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Effects of the Santa Barbara, Calif., Oil Spill on the Apparent Abundance of Pelagic Fishery Resources

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Introduction

Many studies have been made of the effects of oil on marine invertebrates, plants (marine algae and phytoplankton), and vertebrates such as seabirds and marine mammals. An excellent review of these findings, which includes some references to fish and pathological effects of aromatic hydrocarbons, has been published by the Royal Society, London (Clark, 1982). That review dealt with the environmental effects of such major oil spills or releases such as those by the tankers *Torry Canyon* (119,000 t) on the south coast of England, *Metula* (50-56,000 t) in the Straits of Magellan, *Argo Merchant* (26,000 t) off Cape Cod, and the super tanker *Amoco Cadiz* (223,000 t) on the coast of northern Brittany. Those spills were studied to determine their effect on living resources. In contrast there are few references on the impact of oil spills on pelagic fishery resources.

The release of approximately 240,000 barrels (bbl) (34,800 t) of Alaskan crude oil by the tanker *Exxon Valdez* in Prince William Sound, Alaska, in March 1989, has created increased public interest on the effects of petroleum spills on biological resources.

The largest crude oil spill off California resulted from the blowout of the subsurface oil well casing at the Union Oil Company Platform A in the Santa Barbara Channel (Fig. 1) about 6.5 miles southeast of the City of Santa Barbara, California. This spill started on 28 January 1969 and continued at rates of up to an estimated 5,000 bbl per day into April 1969 with some discharge of crude oil continuing after this time. A crude oil line break in December 1969 resulted in a spill of additional oil into the Santa Barbara Channel. Extensive areas of crude oil in the Santa Barbara Channel were evident into 1970. The total amount of crude oil spilled at Platform A is unknown and can only be estimated; this is in contrast to the reasonably accurate measurements from tanker spills. A U.S. Department of the Interior publication (Anonymous, 1979) reported estimates of 33,000 bbl (4,782 t) spilled at Platform A; another reference in the same publication estimated 77,000 bbl (11,159 t).

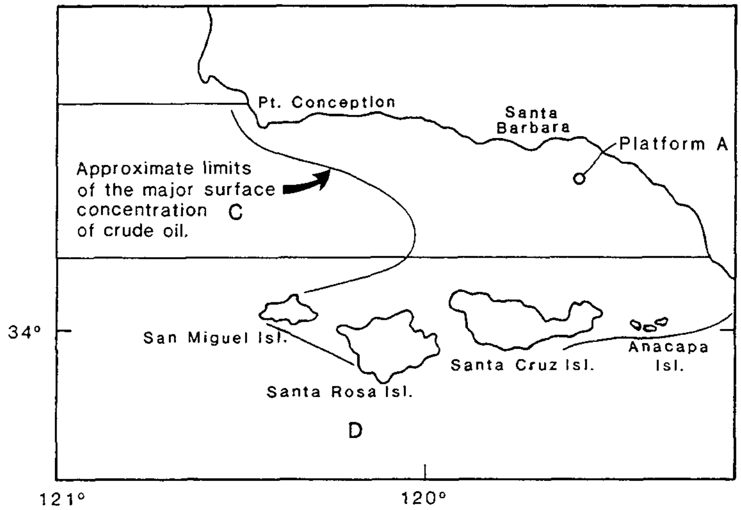

Figure 1.—Approximate limits of major surface concentrations of crude oil.

Crude oil on surface waters in the Santa Barbara Channel is not uncommon. The Santa Barbara Channel and submerged areas about the Islands are known to have several hundred natural subsurface oil seeps. These seeps are variable in their discharge rates and are estimated to have a total spill level of 40-670 bbl per day (Anonymous, 1979). A spill level of 200-400 bbl per day would be a reasonable estimate. At a rate of 300 bbl per day, the natural spill in this area would be over 15,800 t of crude per year. In addition to seeps in this area, other oil seeps are present to the southeast off the southern California coast, some existing in the San Pedro Channel.

The crude oil from the Platform A spill spread throughout the Santa Barbara Channel with major concentrations in the eastern half of the Channel. The surface concentration of crude oil extended offshore to the southeast to

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Anacapa and Santa Cruz Islands in particular (Fig. 1). The distribution of oil on the surface was highly variable after the initial release. Concentrations were continually shifting relative to changes in surface currents.

