Study of the Penaeid Shrimp Population in Relation to Petroleum Hydrocarbons in Campeche Bank

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RESUMEN

El acelerado progreso de la industria petrolera mexicana en las aguas del Banco de Campeche ha hecho más relevante la necesidad de evaluar los posibles efectos de dicho desarrollo sobre los recursos pesqueros que actualmente están sujetos a explotación comercial. Es un hecho bien conocido que los crustáceos que habitan este tipo de ambientes, son capaces de absorber rápidamente compuestos de hidrocarburos disueltos en el agua o contenidos en los alimentos con lo cual, se ven afectados adversamente. Como una respuesta a esta necesidad, en 1978 y 1980 se inició un programa conjunto con el doble propósito de observar las fluctuaciones en distribución, abundancia, composición de la captura de camarón y la cuantificación de hidrocarburos fósiles contenidos tanto en sedimentos como en las especies de peneidos de importancia comercial. El programa incluyó muestreos en julio de 1978 y marzo y septiembre de 1980 en una red de estaciones extendida sobre el Banco de Campeche. Se observaron variaciones en el patrón de distribución de las tres especies de importancia comercial; ésto se atribuyó a fluctuaciones estacionales. Los valores de captura por unidad de esfuerzo de las tres especies de mayor importancia comercial no mostraron cambios drásticos. En contraste, la fauna acompañante no presentó variaciones significantes en la biomasa, pero si en la composición.

El análisis de hidrocarburos en sedimentos y camarones confirman el predominio de las parafinas de números impares sobre las pares en un área en la cual la información era limitada. Este predominio sugiere que el origen de una gran porción de las parafinas proviene a través de organismos planctónicos o son introducidas por detritus de plantas terrestres. La concentración de hidrocarburos en los camarones y sedimentos del área estudiada se presentó en un rango de 13 a 56 ppm (peso seco). Estas cifras se encuentran dentro de los valores reportados para áreas costeras no contaminadas, mares marginales y algunas cuencas (<70 ppm).

INTRODUCTION

The continued expansion of the Mexican petroleum industry on the waters of Campeche Bank has stimulated renewed interest and concern for the study of the possible interactions, both inshore and offshore, that may result between the development of this industry and the fishing resources under exploitation in this productive area.

The fisheries in the Gulf of Mexico have presumably been subjected to chronic oil exposure and to spill accidents for an extended period of time, and apparently no significant decline has yet been detected in production levels. Indeed, this statement is more applicable to the fisheries exploited in the northern Gulf where the Texas and Louisiana continental shelves have served as excellent sources of petroleum production. Reportedly, up until 1970 there were in the Gulf of Mexico, an estimated number of 11,500 oil wells (IMCO et al., 1977), and presently in Campeche Bank there are at least 18 oil rigs in operation.

Korringa (1968) and Simpson (1968) have stated that neither floating oil in the

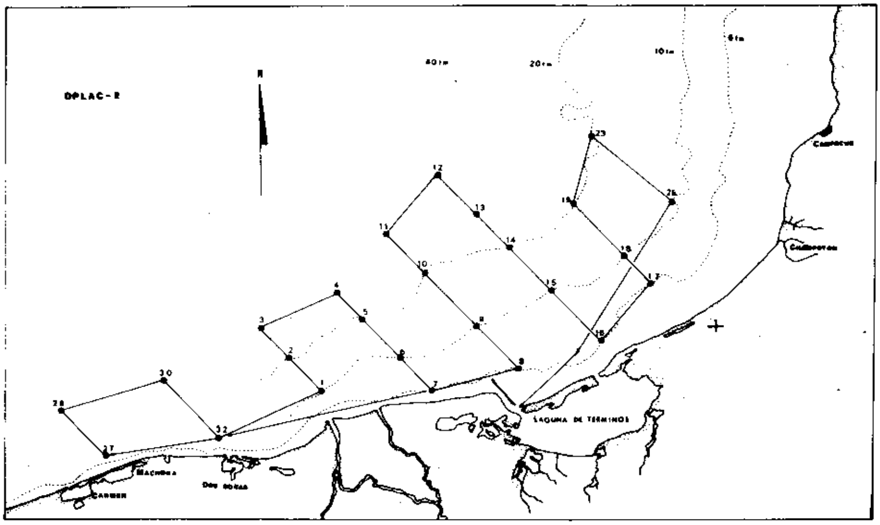


Figure 1. Location of stations of cruise OPLAC-2.

open ocean nor freshly spilled oil have a detrimental effect upon the fish and shellfish stocks from which they could not recuperate. However, these authors are quick to emphasize that the stocks restricted to certain spawning grounds are more vulnerable to oil exposure.

The area of Campeche Bank is an excellent habitat for a number of commercial species which have a marine-estuarine dependent life cycle. Approximately 90% of the commercial catch is made up of coastal and estuarine species which spawn offshore, migrate inshore as larvae and post-larvae and remain in protected areas, such as bays and coastal lagoons, until they attain juvenile sizes.

Undoubtedly the shrimp fishery practiced in Campeche Bank constitutes a good example that conforms closely to the above ecological pattern. This fishery is an industry in itself, which not only generates local and regional revenues, but is also responsible for 21% of the Mexican shrimp exports.

If we are to maintain the proper balance that must exist between the development of a new and aggresive industry, and a traditional one, such as the shrimp fishery, it is imperative first to assume an objective position far from being overprotective, second to draw experience from similar examples (Northern Gulf of Mexico, North Sea, California), and third to delineate deficiencies in our understanding of the impact upon fisheries caused by environmental disturbances.

From the chemical standpoint, detection of petroleum hydrocarbons in the components of a marine ecosystem requires evaluation of the relative quality of the hydrocarbons biosynthesized in the system. This allows distinguishing some of the biogenic hydrocarbon series occurring in marine organisms and sediments from those of fossil origin. This type of approach when applied to the Campeche Bank may certainly contribute to the assessment of a man-induced alteration on the marine environment. Similarly, measurements of organic carbon isotope ratios,

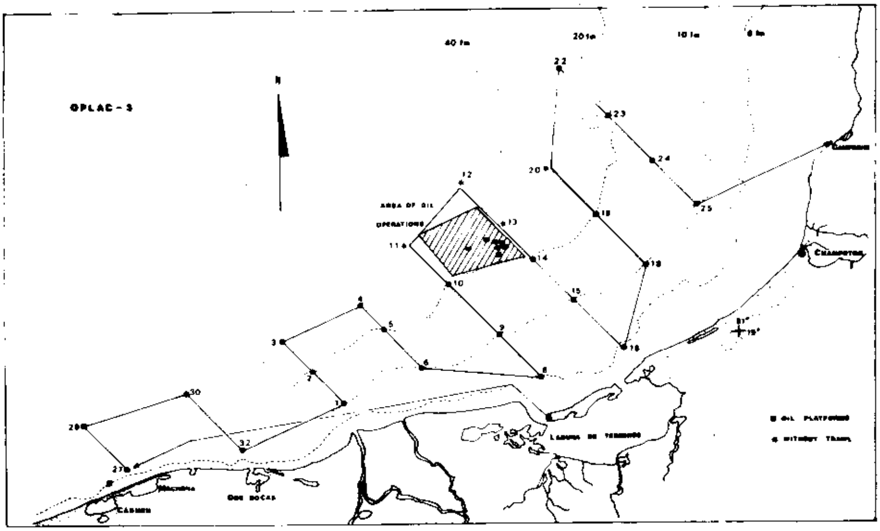


Figure 2. Location of stations of cruise OPLAC-3.

both in marine organisms and in recent sediments, are also a helpful tool in identifying either natural or anthropogenic sources of organic carbon in the marine ecosystem.

