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Evaluation of Demersal Fishery Resources of the Gulf of California using Mexican Shrimp Trawlers*1

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The purpose of this study, Escama '92 project, was to determine resource and economic indicators for demersal fishes with reference to a commercial fishery in the Gulf of California, Mexico. The authors examined actual demersal resources before introducing bottom trawl fishery during the shrimp fishery off season. This study was carried out using a bottom trawl net adapted to the Mexican standard shrimp trawler ITMAR-I (GT=101.42 tons and HP=402 ps). A total of 504 hauls was conducted over a 5-month period between March 12 and August 13, 1992. And a total of 140.0 t was caught during the period. Predominant species found in the Gulf of California were: sea chub (sciaenidae), diamond stingray (dasyatidae), and torpedo ray (rhinobatidae), which comprised about three-fourths of the total catch. Sea chub comprised one third of the total catch. For the overall catch, catch per hour was 92.8 kg/h and catch per area was 370×10^{-6} kg/m^2. Total income and cost were calculated as $80,664 and $46,903, respectively. The net profit was $33,761, while the ratio of income-to-cost was 1.72. Net profit was calculated as: (1) per hour=22.4 $/h; (2) per area=$89 \times 10^{-6}$ \$/m^2; and (3) per catch=0.241 $/kg. Cost was mainly fuel oil and wages (67.2%), with fuel oil comprising about one half of the overall cost (48.4%). Among the four zones studied, zone 3 was a productive fishing ground in weight, while catch from zone 1 was the highest in value. Common sole and sea chub were predominant in the shallower zone 1 located near the Gulf entrance. In contrast, torpedo ray, diamond stingray and Cortez angelfish were abundant in the inner zone of the Gulf of California.

1 Introduction

Demersal fish exploration in Mexican waters has been carried out for the past 20 years. In 1977 the first trial was made in the Gulf of Mexico and the resources were confirmed by Okonski and Martini.[1)] Up to 1978 no systematic surveys had been made.[2)]

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A brief description of demersal fish studies of the Gulf of California follows. In 1979 the National Institute of Fisheries (Instituto Nacional de Pesca) carried out an exploratory study in the MEXICO/PNUD/FAO program.[3] The results obtained indicated a biomass producing 1,347,000 t/year with commercial species comprising about 60% of the catch.[4] Garcia[5] studied the population and the spatial distribution of the resource using the vessel COLUMBIA. Murillo and Flores[6] conducted the Escama '90 project survey using the vessels COLUMBIA and ITMAR-I. Preliminary results indicated that bottom trawls were applicable for commercial fishing. Arriaga et al.[7] studied the economics of the fishery from the viewpoint of an adaptation for the shrimp trawler. In 1978, the bottom trawl fishery was adapted to 12 shrimp trawlers increasing the number to 36 boats working in 1993.

One of the principal activities of the Mexican fishery is found in the shrimp production at a level of international commercial importance. According to FAO fishery statistics, the Mexican *Penaeus* shrimp production in the past five years (1988-1992) has fluctuated between about 62,000 to 75,000 t/year.

The shrimp fishing season on the Pacific coast covers four months from October to January. During the remaining eight months (February to September) this activity completely stops, causing an unemployment problem for personnel engaged in catch, processing, distribution and related industries.

Very few demersal resource studied have been made from the perspective of commercial fishing. The Escama '92 project's objective was to examine the feasibility of bottom trawling for fish with shrimp trawlers during the off-season. Using a standard shrimp trawler, ITMAR-I, in the Pacific coast, the project was carried out during five months between March 12 and August 13, 1992. A fishing base was established in Peñsco, Sonora State.

The purpose of this study, therefore, was to examine the results of fishery resources and their economic value for a commercial fishery in the Gulf of California. Technical operational conditions on fishing boats and bottom trawl nets were also studied.

2 Materials and Methods

2.1 Fishing area studied and fishing boat and gear used

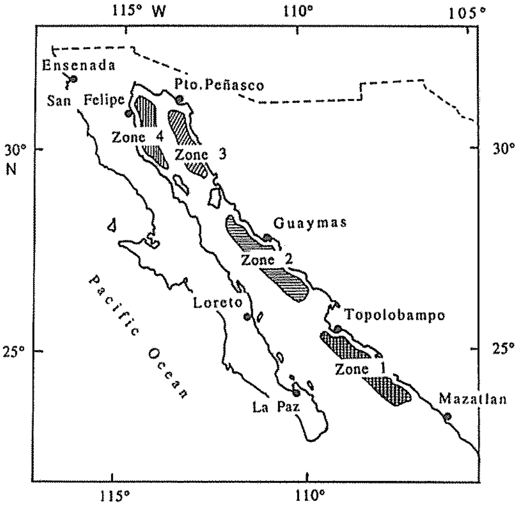

Fig. 1. Studied area in the Gulf of California, Mexico, divided into four zones. The fishing base was in Peñasco, Sonora State.