The area covered by crude oil included one of the more important commercial fishing areas for pelagic fish resources, including the northern anchovy, *Engraulis mordax*; Pacific sardine, *Sardinops sagax*; Pacific mackerel, *Scomber japonicus*; Pacific bonito, *Sarda chiliensis*; and jack mackerel, *Trachurus symmetricus*. Pacific sardine and Pacific mackerel, two important commercial species, were at very low levels of abundance at the time of the oil spill (Squire, 1983).

Surface concentrations of crude oil which spread over the Santa Barbara Channel area affected seine fishing. The oil film and its resulting surface sheen impaired the ability of the boat crews to sight schooling fish. Also, any fish caught would probably have been tainted with hydrocarbons and not desirable for public consumption (McIntyre, 1982). After natural dispersion of the initial oil spill by currents, purse seine operations could be conducted in clear areas. Aerial fish spotters were able to see fish schools swimming below the surface oil slick, and when the fish school would move out from under the oil slick into an area clear of crude oil, purse seining operations could be conducted.

In 1962, several years before the Platform A spill, the National Marine Fisheries Service (then called the Bureau of Commercial Fisheries) started an aerial monitoring program for pelagic fishery resources common to the central and southern California coast (Squire, 1972, 1983). This program utilizes the services of commercial aerial fish spotter pilots who search for the commercial purse seine fleet operating off southern California. The program was operating and collecting data on the relative apparent abundance (Marr, 1951) of pelagic fishery resources in the Santa Barbara Channel and offshore islands area at the time of the Platform A blowout.

This paper reviews the relative apparent abundance of three commercially important pelagic species common to the Santa Barbara Channel and Island areas prior to, during, and for a 3-year period after the oil spill.

Methods

Monitoring Program Procedures

On a flight log sheet, aerial fish spotter pilots under contract to the NMFS Southwest Fisheries Science Center (SWFSC), record information on their flight track, locations of various species observed, and an estimate of tonnage observed. The flight logs are edited and the data are coded into the SWFSC data base. Flight log data were converted to an index of apparent abundance by dividing the tonnage observed by the number of block areas (lat. 10" × long. 10"—about an 8 × 10 n.mi. area at the latitude of southern California) entered into during each flight (a measure of observation effort) to give a measure of tons per block area flight (T/BAF). Flight log data represent a sample estimate of the abundance of pelagic species schooling in near surface layers of the ocean surveyed. Flight tracks flown by the spotter pilots are nonrandom, being determined by previous experience regarding the most likely locations for sighting schools of various species relative to the season of the year, real-time information from other aerial spotters or fishing boats, and other recent experiences. In zones where concentrations of fish are historically found, the same block areas tend to be searched every year. For details of the aerial program see Squire (1972, 1983).

Due to the behavior of schooling fish, some species are observed more frequently and in greater amounts during the day, others at night. Sampling differences during day or night could affect the apparent abundance. The ratio of day to night flight operations, 35% night and 65% day, was similar during the oil spill period as for the total program (1963-88). For night observations, near total darkness is required to observe the bioluminescent glow of plankton organisms being agitated by the fish school. Analysis of time of sighting (day or night) indicates the northern anchovy and jack mackerel are usually observed in greater numbers and more frequently at night, and Pacific bonito in greater frequency and abundance in the day. However, there may be considerable variation in the day/night ratio of sighting during any one year. During the period 1966-72 (before, during, and after the oil spill), 72% of the flight effort was during the day, and 28% was during the night in the Santa Barbara Channel and Islands area (Zones C and D, Fig. 1). In 1969, the year of the oil spill, only a small difference in day/night ratios was noted, with 75% of effort (# BAF searched) during the day and 25% at night. A total of 269 individual survey flights were conducted in 1968, 399 in 1969, and 224 in 1970.

Indices of Abundance

An index of abundance was calculated for each species for groups of block areas or "zones." Zone "C" includes the Santa Barbara Channel and Zone "D" includes the Santa Barbara Channel Islands (Fig. 1). Platform A is located in Zone C, and this zone was the area most affected by the oil spill.