The study here presented, interdisciplinary in nature, is focused on establishing a basis of fisheries and chemical information that may serve two main purposes: one is to assess the degree of fluctuation experienced by the shrimp stocks in their spatial and biomass distribution, catch composition, class group structure and alterations in the recruitment of juveniles. Another is to establish the base line levels of petroleum hydrocarbons both in surface sediments and marine organisms, particularly penaeid shrimp.

METHODS

Materials for this study were obtained from two cruises, OPLAC-2 and OPLAC-3 (Oceanography of the Continental shelf of Campeche) made in the Campeche Bank in March and September of 1980, respectively. Both cruises were conducted on board a commercial vessel NUEVA LEY DE PESCA. Operations on board and processing of biological material were identical to those already described by Soto (1979). For comparative purposes the two cruises followed the same grid of stations adopted by this author in cruise OPLAC-1; two inshore-offshore transects were added to the west, positioned off the Machona and Carmen Lagoon and Dos Bocas Bar, intersecting the 10 and 40 fm isobaths (Figs. 1 and 2). Trawling operations were conducted day and night, obtaining a total of 41 hauls in both cruises. Normally all the catch was weighed according to groups (fish, shrimp, squid and invertebrates). Carapace length measurements were taken for all shrimp captured; minimum subsamples of approximately 200 shrimp were taken when the catch exceeded this number.

Surface sediments were collected with a van Veen grab sampler and

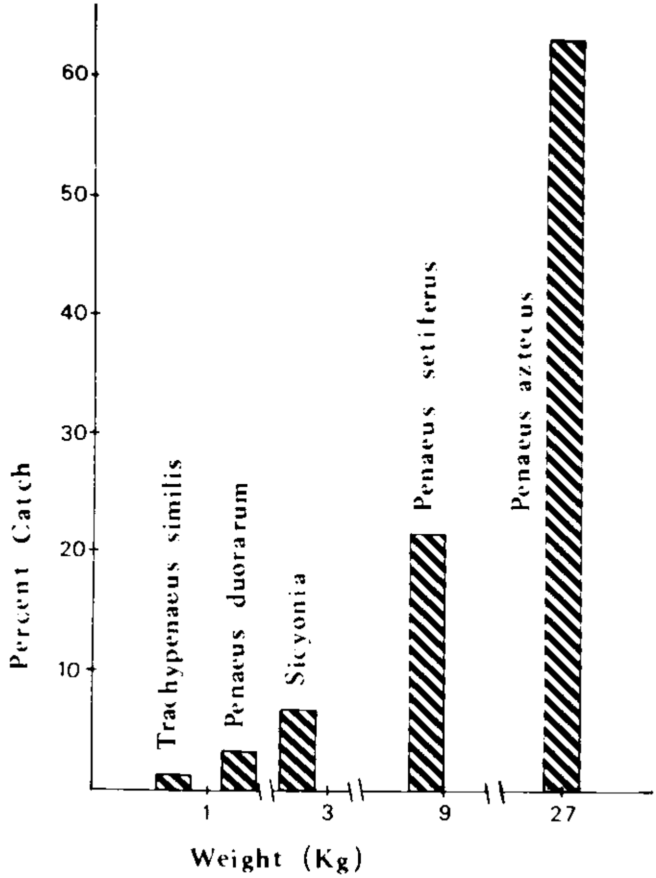


Figure 3. Species composition of penaeid shrimp by weight percentages during cruise OPLAC-2.

representative uncontaminated samples were placed in glass jars prepared as recommended by Clark and Blumer (1967), and immediately frozen.

For carbon isotope ratios the thawed sediments were treated following the procedure of Parker (1964); aliquot samples of sediments were combusted, using a modified LECO radio frequency furnace.

The $\delta^{13}C$ values of the resulting gases were determined with a dual collector isotope ratio mass spectrometer (Nucleide 6-60 RMS). The working standard used was a lubricating oil with a $\delta^{13}C$ of -27.32 ppt versus the Chicago PDB standard. The hydrocarbons were extracted from sediments and organisms with toluene: methanol (2:1 volume) following the procedure of Botello (1978). The concentrate was separated by column chromatography into a hexane and benzane eluate on a mixed bed alumina: silica gel column (3:1 volume).

The fractions were analyzed and quantified by gas chromatography using a Perkin Elmer Gas Chromatograph mod. 910 equipped with glass capillary system

(SP 1 000 or OV 101). The temperature was programmed from 80°C to 240°C increasing at 4°C per minute. Nitrogen flowing at 25 ml/min under 50 psi was the carrier gas.

CATCH ANALYSIS

In the two cruises conducted in Campeche Bank seven common penaeid shrimp were identified: *Penaeus aztecus, P. duorarum, P. setiferus, Sicyonia dorsalis, S. brevirostris, Trachypenaeus similis* and *Solenocera vioscai*. The sea bob, *Xiphopenaeus kroyeri,* was found occasionally in localities near Terminos Lagoon. Their calculated volumes in the total catch, showed interesting changes in composition between the two cruises. In cruise OPLAC-2, the brown shrimp represented 66%, the white shrimp 22%, the rock shrimp 7%, the pink shrimp 3%, and the synthetic only 2%. Occurrence of *S. vioscai* and *X. kroyeri* was merely incidental (Fig. 3). In the cruise made in the fall, OPLAC-3, the catch composition in terms of weight percentages was more evenly distributed among the three major commercial species: brown shrimp amounted to 38%, pink shrimp 22%, white shrimp 20%, *S. dorsalis* 12%, *T. similis* 5%, and *S. vioscai* 3% (Fig. 4).

The maximum shrimp catches recorded in these two surveys (10 and 12 kg/30 min) were taken in night trawls made in the offshore waters off Terminos Lagoon in 20 fm (Tables 1 and 2).