The four zones studied are shown in Fig. 1: (1) two zones in Sonora State (parallel of 30°N and 112°45' to 113°30' W) and (2) two zones in North Baja California State (parallel 30° to 31°N and 114° to 114°25'W).

The ITMAR-I was adopted as a Mexican standard shrimp trawler. Its characteristics are: gross tonnage (GT) = 101.42, engine power (HP) = 402 ps (Fig. 2). The trawl net used was: headrope length (Lh) = 31.8 m and groundrope length (Lg) = 40.7 m (Fig. 3a). The rigging of the net is shown in Fig. 3b. Net towing force (F) for the ITMAR-I was calculated using the method

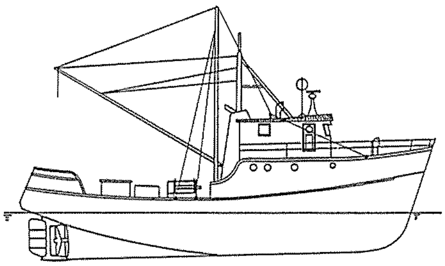

Fig. 2. General view of ITMAR-I, a standard shrimp trawler of the Pacific coast of Mexico.
length (L) = 20.42 m, breadth (B) = 6.10 m, depth (D) = 3.30 m, gross tonnage (GT) = 101.42 tons, engine model = Caterpillar 3408-B, engine power (HP) = 402 ps, and continuous revolution = 1800 rpm.

presented by Koyama:[8-10)]

$$F = HP \times Cp \times Ce \times Cs \times (75/V),$$

where HP is engine power, V trawling velocity, Cp coefficient of propulsion, Ce coefficient of effective engine power, and Cs coefficient of sea margin.

The net has been improved five times since 1976,[11)] adapting it to shrimp trawling and the fishing ground of the Gulf of California (Table 1).

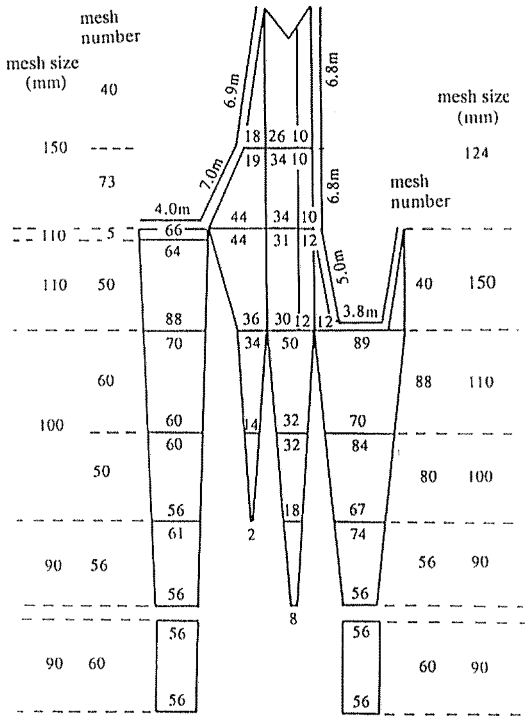

Fig. 3a. Characteristics of trawl net used.
headline length (Lh) = 31.8 m, groundrope length (Lg) = 40.7 m, mesh size = 150/110 and 124/180 mm in wings, 100/90 and 110/100/90 mm in body, and 90 mm in cod-end.

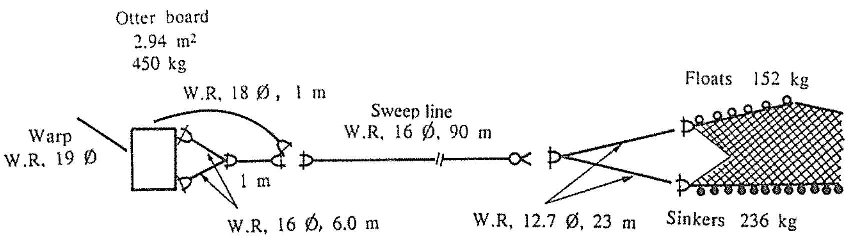

Fig. 3b. Scheme of trawl net riggings.
Otter board dimension = breadth 1.4 m x height 2.1 m each, area(A) = 2.94 m^2 each, and weight (W) = 450 kg each.

