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Fish Bulletin No. 64. The Biology of the Soupfin Galeorhinus zyopterus and Biochemical Studies of the Liver

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STATE OF CALIFORNIA DEPARTMENT OF NATURAL RESOURCES DIVISION OF FISH AND GAME BUREAU OF MARINE FISHERIES

FISH BULLETIN No. 64

The Biology of the Soupfin Galeorhinus zyopterus and Biochemical Studies of the Liver

1946

FOREWORD

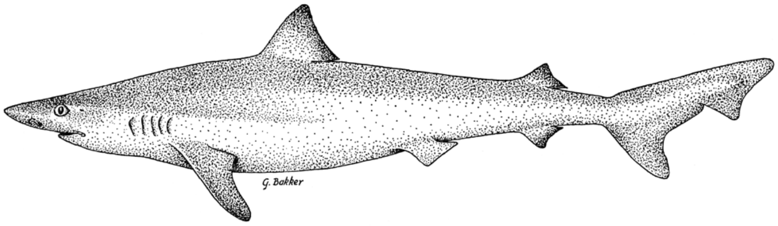
The use of fish liver oils as a dietary supplement has been practiced for hundreds of years but not until a comparatively recent date has it been known that the virtue of these oils lies in their vitamin content. Because of this increased knowledge of vitamins, manufacturers of pharmaceutical products analyzed many species of fish in a search for new sources of this much desired food fortifier. Additional stimulus to the search for vitamins in other fish was also furnished by the second World War which curtailed the production of cod liver oil and eventually cut off European supplies. Laboratory tests showed that the soupfin shark along the Pacific Coast of North America has a liver richer in vitamin A than any other fish yet analyzed. As a result, the California fishery for this shark increased at a spectacular rate.

By 1942 an investigation of the fish and its fishery was deemed necessary. This required study of the biology of the fish to determine if the population could continue to support the fishery, and an analysis of the vitamin A content of the livers both to understand the causes for the variation in yield between individuals and to ascertain whether methods in practice by the industry produced the highest possible vitamin yield.

The biological phases of the work were carried out by the Bureau of Marine Fisheries of the California Division of Fish and Game; and the conclusions drawn are the responsibility of this organization. The chemical analyses were made through a cooperative study with Stanford University. Under this arrangement the Division of Fish and Game collected the livers on fishing boats and in the fish markets and furnished the necessary funds for the chemistry department of Stanford University to make the analyses. That organization is responsible for the conclusions drawn relative to the chemical findings.

Dr. Richard Van Cleve, then Chief of the Bureau of Marine Fisheries, instigated the study and supervised the work throughout. We gratefully acknowledge our indebtedness to him, not only for advice and helpful suggestions, but also for the enthusiasm and stimulus which he contributed to the entire research program.

FRANCES N. CLARK
Bureau Marine Fisheries April 15, 1946



SOUPFIN SHARK
Drawn by Gerhard Bakker, Jr.

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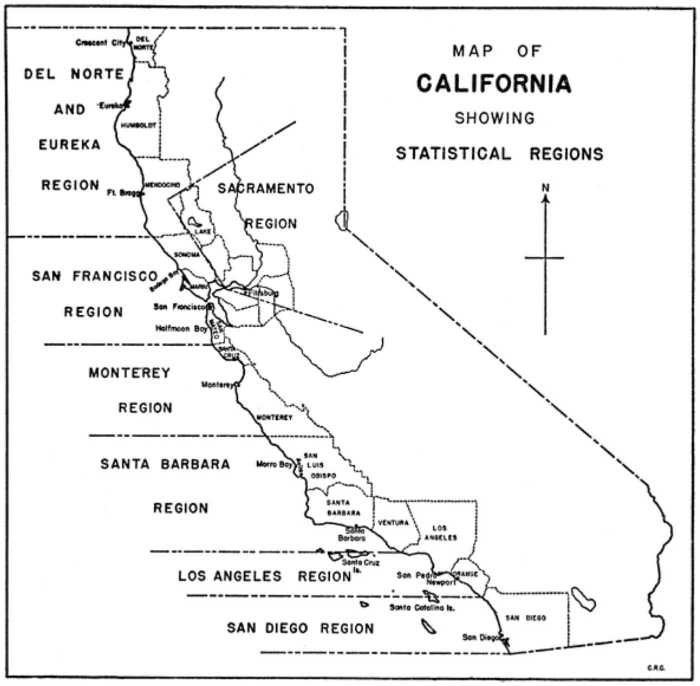


Fig. 1. Map of California showing statistical regions

FIG. 1. Map of California showing statistical regions

1. THE SOUPFIN SHARK AND THE FISHERY

1.1. ACKNOWLEDGMENTS

During the course of this investigation, much assistance and cooperation were given the author by men in the industry; the fishermen, marketmen and processors who contributed time, facilities, material and experience that made this investigation possible. To them I extend my sincere appreciation and thanks. of those who offered their time and accommodations, Mr. William Kay of the "Wolverine" was most helpful. Through his efforts and generosity, much of the source material for the data recorded in the biochemical papers was obtained. Mr. Lionel Shatz of A. Paladini, Inc., assisted immeasureably by his generous loan and subsequent gift of a Klett-Summerson Photoelectric Colorimeter to the biochemical project at the Stanford University laboratory. Mr. Theodore D. Sanford of F. E. Booth Company, Inc., contributed significantly through his sincere and helpful advice on analytical methods and by making his technical files available. Grateful appreciation is extended to the Bureau of Patrol, Division of Fish and Game, for its cooperation in the use of patrol vessels and for the aid given me during the investigation. Drs. W. M. Chapman and J. L. Kask of the California Academy of Sciences and the Steinhart Aquarium were most interested and cooperative in experiments in retaining soupfin in aquaria.

To the staff of the Bureau of Marine Fisheries fell the back-breaking chore of observing the Santa Catalina and Monterey fisheries. To them

goes my most unreserved gratitude. Dr. Frances N. Clark and Dr. Richard Van Cleve offered counsel throughout the investigation and gave unstintingly of their time, experience and advice in the preparation of the manuscript.

To all those other gracious and interested persons, far too numerous to mention, who contributed to this investigation go my wholehearted thanks for their aid.

1.2. DESCRIPTION OF THE SPECIES

The soupfin shark (Galeorhinus zyopterus) is classified with the family of true sharks, Galeidae, in which are included the tiger, great blue, smooth-hounds, leopard, and bay shark. The family has a wide distribution in the oceans of the world. The species Galeorhinus zyopterus is found from Cedros Island, Lower California, to northern British Columbia.

The soupfin attains a size of slightly over six feet. Its head is flattened dorso-ventrally with the snout projecting well beyond the eyes. It has five gill openings and an anal fin. The first dorsal fin is located about midway between the pectorals and ventrals. The tail, not lunate in shape, is considerably shorter than the body and is deeply notched. There is no lateral keel on the caudal peduncle. The teeth are sharp, placed in several rows and are notched on the outer edge below the point, with the lower part of the notch divided into two to five points.

The position of the second dorsal and anal fins offers the simplest means of distinguishing soupfin from other species of sharks found in California. (See Walford, 1935) These fins are inserted opposite each other just anterior to the caudal peduncle and are of about the same height. In lateral view an extension of the anterior and posterior edges of the two fins would intercept to form an almost perfect diamond.

To the casual observer, small specimens of soupfin may be confused with brown and grey smooth-hound sharks. However, the second dorsal fin of the smooth-hounds is inserted in advance of the anal fin and exceeds this fin in both length of base and in height. If close attention is given to the insertion and the relative height of the second dorsal and anal fins, the distinction between small soupfin and smooth-hounds is quite marked and should offer no difficulties.

1.3. THE FISHERY

1.3.1. History

Prior to 1937 shark fishing in California was carried on to supply a limited demand for fresh shark fillet and for reduction purposes. There was also a substantial market for the dried fins of the soupfin shark for the Oriental trade. The annual production during the years 1930 to 1936 averaged 588,373 pounds. In 1937 a new market for sharks suddenly developed as a result of the discovery that the liver of the soupfin was the richest source of high potency vitamin A oil available in commercial quantities. This discovery coupled with the curtailment of former sources of supply as a result of the war, rocketed the prices offered to fishermen for soupfin and the fishery soon took on the aspects of a bonanza. Subsequently the west coast dogfish (Squalus suckleyi) fishery underwent a similar development but was accompanied by lesser economic extremes. Although the liver of this species was of much lower vitamin A potency than that of the soupfin the dogfish were present in sufficient quantity to form a valuable fishery.

The vessels of the northern halibut fleet, able to operate in rough seas, and capable of running large amounts of gear, were the first of the larger boats to enter the fishery. These were rapidly followed by most of the other vessels along the Pacific Coast that were able to modify their operations to fish the set line gear. By 1939, a motley assortment of about 600 boats were avidly searching for soupfin up and down the coast of California.

Prices in the first years of the expanded fishery (1937–1938) varied from $40 to $60 a ton for the shark in the round and rose to a high of $2,000 per ton in 1941. These prices in the round were based on an expected average liver yield of 10 per cent of the round weight. Fishermen soon learned that livers usually averaged more than 10 per cent and trading developed upon actual weights of the livers. Prices have fluctuated from less than $1.50 per pound to as high as $13 per pound for male livers. Female soupfin livers command lower prices than those offered for male livers because of their lower vitamin A concentration.

The fabulous prices offered for soupfin received much publicity. No mention was made of the difficulties involved in the taking of this "gold." Such propaganda influenced the gullible of all walks of life to leave their occupations and invest their time and money in the new strike. For a brief period almost anything that would float, was used for shark fishing. It was only a short while, however, before it became apparent that previous experience in boat operation and maintenance, and in commercial fishing was a requisite for successful shark fishing, and gradually most of the hopeful neophytes filtered out of the fishery.

As most foreign supplies of vitamin A were cut off with the outbreak of World War II, the west coast soupfin and dogfish liver industry became the principal source of vitamin A. The soupfin shark has been the major factor in the production of the vitamin A supply of the United States for the past few years, but recently as the catch dwindled it has been replaced by the dogfish. With the further decline of the local fishery in the past two years, the industry has been forced to depend more and more for their high potency vitamin A fish oils upon Mexican and South American sources and upon the concentration of vitamin A from low potency oils. Recently supplies have again become available from the North Atlantic fisheries.

1.3.2. Fishing Methods

The fishing gear and methods used up to 1939 are described by Byers (1940). During this period, the fishery was carried on chiefly by small boats and drift and set gill nets of various sizes with an eight-inch stretched mesh. In 1938 the northern halibut fleet introduced the halibut long line gear (Thompson, Dunlop & Bell, 1931) handled by machinery.

Until 1940 the improvements in gear were principally adaptations of the set line but about this time the used of "diver" gill nets for the capture of soupfin became popular. This method of fishing proved so successful that by 1941 a majority of the larger shark vessel owners were madly attempting to outfit their boats with nets. So keen was the competition for this type of gear that nets discarded by the salmon fishermen on the Columbia River were purchased for use in the shark fishery at prices in some cases double that of new equipment.

Most of the first nets were of 10-inch mesh, varying from 9 to 11 inches stretched measure, hung from 15 to 30 meshes deep. They were made of 18- to 30-thread medium or hard laid cotton twine. Cork and lead lines were of three-eighths to three-quarters inch manila or sisal line, usually with the heavier line for the lead because of the increased wear to which it was subjected by contact with the bottom.

Cork floats three to five inches in diameter were adapted from the other gill net fisheries. Sufficient weight was spaced along the lead line to sink the net. The nets were rigged in units, called "shakles" or "shots" which varied from 25 to 50 fathoms in length. When fishing, two to eight or more pieces of net were joined end to end to form a "string" of gear. The ends of the "strings" terminated with a bridle connected to an anchor of 45 to 75 pounds weight. (*Pacific Fisherman*, 1943a.)

These nets were first pulled by hand, however, by 1942 most fishermen were pulling their nets with a modified power gurdey. (*Pacific Fisherman*, 1943b.) The introduction of this mechanical puller allowed fishing to be carried on in greater depths than were practical for hand-operated gear.

As the depth of fishing increased, sealed glass beer bottles and then glass balls were substituted for the cork floats since the latter soon became water logged at depths greater than 25 fathoms. The use of spherical glass floats increased fishing depths to 150 fathoms. However, fishing in waters over 80 fathoms is not common. The next change occurred with the entrance of the drift net (*Pacific Fisherman*, 1943b) into the fishery, although in California it was not widely used in its new form until 1944. Variously modified diver and drift gill nets now comprise most of the fishing gear.

1.4. CATCH RECORDS

1.4.1. TOTAL LANDINGS

Total landings of shark have been obtained from the Division of Fish and Game records of fishermen's sales to the dealers. These records should show the landings of shark in round weight. Inaccuracies have arisen due to the variations in marketing practices of the fishermen, and due to the lack of sufficient staff to obtain records in the field. In the earlier years, sharks were cleaned at sea and only the carcasses were delivered to the markets. No distinction was made between species in the catch before 1937. After 1937 landings were either in the round or car-cassed and the records over this period are subject to error due to the practice of selling livers and discarding carcasses at sea. The 1944 landings have still an additional source of error. The change in marketing practices that took place during this year from the sale of liver on a poundage basis to the sale of liver on a vitamin potency basis caused some confusion in the industry as to who was responsible for the issuance of the Fish and Game receipt to the fishermen. Frequently the original dealer unloading the livers from the fishing vessel did not purchase the livers but held them in storage while awaiting the results of a chemical analysis of their vitamin content. If a dealer other than the original one unloading the fare, purchased the livers it was at times assumed that a Fish and Game receipt had already been issued. Consequently some records were not obtained of deliveries that were handled in this manner.

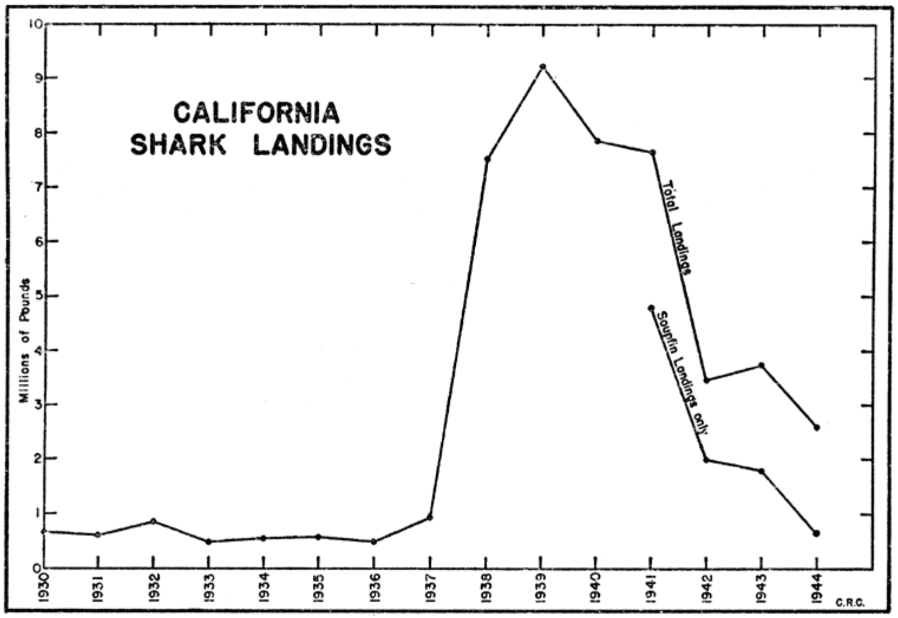


FIG. 2. Total landings of all species of shark delivered to California ports. As cleaning and dressing practices vary from port to port and season to season, the weights are not adjusted for the condition of the shark when landed

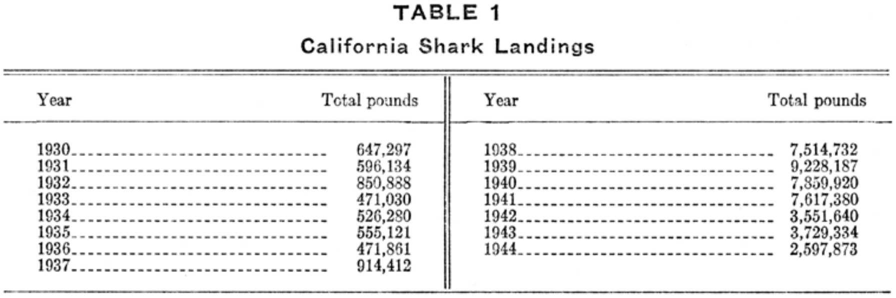


TABLE 1

California Shark Landings

Year	Total pounds	Year	Total pounds
1930	647,297	1938	7,514,732
1931	596,134	1939	9,228,187
1932	850,888	1940	7,859,920
1933	471,030	1941	7,617,380
1934	526,280	1942	3,551,640
1935	555,121	1943	3,729,334
1936	471,861	1944	2,597,873
1937	914,412		