In OPLAC-2, the total shrimp catch was lower than expected due to malfunction of the nets in 5 attempted tows; consequently the average catch was reduced (Table 1). Cruise OPLAC-3 yielded a total shrimp catch of 54.3 kg/30 min (Table 1) which

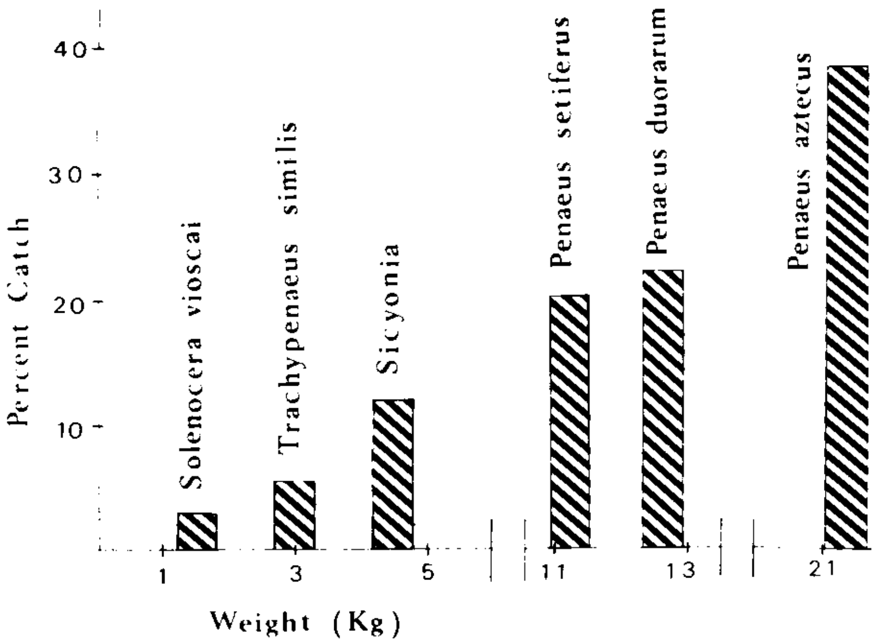


Figure 4. Species composition of penaeid shrimp by weight percentages during cruise OPLAC-3.

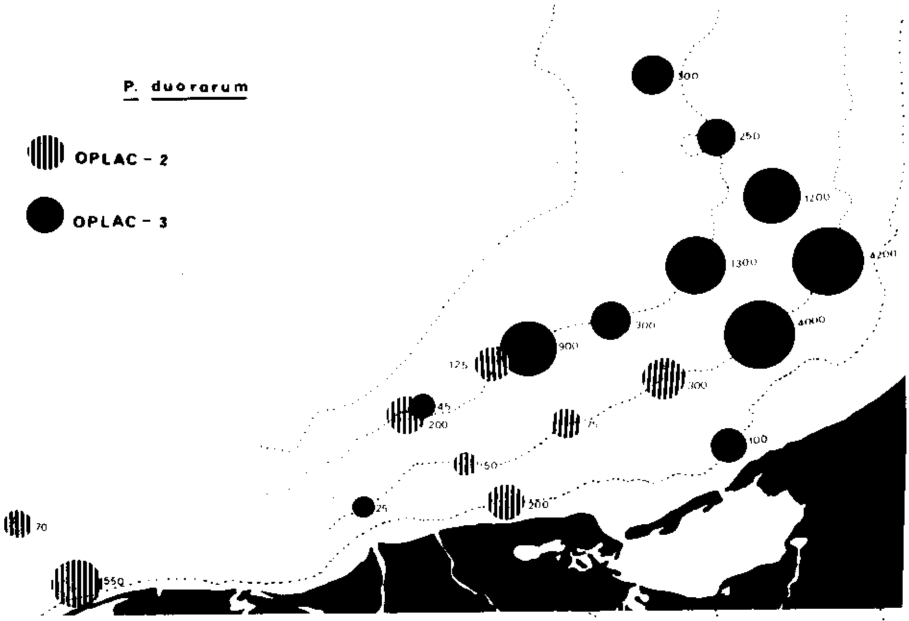
Table 1. Shrimp catch per unit of effort from OPLAC cruises

Cruise OPLAC-2			Cruise OPLAC-3		
Station No.		Catch (g)	Station No.		Catch (g)
1		210	1	N	4525
2		600	2	N	6000
3		2835	3	N	2250
4	N	7075	4	N	7180
5	N	9725*	5		1225
6	N	4510	6		320
7	N	3910	8		25
8		20	9		450
9		235	10	N	11850*
10		2075	14		3450
11		900	15		
14	N	275	16	N	170
15		475	18	N	4150
18		550	19		3550
19			22		450
23			23		450
27	N		24	N	3600
29	N	6880	25	N	4325
30	N	400	27		150
32		475	29		50
			30		50
			32		30
Total Shrimp Catch = 41.15 Kg			Total Shrimp Catch = 54.25 Kg		
Average Catch/30' = 2.06 Kg			Average Catch/30' = 2.58 Kg		

*Maximum Catch. N = Night Trawl Stations

did not differ much from that reported for the summer season (Soto, 1979). The most productive depth interval on Campeche Bank was from 20-30 fm (Table 2); however, during the early spring the center of abundance includes depths between 30 to 40 fm. In general terms, a reduced number of trawl stations (6) had catches of commercial size (11 kg/h); such localities were positioned over the area of riverine influence just off Carmen and Machona Lagoons on one end, and Terminos Lagoon on the other.

Pink Shrimp. It displays a wide areal distribution in Campeche Bank. During the spring this penaeid shrimp is essentially confined to the area off Terminos Lagoon, though it also occurred on the western end of the area of study, off Machona Lagoon (Fig. 5). In contrast, in the fall season its pattern tended to be concentrated towards the Yucatan Peninsula. Its bathymetric range extended from 6 to 44 fm, but it was more frequently captured between 10 and 20 fm (Fig. 11). In cruise OPLAC-2 from 8 trawl stations just 54 individuals were obtained, 1.4 kg of the total catch. CPUE values were negligible except for one obtained at nightime in the nutrient enriched area off Machona Lagoon. Cruise OPLAC-3 yielded 735 pink



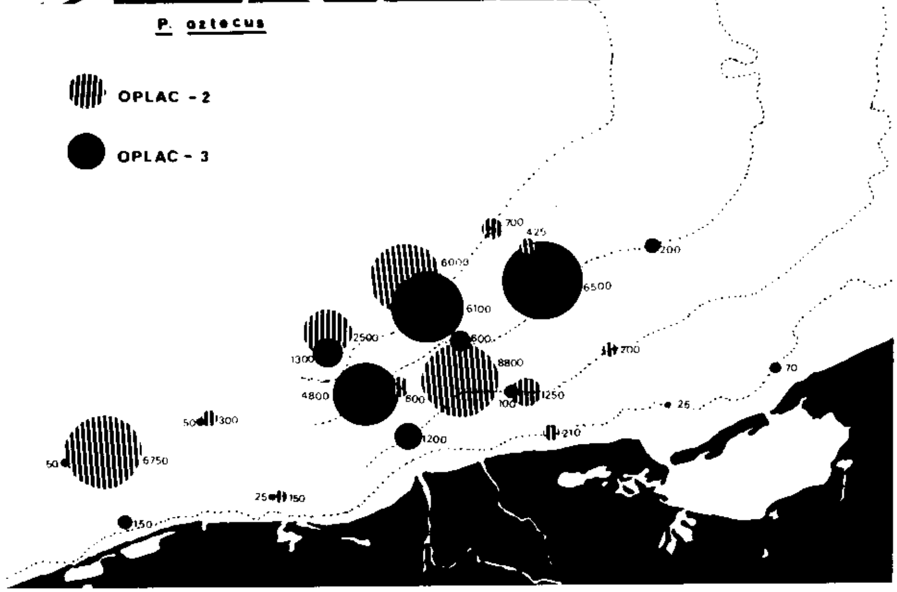


Figure 5. (Upper) Distribution and catch rate of *Penaeus duorarum*.