Table 1. Evolution of bottom trawl net by improvement from 1976 to present

Characterisitics	Units	Trawler "BID" 1976	Trawler "BI" 1980	Escama-original 1982	Escama-reformed 1982	New design 1990/1992
Length: head rope	m	25.9	32.0	33.0	34.0	31.8
Length: ground rope	m	36.0	51.6	12.0	39.7	40.7
Top net height	m	6.4	11.3	5.3	4.0	6.2
Float (unitary)	kg	4.1	3.3	—	—	4.8
Sinker (unitary)	kg	2.5	2.5	—	1.3	5.8
Perimeter: wing	m	35.6	39.0	45.4	37.4	26.6
Perimeter: body	m	5.1	6.0	7.7	5.0	11.5
Perimeter: cod-end	m	5.6	5.6	7.7	5.0	11.5
Length: body	m	25.8	24.6	15.7	30.5	10.2
Length: cod-end	m	6.4	10.0	15.0	18.0	5.4
Net area: wing	m^2	257.4	384.9	212.7	279.1	154.4
Net area: body	m^2	220.0	280.2	244.4	372.3	143.3
Net area: cod-end	m^2	98.0	34.1	98.8	65.0	23.4
Net area: total	m^2	575.4	699.2	556.0	716.3	321.3
Mesh length: wing	mm	107	150	144	200	150/124
Mesh length: body	mm	107	150/120/80/60	144/90	200/150/120/90/60	110/100/90
Mesh length: cod-end	mm	51	51	51	60	90

2.2 Fishing efforts, catch and economic data

Catch data were expressed as a fishing effort, a fishing hour and a swept area to determine resource indicators. Fishing hour (t, h) and trawling velocity (V, m/s) were measured for each operation. The swept area (S, m^2) was defined as:

$$S = V \times B \times t,$$

where B (m) is the breadth between boards. Wind conditions during the operations were below or equal to the Beaufort Scale 3.

The following data were collected for each operation: (1) catch weight (kg) and value (Mexican Peso Viejo), and (2) fishing boat operation costs. The beach wholesale price was used for converting catch weight into economic value for each species. The exchange rate set in this study was equivalent to US$1 = 3,100 Mexican Peso Viejo.

3 Results and Discussion

3.1 Technical indicators

Details of fishing hours, swept areas, and operating depths obtained are shown for each zone in Table 2. The study constituted a total of 504 hauls, 1,509 fishing hours, and 378×10^6 m^2 swept areas. For the whole haul, mean operating depth varied from 23.0 to 40.3 fathoms.

Table 2. Fishing effort and operating depth in each zone

Zone No.	No. of hauls	Fishing hours (h)	Swept area (m^2)	Operating depth (fathoms) Min.	Max.	Mean
1	65	195	49×10^6	8.5	45.5	23.0
2	115	345	86	13.0	51.0	40.3
3	95	285	71	22.7	46.0	26.0
4	229	684	171	20.8	43.4	32.0
Total	504	1509	378×10^6			

Tablle 3. Technicall indicators obtained

Indicators	Data obtained
Operating time	
paying out net	11.2 min.
hauling net	21.9 min.
fishing hour	3 hour
Breadth	
between otter boards	50 m
Engine revolution	
paying out net	1650 rpm
hauling net	820 rpm
trawling	1420 rpm

Indicators were obtained measuring each haul as a medium value. During hauling net reduced motor revolution a half of the continuous revolution.

Technical indicators obtained are listed in Table 3; V = 1.39 m/s, B = 50 m and t = 3 h (hours), with a swept area of S = $750x10^3$ m^2 for each haul.

The net towing force of ITMAR-I was calculated as F = 3,330 kg, using HP = 402 ps, V = 1.39 m/s (= 2.7 knots), Cp = 0.22 (at 300 rpm of fixed pitch propeller), Ce = 0.775, and Cs = 0.9 (at the Beaufort Scale 2 to 3) for the Bucki's method.[11] Table 4 shows the net towing force of ITMAR-I at different towing velocities.

Table 4. Net towing force of ITMAR-I in different towing velocities

Towing velocity (knot)	Towing velocity (m/s)	Net towing force (kg)
2.0	1.03	4490
2.5	1.29	3590
3.0	1.54	3000
3.5	1.80	2570

Engine power is 402 ps (62 ps). Parenthesis indicates the available horse power for the net towing of trawler.

In Fig. 4 the relationship between warp length and operating depth is shown. Warp length corresponds to about three times the operating depth.