A simple, direct formula is used for the calculation of an index of apparent abundance for each species in the various zones such as Zones C and D, and procedures on calculation are given by Squire (1972, 1983). The index of apparent abundance is expressed in terms of tons per block area flight (T/BAF). Figure 2 gives the amount of search effort (# BAF) for 3 years before and after the oil spill period of 1966-72.

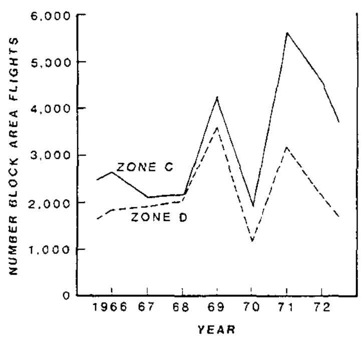

Figure 2.—Number of block area flights conducted in Zones C and D by year, 1966-72.

Results

Distribution of Species Sightings

The geographical distribution of the sightings in the Santa Barbara Channel and about the Channel Islands of the northern anchovy, Pacific bonito, and jack mackerel for the periods 1966-69, and 1970-73 are given in Figures 3-5. Each dot represents the sighting location by a spotter pilot indicating the location of one or more schools (school group) of fish sighted.

Changes in Abundance

Sightings records (1963-88) for the Santa Barbara Channel and Islands areas indicate that the summer-to-winter period has a greater abundance of northern anchovy, jack mackerel, and Pacific bonito. In some years the fishing season for Pacific bonito extends into February or March. The abundance levels of each species of interest are reviewed in the following section by monthly periods before and after the January 1969 oil spill. Flights conducted in the Santa Barbara Channel and Island areas were examined for a 36-month period, 1 year before the oil spill, the year of the oil spill, and 1 year after (January 1968 to December 1970). A total of 269 flights were recorded in 1968, 399 in 1969, and 224 in 1970. Information is given regarding total tonnage observed by month for Pacific bonito, northern anchovy, and jack mackerel (Table 1).

The trend of the abundance index (night index for anchovy and jack mackerel and day index for bonito) for Zones C and D, all sightings, calculated in T/BAF for the three species, 1966-72 is given in Figures 6-8.

Discussion

In contrast to extensive studies on birds and invertebrates, there have been some studies on the effects of the Santa Barbara oil spill on fishes. In February 1969, the NOAA research vessel *David Starr Jordan* sampled the area with plankton nets and found no oil adhering to the fish eggs or any abnormalities in them (Anonymous, 1979). Samples taken directly under the oil indicated fish larvae were in usual numbers and kinds representative of that area at that time of the year. NOAA concluded that the oil spill at that time had no major discernible effect on the planktonic biota (Anonymous, 1970).

The California Department of Fish and Game sampled pelagic species in the Santa Barbara Channel about 15 days after the initial oil spill and found no evidence of starvation in the northern anchovy that might have resulted from impairment of the planktonic food chain (Anonymous, 1979). No changes from the expected composition of ichthyoplankton were observed. Preliminary information on the results (number of flights and estimates of tons observed) of aerial spotting flights in the Santa Barbara Channel area were made available and were used in development of the conclusion by Straughan (1971) that fish were still present in the Santa Barbara Channel after February 1969. However, no supportive analysis was given relative to changes in abundance before, during,