Figure 6. (Lower) Distribution and catch rate of *Penaeus aztecus*.

Table 2. Total average catch (g/h/Z)

Cruise	Depth Interval (fm)			
	<9.9	10 - 19.9	20 - 29.9	30 - 40
OPLAC-1	1 644	2 426	10 094	3 210
OPLAC-2	2 937	2 392	6 338	7 076
OPLAC-3	150	4 459	8 880	4 765

shrimp taken in 10 trawls, which amounted to 13 kg of the total catch. Maximum CPUE's were recorded in the inshore waters off Champoton.

According to size categories, the pink shrimp ranked second and third in the above two cruises respectively (Figs. 9 and 10). Carapace lengths ranged from 13 to 48 mm with mean values of 32 and 27 mm in both cruises. The calculated sex ratio favored the females (1.7:1) in the spring, and it was almost equal (1.2:1) in the fall.

In spite of the reduced number of individuals taken during the spring, the analysis of carapace length-frequency indicated a certain similarity between both sexes, although males were predominant in the categories between 22 to 40 mm; the largest individuals (>40 mm) were exclusively females. In the fall a larger number of pink shrimp were caught, and both sexes appeared distributed over the entire size range; however, males were best represented by subadult shrimp with a single modal value (28 mm), whereas the females displayed a bimodal distribution (22-34 mm) probably due to a mixed population of subadult and adult shrimp.

In cruise OPLAC-2, the size distributional trend of *P. duorarum* clearly increased towards the offshore region; however, there are areas in the northeast of Terminos Lagoon which apparently contradict such a trend. Regardless of the distance from the coast, these areas usually produced juvenile sizes that could represent recruits to the fishing stock.

Interestingly enough in OPLAC-3 no progression of size categories was detected in relation to distance from the coast. This can be explained by the predominance of subadult individuals (90%) which seem evenly distributed over the area studied. Only at the site locations near Arcas Reef were larger sizes recorded.

Brown Shrimp. Its areal distribution mainly encompassed the offshore portion of the area studied. In OPLAC-2 the pattern is basically oriented along the 40 fm line, and includes parts of a sector southwest of the restricted zone of oil operation (Fig. 6). In OPLAC-3 brown shrimp were caught on the western and central sector of Campeche Bank at the 20 fm isobath. Bathymetric range of this species extended from 6 to 44 fm but its mean depth was usually between 22 and 27 fm (Fig. 11).

During the spring cruise, 1,132 individuals weighing 27 kg were obtained from 9 trawl station mostly made at night. The depth interval between 20 and 40 fm proved to be quite productive for this species (Fig. 6), recording an average catch of 7.3 kg/h. In contrast, in the fall the catch of brown shrimp was reduced to 21 kg (approximately 764 individuals) taken in 15 hauls made both during the day and night. Largest CPUE's were obtained at two offshore locations west of the restricted zone, at 20 and 40 fm.

In terms of size, the brown shrimp occupied the second category in both cruises, with a carapace length range of 16 to 56 mm (Figs. 9 and 10) and its respective mean values had a slight difference (32-32.9 m). Sex ratio did not show any difference (1:1); however, the size class composition was different during the spring and fall. In the first case the males exhibited two modal values at 27 and 31 mm with roughly more than 50% of the population concentrated between 22 to 36 mm. The females presented modal values with a wider spread (27 to 35 mm). In the second case, males were mainly represented by subadult stages, and in less proportion (20%) by adult individuals; modal values for each category were 29 and 39 mm respectively. Females seemed better represented by adult sizes (>32 mm), displaying a single modal value (37 mm).

As in the case of *P. duorarum*, the size distribution trend of brown shrimp showed also an offshore progression, attaining maximum carapace length averages (35.4 for males and 48 for females) along the 40 fm isobath. This supports the idea of a displacement of young shrimp moving from inshore waters to greater depths as they grow.

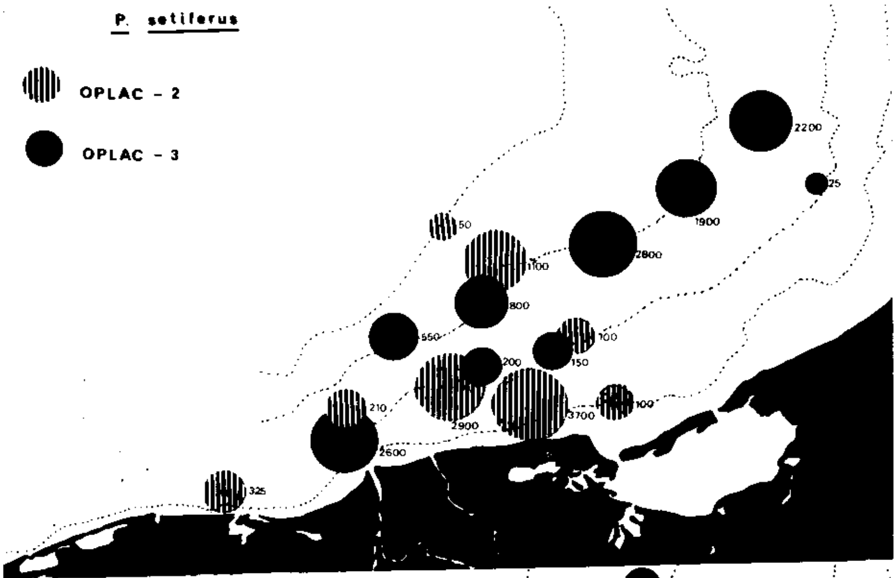
White Shrimp. In the spring this species was roughly distributed over the central and western portions of the area of study, particularly along the 10 fm isobath; during the fall, it was found essentially concentrated on the central sector (Fig. 7), where it normally occurs with *P. duorarum* and *P. aztecus*. Average depth for *P. setiferus* varies from 14 to 16 fm (Fig. 11).

Captures of white shrimp during the spring were mostly made in daylight at depths ranging from 7 to 42 fm. In 8 successful tows, 209 specimens were caught representing only 8.5 kg of the total catch. In the fall 9 tows yielded 298 white shrimp with a weight of 11.3 kg. In OPLAC-2, the only significant CPUE values were recorded at night in the inshore waters close to the San Pedro River's mouth, an area recognized earlier (Machado et al., 1979) for the high content of organic matter in the sediments. In OPLAC-3, CPUE values were distributed also in accordance with the areas subjected to riverine influence, such as the localities off Terminos Lagoon (Fig. 7).

P. setiferus continued occupying the first category in size among the penaeid shrimp of Campeche Bank (Figs. 9 and 10). The carapace length ranged from 22 to 55 mm with mean values of 34.5 and 33.7 in the spring and fall, respectively.