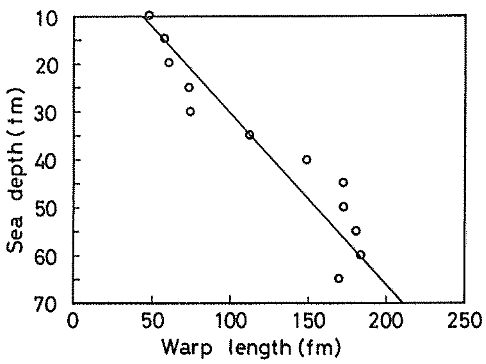

Fig. 4. Obtained relationship between warp length (fathom) and operating depth (fathom).

3.2 Fishery resource indicators

A total of 140.0 t was caught during the period studied (Table 5). Five main species comprised 94.2% of weight of the overall catch (Fig. 5). Sea chub was one third of the total catch. The three principal species, i.e., sea chub, diamond stingray and torpedo ray, represented about three-fourths of the overall catch (Fig. 5), indicating that sciaenidae, dasyatidae and rhinobatidae are predominant in the Gulf of California. Other species caught were: dog fish (*Mustelus californicus*), finescale triggerfish (*Balistes polyepis*), silver seatrout (*Synoscion nobilis*), green jack (*Caranx caballus*), Cortez chub (*Kyphosus elegans*), etc.

Table 5. Weights of main species caught

Species	Weight (tons)	Weight (kg/h)
Sea chubs (*Ophioscion scierus*)	46.7	31.0
Diamond stingray (*Dasyatis sp.*)	36.5	24.2
Torpedo ray (*Rhinobatos glaucostigma*)	25.1	16.6
Common sole (*Hypsopsotta guttulata*)	12.1	8.0
Cortez angelfish (*Pomacanthus zonipectus*)	11.5	7.6
Others	8.0	5.4
Total	140.0	

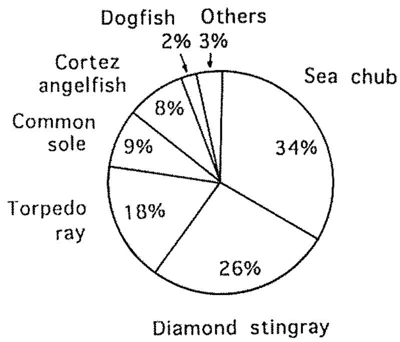

Fig. 5. Weight of species as a percentage of total catch.

For the overall catch, catch per hour = 92.8 kg/h and catch per area = $371x\ 10^{-6}$ kg/m^2 were indicated. Details of the whole catch in each zone are shown in Fig. 6. It is important to note that the catch per hour (kg/h, Fig. 6-(a)) was proportional to that per area (kg/m^2, Fig. 6-(b)). In Fig. 6, the catch of the zones 1 and 3 are 1.27 and 1.39 times more respectively, than that of the zone 4. The zone 3 showed a productive fishing ground within the four zones studied.

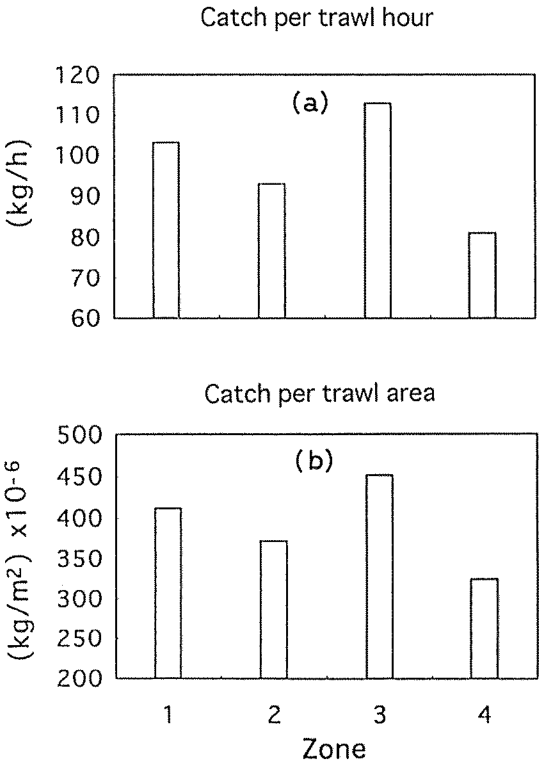

Fig. 6. Resource indicators of the average catch by zone. (a); kg/h and (b); kg/m·

The catch per hour for the main species caught is presented on the right side of Table 5; sea chub = 31.0 kg/h, diamond stingray = 24.2 kg/h, torpedo ray = 16.6 kg/h. The catch per hour for each species and zone is shown in Fig. 7. Dominant species in each zone were: in the zone 1; sea chub and common sole; in the zone 2; finescale triggerfish; in the zone 3; torpedo ray, diamond stingray, Cortez angelfish and silver seatrout; and in the zone 4; dogfish.