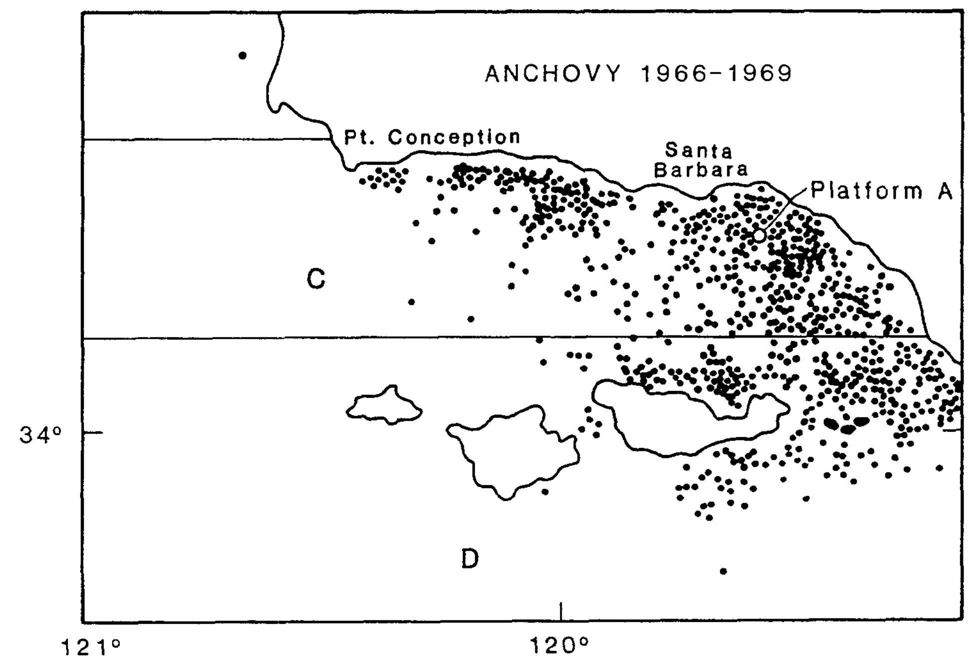

Figure 3a.—Northern anchovy sightings of school or school groups, 1966-69.

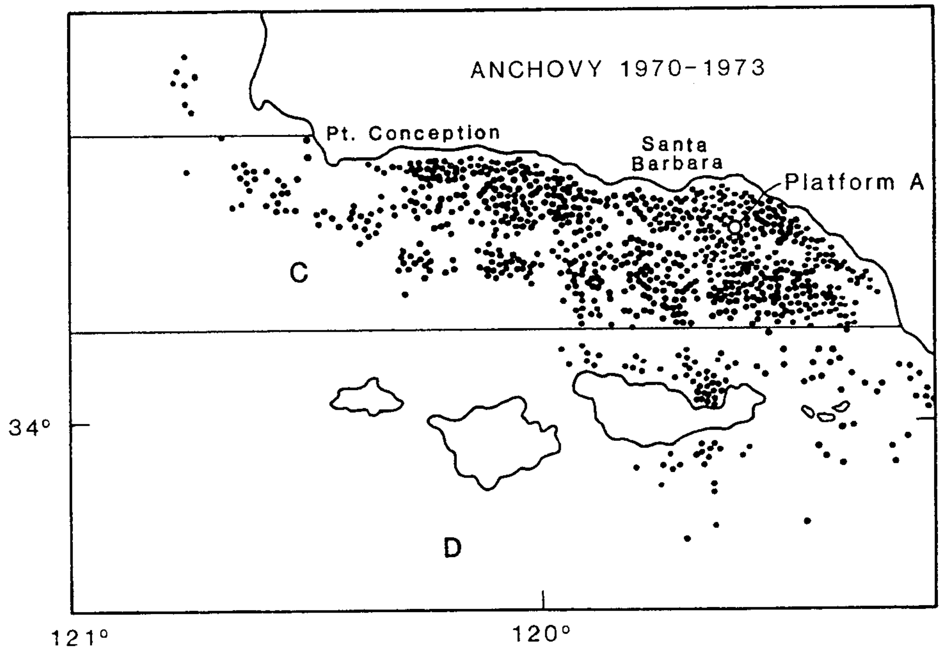

Figure 3b.—Northern anchovy sightings of school or school groups, 1970-73.