No sex ratio differences were observed in this species. Size class composition in both cruises had only minor discrepancies. In OPLAC-2, the range size of males tended to be concentrated between 30 to 38 mm, while females displayed a wider spread in carapace length frequencies; however, they differed slightly in their respective modal values (2 mm). In OPLAC-3, males and females displayed a similar size class composition, both seemed concentrated (99%) between 30 and 42 mm; modal value difference between the two sexes was 4 mm. Nearly 80% of white shrimp captured constituted subadult forms that appear distributed in the offshore waters of Campeche Bank.

Trachypenaeus similis. This is a fairly common penaeid shrimp which was captured in the tows made at nightime, but it never occurred in large numbers. Presumably this species should be more abundant within the boundaries of the middle and outer shelf. The spatial distribution of *T. similis* in Campeche Bank includes both the inshore and offshore waters of the area subjected to the river run-



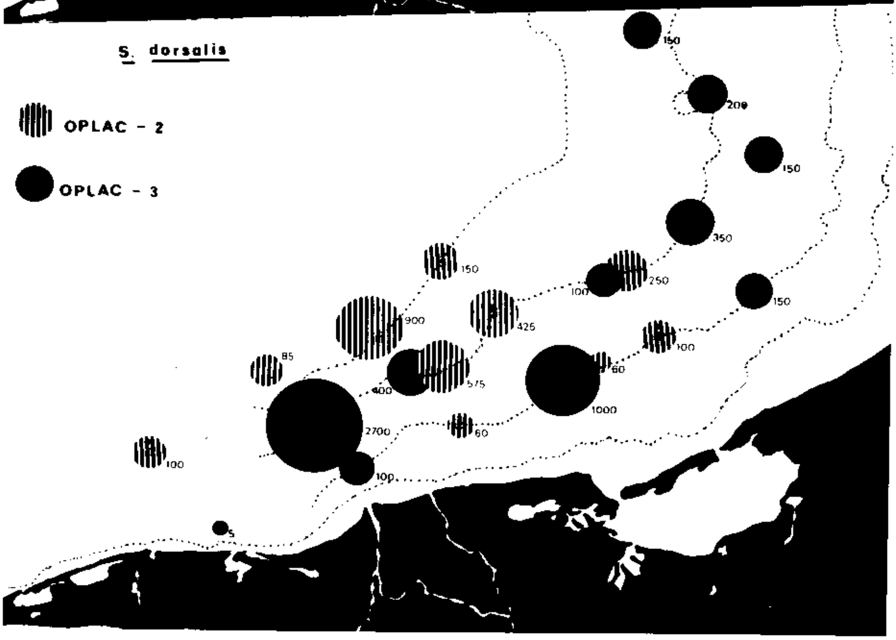
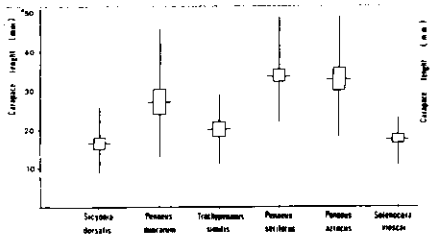


Figure 7. (Upper) Distribution and catch rate of *Penaeus setiferus*.

Figure 8. (Lower) Distribution and catch rate of *Sicyonia dorsalis*.



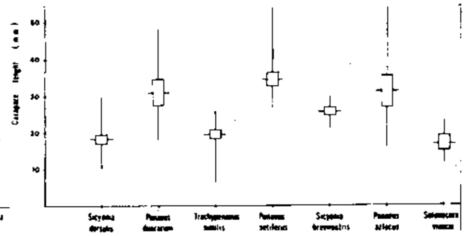


Figure 9. (Left) Mean, standard deviation, and range of penaeid shrimp during cruise OPLAC-2.

Figure 10. (Right) Mean, standard deviation, and range of penaeid shrimp during cruise OPLAC-3.

off adjacent to Terminos Lagoon. During the fall this penaeid had a bathymetric distribution basically concentrated along the 20 fm line. The cruise made in the spring yielded only 67 specimens with a reported weight of 1.8 kg from 7 trawl stations. This situation changed in the fall, when from 8 successful tows 477 shrimp were caught weighing 3 kg. In all site locations a strong sex segregation in favor of the females was noticed. Calculated sex ratios fluctuated from 17:1 to 13:1.

The size range of *T. similis* (Figs. 9 and 10) fell far below those of 22 to 47.5 mm previously recorded in this area (Soto, 1979). In the two cruises conducted in 1980 the carapace length of this species ranged from 6 to 29 mm with very similar mean values of 19.5 and 20.5 mm. The size distributional analysis over the area of study seemed to indicate that the locations close to shore contribute smaller sizes to the population sampled.

Rock Shrimp. Among the rock shrimp known to inhabit the Campeche Bank, *Sicyonia dorsalis* prevails over its much larger and more robust congener *S. brevirostris*. These were captured together (Soto, 1979), at several stations at which the calculated ratio between them was 9:1.

S. dorsalis displayed a distributional pattern over much of the area sampled from 9 to 40 fm, especially in the sector located just off Terminos Lagoon (Fig. 8). This penaeid shrimp appeared both during the day and night catches although nearly 80% were captured at night. The number of rock shrimp increased from 252 to 1 397 in the cruises made in spring and fall. Total biomass recorded in this study for *S. dorsalis* and *S. brevirostris* amounted to almost 7 kg in both seasons. CPUE values fluctuated from 20 to 2,850 g, but they can be considered as poor if one compares them with earlier records (Soto, 1979).

In the mixed shrimp catches obtained on Campeche Bank, *S. dorsalis* is usually the smallest penaeid (Figs. 9 and 10). Measurements of carapace length ranged from 9 to 30 mm with average mean values of 18 and 16.7 mm for both seasons. The calculated sex ratio for this population was 2:1 in favor of the females. Normally the two sexes present similar size composition even though occasionally, the females are larger. Males and females tend to have similar modal values (19-21 mm).