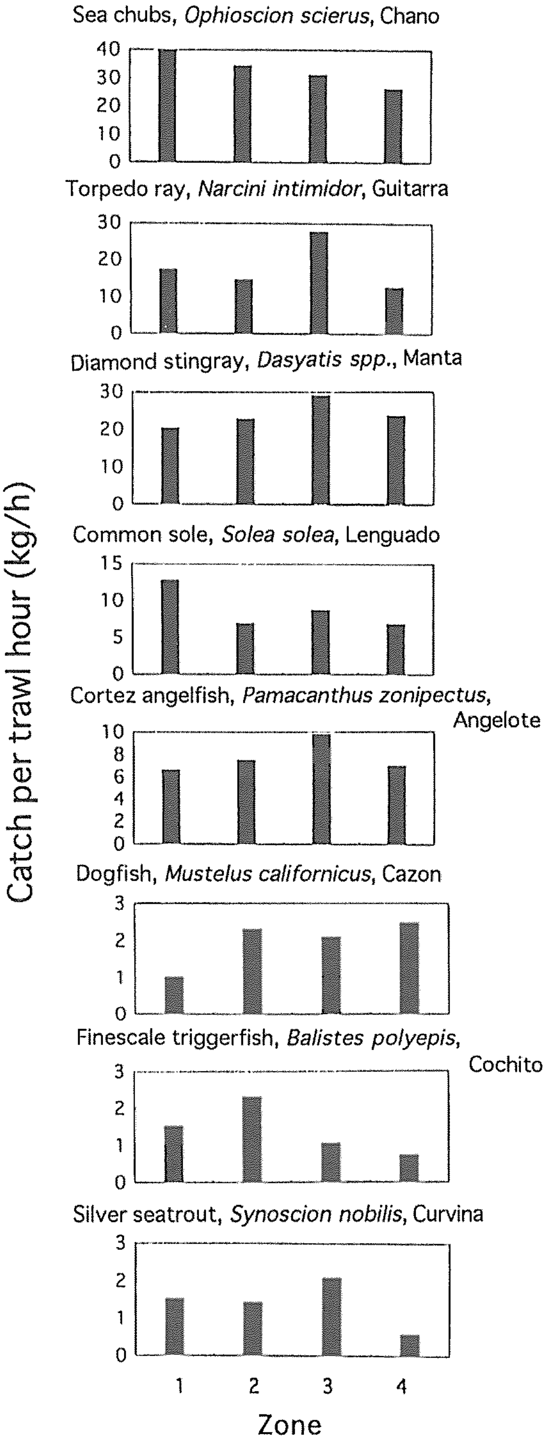

Fig. 7. Catch per hour (kg/h) for the overall catch of each species and zone.

The relationship between operating depth and catch per hour is shown in Fig. 8. The catch in the shallower zones 1 and 3 was high compared with that in the deeper zones 2 and 3. Common sole and sea chub were the predominant species in the shallower zone 1 located near the Pacific Ocean. In contrast, torpedo ray, diamond stingray, and Cortez angelfish were productive in the inner zone of the Gulf of California.

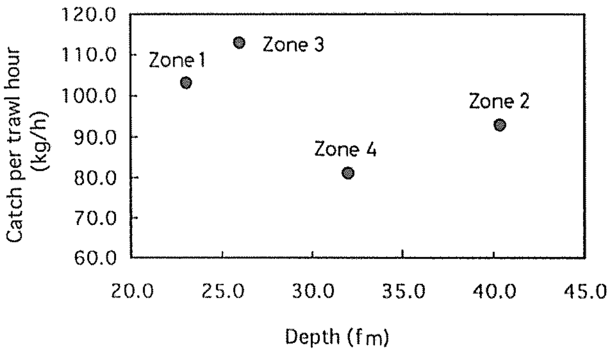

Fig. 8. Relationship between operating depth (fathom) and catch per fishing hour (kg/h).

3.3 Economic indicators

The beach wholesale price of six main species is shown in Table 6. Using this table, weight was transformed into value to determine the economic indicators. In Fig. 9, five principal species in Table 5 accounted for 94.5% of the total value. Arranged in order of value these were: common sole, sea chub, diamond stingray, torpedo ray, and Cortez angelfish. The top four species represented 85.3% of the overall value.