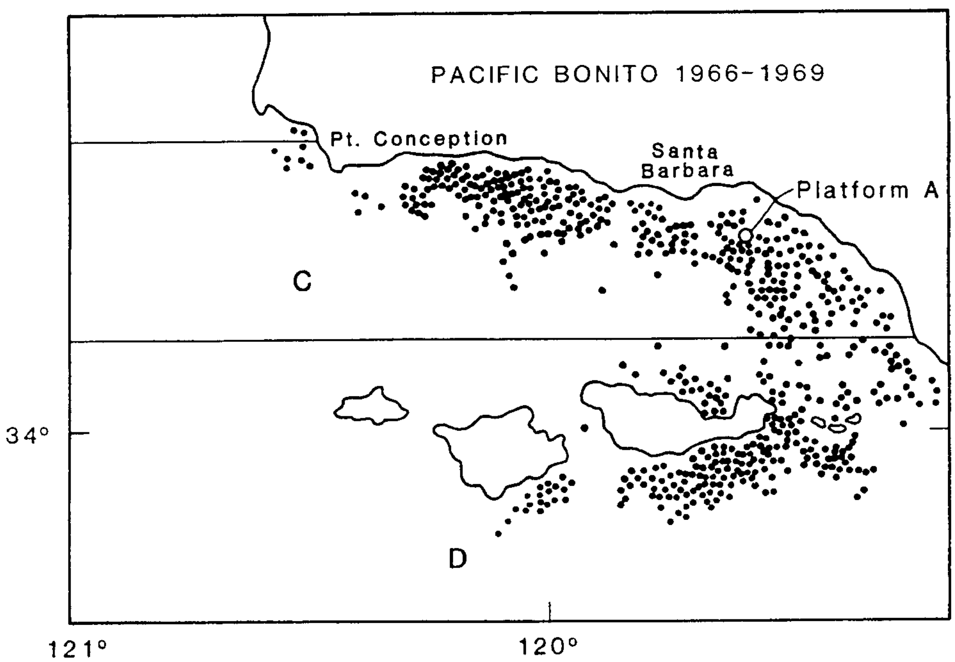

Figure 4a.—Pacific bonito sightings of school or school groups, 1966-69.

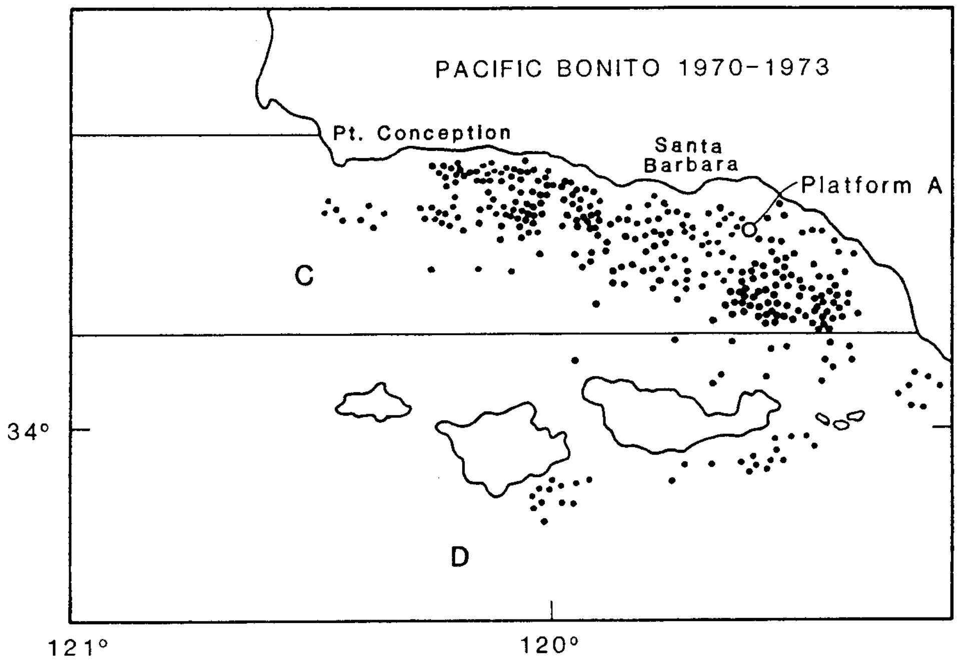

Figure 4b.—Pacific bonito sightings of school or school groups, 1970-73.