TABLE 1
California Shark Landings

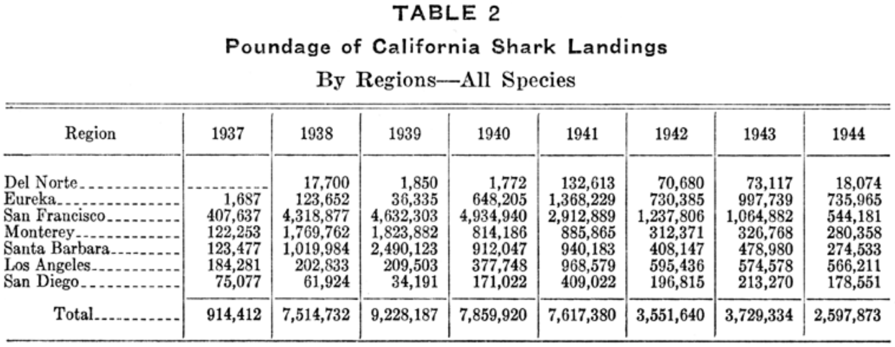


TABLE 2

Poundage of California Shark Landings

By Regions—All Species

Region	1937	1938	1939	1940	1941	1942	1943	1944
Del Norte	----------	17,700	1,850	1,772	132,613	70,680	73,117	18,074
Eureka	1,687	123,652	36,335	648,205	1,368,229	730,385	997,739	735,965
San Francisco	407,637	4,318,877	4,632,303	4,934,940	2,912,889	1,237,806	1,064,882	544,181
Monterey	122,253	1,769,762	1,823,882	814,186	885,865	312,371	326,768	280,358
Santa Barbara	123,477	1,019,984	2,490,123	912,047	940,183	408,147	478,980	274,533
Los Angeles	184,281	202,833	209,503	377,748	968,579	595,436	574,578	566,211
San Diego	75,077	61,924	34,191	171,022	409,022	196,815	213,270	178,551
Total	914,412	7,514,732	9,228,187	7,859,920	7,617,380	3,551,640	3,729,334	2,597,873

TABLE 2
Poundage of California Shark Landings
By Regions—All Species

The total landings as shown in figure 2 and table 1 increased over eight times between 1937 and 1938 and in 1942 fell to less than half the total landed in 1941. The changes in total catch that have occurred between 1937 and 1944 are so great that even though they may be incomplete the inaccuracies can not conceal the events that have taken place in the fishery. A great increase took place in 1938 and 1939. In the following years a decrease in total landings occurred in spite of a continued increase in fishing effort encouraged by high prices, hence this latter change must reflect a decrease in abundance. In view of the present critical state of the fishery, the total landings are presented as part of the brief history of the California fishery. They are also used to show the seasonal variation in the fishing off different sections of the coast.

The landings for soupfin shark alone are shown for the years following 1941 in figure 2. In these years the soupfin comprised 52.9 per cent of the total shark landings. This is a minimum figure since it represents only the soupfin recorded as such on the delivery receipt. Soupfin landed but recorded only as shark would not enter the soupfin records but would be included in the total shark catch records. The percentage that soupfin formed of the total landings between 1939 and 1941 was undoubtedly higher than in the years following 1941.

1.4.2. Return Per-Unit-of-Effort

Evidence of the decline in the abundance of soupfin is found in the return of catch-per-unit-of-effort. A widespread investigation of the detailed operations of the shark fleet has been impossible. Sufficient personnel was not available to inaugurate a system of boat logs, and the erratic nature of the landings precluded obtaining interviews from many of the boats, except in the case of the Santa Catalina Island fishery.

For other localities detailed information was obtained about the operation of the boats for those deliveries from which samples of livers were purchased. In addition, catch data from other boats were obtained whenever possible. Detailed data on all trips to Santa Catalina were recorded since these were made under special permit. This fishery, however, can not be considered typical because it began suddenly in 1942 when special licenses were issued to the boats for the purpose of fishing in that locality, and stopped at the end of 1943 when the licenses were not renewed.

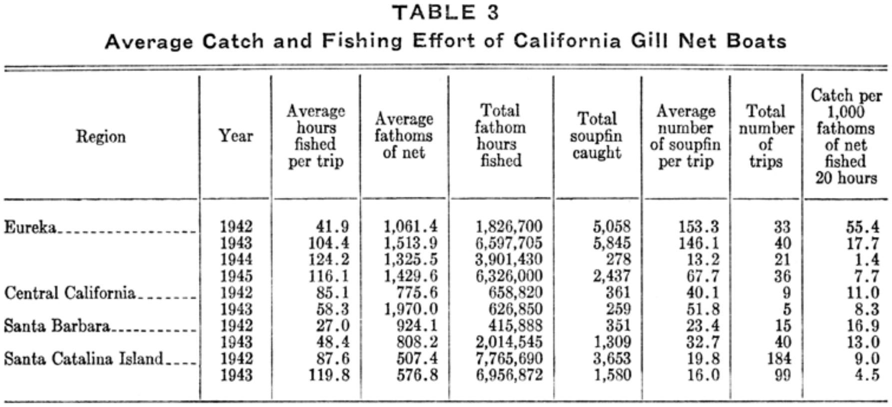


TABLE 3

Average Catch and Fishing Effort of California Gill Net Boats

Region	Year	Average hours fished per trip	Average fathoms of net	Total fathom hours fished	Total soupfin caught	Average number of soupfin per trip	Total number of trips	Catch per 1,000 fathoms of net fished 20 hours
Eureka	1942	41.9	1,061.4	1,826,700	5,058	153.3	33	55.4
	1943	104.4	1,513.9	6,597,705	5,845	146.1	40	17.7
	1944	124.2	1,325.5	3,901,430	278	13.2	21	1.4
	1945	116.1	1,429.6	6,326,000	2,437	67.7	36	7.7
Central California	1942	85.1	775.6	658,820	361	40.1	9	11.0
	1943	58.3	1,970.0	626,850	259	51.8	5	8.3
Santa Barbara	1942	27.0	924.1	415,888	351	23.4	15	16.9
	1943	48.4	808.2	2,014,545	1,309	32.7	40	13.0
Santa Catalina Island	1942	87.6	507.4	7,765,690	3,653	19.8	184	9.0
	1943	119.8	576.8	6,956,872	1,580	16.0	99	4.5

TABLE 3

Average Catch and Fishing Effort of California Gill Net Boats

The information obtained from the interviews is summarized in table 3. The basic data consisted of boat records of total fathoms of net fished each day and the number of hours fished. Total fathom hours were obtained by summing (for each trip covered by the records) the products of the number of hours fished each day, multiplied by the fathoms of net fished. Combining trips for all boats from which records were obtained, the number of fathom hours was divided into the total number of shark caught on all these trips and the quotient was multiplied by 20,000 to give the average number of shark taken by 1,000 fathoms of net fished for 20 hours. These figures are given in column 8 in the table. It was difficult to obtain records of trips on which no shark were caught. The average catch shown is therefore high except in the case of the Santa Catalina fishery. The average found for Eureka in 1944 is probably too low since it includes trips landed in that port during only one week at the last of that year's fishing season. Previous years' data for this port were obtained during the peak of the season. The number of trips for which data have been obtained is given in column 7. The numbers involved in all ports are small and caution must be used in interpretating the data. The trends at all ports are downward, however, and this similarity indicates a general decline in the supply of sharks off the California coast. The decrease in total catch over the same time interval supports this conclusion. The trends are given in figure 3.

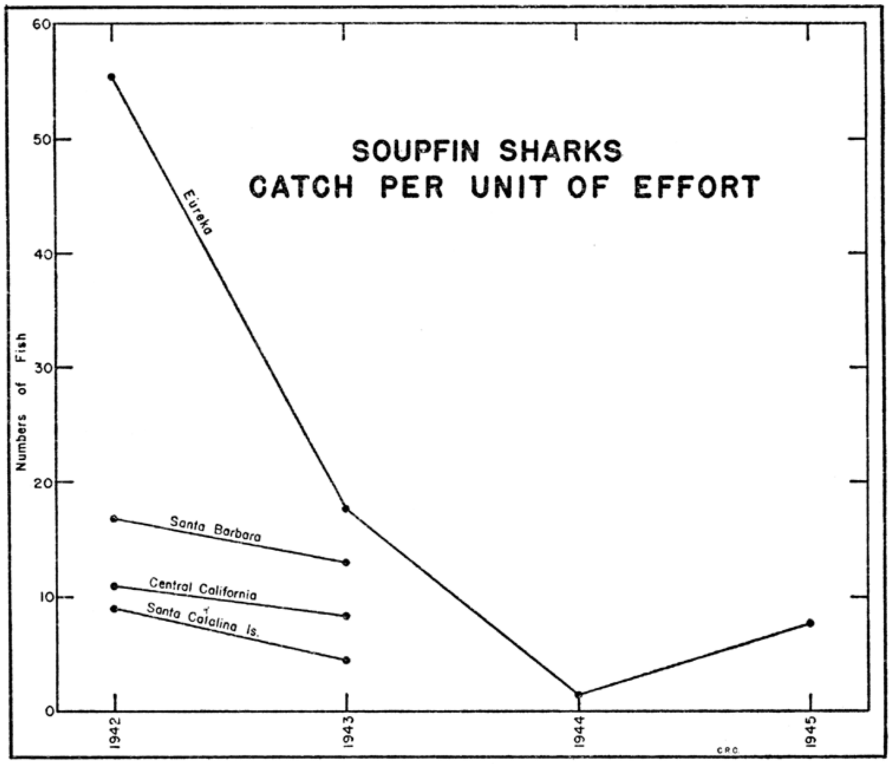


FIG. 3. Catch-per-unit-of-effort based on numbers of fish taken in 1,000 fathoms of diver gill net fished for 20 hours.

FIG. 3. Catch-per-unit-of-effort based on numbers of fish taken in 1,000 fathoms of diver gill net fished for 20 hours

Data are available for comparing trends in catch-per-unit for the years 1942 and 1943 in four areas. For these two years the catch in the different regions declined 23.1 to 68.1 per cent. At Eureka two additional year's data are at hand. Although for 1944 and 1945 the data are irregular, a continued decline is shown. The irregularities result from the limitations of the 1944 records. Those for 1942, 1943 and 1945 were obtained during the peak of the season whereas those for 1944 were collected near the end and are in all probability too low. In spite of irregularities there seems little doubt, however, that fishing success was at a lower level in the latter two years of the time interval. From information obtained from the industry and as evidenced by a declining total catch, the change noted in the average catch at Eureka is probably indicative of a change that took place along the entire coast.

1.4.3. Catch by Regions

The soupfin fishery is seasonal in nature. In northern California, there is a fall and winter fishery. Southern California has a spring and summer fishery. The monthly landings of soupfin shark from six different regions in which the coastal areas of California have been divided are shown in figure 4 and table 4. Although the data included are subject to the same errors as noted for the total landings, there is no reason to believe that they have acted selectively to render the seasonal nature of the landings inaccurate.

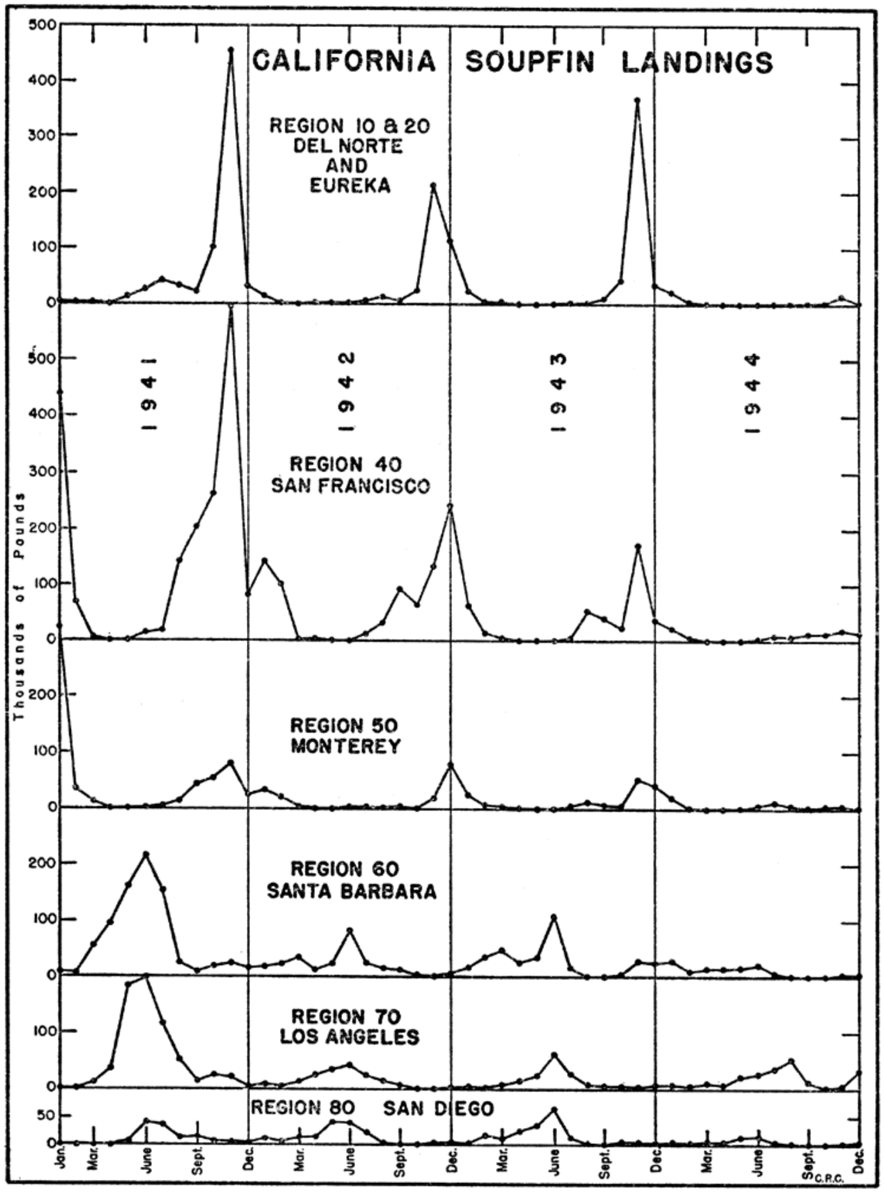
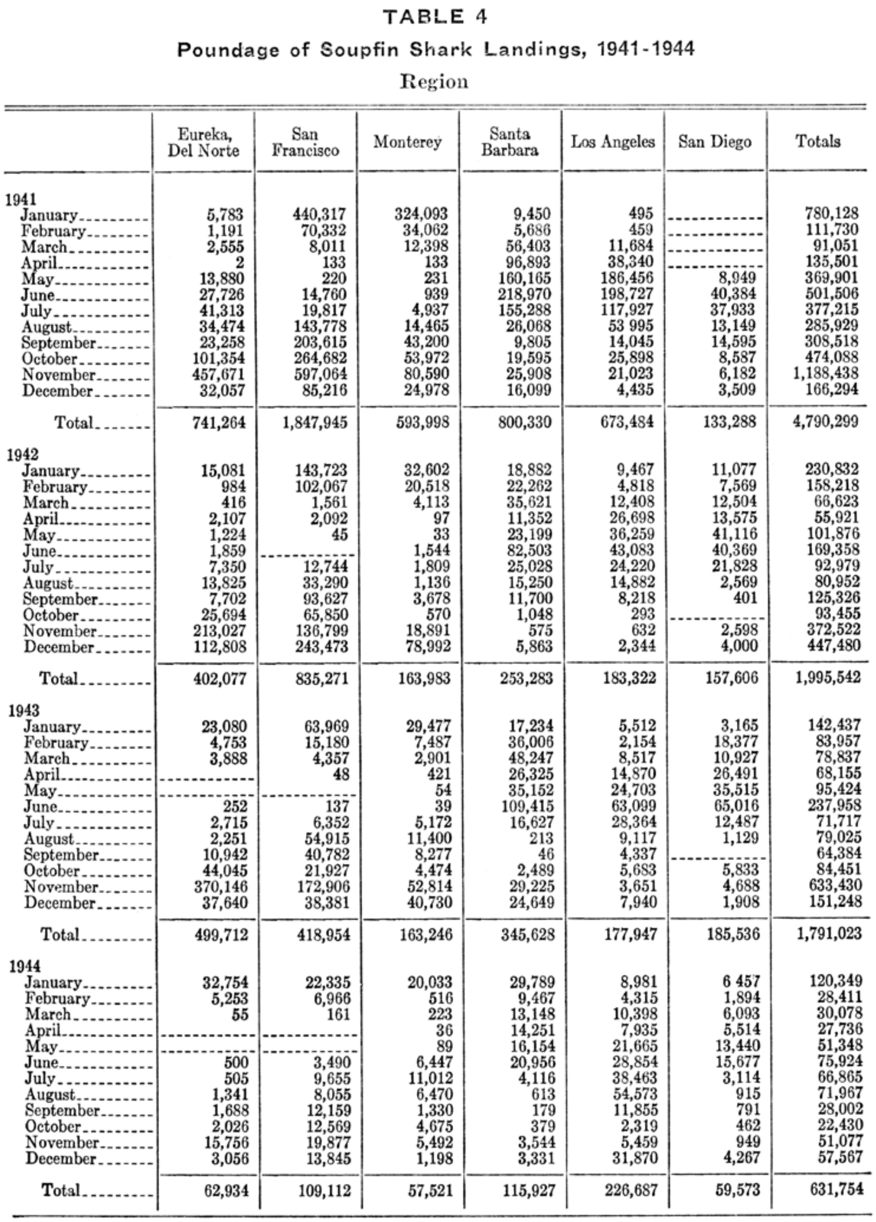