Economic indicators obtained for the overall operation were as follows: total income (A)= \$80,664 and total cost (B) = \$46,903. Therefore, total net profit (A-B) was calculated as \$33,761, and the ratio of income-to-cost was obtained as A/B=1.72

Income (A) can be obtained only from weight and/or value of fish caught. For the whole catch, income obtained was: (1) per hour =53.5 \$/h: (2) per area= $214\text{x}10^{-6}$ \$/m^2, and (3) per catch = 0.576 \$/kg. Details of species and zone of income per hour (\$/h) are shown in Fig. 10 and Tables 7 and 9. From Fig. 10, it can be observed that the income per hour covaried that with catch per hour (Fig. 7). The income in different units (\$/h, \$/m^2 and \$/kg) in each zone are shown in Fig. 11-(a). The income per catch (\$/kg) among zones represents the value of the commercial fishing ground. Then, as previously indicated, it can be determined that the zone 1 was the most productive fishing ground. This could possibly be attributed to the

Table 6. Beach wholesale price of main species caught

Species name	Values (\$/kg)
Common sole	1.774
Dog fish	0.806
Cortez angelfish	0.645
Torpedo ray	0.510
Diamond stingray	0.452
Sea chubs	0.387

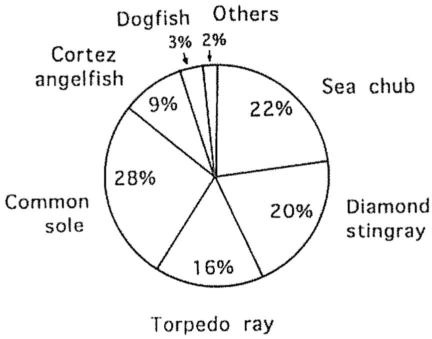

Fig. 9. Value of species as a percentage of total value.

Table 7. Income per hour of hauling by species

Species name	Values (\$/kg)
Common sole	14.2
Sea chub	12.0
Diamond stingray	10.9
Torpedo ray	8.5
Cortez angelfish	4.9
Others	2.0

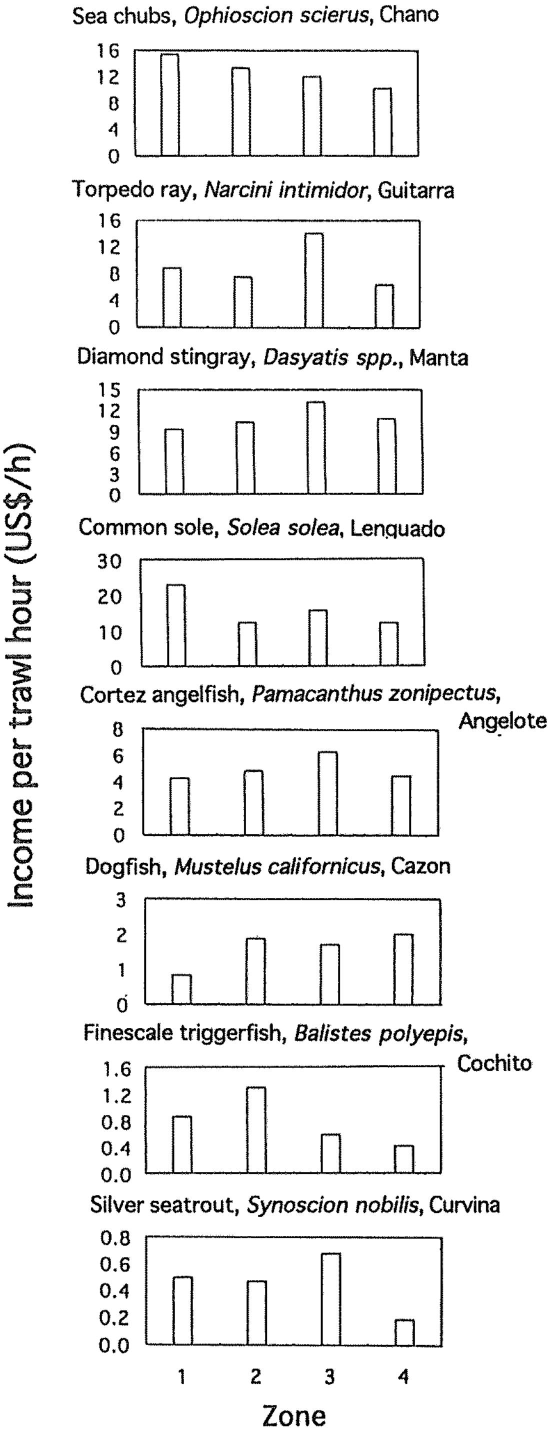

Fig. 10. Economic indicator income ($/h) for the overall catch of each species and zone.

direct oceanographic influences of the Pacific Ocean.