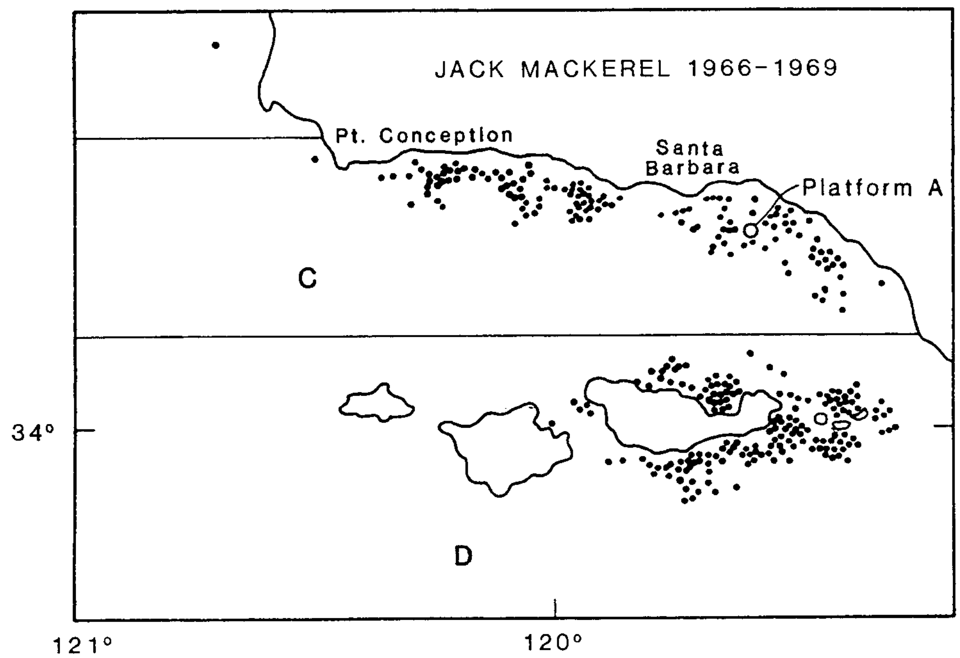

Figure 5a.—Jack mackerel sightings of school or school groups, 1966-69.

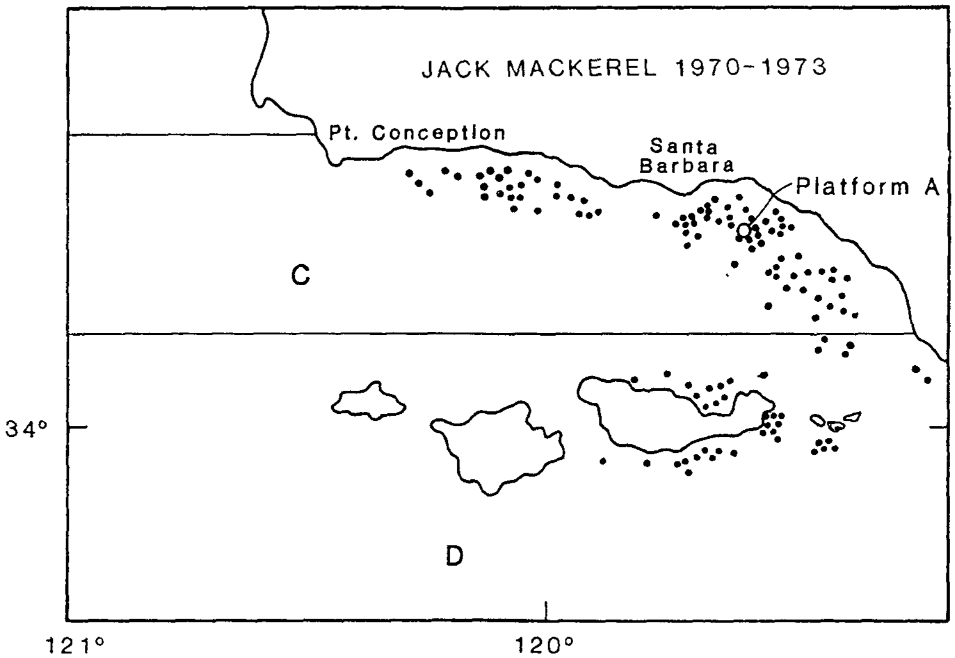

Figure 5b.—Jack mackerel sightings of school or school groups, 1970-73.

or after the oil spill. Straughan (1971) also concluded that the reduction in fish catch was probably due to the problems of fishing in oily waters rather than the lack of fish.