FIG. 4. California soupfin landings by months and regions for years 1941 to 1944. All regions are plotted on the same scale



	Eureka, Del Norte	San Francisco	Monterey	Santa Barbara	Los Angeles	San Diego	Totals
1941							
January	5,783	440,317	324,093	9,450	495	----------	780,128
February	1,191	70,332	34,062	5,686	459	----------	111,730
March	2,555	8,011	12,398	56,403	11,684	----------	91,051
April	2	133	133	96,893	38,340	----------	135,501
May	13,880	220	231	160,165	186,456	8,949	369,901
June	27,726	14,760	939	218,970	198,727	40,384	501,506
July	41,313	19,817	4,937	155,288	117,927	37,933	377,215
August	34,474	143,778	14,465	26,068	53 995	13,149	285,929
September	23,258	203,615	43,200	9,805	14,045	14,595	308,518
October	101,354	264,682	53,972	19,595	25,898	8,587	474,088
November	457,671	597,064	80,590	25,908	21,023	6,182	1,188,438
December	32,057	85,216	24,978	16,099	4,435	3,509	166,294
Total	741,264	1,847,945	593,998	800,330	673,484	133,288	4,790,299
1942							
January	15,081	143,723	32,602	18,882	9,467	11,077	230,832
February	984	102,067	20,518	22,262	4,818	7,569	158,218
March	416	1,561	4,113	35,621	12,408	12,504	66,623
April	2,107	2,092	97	11,352	26,698	13,575	55,921
May	1,224	45	33	23,199	36,259	41,116	101,876
June	1,859	----------	1,544	82,503	43,083	40,369	169,358
July	7,350	12,744	1,809	25,028	24,220	21,828	92,979
August	13,825	33,290	1,136	15,250	14,882	2,569	80,952
September	7,702	93,627	3,678	11,700	8,218	401	125,326
October	25,694	65,850	570	1,048	293	----------	93,455
November	213,027	136,799	18,891	575	632	2,598	372,522
December	112,808	243,473	78,992	5,863	2,344	4,000	447,480
Total	402,077	835,271	163,983	253,283	183,322	157,606	1,995,542
1943							
January	23,080	63,969	29,477	17,234	5,512	3,165	142,437
February	4,753	15,180	7,487	36,006	2,154	18,377	83,957
March	3,888	4,357	2,901	48,247	8,517	10,927	78,837
April	----------	48	421	26,325	14,870	26,491	68,155
May	----------	----------	54	35,152	24,703	35,515	95,424
June	252	137	39	109,415	63,099	65,016	237,958
July	2,715	6,352	5,172	16,627	28,364	12,487	71,717
August	2,251	54,915	11,400	213	9,117	1,129	79,025
September	10,942	40,782	8,277	46	4,337	----------	64,384
October	44,045	21,927	4,474	2,489	5,683	5,833	84,451
November	370,146	172,906	52,814	29,225	3,651	4,688	633,430
December	37,640	38,381	40,730	24,649	7,940	1,908	151,248
Total	499,712	418,954	163,246	345,628	177,947	185,536	1,791,023
1944							
January	32,754	22,335	20,033	29,789	8,981	6 457	120,349
February	5,253	6,966	516	9,467	4,315	1,894	28,411
March	55	161	223	13,148	10,398	6,093	30,078
April	----------	----------	36	14,251	7,935	5,514	27,736
May	----------	----------	89	16,154	21,665	13,440	51,348
June	500	3,490	6,447	20,956	28,854	15,677	75,924
July	505	9,655	11,012	4,116	38,463	3,114	66,865
August	1,341	8,055	6,470	613	54,573	915	71,967
September	1,688	12,159	1,330	179	11,855	791	28,002
October	2,026	12,569	4,675	379	2,319	462	22,430
November	15,756	19,877	5,492	3,544	5,459	949	51,077
December	3,056	13,845	1,198	3,331	31,870	4,267	57,567
Total	62,934	109,112	57,521	115,927	226,687	59,573	631,754

TABLE 4
Poundage of Soupfin Shark Landings, 1941–1944
Region

The regional distribution of landings does not indicate the region of catch for individual trips. The larger boats in some cases have fished as they move south along the coast from Washington and Oregon, landing their entire catch in Eureka or in San Francisco. Other landings represent catches obtained along much of the coast of California. However, in general, when fish are running in any quantity the boats land their catches in the nearest port and reoutfit, leaving their gear set on the grounds. An intense fishery is built up wherever the sharks are abundant. Therefore, the total landings in the regions may be accepted as representative of the seasonal fluctuations of abundance of shark in these localities.

Apparently the California shark fishery is divided by Point Conception into two areas. North of Point Conception the fishery is confined principally to the fall and winter months whereas south of this point, it is most successful during the spring and summer. The monthly catches of the three northern California regions show slight differences. off Eureka, soupfin are found in their greatest abundance during the months of October, November and December. Landings in San Francisco and Monterey are greatest from August to February. Substantial landings of soupfin occur earlier and continue later in San Francisco than at Eureka. Although the catch at Monterey did not reach the volume of either Eureka or San Francisco, the monthly trend of its fishery follows that of San Francisco.

The small increase in landings in the Santa Barbara region during the last few months of the year reflects mainly the landings made in Avila. This port is located north of Point Conception but is within the statistical region of Santa Barbara. Although Avila's shark landings follow the seasonal fluctuations of the northern region, they are so small that separation was not warranted. The Santa Barbara, Los Angeles and San Diego regions produce their greatest volume during April, May, June and July.

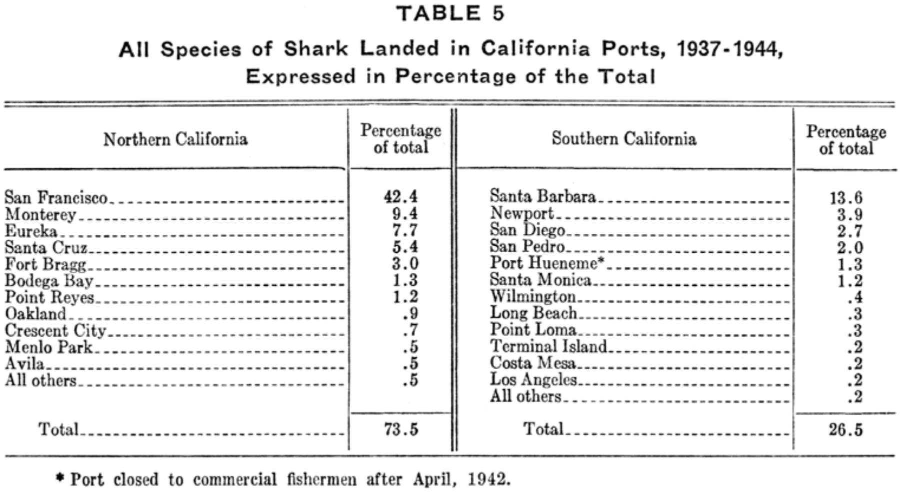


TABLE 5

All Species of Shark Landed in California Ports, 1937-1944, Expressed in Percentage of the Total

Northern California	Percentage of total	Southern California	Percentage of total
San Francisco	42.4	Santa Barbara	13.6
Monterey	9.4	Newport	3.9
Eureka	7.7	San Diego	2.7
Santa Cruz	5.4	San Pedro	2.0
Fort Bragg	3.0	Port Hueneme*	1.3
Bodega Bay	1.3	Santa Monica	1.2
Point Reyes	1.2	Wilmington	.4
Oakland	.9	Long Beach	.3
Crescent City	.7	Point Loma	.3
Menlo Park	.5	Terminal Island	.2
Avila	.5	Costa Mesa	.2
All others	.5	Los Angeles	.2
		All others	.2
Total	73.5	Total	26.5

* Port closed to commercial fishermen after April, 1942.

TABLE 5

All Species of Shark Landed in California Ports, 1937–1944, Expressed in Percentage of the Total

The importance of the various regions and cities in the State in the production of shark was obtained from the catch records of 1937 to 1944. The landings made in each California port during this time were summed and the result expressed as a percentage of the total. These are given in table 5. During the past eight years San Francisco received 42.4 per cent of all shark landed. Santa Barbara followed with 13.6 per cent. Divided into northern and southern California, the area north of Point Conception produced 73.5 per cent of the total catch. South of this point the catch amounted to 26.5 per cent. With Santa Barbara excluded the whole of southern California produced only 12.9 per cent of the shark catch.

1.5. SEX RATIOS

1.5.1. By Region

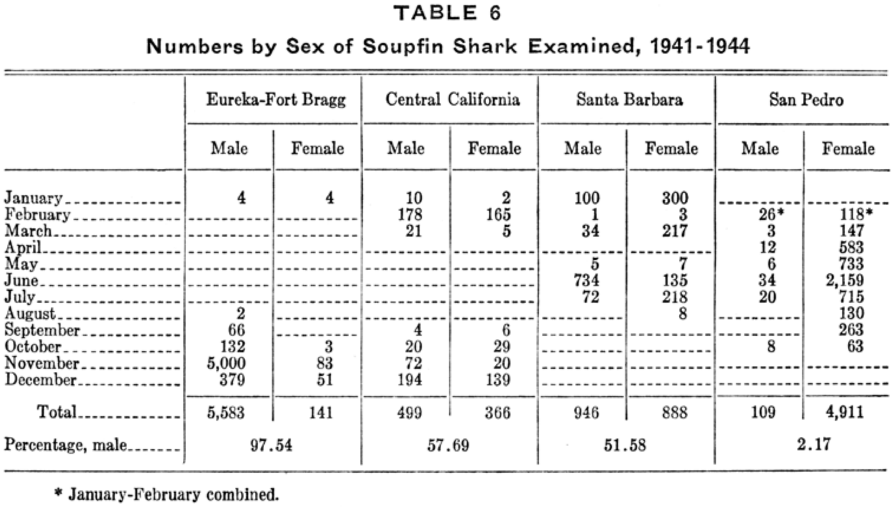


TABLE 6

Numbers by Sex of Soupfin Shark Examined, 1941-1944

	Eureka-Fort Bragg		Central California		Santa Barbara		San Pedro	
	Male	Female	Male	Female	Male	Female	Male	Female
January	4	4	10	2	100	300	-----	-----
February	-----	-----	178	165	1	3	26*	118*
March	-----	-----	21	5	34	217	3	147
April	-----	-----	-----	-----	-----	-----	12	583
May	-----	-----	-----	-----	5	7	6	733
June	-----	-----	-----	-----	734	135	34	2,159
July	-----	-----	-----	-----	72	218	20	715
August	2	-----	-----	-----	-----	8	-----	130
September	66	-----	4	6	-----	-----	-----	263
October	132	3	20	29	-----	-----	8	63
November	5,000	83	72	20	-----	-----	-----	-----
December	379	51	194	139	-----	-----	-----	-----
Total	5,583	141	499	366	946	888	109	4,911
Percentage, male	97.54		57.69		51.58		2.17	

* January-February combined.

TABLE 6

Numbers by Sex of Soupfin Shark Examined, 1941–1944

Sex ratios were obtained from records collected by examining catches when landed, and from records kept by the more enterprising captains. The data are summarized in table 6. Material from San Francisco and Monterey was insufficient to present separately, and since the fishing grounds for these two ports overlap the records have been combined. The samples obtained from the Eureka-Fort Bragg region consisted of 97.5 per cent males. In contrast the samples from the Central California and Santa Barbara regions gave 57.7 and 51.6 per cent males respectively and the samples obtained from the San Pedro region were composed of 2.2 per cent males and 97.8 per cent females. During the period of sampling in the San Pedro region, the catch was dominated by the Santa Catalina Island fishery. However, male sharks have been so scarce in this entire region that dealers have seldom quoted prices for males south of Point Dume. Dr. Carl L. Hubbs of the Scripps Institution of Oceanography at La Jolla, California, states fishermen have informed him that catches of adult males are made in deep water with set line gear. The closure of most of the outer Channel Islands to fishing operations as a war measure may have prevented the development of a deep water fishery for males.

Table 6 gives by months the numbers of shark of each sex in the sampled commercial catch in the four regions. The data indicate, with the exception of Santa Barbara, that the distribution of the sexes is more or less similar whether considered by months or for the entire year. The landings by months during the season at Santa Barbara are predominantly female except during the month of June. At this time the sampling reflects the catches of males taken off Santa Cruz Island by an intensive, localized, deep water fishery. When the male soupfin appear off the Island most of the boats able to fish the area abandon other locations and concentrate on the male fishery. For the brief season the grounds off Yellow Bluff (Santa Cruz Island) are throttled by gill nets. The concentration of male soupfin in the area lasts for a short time, and as the males move off or are captured, the fishery collapses as suddenly as it appears.

1.5.2. By Depth

Preliminary examination of the data indicated that the variations in the sex ratios of the catch might be associated with depth of capture. In many cases it was possible to match the samples with an average depth that was representative of the area of fishing. The total number of shark taken that could be analyzed in this manner is shown in figure 5 and table 7.

