the latter part of 1975 due to an increase in ex-vessel price.

[9] Based on recent unpublished cost and returns data collected by the senior author, inflation since 1973 to present has been approximately 60 percent. Thus, the unit cost proportional to effort in 1975 would be $389 per unit.

Table 10. Estimated Equilibrium Price for Given Levels of Effort, Estimated Yield and Costs Proportional to Effort

Unit Cost Proportional to Effort (r)	Effort (1000)				
	260	270	280	290	300
$	- - - - - - - - - - $ - - - - - - - - - -				
243.0	1.25	1.27	1.29	1.31	1.33
291.6 (20%)	1.48	1.51	1.53	1.56	1.58
340.2 (40%)	1.72	1.74	1.77	1.80	1.83
388.8 (60%)	1.95	1.98	2.01	2.05	2.08
413.1 (70%)	2.06	2.10	2.13	2.17	2.21
437.4 (80%)	2.18	2.22	2.26	2.29	2.33
485.6 (100%)	2.41	2.46	2.50	2.54	2.58

*Percent increase over $243.

In 1976 product price increased to even higher levels and landings were normal as suggested by the yield equation. Thus it appears that the U.S. Gulf shrimp fleet benefited from positive rent in 1976. Further, this rent occurred during a period when virtually all of the catch was from U.S. waters. That is, the U.S. fleet was denied access to Mexican waters from August to December of 1976 while the phaseout treaty was being negotiated. (Historically, approximately 52 percent of landings from Mexican waters are harvested during this period.)

Given the present shrimp price and cost of production situation, it appears that adjustment to Mexico's 200-mile extended jurisdiction will not result in negative rents for the U.S. Gulf shrimp fleet. Additional evidence supporting this conclusion is the present backlog of orders for new vessels. Clearly firm exit will not be required to "reestablish equilibrium". However, it should be noted that past U.S. shrimping activity in Mexican waters has been by vessels landing their catch in Southern Texas and Florida ports. An adjustment process may be required in these localized areas as certain firms might find it economic to relocate their home base more centrally.

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