The Platform A blowout spilled a large quantity of crude oil into the waters of the Santa Barbara Channel and Islands. A small amount of crude oil was noted along the coast as far southeast as Newport Beach, Calif. This crude oil spill is the largest recorded in California waters. The major difference between the Platform A blowout and tanker disasters is that the crude oil release from the blowout extended over a period of time in contrast to the short-term release of oil in most tanker accidents.

In addition to the accidental release in 1969, the marine environment of the Santa Barbara Channel and other southern California areas have been subjected historically to a continuing seepage of crude oil into the water column. What effect this has had in the pelagic fishery resources and other biological resources common to the area is unknown. The pelagic species with which this paper is concerned are commonly found in the Channel, primarily in the eastern half and about the Islands as the sighting graphics (Fig. 3a-5b) would indicate. In an analysis of the aerial monitoring program (1963-89) (Squire[1]), "core areas" of distribution and abundance were defined for each species. Zones having considerable crude oil release are included in the core areas for Pacific sardine, northern anchovy, Pacific mackerel, Pacific bonito, and jack mackerel. This analysis would indicate that the natural oil seepage is not having substantial negative effect on the distribution of these pelagic resources.

The results of aerial spotting records for Zones C and D (Fig. 6-8) and monthly summaries of tonnages from flight observations in the Santa Barbara Channel and Islands area, (Table 1) are reviewed for Pacific bonito, northern anchovy, and jack mackerel.

[1]Squire, L. 1992. Apparent abundance indices for six pelagic species—1962-1990, as determined by an aerial monitoring program. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Sci. Cent., Admin. Rep. LJ-92-12, 15 p.

Northern Anchovy

After the oil spill at the end of January 1969, the northern anchovy was absent in February but was observed during the late spring early-summer months at higher abundance levels than observed in either 1968 or 1970; however, the abundance level showed a decline in 1970 (Table 1).

The trend of abundance index (day index, T/BAF) for Zones C and D are given in Figure 6. Zones C and D are zones where high abundance index levels of anchovy are normally observed, with Zone C an important area for the northern anchovy. Zone C peaked in 1967 with a low in 1968, but increased during the oil spill year, 1969. Zone D peaked in 1968 with a low index level in 1969. Both Zones C and D were at lower levels in 1970, increasing in 1971 (Fig. 6).

Table 1.—Summary of individual aerial fish spotting flights (1968-70) for the Santa Barbara Channel and Islands (for Zones C and D combined) and the estimated tonnage sighted, by month, from records of five spotters.

Year	Distribution of individual flights	Estimated tonnage[1] sighted		
		Bonito	Anchovy	Jack mackerel
1968				
Jan.	31	4,042	1,450	22
Feb.	29	1,892	4,100	140 C
Mar.	23	203	840	87
April	0			
May	9	0	70	651
June	20	0	2,670	198
July	21	245	4,506	974
Aug.	32	1,650	595	539
Sept.	53	3,784	3,978	1,085
Oct.	17	166	55,000	210
Nov.	18	445	149,800	0
Dec.	16	1,400	46,900	10
	269			
1969				
Jan.[2]	13	1,799	7,000	415
Feb.	14	0	0	30
Mar.	28	0	39	1,610
April	19	0	435	602
May	20	0	20,310	142
June	34	5	76,236	580
July	52	399	101,036	2,071
Aug.	58	2,531	649	106
Sept.	28	348	53,130	260
Oct.	48	4,350	26,885	40
Nov.	45	525	80	683
Dec.	40	999	51,560	287
	399			
1970				
Jan.	23	310	4,030	885
Feb.	23	0	207	1,104
Mar.	37	0	3,614	865
April	24	0	4,100	315
May	19	0	8,406	84
June	18	2	11,750	305
July	12	10	8,452	4
Aug.	17	1,221	2,113	17
Sept.	17	2,627	13,130	14
Oct.	13	1,103	4,799	43
Nov.	12	484	945	6
Dec.	9	851	522	0
	224			

[1]Short tons.
[2]Oil spill started January 28, 1969, continued unchecked to April 1969, and continued a minor flow until late in the year.

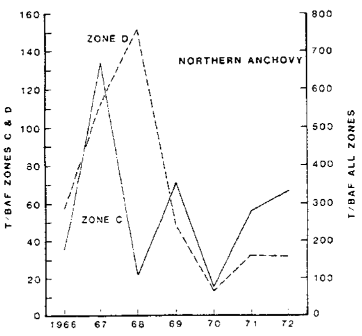

Figure 6.—Trend of abundance in T/BAF for northern anchovy (night index) in Zones C and D, 1966-72.