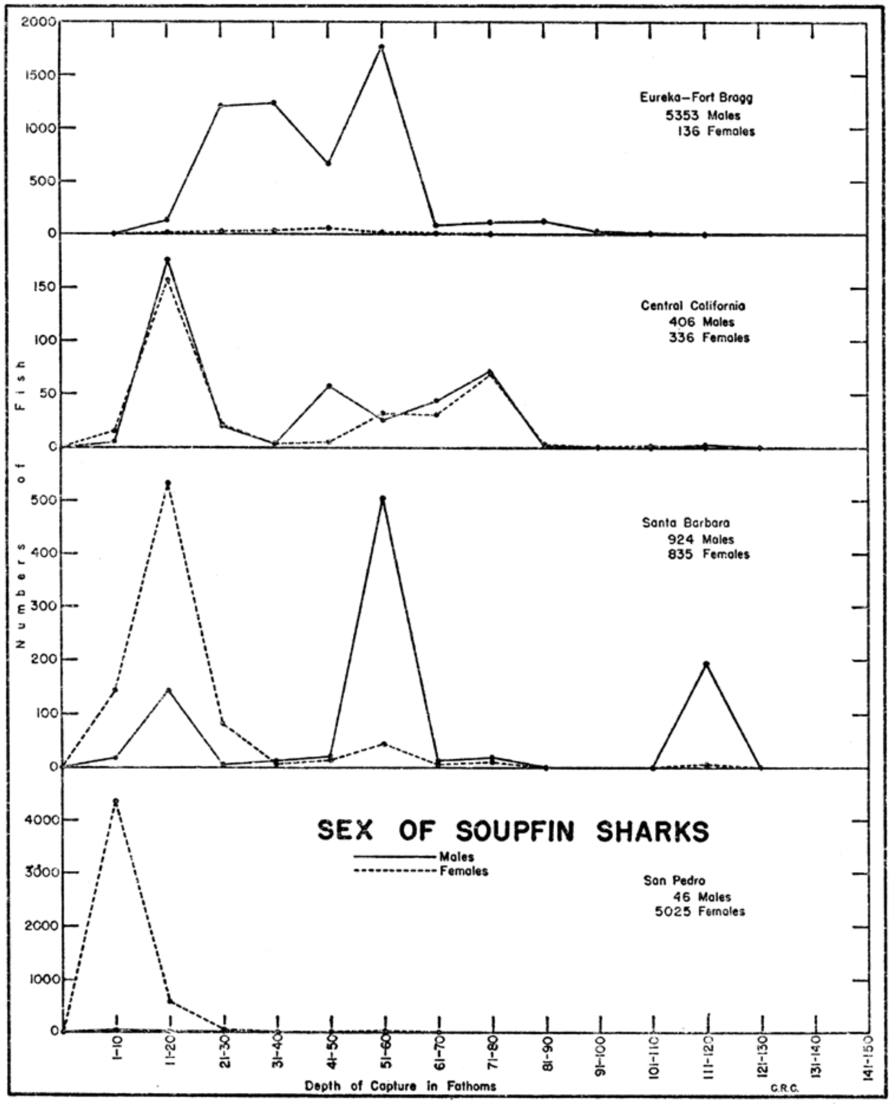
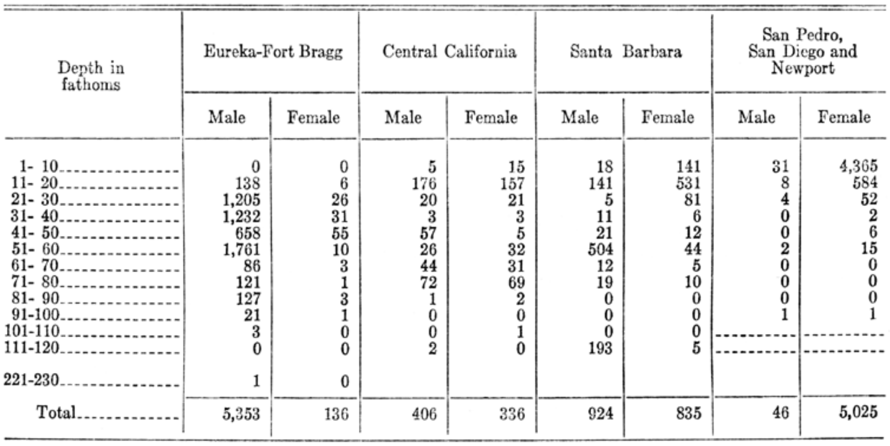


FIG. 5. Sex of soupfin shark and depth of capture.

FIG. 5. Sex of soupfin shark and depth of capture

TABLE 7

Sex of Soupfin Shark and Depth of Capture, 1941-1944



Depth in fathoms	Eureka-Fort Bragg		Central California		Santa Barbara		San Pedro, San Diego and Newport	
	Male	Female	Male	Female	Male	Female	Male	Female
1- 10	0	0	5	15	18	141	31	4,365
11- 20	138	6	176	157	141	531	8	584
21- 30	1,205	26	20	21	5	81	4	52
31- 40	1,232	31	3	3	11	6	0	2
41- 50	658	55	57	5	21	12	0	6
51- 60	1,761	10	26	32	504	44	2	15
61- 70	86	3	44	31	12	5	0	0
71- 80	121	1	72	69	19	10	0	0
81- 90	127	3	1	2	0	0	0	0
91-100	21	1	0	0	0	0	1	1
101-110	3	0	0	1	0	0	----------	----------
111-120	0	0	2	0	193	5	----------	----------
221-230	1	0						
Total	5,353	136	406	336	924	835	46	5,025

TABLE 7

Sex of Soupfin Shark and Depth of Capture, 1941–1944

In northern and central California, the sexes seem to be distributed through the total range of depth of fishing in about the same proportion as they occur in the catch. In Santa Barbara, however, there is indicated a preponderance of females in depths less than 30 fathoms. Little information on catches has been obtained from the San Pedro region from depths greater than 35 fathoms. However it is obvious that south of Point Conception catches made in depths less than 30 fathoms may be expected to consist mostly of females. The males taken in the Santa Barbara region were taken for the main part in the vicinity of Santa Cruz Island during June and July.

It is evident from the data that there is a segregation of sexes in the different fishing areas of California. In northern California, the fishery is concentrated upon males. In central California and in the Santa Barbara region, males and females occur in about equal numbers in the catch. But in the latter region, a predominance of females is found in depths less than 30 fathoms. Although the records of catches of San Pedro do not include many fares from deep waters, 97.8 per cent of the sharks sampled were female. Those Santa Catalina Island fishermen who did prospect in deep water did not catch shark. The ratio of sexes is considered characteristic of the population inhabiting depths less than 30 fathoms in this area.

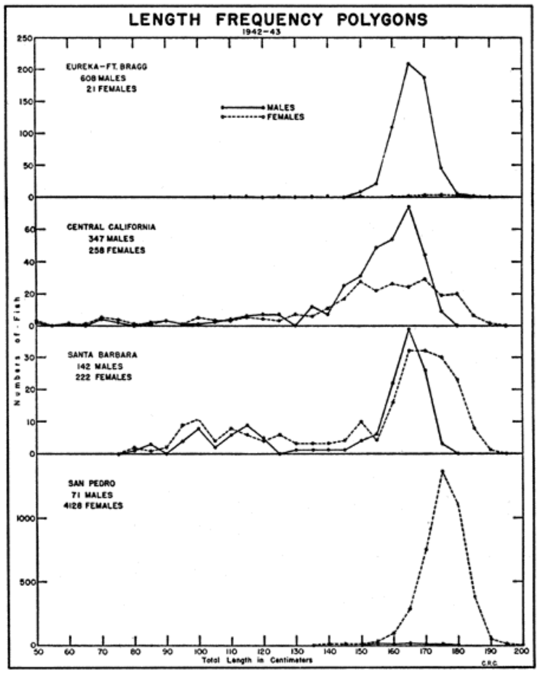


FIG. 6. Size of soupfin shark by region. The data are grouped by 5 cm. classes.

FIG. 6. Size of soupfin shark by region. The data are grouped by 5 cm. classes

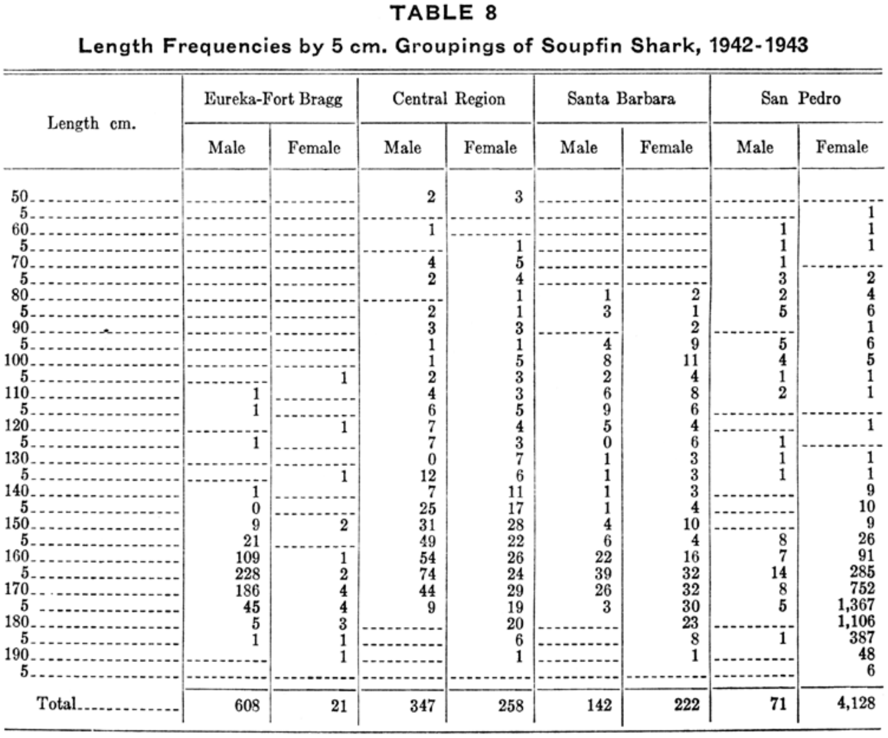


TABLE 8

Length Frequencies by 5 cm. Groupings of Soupfin Shark, 1942-1943

Length cm.	Eureka-Fort Bragg		Central Region		Santa Barbara		San Pedro	
	Male	Female	Male	Female	Male	Female	Male	Female
50			2	3				
5								1
60			1				1	1
5				1			1	1
70			4	5			1	
5			2	4			3	2
80				1	1	2	2	4
5			2	1	3	1	5	6
90			3	3		2		1
5			1	1	4	9	5	6
100			1	5	8	11	4	5
5		1	2	3	2	4	1	1
110	1		4	3	6	8	2	1
5	1		6	5	9	6		
120		1	7	4	5	4		1
5	1		7	3	0	6	1	
130			0	7	1	3	1	1
5		1	12	6	1	3	1	1
140	1		7	11	1	3		9
5	0		25	17	1	4		10
150	9	2	31	28	4	10		9
5	21		49	22	6	4	8	26
160	109	1	54	26	22	16	7	91
5	228	2	74	24	39	32	14	285
170	186	4	44	29	26	32	8	752
5	45	4	9	19	3	30	5	1,367
180	5	3		20		23		1,106
5	1	1		6		8	1	387
190		1		1		1		48
5								6
Total	608	21	347	258	142	222	71	4,128

TABLE 8

Length frequencies by 5 cm. Groupings of Soupfin Shark, 1942–1943

1.5.3. Size by Region

Total length measurements were made of all shark from which liver samples were obtained and from fish in samples of commercial catches. In addition small shark were obtained from the hook and line fishery of San Francisco Bay and the sea-bass net-fishery of Santa Barbara. The lengths of the fish obtained from the various areas are shown in figure 6, table 8. In making these measurements the tail was straightened and the length was taken to the nearest centimeter from the tip of the nose to the end of the tail. The lengths are grouped in five centimeter classes. Most of the small fish were taken in the Central California and the Santa Barbara areas. The occurrence of these small fish in the landings depends to a great extent upon their incidental capture wherever gear is run that is suitable for their taking. Considerable numbers of young soupfin were taken by hook and line bottom fishing in San Francisco Bay and in the Monterey area. A few were also taken by gill nets fished in Tomales Bay. Small soupfin are said to be taken in large numbers in hook and line and dragnet fisheries operating out of Avila. Few measurements have been obtained of the small fish from Avila. The negatively skewed frequency polygons of Central California and Santa Barbara regions therefore are not entirely representative of the commercial 10½-inch net catch. Many of the small sized shark were obtained from vessels fishing hook and line or from net boats fishing a smaller meshed gear than that customarily used.

As a substantial proportion of the samples from the central region were derived from Monterey hook and line boats, the data from this port were separated into hook and line caught fish and net caught fish to test the selectivity of the two types of gear, (table 9). Classified in this manner the data reveals that the size distribution of sharks taken by hook and line covers a greater range than that of net gear. From a total of 173 net caught fish in the Monterey region none were taken below the 140 cm. class, whereas from a total of 259 hook and line caught fish, 64 specimens were recorded ranging from the 50 to 135 cm. classes. The net, and hook and line frequencies were tested by chi square. For both males and females P has a value of less than 0.0001 showing that the differences are significant and that the net gear selects the larger sized shark. This in part would account for the greater proportion of smaller sized shark in the length frequency distribution from the Central region. However in a study of the size distributions of the Central and Eureka-Fort Bragg regions, using for the Central region net caught fish only, P had a value of less than 0.0001 and showed that larger numbers of small fish were taken in Central California (Fig. 7).

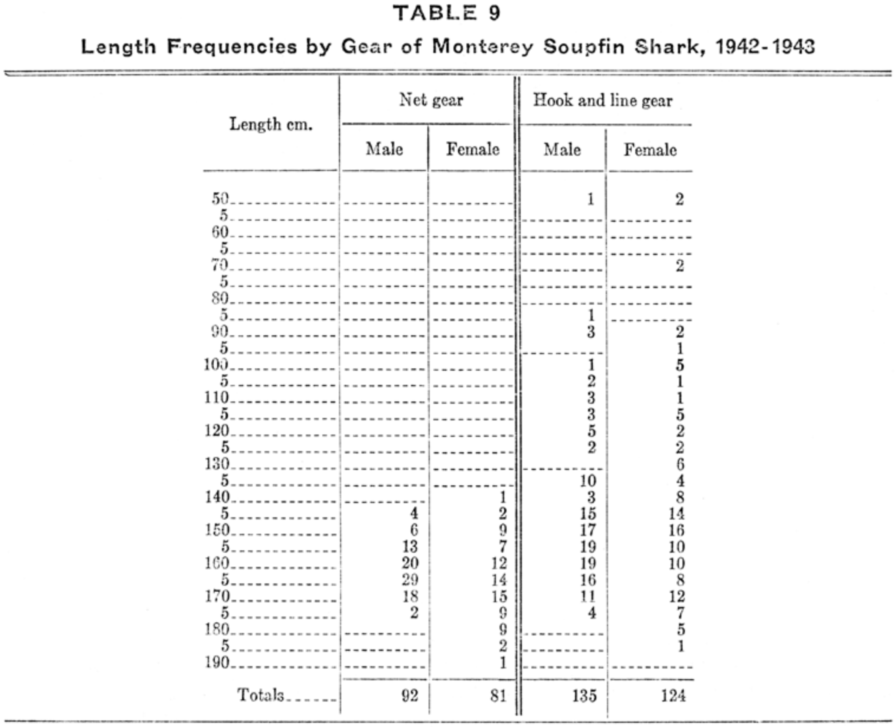


TABLE 9

Length Frequencies by Gear of Monterey Soupfin Shark, 1942-1943

Length cm.	Net gear		Hook and line gear	
	Male	Female	Male	Female
50	----	----	1	2
5	----	----	----	----
60	----	----	----	----
5	----	----	----	----
70	----	----	----	2
5	----	----	----	----
80	----	----	----	----
5	----	----	1	----
90	----	----	3	2
5	----	----	----	1
100	----	----	1	5
5	----	----	2	1
110	----	----	3	1
5	----	----	3	5
120	----	----	5	2
5	----	----	2	2
130	----	----	----	6
5	----	----	10	4
140	----	1	3	8
5	4	2	15	14
150	6	9	17	16
5	13	7	19	10
160	20	12	19	10
5	29	14	16	8
170	18	15	11	12
5	2	9	4	7
180	----	9	----	5
5	----	2	----	1
190	----	1	----	----
Totals	92	81	135	124

TABLE 9

Length Frequencies by Gear of Monterey Soupfin Shark, 1942–1943

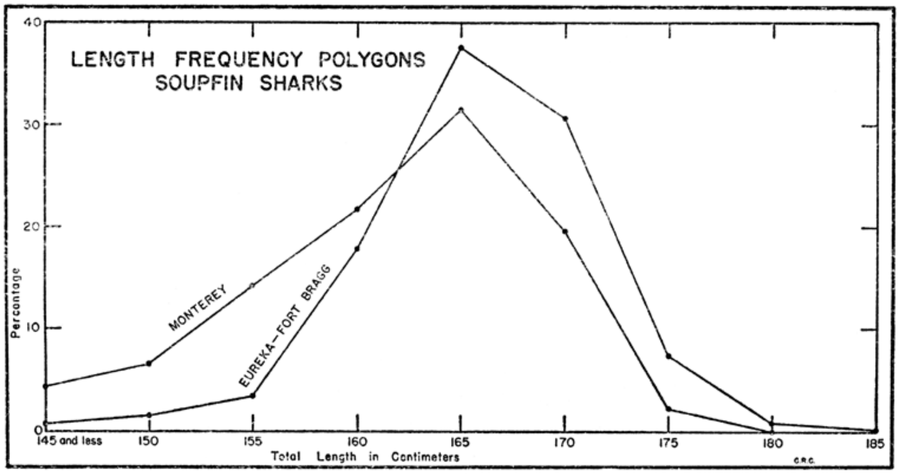


FIG. 7. Comparison of length frequency polygons of Monterey and Eureka-Fort Bragg fisheries.