S. dorsalis showed a size progression in relation to depth; larger individuals were found at greater depths.

As far as the second species of rock shrimp is concerned, *S. brevirostris* occurred sporadically throughout both surveys. Its areal distribution included the area west

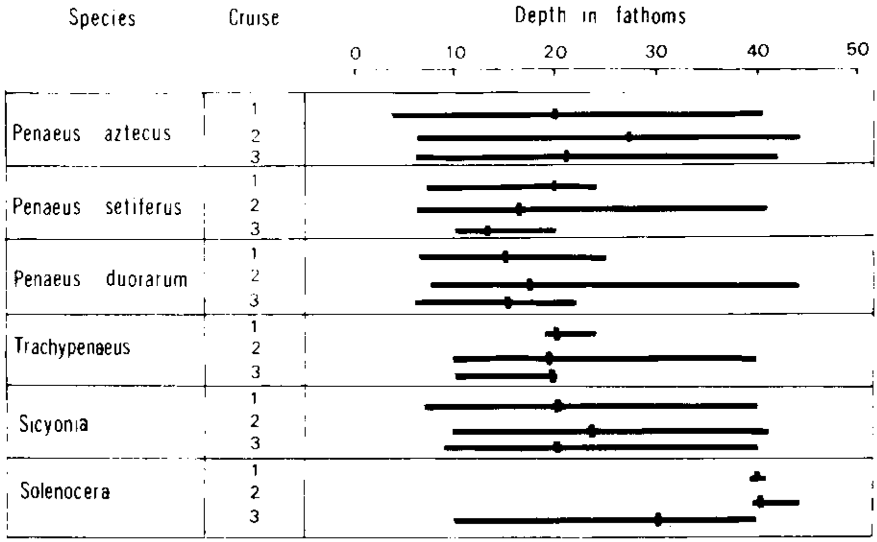


Figure 11. Bathymetric range and mean depth of penaeid shrimp during cruises OPLAC-1, 2 and 3.

of the restricted zone of oil operations, just off Terminos Lagoon. No more than 7 individuals were taken per trawl made in the offshore waters of Campeche Bank.

In the early spring, the calculated mean of carapace length (26 mm) coincided with that previously reported for this species (Soto, 1979). In the fall the mean value experienced a reduction (21 mm) probably due to the predominance of immature individuals.

Personal observations by the first author of the landings obtained by shrimp trawlers operating on the shelf of Yucatan revealed higher CPUE than those recorded in Campeche Bank; a conservative estimate made on the spot roughly indicated a catch rate of 9 kg/h. It should be pointed out here that this is an incidental fishery.

Solenocera vioscai. This deep water penaeid contributes little in terms of biomass to the total shrimp catch. It usually appears in hauls made at night along the 20 and 40 fm isobaths at the nutrient enriched area west of Terminos Lagoon. Its small size (Figs. 9 and 10) makes it unattractive to the fishermen, though it is frozen with other small shrimp like *Trachypenaeus similis* for local consumption. Only during OPLAC-3 were a significant number of individuals caught (226). Their mean carapace length was 17.6 mm. They were predominantly females (10:1).

By-catch Analysis. The by-catch taken from shrimp trawling on Campeche Bank showed reasonable fluctuations of general composition and no major changes in the total biomass. In order of their importance, the four major faunal components comprising the total biomass for OPLAC cruises two and three respectively were in kg: fishes, 852 and 741; shrimps, 41.2 and 54.3; crabs (Callinectids and Portunids) 14 and 95.4; macroinvertebrates (squids, decapod crustaceans, echinoderms and stomatopods) 13 and 31. The total biomasses for these respective cruises were 919.2 kg and 921.7 kg and the average catches were 45 kg and 41 kg per 30-foot tow. In relation to total biomass the calculated ratios among the above components in OPLAC-2 and OPLAC-3 were 60:3:1:1 and 23:2:3:1, respectively.

The first faunal component consisted of a diversified number of species, though only few are conspicuous in total fish biomass. Among such are: *Priacanthus arenatus, Harengula pensacolae, Ophistonema* sp, *Sardinella* sp, *Synodus foetens, Diapterus* sp, *Chloroscombrus crysurus, Vomer setapinnis, Selene vomer, Selar crumenophthalmus, Caranx latus, Prionotus* sp, *Trichiurus lepturus, Lutjanus campechanus, Spheroides* sp, *Lagocephalus* sp, *Bagre marinus* and *Sphyraena barracuda.* Most of these species have previously been reported by FAO (1970) and more recently by Yáñez et al. (1979) as important due to their biomass.

Usually the trawls made in daytime and in inshore waters yielded the highest catches of fish. The spatial distribution seems to shift from the deltaic plains west of Terminos Lagoon in the spring, to the carbonate province off Champoton during the fall season. In both cases a predominance of small size classes of fish was observed.

CHEMICAL ANALYSIS

The distribution of $\delta^{13}C$ values and the concentration of hydrocarbons for sediments and organisms for the OPLAC-1 cruise in July 1978 are shown in Table 3.

The range of $\delta^{13}C$ values found in the sediments studied varied from -19.8 ppt to - 23.2 ppt. These values are very similar to those reported by Gearing, et al. (1977) for nearshore sediments of the northern and western Gulf of Mexico with $\delta^{13}C$ values ranging from δ -21 to -24 ppt.

These values for carbon isotope ratios show three different sedimentary organic carbon environments: one zone with values $\delta^{13}C$ = -22.4 to -23.2 ppt which is influenced by runoff of Usumacinta and Grijalva rivers, another zone typically marine with $\delta^{13}C$ values between -20.5 to -21.9 ppt, and the last zone with lower values due to the influence of carbonates in Campeche Bank area ($\delta^{13}C$ = -19.8 ppt).

According to Sackett (1964), the isotopic composition of the Gulf coast sediments is usually fairly constant and any drift from the normal level could indicate a major change in the source and isotopic composition of the organic carbon contributing to the sediments.

The more negative $\delta^{13}C$ values of the organic matter in the sediments of the studied area before the oil activities were initiated ($\delta^{13}C$ = -23.2 ppt) can be attributed to organic matter with lighter carbon isotope ratios originating from terrestrial, industrial and urban sources.

In cruise OPLAC-2 (March, 1980) the $\delta^{13}C$ values were constant and showed the same pattern of distribution (Table 4), with the exception of the values recorded in the sampling sites Nos. 12 and 13 ($\delta^{13}C$ = -27.2; -26.6 ppt). This is a clear indication that hydrocarbons originating from the oil activities have been settling in the column sediment changing considerably the prerecorded $\delta^{13}C$ values (Botello and Castro 1980).

The analysis of hydrocarbons in sediments and organisms (Tables 4 and 6) of Campeche Bank confirmed the predominance of odd-carbon number n-paraffins in an area for which no analysis was available. The odd-carbon predominance was well within the range reported by Cooper and Bray (1963). The predominance of odd-carbon number paraffins in recent sediments from the continental shelf adjacent to Terminos Lagoon suggests that the source of a large fraction of the

Table 3

Summary of the $\delta^{13}C$ values and total hydrocarbons concentration in marine recent sediments from the Bank of Campeche, México

Cruise OPLAC - 1, July, 1978

Station No.	Location: Latitude	Location: Longitude	$\delta^{13}C$ ‰	Total Hydrocarbons (ppm dry wt)
1	18°42'	92°46'	-23.0	56
2	18°50'	92°54'	-23.2	48
3	18°55'	92°58'	-22.4	51
4	19°10'	92°34'	-21.9	46
5	19°04'	92°28'	-21.9	43
6	18°50'	92°14'	-21.1	42
7	18°44'	92°08'	-21.4	51
8	18°50'	91°38'	-21.1	37
9	18°59'	91°57'	-23.0	48
10	19°12'	92°14'	-21.2	35
11	19°26'	91°45'	-20.5	23
12	19°12'	91°32'	-19.8	26
13	19°05'	91°26'	-21.9	25
14	19°23'	91°10'	-19.9	18
15	19°29'	91°15'	-19.8	21
16	19°45'	91°32'	-21.7	15
17	20°11'	91°47'	-21.0	12
18	19°57'	91°33'	-20.9	16
19	19°47'	91°23'	-20.7	14
20	19°38'	91°14'	-20.3	16
21	19°28'	91°04'	-21.2	18