Jack Mackerel

The jack mackerel resource has a distribution of older adults generally offshore from which the younger year classes recruit into the southern California fishery. The jack mackerel tonnages decreased after the spill, but, overall, increased slightly in 1969, then decreased in 1970 (Table 1). For Zones C and D the index of apparent abundance (night index, T/BAF) was at a low level in 1968 prior to the oil spill and remained at a low level after 1969 through 1972 until showing an increase in 1975 (Fig. 7) (Squire, 1983).

Pacific Bonito

The Pacific bonito fishing season in the Santa Barbara area usually extends from the summer months into the following winter months of February or March. The 1967-68 fishing season ended in February/March 1968. Starting in August 1968, prior to the oil spill, these high abundance levels extended through January 1969, with very high levels just prior to the oil spill. After the oil spill, Pacific bonito were not observed, but they were again observed in increased abundance in July/August 1969, about the same months as initially observed in 1968. Abundance levels remained up until January 1970. Again in 1970, as in previous years, Pacific bonito were absent from February to May with a substantial increase in abundance noted in August (Table 1).

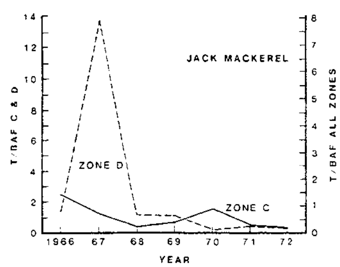

Figure 7.—Trends of abundance in T/BAF for jack mackerel (night index) in Zones C and D, 1966-72.

The apparent abundance index trend (day index, T/BAF) of Pacific bonito in Zones C and D (Fig. 8) follows a steady overall decline (1966-70) in its apparent abundance index prior to the oil spill. The declining trend then shifted to an increase in apparent abundance starting in 1971 and continued into 1972.

Conclusions

A review of the trends of abundance index as calculated for Zones C and D (Figs. 6-8) and of tonnages sighted during observational flights prior to, during, and after the Platform A blowout (Table 1), indicates that the oil spill had some immediate short-term (monthly) negative effects on the apparent abundance of Pacific bonito and jack mackerel. The northern anchovy abundance index in the important Zones C and D were relatively stable from 1968 through 1971, particularly for Zone C, one of the more important zones for evaluating changes during the oil spill period.

The variability in the occurrence and concentrations of pelagic species is difficult to measure and is confounded by variables in the abundance and behavior, the fishes' relation to their environment and its changes, interaction with predators, and wide fluctuations in recruitment. The oil spill occurred

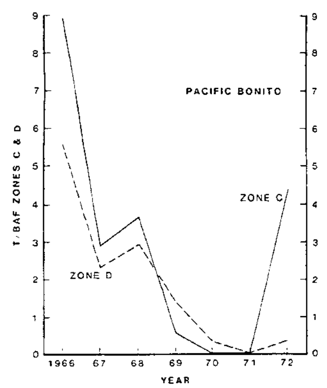

Figure 8.—Trend of abundance in T/BAF for Pacific bonito (day index) in Zones C and D, 1966-72.

in an environmentally unique area where, historically, high levels of crude oil, emanating from underwater oil seepage, are present. Fluctuations in sea surface temperature has a substantial effect on fish distribution. An El Niño event occurred in 1972 and may have been a contributor to increased abundance of Pacific bonito and movement of the northern anchovy in more northern waters including the study area. However, abundance index values during the oil spill year of 1969 do not indicate any unusually reduced fish abundance levels resulting from the oil spill.

Observations during the oil spill period indicated that schools of anchovy, bonito, and jack mackerel were in the normal geographical areas of distribution within the Santa Barbara Channel and Islands, and that their behavior, below the oil slick was normal relative to depth, movement, and school shape[2]. Data would indicate that pelagic fish resources, with their capability of moving widely in their environment, do not suffer short-term debility from localized oil spills, such as the type that occurred during January 1969 in the Santa Barbara Channel.

Acknowledgments

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