FIG. 7. Comparison of length frequency polygons of Monterey and Eureka-Fort Bragg fisheries

1.5.4. Females

The females taken in the San Pedro region by the Santa Catalina fishery were uniformly of a large size with the mode at approximately 175 cms. A group of large females with a mode between 165 and 170 cm. characterizes the Santa Barbara fishery. No definite mode is shown by the females taken in Central California. However, although data for female soupfin in Central California were not characterized by a well defined mode, the frequency distribution of this area revealed a relatively large proportion of immature fish. So few females were taken in the Eureka-Fort Bragg samples that no conclusion can be drawn regarding the sizes. The Santa Barbara fishery produced a greater proportion of small females than San Pedro. With the exception of January and February 1942, the mode for each month of the year in the San Pedro fishery remained at 175 cm.

The homogeneity of the size distributions from these three regions, excluding all fish of lengths below the 140 cm. group, was tested by chi square.

The length frequencies of female soupfin taken in Central California were compared with those of Santa Barbara and San Pedro; those of San Pedro were compared with Santa Barbara. In all cases P was less than 0.0001 indicating that the sizes of fish available to the fishery in the three regions are significantly different.

The frequency distributions of female soupfin in the various areas demonstrate several facts. Not only is there a sexual difference in the commercial catch in each region but there is also a size difference. Progressing southward, the fishery consists of greater numbers of more mature female soupfin. The northern and central regions have greater proportions of smaller immature female shark. The area north of Point Arena is of no particular importance in the capture of females. In the Santa Barbara region, the bulk of the fishery draws on females of somewhat larger sizes than those taken north of this area. The San Pedro fishery draws on mature fish.

1.5.5. Males

In the three regions where males are taken in significant numbers the modes of the length frequencies lie at 165 cm. The Eureka-Fort Bragg area, however, has a greater frequency of males in the larger size groups than does either the central or the Santa Barbara region. The homogeneity of the size distributions from all groups 140 cm. and over was tested by chi square. The length frequencies of Central California male soupfin differ significantly from those of Eureka-Fort Bragg and from Santa Barbara with P in both cases less than 0.0001. The size distributions of Eureka-Fort Bragg and Santa Barbara are also probably significantly different as in this comparison P had a value of 0.022. The few males taken in the San Pedro region indicate the same mode as those taken in the regions to the north. The number of specimens examined in this area is not sufficient to draw any further conclusions. For the entire coast, the data indicate that the size distributions of male soupfin by area are the reverse of those of the females. That is, progressing northward the catch consists of larger and more mature males.

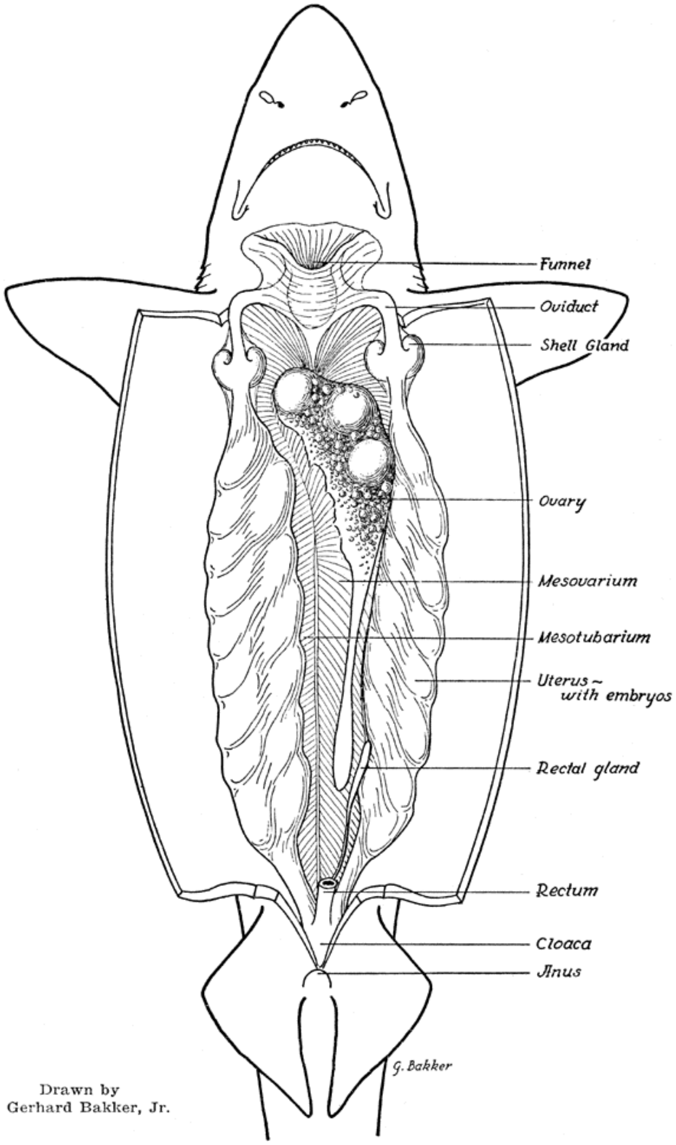
1.5.6. Nursery Grounds

The location of nursery areas are indicated from these and other data. Some young are found in Tomales and San Francisco Bays but they are apparently more abundant south of Point Conception. In the course of obtaining specimens of soupfin for tagging several young soupfin between 34 and 38 cm. in length were taken with a drift line off the Santa Barbara Coast. Young soupfin are taken in considerable numbers on the Ventura Flats east of Santa Barbara where trawlers occasionally load up with them. Hook and line gear operates with fair efficiency and smaller mesh nets capture immature soupfin in significant numbers in that locality.

In addition to the fact that young soupfin are more abundant on the southern California grounds, adult female soupfin are taken in greatest quantity in this area. The average size of the females taken in southern California is larger and the percentage of mature females is also greater. These facts point to the importance of southern California as a nursery for soupfin but other areas where young soupfin are found in sufficient numbers to warrant their protection, may exist and their importance should not be minimized.

1.6. SIZE AT MATURITY

The soupfin shark is ovoviviparous. The eggs and embryos are carried in the uterus through the period of development, although the nourishment of the embryo is considered to come entirely from the large egg. The egg develops in the ovary, breaks through the wall, enters the funnel, is fertilized and passes through the shell gland, receiving its protective cloak there. It is then carried into the uterus where the embryo grows until birth. In figure 8 which shows the female sex organs the funnel has been turned up toward the head. In life the funnel is folded back and lies under the ovary.



Drawn by
Gerhard Bakker, Jr.

FIG. 8. Reproductive system of a female soupfin containing fertilized eggs in the uteri. Note the developing eggs in the ovary

The gross internal anatomy of the male is similar to that of the female except for the urogenital system. The testes of the male produce the sex cells which pass through the vasa efferentia into the vas deferens and empty into the sperm sac where the sperm cells remain until copulation takes place. At the terminal portion of the system are the secondary sexual organs. These are the claspers, two fingerlike modifications of the median margins of the ventral fins which function as an intromittent organ to transfer sperm into the cloaca of the female. They serve as a convenient means of identification of males.

Maturity in female shark is here defined as that state of sexual development in which large ovarian eggs, embryos (fertilized eggs), or pups (near term embryos) are evident. Large ovarian eggs are roughly the size of a golf ball, four to six centimeters in diameter. Such eggs are present in the ovary immediately prior to fertilization. The adopted criterion of maturity in males was the presence of seminal fluid or an enlarged and vascular appearance of the gonads. When in this condition, the testes are enlarged and are roughly triangular in cross section. All males noted with either or both of these characteristics were considered mature.

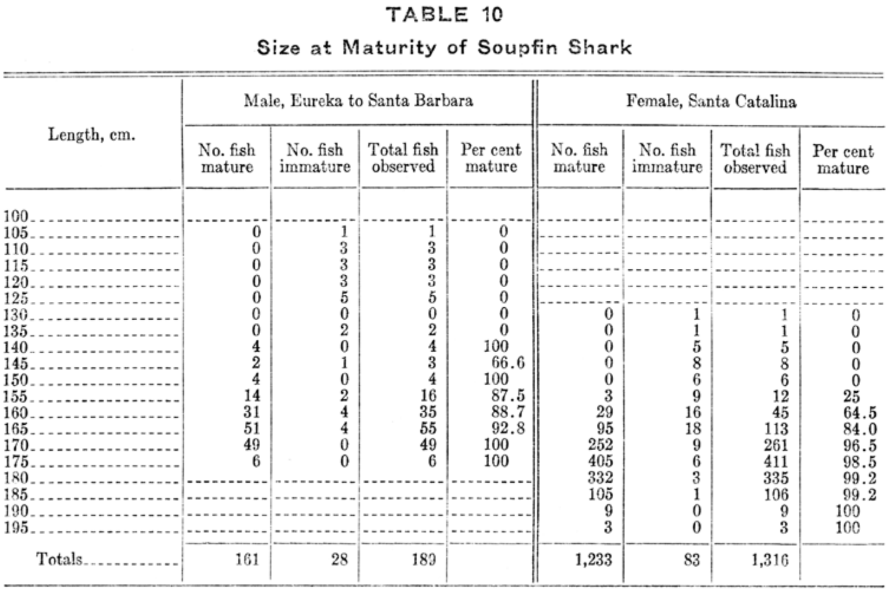


TABLE 10

Size at Maturity of Soupfin Shark

Length, cm.	Male, Eureka to Santa Barbara				Female, Santa Catalina			
	No. fish mature	No. fish immature	Total fish observed	Per cent mature	No. fish mature	No. fish immature	Total fish observed	Per cent mature
100	---	---	---	---	---	---	---	---
105	0	1	1	0	---	---	---	---
110	0	3	3	0	---	---	---	---
115	0	3	3	0	---	---	---	---
120	0	3	3	0	---	---	---	---
125	0	5	5	0	---	---	---	---
130	0	0	0	0	0	1	1	0
135	0	2	2	0	0	1	1	0
140	4	0	4	100	0	5	5	0
145	2	1	3	66.6	0	8	8	0
150	4	0	4	100	0	6	6	0
155	14	2	16	87.5	3	9	12	25
160	31	4	35	88.7	29	16	45	64.5
165	51	4	55	92.8	95	18	113	84.0
170	49	0	49	100	252	9	261	96.5
175	6	0	6	100	405	6	411	98.5
180	---	---	---	---	332	3	335	99.2
185	---	---	---	---	105	1	106	99.2
190	---	---	---	---	9	0	9	100
195	---	---	---	---	3	0	3	100
Totals	161	28	189		1,233	83	1,316	

TABLE 10
Size at Maturity of Soupfin Shark

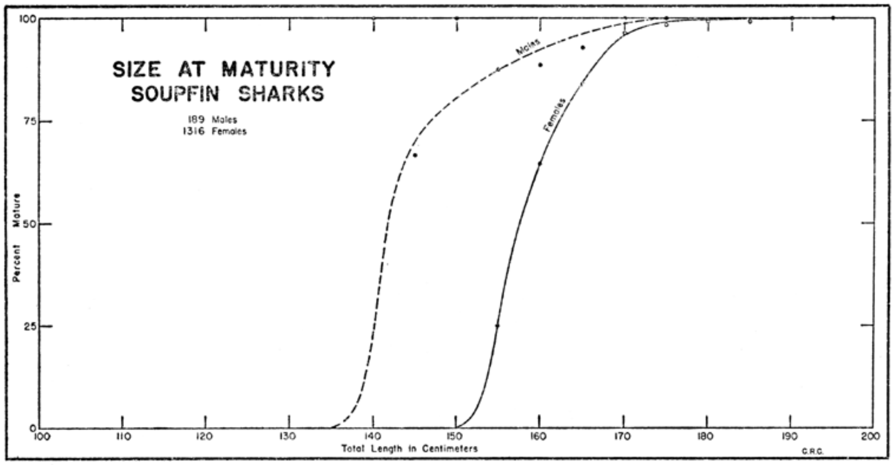


FIG. 9. The male curve between 135 and 155 cm. is based on so few specimens that it may not be indicative of the true trend. Note the two points at 140 and 150 cm.

FIG. 9. The male curve between 135 and 155 cm. is based on so few specimens that it may not be indicative of the true trend. Note the two points at 140 and 150 cm

The maturity data are based on 189 males and 1316 females. The numbers of immature and mature shark of both sexes grouped by five centimeter length classes are shown in table 10. The percentage mature for each length group is plotted in figure 9. The percentage mature in the males is irregular between 135 cm. and 155 cm. and due to lack of data, it is impossible to establish the percentage mature within this length range. No mature fish were found with a length less than 135 cm. and at a length of 155 cm., approximately 87 per cent were mature. Measurements were obtained on enough females to establish the percentage mature throughout the range of sizes. No mature females were observed under 150 cm. At 155 cm., 25 per cent of the females were mature and at 160 cm., 65 per cent. The percentage gradually increased therafter until all females over 190 cm. were mature.

1.7. REPRODUCTIVE CYCLE

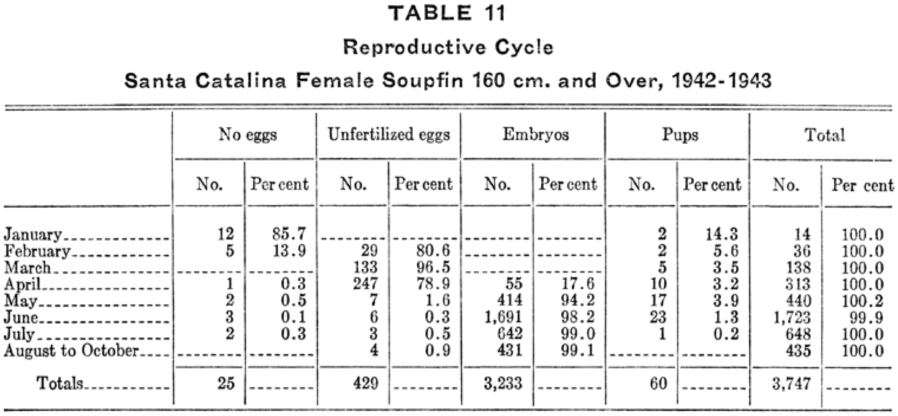


TABLE 11

Reproductive Cycle

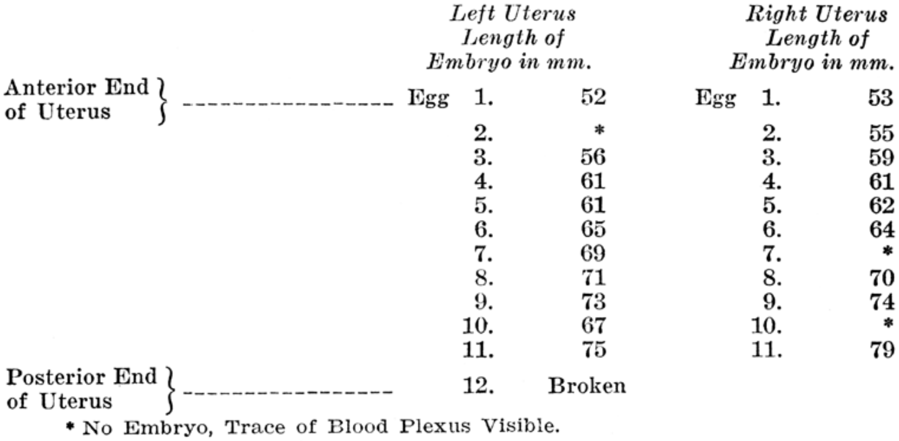
Santa Catalina Female Soupfin 160 cm. and Over, 1942-1943

	No eggs		Unfertilized eggs		Embryos		Pups		Total	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
January	12	85.7	--------	--------	--------	--------	2	14.3	14	100.0
February	5	13.9	29	80.6	--------	--------	2	5.6	36	100.0
March	--------	--------	133	96.5	--------	--------	5	3.5	138	100.0
April	1	0.3	247	78.9	55	17.6	10	3.2	313	100.0
May	2	0.5	7	1.6	414	94.2	17	3.9	440	100.2
June	3	0.1	6	0.3	1,691	98.2	23	1.3	1,723	99.9
July	2	0.3	3	0.5	642	99.0	1	0.2	648	100.0
August to October	--------	--------	4	0.9	431	99.1	--------	--------	435	100.0
Totals	25	--------	429	--------	3,233	--------	60	--------	3,747	--------

TABLE 11

Reproductive Cycle Santa Catalina Female Soupfin 160 cm. and Over, 1942–1943

The annual reproductive cycle of female soupfin has been worked out for the Santa Catalina Island females only. All fish 160 cm. and greater in total length were classified into four groups as follows: those with no ovarian eggs, those with ovarian eggs, those with embryos (fertilized eggs) and those containing pups. The number and percentage of fish falling into each group is shown for each month in table 11. The data were collected during 1942 and 1943. There was no fishing in this area in January and February of 1943 and only a few specimens were available for these two months in 1942. The percentages of table 11 must be interpreted with care since it is evident that few of the females remain in this area to give birth to their young. The proportion of fish in different stages is therefore affected by emigration and immigration of females in different stages of development. They are sufficient to indicate, however, that fertilization of the eggs takes place during the spring. By May, few females were found which contained unfertilized eggs. The growth of the embryos through the succeeding months has been followed in the Santa Catalina specimens. In each female the embryos in the posterior portion of the uteri were of larger size than in the anterior portion. This size difference is illustrated in the following table which gives the measurements of all embryos taken from a 170 cm. female.