Table 4

Summary of the $\delta^{13}C$ values and total hydrocarbons concentration in marine recent sediments from the Bank of Campeche, México

Cruise OPLAC-2, March, 1980

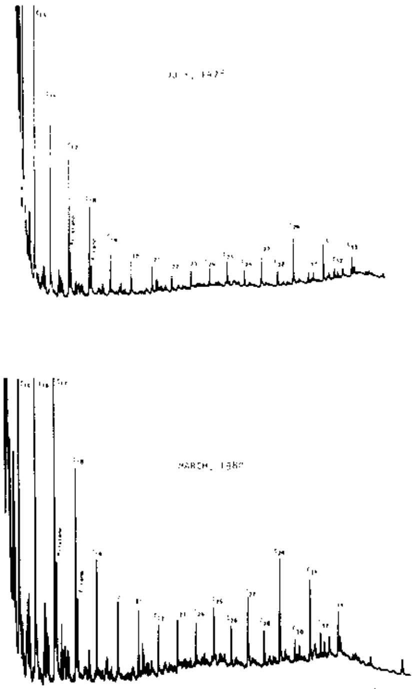
Station No.	Location: Latitude	Location: Longitude	$\delta^{13}C$ ‰	Total Hydrocarbons (ppm dry wt)
01	18°43'30''	92°44'	-22.7	42
02	18°42'	92°53'	-23.3	92
03	19°00'	93°00'	-22.1	73
04	19°09'	92°39'	-19.7	76
05	19°02'30''	92°34'	-19.9	55
06	18°52'	92°23'	-21.0	68
07	18°44'	92°15'	-21.2	27
08	18°49'	91°52'	-20.2	51
09	19°00'30''	92°03'	-19.5	57
10	19°14'	92°17'	-20.3	75
11	19°24'	92°27'	-20.9	81
12	19°30'	92°14'	-27.0	715
13	19°23'	92°03'	-26.6	117
14	19°21'	91°55'	-19.7	44
15	19°09'	91°43'	-19.5	43
16	18°56'	91°30'	-19.3	9
17	19°11'	91°17'	-18.2	51
18	19°19'	91°24'	-19.0	47
19	19°32'	91°38'	-19.9	40
23	19°49'	91°33'	-10.5	52
25	19°32'	91°12'	-20.2	27
27	18°26'30''	93°42'	-20.2	32
29	18°38'30''	93°53'	-21.4	35
30	18°47'	93°26'	-21.8	52
32	18°31'	93°11'	-22.2	35

Table 5

Summary of the $\delta^{13}C$ values and total hydrocarbons concentration in marine recent sediments from the Bank of Campeche, México

Cruise OPLAC-3, September, 1980

Station	Latitude	Longitude	$\delta^{13}C$ ‰	Total Hydrocarbons (ppm dry wt)
01	18°43'	92°44'		16
02	18°42'	92°53'		11
04	19°09'	92°39'		17
06	18°57'	92°23'		13
08	18°49'	91°52'	IN PROCESS	6
09	19°00'30''	92°03'		17
10	19°14'	92°17'		11
11	19°24'	92°27'		28
12	19°30'	92°14'		516
13	19°23'	92°03'		71
14	19°21'	91°55'		16
15	19°09'	91°43'		26
Ixtoc I	-	-		70
Azteca Y	-	-		133
Akal C	-	-		231
18	19°19'	91°24'		71
19	19°32'	91°38'		17
20	19°38'	91°14'		13
22	20°10'30''	91°47'		16
23	19°49'	91°33'		7
24	19°45'	91°45'		3
25	19°32'	91°12'		8
26	19°23'30''	91°00'		15
27	18°26'30''	93°42'		32
29	18°38'30''	93°53'		117
30	18°47'	93°26'		56
31	18°31'	93°11'		71



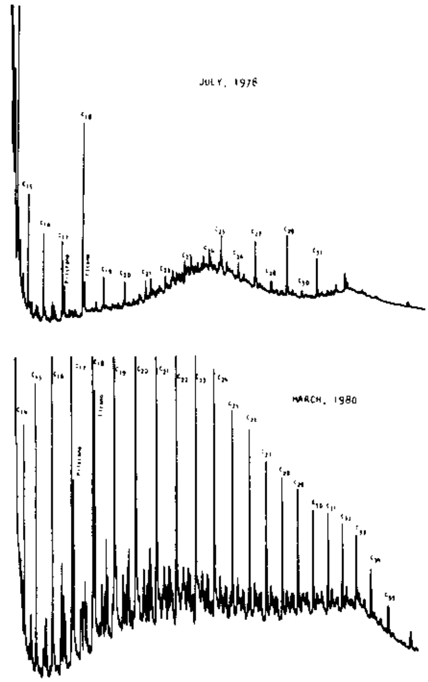


Figure 12. (Left) Distribution of n-paraffins in sediments from the sampling site No. 1 during cruises OPLAC-1 and OPLAC-2.

Figure 13. (Right) Distribution of n-paraffins in sediments from the sampling site No. 12 during cruises OPLAC-1 and OPLAC-2.

paraffins may be through organisms indigenous to the sediments or introduced by terrestrial plant detritus.

In cruise OPLAC-1 (July 1978) the concentration of n-paraffins in the surface sediments ranged from 13 to 56 ppm dry weight. These figures are within the values recorded (<70 ppm) for unpolluted coastal areas and deep marginal seas and basins (National Academy of Sciences, 1975).

Figures 12 and 13 represented chromatograms for n-paraffins of the sampling sites No. 1 and 12. There is a clear predominance of odd n-paraffins mainly C_{15}, C_{17}, C_{19}, C_{25}, C_{27}, C_{29}, C_{31} and C_{33}. However, this predominance is absent in March 1980 for site No. 12, due to the introduction of hydrocarbons in the sediments by the oil activities in the area. The chromatogram (Fig. 13) shows the saturated fraction containing the normal paraffins from those with a low molecular weight like the n-tetradecane (C_{14}) to n-pentatriacontane (C_{35}); the isoprenes pristane and phytane are also present. The ratio pristane/phytane was 1.2, and the OEP value (odd-even predominance) was 1.0, which agrees with previously reported values for the crude oils that have not had a remarkable weathering (Scalan et al., 1970; Botello and Castro, 1980).

Table 5 shows that locations on OPLAC-3 with higher hydrocarbon

Table 6

Summary of the $\delta^{13}C$ values and total hydrocarbons concentration in marine organisms from Campeche Bank, México.