The costs (B) consist of fuel oil, wages, ice, food expense, lubrication oil and maintenance (Table 8). Costs for the overall haul were: (1) per hour = 31.1 $/h, (2) per area = $124\text{x}10^{-6}$ $\$/m^2$, and (3) per catch = 0.335 $/kg. Details of item and zone of the costs per hour ($/h) are shown in Fig. 12 and Tables 8 and 9. Fuel oil comprised about one half of the overall cost (48.4%). Fortunately from December 1st. 1993, the fuel oil price for fishing boats was reduced to half of what it had been, significantly reducing operational cost. The costs in different units ($/h, $\$/m^2$ and $/kg) in each zone are shown in Fig. 11-(b). The zone 1 presents the highest value for cost per catch ($/kg). This is due to the fact that the fishing base (Peñasco, Sonora State) was very distant from the zone 1.

Table 8. Cost per hour of hauling by items

Species name	Values ($/kg)
Fuel oil	15.0
Wages	5.8
Ice	3.3
Foods	3.1
Lubrication oil	1.9
Maintenance	1.5
Others	0.5

Table 9. Economical indicators by zone per hour

Zone	Income (A) ($/h)	Cost (B) ($/h)	Net profit (A-B) ($/h)	A/B
1	63.0	38.7	24.3	1.63
2	52.1	30.6	21.5	1.70
3	64.3	37.5	26.9	1.71
4	46.9	26.5	20.4	1.77

Net profit (A-B), for the whole haul, can be calculated as: (1) per hour = 22.4 $/h; (2) per area = $89\text{x}10^{-6}$ $\$/m^2$; and (3) per catch = 0.241 $/kg. The details of the net profits for each zone are shown in Fig. 11-(c). From this figure, the zone 1, in spite of being the most productive fishing ground, was also high in cost compared