		Left Uterus Length of Embryo in mm.		*Right Uterus Length of Embryo in mm.*
Anterior End of Uterus	Egg 1.	52	Egg 1.	53
	2.	*	2.	55
	3.	56	3.	59
	4.	61	4.	61
	5.	61	5.	62
	6.	65	6.	64
	7.	69	7.	*
	8.	71	8.	70
	9.	73	9.	74
	10.	67	10.	*
	11.	75	11.	79
Posterior End of Uterus	12.	Broken		

* No Embryo, Trace of Blood Plexus Visible.

TABLE

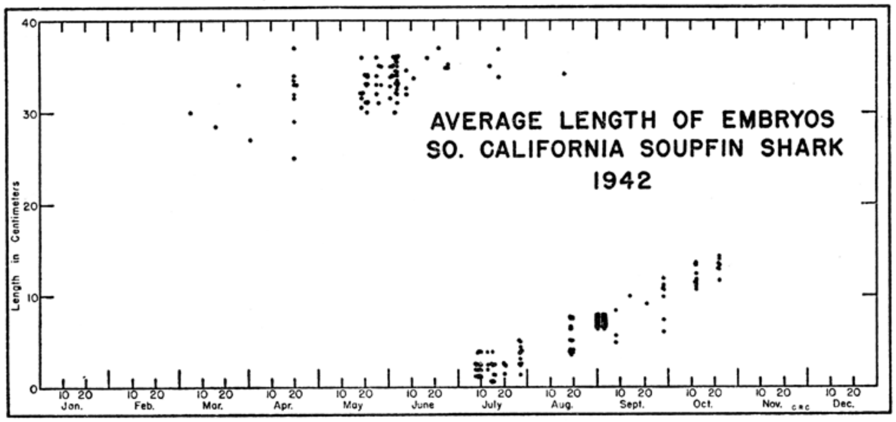


FIG. 10. Each dot represents the average size of litter in a single specimen except in those litters where the average falls under 15 cm. in which cases each dot represents the approximate average length of the posterior uterine embryos. At birth soupfin average 35 to 37 cm.

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In figure 10 is shown the seasonal size increase of the embryos from fertilization until birth. In this figure each dot represents the approximate average size of embryos in one female. The data from July through October are from the Santa Catalina collections. These show a progressive size increase to over 10 cm. No more collections were available until the succeeding March. For the following months, samples from the entire coast have been included. By April the pups varied in size from 28 to 37 cm. and showed little growth through the succeeding months: May, June and July. This lack of growth would occur if the pups were born during this time interval at approximately 35 cm. in length. (Figure 10 represents measurements of uterine pups only.) Thus the embryonic growth suggests a gestation period of about one year.

1.8. FECUNDITY

Two measures of the fecundity of soupfin shark are available—embryo counts and pup counts. Both are subject to error. However, the embryo count has been taken as more reliable because the possibility of error in this observation is less than that in the pup count. Not uncommonly, females containing pups near term, also possessed one or two undeveloped eggs in the uteri. As noted by Mr. Charles Clothier of the California State Fisheries Laboratory, these eggs located in the posterior positions in the uteri, did not contain embryos nor did they show any sign of development. This, of course, subjects the embryo counts to an error, but as this condition was not evident during the early developmental period, no allowance could be made for this factor. The counts of pups are variable but are subject to even greater error since pregnant females frequently give premature birth to near term young after capture. On several occasions a gravid female shark was observed liberating her young as she was being hauled out of water or as she lay on deck.

1.8.1. Pup Count

Pregnant female soupfin near term examined for fecundity contained from 6 to 52 pups in the uteri.

1.8.2. Embryo Count

Size and fertilized egg counts for June and July of Santa Catalina Island female soupfin were grouped and plotted to show the relationship of fecundity to the size of the fish. A least squares line was fitted to the averages. (Fig. 11) The numbers of fertilized eggs vary from 16 to 54. Counts taken of the fertilized eggs were accompanied by observation of whether small or large eggs were present in the ovary. Some of the lower counts are due to the fact that one to several large unfertilized eggs were still in the ovary when the fish were taken. (Fig. 8)

The numbers increase with the size of the parent at the rate expressed by the formula $Y = -54.037 + .512X$ where X is the length in centimeters and Y is the number of fertilized eggs. The calculated number of fertilized eggs contained in a shark 160 cm. in total length is 28, at 170 cm. 33 and at 180 cm. 38. Soupfin 175 cm. in length, the size of females most frequently taken by the Santa Catalina Island commercial fishery, average 35 embryos.

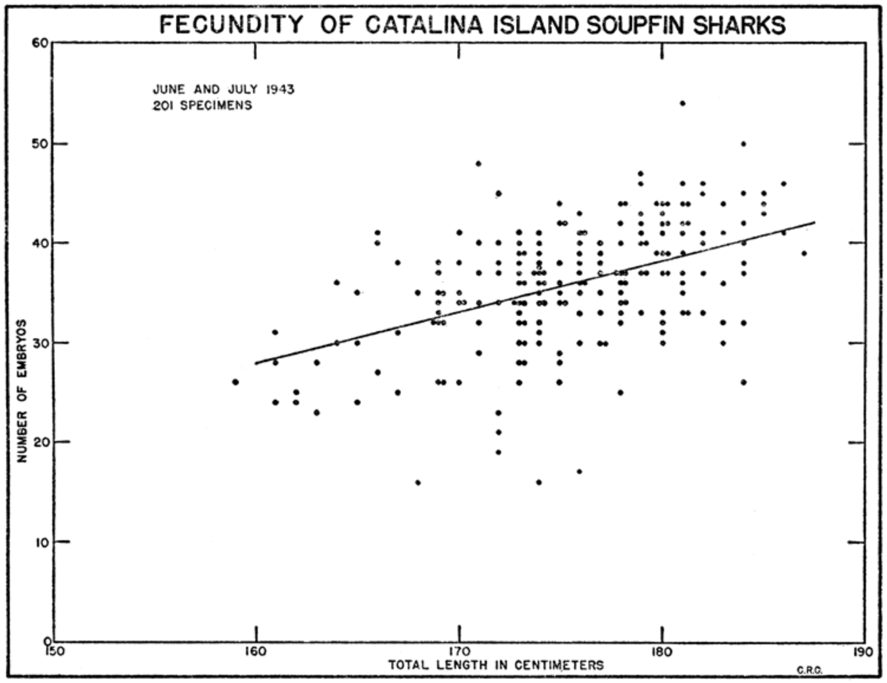

FIG. 11. The regression line is fitted by the method of least squares.

FIG. 11. The regression line is fitted by the method of least squares

1.9. WEIGHT-LENGTH RELATIONSHIP

Data for the weight-length relationship were assembled from shark measurements taken with liver samples and from measurements made by sampling the commercial catch in the various ports of California. The data represent fish in all states of sexual maturity and no attempt was made to correct for this factor in the males. However, as there was an obvious change in rate of increase of weight with increase of length in females over 150 cm. in length, separate curves were calculated for females under 150 cm. and for those over 150 cm. in length. One curve was calculated for male soupfin 40 to 180 cm. in length. The data were grouped by 10 cm. classes and the average lengths and average weights were calculated. These average values with appropriate weights were fitted by the method of least squares, to the curve of $Y = a x^b$. (Clark, 1928) This formula can be expressed as $\log Y = \log a + b \log X$, where $\log Y$ represents the logarithm of the weight in pounds and $\log X$ is the logarithm of the length in centimeters.

The weight of male soupfin sharks increases as the length to the 3.2 power. No significant change in rate of increase of weight is observed after the fish reach maturity. The relationship is shown graphically in figure 12. A line was fitted to the data by the formula $\log Y = -5.41124 + 3.18564 \log X$.

The increase of the weight of females with increase in length for fish 40 to 149 cm. long was measured by $\log Y = -5.57297 + 3.26954 \log X$. The formula for female soupfin 150 cm. and greater is $\log Y = -7.48993 + 4.15605 X$. Above 150 cm. the weight of mature females increases rapidly. The change in the weight-length relationship noted at this point is associated with the development of the ovary and of the sex products. (Fig. 13). Immature females increase in

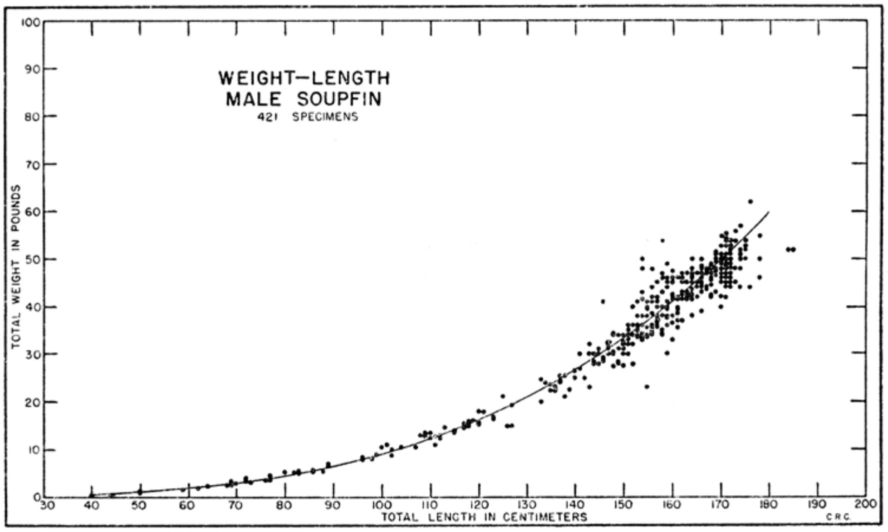

Fig. 12

Fig. 12

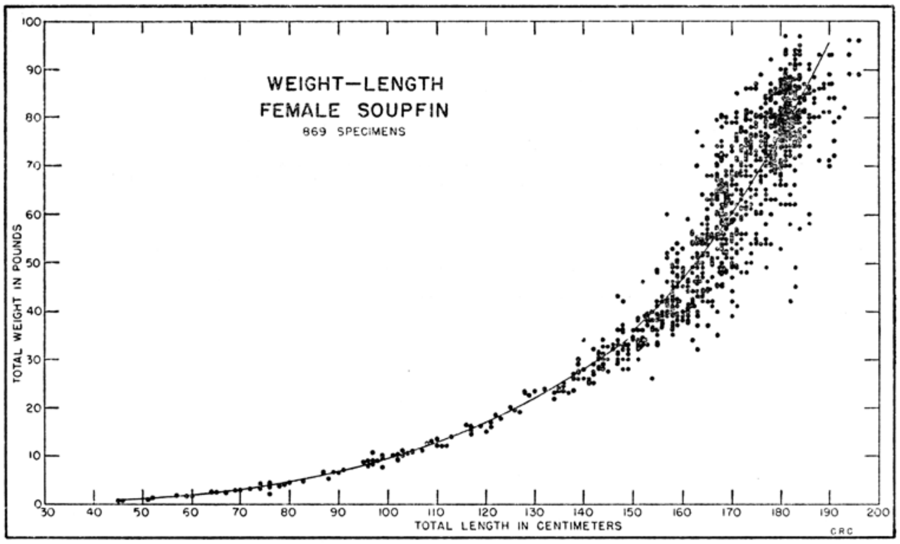

FIG. 13. Note that there is a break in the line of regression at 149 cm. In females larger than 150 cm. sexual development influences the weight-length relationship quite markedly.

FIG. 13. Note that there is a break in the line of regression at 149 cm. In females larger than 150 cm. sexual development influences the weight-length relationship quite markedly

weight as the 3.3 power of the length which is similar to the rate for the males, and mature females as the length to the 4.2 power.

1.10. LIVER WEIGHT—TOTAL WEIGHT RELATIONSHIP

The state of maturity and the associated changes that occur during the reproductive cycle produce certain changes in the liver of the female shark. The liver is utilized for the storage of oil and vitamin A. Females containing no eggs have slightly larger livers than do females of the same sizes containing eggs. When the size of the eggs in the ovary increases to 6 cm. in diameter, the liver weight represents between 10 and 20 per cent of the total body weight. After fertilization of the eggs the weight of the liver increases to about 20 per cent of the body weight. The liver during this period is enlarged and gorged with oil. Gradually, as the embryos develop, oil reserves are withdrawn and the liver of the pregnant female decreases in size. In females recently spent, or those containing full term embryos, the liver appears as a shrunken, hard, dark-colored organ and contains relatively little oil. (Actual values of liver oil content are given in The Relation of the Biology of the Soupfin Shark to the Liver Yield of Vitamin A.) The percentage of liver weight to body weight at this time is as little as 2 per cent but usually lies between 3 and 6 per cent. (Figs. 14 and 15)

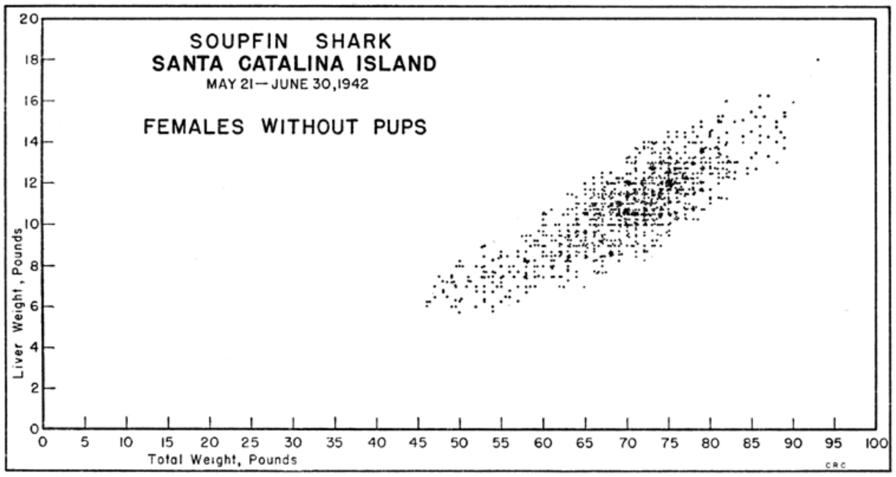

FIG. 14. Liver weight-total weight relationship for females without pups.