Specie	Cruise OPLAC-1 (July, 1978) $\delta^{13}C$ ‰	Cruise OPLAC-1 (July, 1978) Total Hydrocarbons ppm (dry weight)	Cruise OPLAC-2 (March, 1978) $\delta^{13}C$ ‰	Cruise OPLAC-2 (March, 1978) Total Hydrocarbons ppm (dry weight)
Penaeus aztecus	-18.5	52	-18.2	66
Penaeus duorarum	-19.7	63	-19.7	86
Penaeus setiferus	-17.2	46	-16.8	34
Harengula pensacolae	-20.8	24	-20.4	32
Synodus foetens	-21.4	32	-21.2	26
Loligo pealei	-22.2	68	-22.0	60
Chloroscombrus crysurus	-20.4	37	-20.6	42
Priacanthus arenatus	-21.0	30	-21.2	36

concentrations corresponded to the samples taken near the restricted area of oil operations (stations 12 and 13). As one could expect, higher values (133 and 231 ppm) were also recorded at the oil-rig platforms Azteca-Y, and Akal-C. Other high concentrations of hydrocarbons were determined along the two additional transects positioned off Carmen and Machona Lagoon and Dos Bocas Bar. This may be explained by input of plant detrital material supplied by the adjacent rivers.

DISCUSSION

Our present knowledge of the lethal and sublethal effects of petroleum hydrocarbons on the marine environment has greatly benefited from the results of a series of important scientific contributions which have shed light on the physiological response of a good number of marine organisms exposed to oil, as well as on the impact caused by spill accidents on both coastal and oceanic ecosystems (Reish et al, 1979; Filion-Myklebust and Johannessen, 1980). Unfortunately there have been few attempts to evaluate the impact of the offshore petroleum industry upon fishery resources (Gusey and Maturgo, 1971; Allen et al., 1976; Kumpf, 1977).

It has generally been conceded in the literature that chronic exposure to oil can be more harmful to the environment than the effects derived from the always dramatic oil blow-outs. In this respect, Hall et al. (1978) have pointed out that day-to-day offshore-rig operations introduce into the local ecosystem an amount of pollutants whose consequences can be quite adverse, particularly to the coastal environment. Under these circumstances petroleum hydrocarbons in or on seawater can become associated with suspended sediment particles, and be transported downwards and incorporated into the sediments. In this kind of environment crustaceans such as penaeid can rapidly take up petroleum hydrocarbons from the water, or their food can become adversely affected (Meyers, 1978). The degree of toxicity will greatly depend on the type of oil introduced into the ecosystem, and the changes produced by weathering factors on the different oil components. Recent findings by Lee et al. (1980) indicate, for instance, that spilled Mexican oil failed to induce acute effects upon marine organisms due to the evaporation of the most toxic components, such as benzenes and naphthalenes.

Since 1979 the offshore oil operations conducted by PEMEX (Mexican Petroleum Company) in the Campeche Bank have maintained an accelerated pace of exploration and extraction which very likely will extend in the future over other areas of the Bank where important fishing grounds are located. To minimize the undesired consequences that this development may cause upon a renewable resource, such as the shrimp fishery, it is imperative to gain accurate data on the behavior of the stocks being commercially exploited. Even though the information presented here is by no means a through analysis of the interaction between petroleum hydrocarbons and shrimp fishery, it does provide a base line to detect changes in composition, biomass, biological stage of the populations studied, in addition to the establishment of critical levels of hydrocarbon concentrations in marine organisms belonging to the "shrimp ground community," and their surrounding environment.

In 1978 Soto conducted an exploratory survey (OPLAC-1) in Campeche Bank which served to identify the basic pattern of spatial and biomass distribution of the three major commercial species of shrimp, and to determine the by - catch composition. In two subsequent surveys, OPLAC-2 and 3, two additional transects were added on the western end of Campeche Bank, in view of the richness of organic matter of this area and of the potential effects that might be caused to local fisheries by oil pipelines and port facilities established at Mecoacán, Tabasco. Accumulation of organic matter on the western end of Campeche Bank primarily originates from the Grijalva and Usumacinta's run-off, though according to Bessonov et al. (1971), the Bank's circulation also contributes to this process which, in their opinion, influences favorably the distribution and concentration of demersal fish.

Shrimp catch per unit effort values obtained in OPLAC's trawling operations were lower than those taken in a normal commercial catch. There is the possibility that 30 min of trawling may be insufficient time to allow the net to stabilize on the bottom as suggested by Dragovich et al. (1980); obviously, this could introduce a bias in the catch results. Another matter that requires attention is the fact that total shrimp catch calculations submitted here included day and night operations. Nonetheless the overall analysis of our results obtained in summer (Soto, 1979), spring and fall did not disclose drastic changes in production.

In reference to the species composition of the shrimp catch, it is interesting to observe the replacement that has taken place of the pink shrimp *P. duorarum* by the brown shrimp *P. aztecus*. Displacement of the stocks of the former species towards Yucatan Peninsula may be held accountable for this shift in composition.

Initially in this study, an attempt was made to estimate areas of different shrimp densities on Campeche Bank; for this purpose the method recommended by Alverson and Pereyra (1969) was applied to the OPLAC data. The results of this procedure suggested the existence on the shelf of three basic areas of concentration for *P. aztecus, P. duorarum,* and *P. setiferus.* The first species tended to be aggregated on the nutrient enriched area between 20 and 40 fm; the second species in the carbonate environment from 10 to 20 fm; the third species displayed an overlapping pattern in relation to the above two species.

The drawing of biomass isolines became difficult due to the nature of the data employed (day and night catch) and to the large distance between the sampling sites. Future surveys would prove more profitable if different catch effort is applied to the recognized strata in accordance to their average biomass.

In reference to the size structure of the shrimp population studied, no significant alterations were observed in the general class composition, as the predominance of juvenile and subadult individuals in both cruises shows. This could mean that the recruitment pattern to the fishing stock has not been upset.

To a shrimp fishery like the one practiced in Campeche Bank, the determination of fossil fuel levels in biota and sediments and the identification of the sources of organic matter that support a benthic ecosystem constitute a valuable tool that might elucidate the impact of ecological disturbances such as those due to chronic oil exposure. During the present study, special care was given to the detection of tainted organisms and oil remains in sediments. Up until now, no visible signs have been observed in any of these cases.

Penaeid shrimp are known for their ability to metabolize petroleum hydrocarbons (Botello, 1975; Cox and Anderson, 1973; Neff et al., 1976), and reportedly, after a certain period of time when placed under oil-free conditions, they can discharge accumulated hydrocarbons from their tissues through a process associated with detoxifying enzymes. The same ability of detoxification has been attributed to fish.

The 8 species of marine organisms tested for petroleum hydrocarbons did not show concentrations that could be considered critical; minor fluctuations of roughly 6 ppm were recorded. Similarly, our $\delta^{13}C$ values showed little change, which proves that the species we analyzed utilize organic carbon of the biogenic type, rather than carbon supplied by anthropogenic sources. This revealing fact may support the contention that the principal source of organic carbon to the benthic ecosystem of Campeche Bank is represented by the plant material exported from Terminos Lagoon, and by the Grijalva-Usumacinta System. It is therefore quite possible to assume that much of the shrimp production may derive its nutrition from a detrital food web, as it has been suggested by Flint (1980) for the Texas shrimp fishery.

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