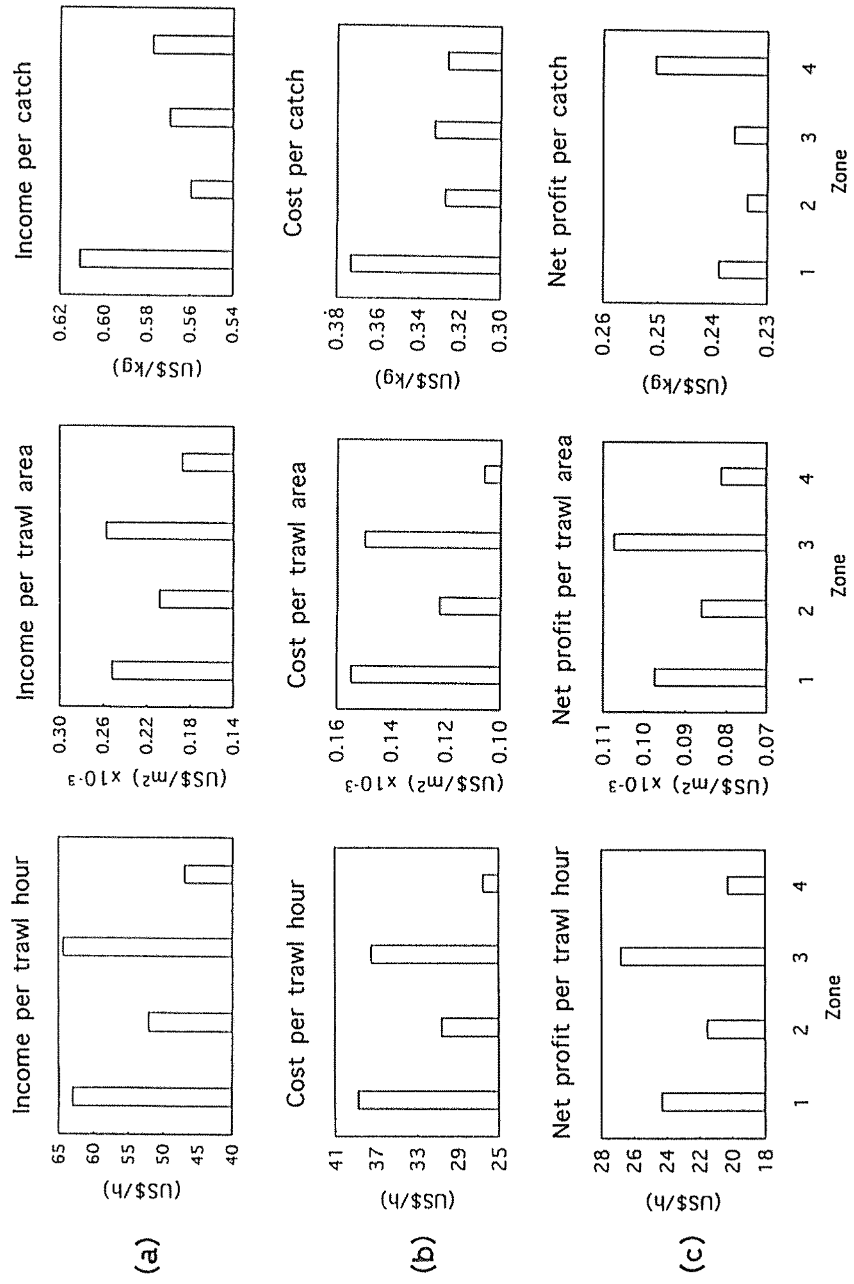

Fig. 11. Economic indicators ($/h, $/m^2 and $/kg) for the overall catch by each zone. (a) income; (b) costs; and (c) net profits.

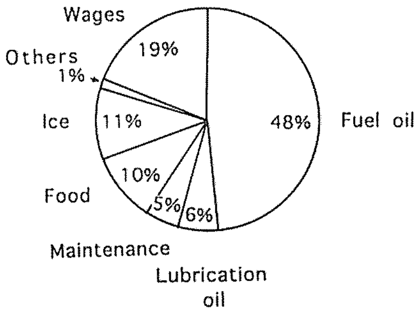

Fig. 12. Costs of items as a percentage of total cost.

with other zones. This led to a lower ratio of income-to-cost (A/B) = 1.63 compared with other zones. In contrast, although income was low in the zone 4, the value of the ratio A/B was the highest (1.77) among the zones. This was because the fishing ground was located very near Peñsco, Sonora State, the fishing base. Net profit and the ratio of income-to-cost obtained for each zone is shown in Table 9.

4 Conclusion

Shrimp fishery has been carried out mainly along the Pacific coast of Mexico. In 1991 about 78% of the operating 1,187 shrimp trawlers concentrated in Sonora and Sinaloa States. The number of shrimp trawlers in 1993 was reduced to about 25% compared to that in 1987. Although the decrease may continue in the future, work for only one third of the year is a problem in these two States. The other demersal resources in the Gulf of California were studied.

The possibility of a viable bottom trawl fishery for other resource can not be presented from the results of only the Escama '90 and '92 projects, due to the lack of more objective data; e.g., (1) biological studies to determine spawning seasons of targeted species; (2) national and/or international marketing studies for the main species; (3) cold plant capacity and network studies along the Pacific coast.

The results obtained should be integrally examined by a fishery company and by economists from the viewpoint of commercial fishery. The depreciation of fishing boats and fishing gear, and administration costs should also be considered.

Mexican Federal Organization must take into account the sustainable development and/or responsible fishery of the demeral resource of the Gulf of California determining: (1) permissible catch weight by species; (2) optimum number of fishing boats; and (3) permissible fishing period and season.

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メキシコ・エビトロール漁船を用いたカリフォルニア湾底魚資源評価

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本研究「Escama '92」の目的は，商業漁業的見地から，メキシコ領海カリフォルニア湾の底魚資源とその経済指標を評価することである。メキシコではエビ漁業の休漁期に，トロール漁業を導入する計画があるので，著者らは導入前に，底魚資源の現状把握を行った。本研究は，1992年３月12日から８月13日までの５箇月間に，ITMAR-１号を用いて504回操業して140トン漁獲した。カリフォルニア湾には，ニベ科，アカエイ科，サカタザメ科，の３種類が卓越しており，全漁獲量の約2/3を構成した。特に，ニベ科の魚類は全体の1/3を占めた。時間（h）および掃海面積（m²）当りの漁獲量（kg）は，それぞれ92.8（kg/h），370×10⁻⁶（kg/m²）となった。全収入と全経費は，それぞれ$80,664，$46,093，純利益は$33,761，収入/経費は1.72を得た。純利益は；22.4（$/h），89×10⁻⁶（$/m²），0.241（$/kg）となった。経費は，主として燃料費と給料（67.2%）で占められれ，なかでも，燃料費が全経費の約1/2（48.4%）を構成した。調査した４海域のうち，第３海域は生産量が高く、第１海域は生産額が高かった。ヒラメやニベ類は，調査した海域のなかで操業水深が深く，太平洋に開けた第１海域に卓越していた。反対に，エイ類やカスザメは，カリフォルニア湾の内湾（北部）に卓越していることが分かった。