FIG. 14. Liver weight-total weight relationship for females without pups

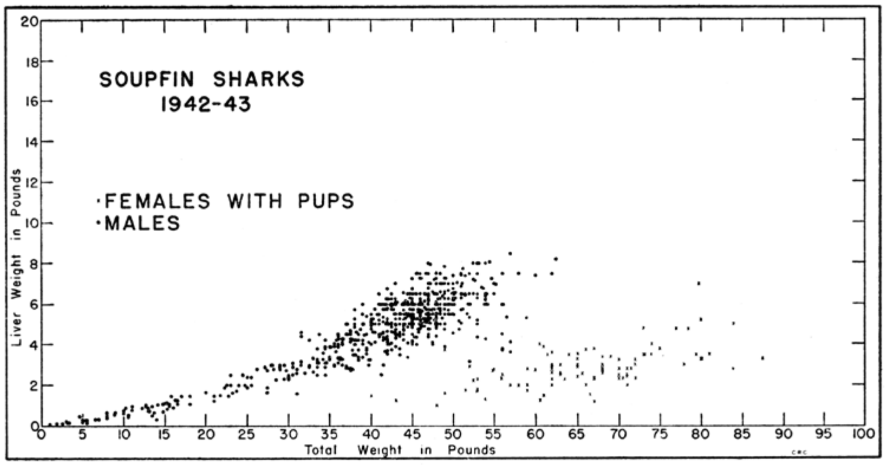

FIG. 15. Liver weight-total weight relationship for males and for females with pups. The low values for females with pups as compared with females without pups results from a decrease in liver oil content. The females were taken in southern California.

FIG. 15. Liver weight-total weight relationship for males and for females with pups. The low values for females with pups as compared with females without pups results from a decrease in liver oil content. The females were taken in southern California

That there is a gradual loss in weight during gestation is demonstrated by figure 16 and table 11. Table 11 illlustrates that from January to April, over 90 per cent of females greater than 160 cm. contained unfertilized eggs. During the month of May over 90 per cent of the females had fertilized eggs (embryos). For the remainder of the year nearly all females examined were in the latter condition. From the period, March to October 1942, the modal length of the females remained at 175 cm. Thus, while the length frequency distribution of the shark remained substantially the same, the total weight of these sharks and proportion of liver to body weight progressively dropped. The decrease from an average of 75 pounds in March to 59 pounds in October combined with the decreasing percentage of liver demonstrates the gradual withdrawing of oil reserves as gestation advances. The abrupt decrease from April to May when considered with the reproductive cycle may indicate that the growth of the eggs in the ovary draws heavily upon the oil reserves of the parent liver at this time.

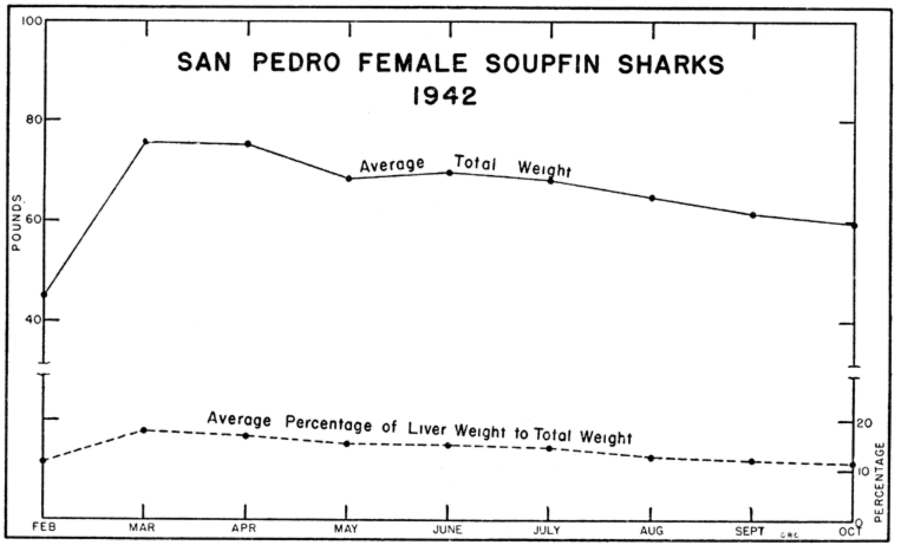

Fig. 16. Loss of total weight and liver weight of female sharks during pregnancy.

FIG. 16. Loss of total weight and liver weight of female sharks during pregnancy

1.11. FOOD

The food study undertaken during the investigation of the soupfin shark was of necessity limited to qualitative observations only. However the preliminary work was undertaken to indicate, among other things, whether or not the food habits would reveal the cause of the variations of vitamin and oil content. Although this was not established, it did demonstrate the diversity of diet.

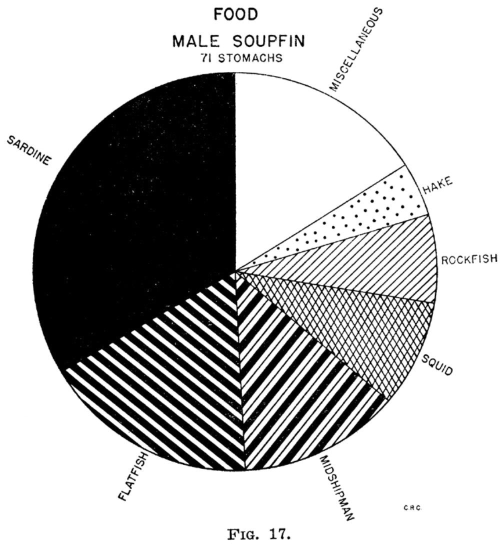

Fig. 17.

FIG. 17

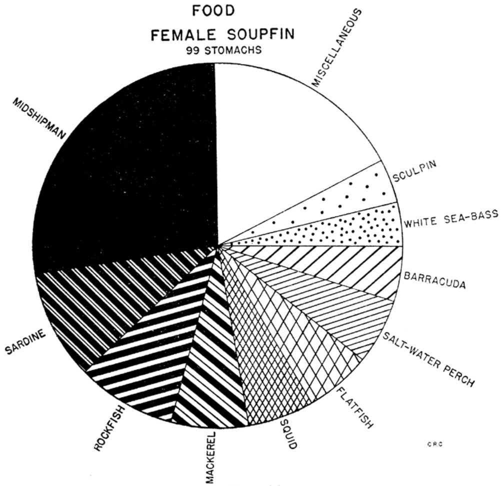

Fig. 18.

FIG. 18

The stomachs of males examined revealed 71 with food. In two of these none of the food could be identified. Ninety-nine female stomachs contained food. The diets of male and female soupfin are shown graphically in figures 17 and 18. The food charts are composed of the percentages of stomachs observed with the type of food listed, but do not include the perecentage of stomachs containing unidentifiable remains. No record was made of those sharks examined that did not have food in their stomachs. The data are given in table 12.

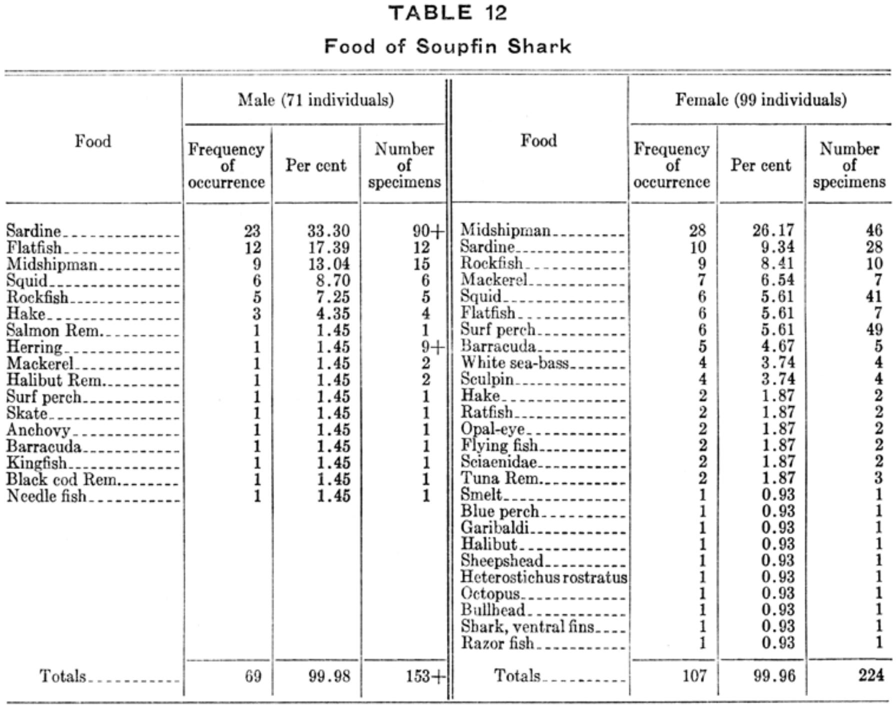

TABLE 12

Food of Soupfin Shark

Food	Male (71 individuals)			Food	Female (99 individuals)		
	Frequency of occurrence	Per cent	Number of specimens		Frequency of occurrence	Per cent	Number of specimens
Sardine	23	33.30	90+	Midshipman	28	26.17	46
Flatfish	12	17.39	12	Sardine	10	9.34	28
Midshipman	9	13.04	15	Rockfish	9	8.41	10
Squid	6	8.70	6	Mackerel	7	6.54	7
Rockfish	5	7.25	5	Squid	6	5.61	41
Hake	3	4.35	4	Flatfish	6	5.61	7
Salmon Rem.	1	1.45	1	Surf perch	6	5.61	49
Herring	1	1.45	9+	Barracuda	5	4.67	5
Mackerel	1	1.45	2	White sea-bass	4	3.74	4
Halibut Rem.	1	1.45	2	Sculpin	4	3.74	4
Surf perch	1	1.45	1	Hake	2	1.87	2
Skate	1	1.45	1	Ratfish	2	1.87	2
Anchovy	1	1.45	1	Opal-eye	2	1.87	2
Barracuda	1	1.45	1	Flying fish	2	1.87	2
Kingfish	1	1.45	1	Sciaenidae	2	1.87	2
Black cod Rem.	1	1.45	1	Tuna Rem.	2	1.87	3
Needle fish	1	1.45	1	Smelt	1	0.93	1
				Blue perch	1	0.93	1
				Garibaldi	1	0.93	1
				Halibut	1	0.93	1
				Sheepshead	1	0.93	1
				Heterostichus rostratus	1	0.93	1
				Octopus	1	0.93	1
				Bullhead	1	0.93	1
				Shark, ventral fins	1	0.93	1
				Razor fish	1	0.93	1
Totals	69	99.98	153+	Totals	107	99.96	224

TABLE 12

Food of Soupfin Shark

The differences in food habits noted in male and female shark are apparently the result of availability and change rather than that of preference. The lists of various species and types ingested demonstrate that the shark possess a catholic taste, and when hungry will accept the type of food most available. For females, the midshipman, Porichthys, occurs with the greatest frequency. However, the relative abundance of Porichthys at the time of capture of the females examined undoubtedly is an important factor in its acceptance as the main item of diet. As has been previously shown, females are taken in southern California in greatest abundance during the months of May, June and July. At this time, sardines are not abundant in the inshore waters of southern California and thus were not available in quantity to the female soupfin.

Sardines were observed with the greatest frequency in the male soupfin stomachs. As in the females, the seasonal abundance and availability of various types of food are reflected in the stomach contents of the males.

The variety of food taken by soupfin sheds some light upon their habits. Both sexes take sardines, midshipmen, rockfish, and squid.

Rockfish and midshipmen are mainly bottom living fish. Sardines and squid are pelagic forms. That they take both pelagic and bottom forms indicates that soupfin do not restrict themselves solely to a bottom existence but when the occasion warrants, will pursue food where food is available. The success of the floating drift net is a reflection of the pelagic wanderings of soupfin in search of food.

SUMMARY

1. Prices offered for soupfin have varied from $40 to $2,000 a ton for round fish and from less than $1.50 to $13 a pound for liver.
2. The gear used for capturing soupfin shark has evolved from hook and line bottom gear to the present set net and drift net.
3. The intensive fishery began in 1937 and total landings reached a peak in 1939 of 9,227,750 pounds. The landings since 1939 to the present have shown a marked decrease.
4. The catch-per-unit-of-effort for all areas indicates a serious decline.
5. In southern California best catches are made during the spring and summer. In northern California the best fishery is during the fall and winter.
6. San Francisco has produced 42.4 per cent of all shark landed in California, northern California produced 73.5 per cent, and southern California 26.5 per cent.
7. The northern California fishery produced 97.5 per cent males, central California 57.7 per cent, Santa Barbara 51.6 per cent and San Pedro 2.2 per cent.
8. In northern California and central California the sexes are distributed throughout the fishing range in about the same proportion as in the catch. In Santa Barbara there is a preponderance of females in less than 30 fathoms and a preponderance of males deeper than 40. The shallow water San Pedro fishery is based almost entirely on females.
9. Of males 155 cm. in total length, 87 per cent are mature and of females 165 cm. in total length, 84 per cent are mature.
10. By May most female shark taken off Santa Catalina Island contain fertilized eggs.
11. The mode of the male length frequency distribution falls at 165 cm. A greater proportion of large fish are taken in the Eureka-Fort Bragg fisheries. Large mature females are taken in greatest quantity in the San Pedro area. The catches in the areas to the northward consist of smaller females. Young and immature fish are taken on the Ventura Flats, San Francisco Bay, Monterey region and Tomales Bay.
12. The weight of male and immature female sharks increase at the 3.2 and 3.3 power of the length, respectively. Mature females increase in weight at the 4.2 power. The percentage of liver weight to body weight varies in females with the reproductive cycle. There is no indication that such is the case with male soupfin.
13. Female soupfin contain on the average 35 young.
14. Soupfin have a catholic appetite, eating those fish which are available in the locality where the sharks are found.

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2. THE RELATION OF THE BIOLOGY OF THE SOUPFIN SHARK TO THE LIVER YIELD OF VITAMIN A

By WM. ELLIS RIPLEY, *Division of Fish and Game*
and
RENÉ A. BOLOMEY, *Stanford University*

2.1. INTRODUCTION

Several marine mammals and many species of marine fish are known to have livers rich in extractable oil containing vitamin A. Among the species that have been proven to be of commercial value as a source of vitamin A, a few have been studied with the purpose of elucidating the various biological and physical factors that influence the vitamin content of the liver. The most important are the studies of Shorland (1935) upon the ling cod, of Lovern *et al.* (1933) upon the halibut, and of Pugsley (1939) and Sanford[*] (personal communication) upon the dog fish, and Macpherson and Wilson (1934) upon the cod.

The average vitamin A content of the liver of the soupfin shark far surpasses that of any other known commercial source. The variations in the vitamin A content within the species are great; some individuals have comparatively insignificant amounts in the liver, whereas, others may have as much as 640,000 international units per gram of liver oil.

2.2. METHOD OF SAMPLING

In the preliminary course of the investigation considerable thought was given to the possibility of decomposition of vitamin A in shark livers kept under commercial fishing storage conditions; therefore, the stability

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[*] F. N. Sanford—U. S. Fish and Wildlife Service, Technological Laboratory, Seattle, Washington.

experiments described in the section, The Stability of Vitamin A in Whole Shark Liver and in the Extracted Oil, were initiated. The first 89 samples were collected at sea pending completion of the introductory experiments on the stability of vitamin A which ultimately proved that collection of the samples could be made at the point of landing.

Total shark weights for the first 89 samples were recorded from a scale usually suspended from the boom. In order to minimize the weighing errors, the weights were taken only when the boat reached the center of a roll and was on a comparatively level keel. Even with these precautions or for that matter with the boat at anchor, the roll and pitch under the most favorable conditions were sufficient to make the weighing procedure a difficult operation. All later samples were weighed at the port of landing.

Body length was recorded to the nearest centimeter. Specimens were stretched full length upon the deck and were measured in a straight line from the tip of the nose to the tip of the tail.

The livers of the first 89 sharks were placed in cartons and frozen in dry ice as soon as they were excised from the carcass. Then they were shipped to the Stanford laboratory where they were weighed and analyzed for oil and vitamin A. All subsequent livers which would not fit into pint cartons were weighed at the port of landing, ground in an electrically driven grinder, and mixed thoroughly. A sample of the ground material was transferred to pint cartons, frozen in dry ice, and shipped for analysis to the Stanford laboratory. Dry ice was chosen as the refrigerant since it is easy to handle, is sufficiently cold to prevent autolysis of the tissue, and displaces air from the containers, thereby reducing the danger of oxidative decomposition of the vitamin.

The livers were analyzed by the methylene chloride (Tompkins and Bolomey, 1943) and xylene (Sycheff, 1944) methods for oil and by the colorimetric reaction for vitamin A (Rosenthal and Erdelyi, 1934). The results were expressed in terms of percentage of oil, international units of vitamin A per gram of oil, international units of vitamin A per pound of liver, and total international units of vitamin A in the liver.

The relation of total length, total weight, liver weight, geographic location of catch, and of season to the oil and vitamin A content of the livers was determined within the limits of the available data. Unfortunately, no satisfactory method for determination of age has yet been developed for the soupfin shark, and the effect of age on the oil and vitamin A content could not be measured.

2.3. INFLUENCE OF TOTAL LENGTH ON THE OIL AND VITAMIN A CONTENT

The effect of length on the dependent variables, has been found to be influenced by the sexual development of these sharks. The first paper of this bulletin indicates that about 90 per cent of males greater than 155 cm. and of females greater than 170 cm. in length are mature. At approximately these lengths the average vitamin A content begins to increase rapidly with an increase in the length of the shark. Male sharks of comparable lengths showed no variation in oil or vitamin A content that seemed dependent on the presence or absence of ripe sperm. Therefore, all males were classified according to their lengths irrespective of variations in their sexual condition. Female sharks, on the other hand, showed marked variations associated with sexual condition as well as length. In order to obtain a better understanding of the effect of both factors on the dependent variables, the females were subdivided into five arbitrary categories as follows:

Stage A. Females having no eggs evident on gross examination of the ovary.

Stage B. Females having unfertilized eggs in the ovary. The eggs were spherical and in some had attained a diameter of 6 cm.

Stage C. Females having fertilized eggs (embryos) in the uteri. The eggs were elliptically shaped and attained a length of 9 to 12 cm.

Stage D. Females having pups (near term embryos) in their uteri. The pups were over 25 cm. in length.

Stage E. Females having recently spent their young. The uteri were distended and vascular (evidence of recent birth of the young) and their livers were very small and dark. Females showing these uterine characteristics but also containing unfertilized eggs in their ovaries were considered as of Stage B.

The sharks were grouped in 5 cm. length classes. Average values were obtained for the lengths and for the oil and vitamin A content for each group. From these values, with their appropriate weights, lines of regression were fitted by the method of least squares. The curves in figures 1, 3, 4, 6, 7, 9, 10 and 12 were obtained by plotting the calculated lines. In the case of the females considered in the different stages described above, figures 2, 5, 8 and 11 were drawn with the average values of the dependent variable plotted against the average total length calculated for each 5 cm. length group. In order to show the spread in the distributions, the individual values are plotted on the same figure. The formulas for the lines of regression are given in table 1.

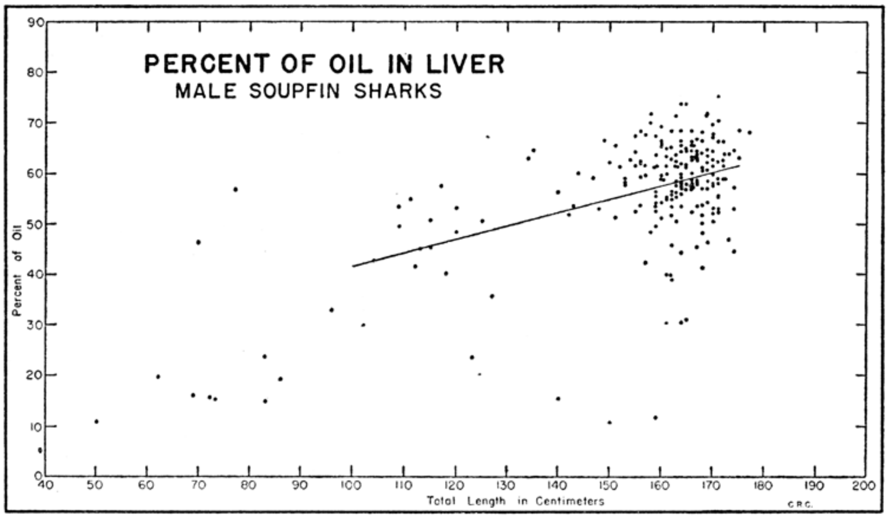


FIG. 1.

FIG. 1

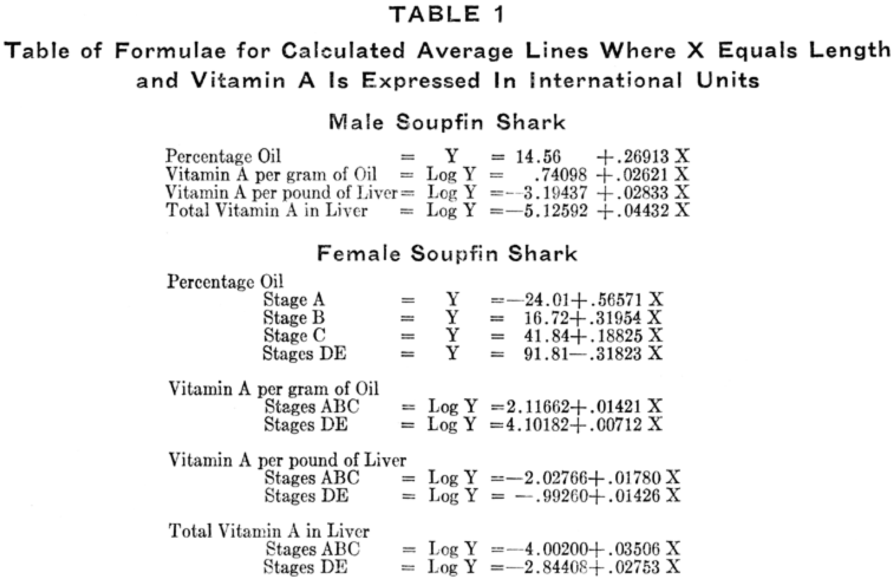


TABLE 1

Table of Formulae for Calculated Average Lines Where X Equals Length and Vitamin A Is Expressed In International Units

Male Soupfin Shark

Percentage Oil = $Y = 14.56 + .26913X$
Vitamin A per gram of Oil = $\text{Log } Y = .74098 + .02621X$
Vitamin A per pound of Liver = $\text{Log } Y = -3.19437 + .02833X$
Total Vitamin A in Liver = $\text{Log } Y = -5.12592 + .04432X$

Female Soupfin Shark

Percentage Oil
  Stage A = $Y = -24.01 + .56571X$
  Stage B = $Y = 16.72 + .31954X$
  Stage C = $Y = 41.84 + .18825X$
  Stages DE = $Y = 91.81 - .31823X$

Vitamin A per gram of Oil
  Stages ABC = $\text{Log } Y = 2.11662 + .01421X$
  Stages DE = $\text{Log } Y = 4.10182 + .00712X$

Vitamin A per pound of Liver
  Stages ABC = $\text{Log } Y = -2.02766 + .01780X$
  Stages DE = $\text{Log } Y = -.99260 + .01426X$

Total Vitamin A in Liver
  Stages ABC = $\text{Log } Y = -4.00200 + .03506X$
  Stages DE = $\text{Log } Y = -2.84408 + .02753X$

TABLE 1

Table of Formulae for Calculated Average Lines Where X Equals Length and Vitamin A Is Expressed In International Units

2.4. OIL CONTENT

2.4.1. Males

The livers of male soupfin sharks show a gradual increase in the average percentage of oil with increasing length (Fig. 1). The individual values are widely distributed about the line of regression. Values for mature male sharks vary from 56 to 61 per cent with extremes ranging between 30 and 75 per cent.

Not included in figure 1 are analyses of the livers of nine male pups shown in Appendix II. In all of these pups there was no external evidence of a yolk sac although there remained an umbilical slit of about 5 mm. which had not yet completely closed. The mean length of the embryos was 35.7 cm. and the average oil content was 28.7 per cent. The latter value is somewhat higher than those which have been found for the smaller soupfin sharks.

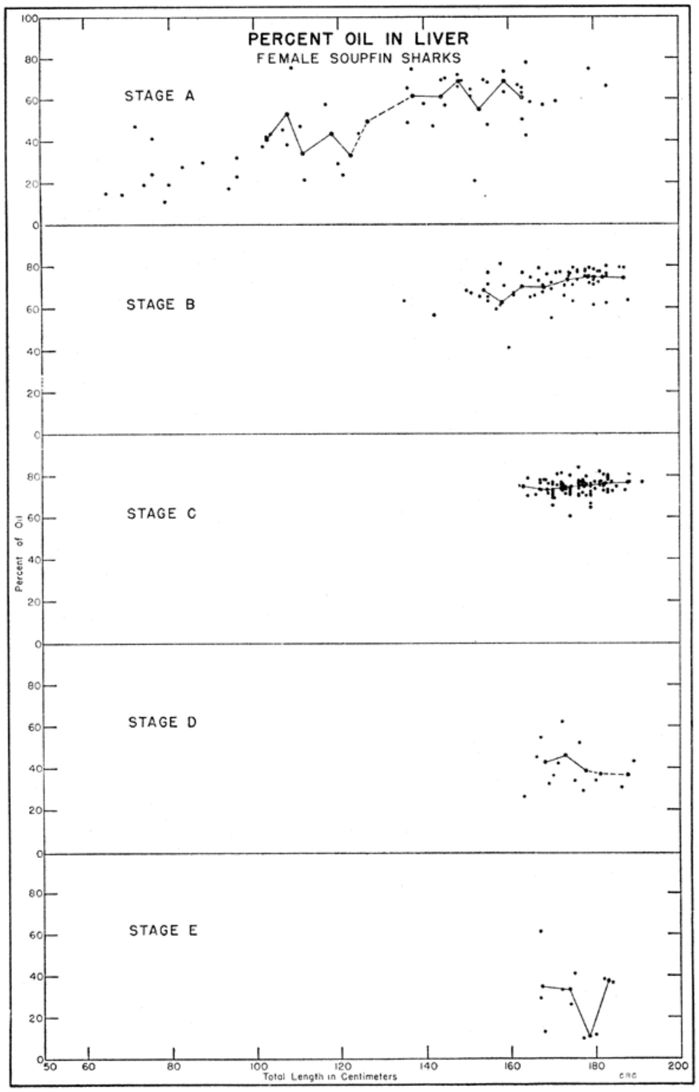

PERCENT OIL IN LIVER
FEMALE SOUPFIN SHARKS
STAGE A
STAGE B
STAGE C
STAGE D
STAGE E
Percent of Oil
0
20
40
60
80
100
50
60
80
100
120
140
160
180
200
Total Length in Centimeters
CRC

Fig. 2.

FIG. 2

2.4.2. Females

The percentage of oil in the livers of female soupfin presents a somewhat different picture than that of the males due to differences between stages in the reproductive cycle. A least squares straight line was calculated separately for Stages A, B and C and for Stages D and E combined.

Females having no eggs (Stage A) show an increase in the percentage of oil in their livers with increasing length (Figs. 2 and 3), the regression coefficient being .57. The variation about both the line of regression and the mean values at any given length class is, however, not as great as in the case of the males. Females with unfertilized eggs in their ovaries (Stage B) gave a regression coefficient of .32, thus the rate of increase of oil with increase of length has decreased 44 per cent from that of Stage A. Likewise females with fertilized eggs in their uteri (Stage C) with a regression coefficient .19 showed a similar decrease from Stage B in the slope of the line relating percentage of oil to length. The three groups have been combined into one (Stages ABC) in figure 3, and the line for each stage superimposed upon the scatter diagram. Figures 2 and 3 indicate that the percentage of oil in the livers of the female increases with the length of the shark through Stage C. A value of 75 per cent oil content is apparently close to the average upper limits that are reached in female livers. The highest individual value encountered was 84 per cent.

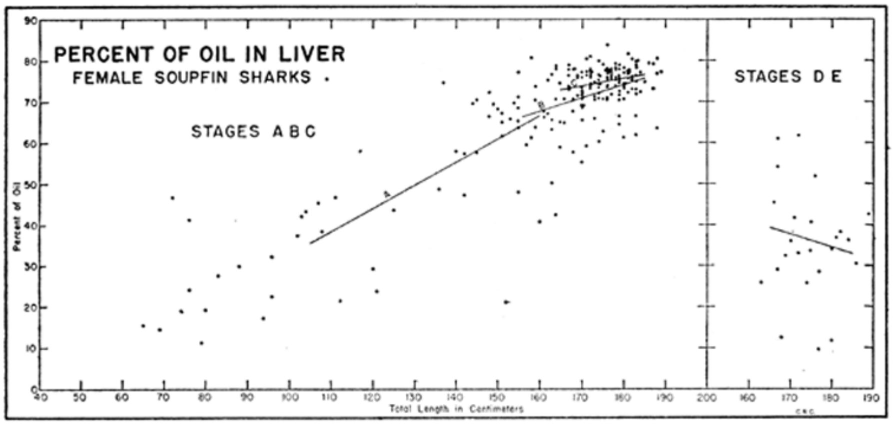


FIG. 3.

FIG. 3

The percentage oil content of livers from females of Stages D and E shown in figures 1 and 2 reveals a wide spread in the values and no correlation with length. It drops from an average value of about 75 per cent in Stage C to less than 40 per cent in Stage DE. It would appear that the sharks use up their "liver oil reserves" in the later stages of pregnancy. The increase in the percentage of oil with increasing length of the shark is only apparent in Stages A, B and C.

2.4.3. Summary

The mean oil values for the mature sharks are approximately 60 per cent for males and 75 per cent for females of the first three stages, namely: females without eggs, those with unfertilized eggs in their ovaries, and those with young embryos in their uteri. No definite percentage value can be assigned to the oil content of the livers of females in the later period of pregnancy nor for those that have recently spent their pups since the data concerning these groups are limited and variations in oil content are great. However, the oil yield of the livers of female sharks belonging to these last two groups is indicated to be considerably lower than that of other adult sharks of either sex. The positive correlation between oil content of the liver and length found by Pugsley (1939) and Sanford (personal communication) for dogfish holds for the male soupfin and for female soupfin in the first three stages of the reproductive cycle. It breaks down in females belonging to the last two stages. These fish show a lower oil content than other females of the same size. This decrease corresponds with the decrease noted by Shorland (1935) in ling cod livers during the spawning period.

2.5. VITAMIN A CONTENT

A clearer understanding of the complexities underlying the vitamin A content and its relationship to the length of the soupfin shark is obtained when the vitamin content is expressed as the concentration of vitamin A in the oil, the amount of vitamin A per pound of liver, and the total amount of vitamin A in the liver.

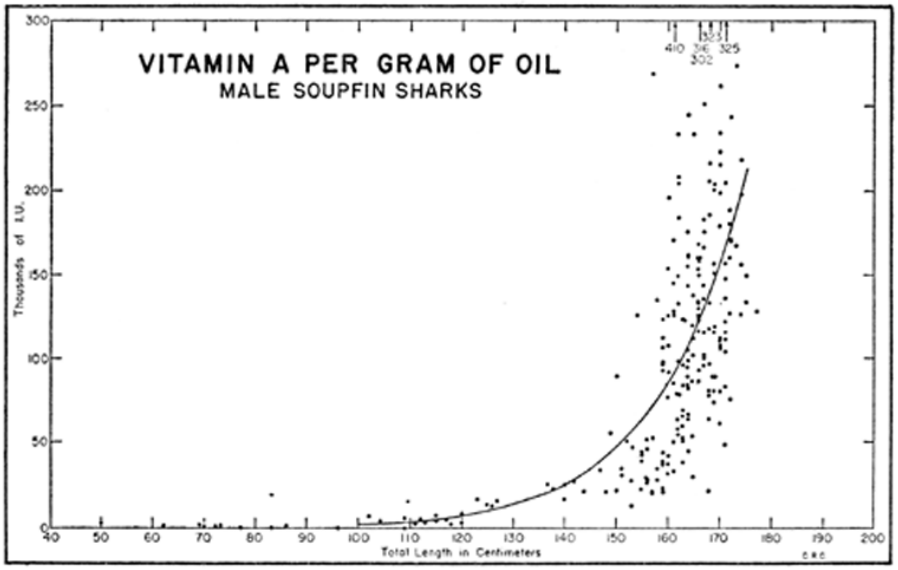


FIG. 4.

FIG. 4

2.5.1. International Units of Vitamin A per Gram of Oil

Males. In male sharks the average potency of vitamin A expressed in terms of international units per gram of oil (Fig. 4) increases with length from comparatively insignificant amounts in the smaller sharks to high values in the larger members of the species. The values increase progressively from the smaller to the larger sharks at an exponential rate. The steepest portion of the curve occurs at lengths greater than 155 cm. At least 90 per cent of male sharks of these lengths are mature. Males smaller than 155 cm. have on the average less than 50,000 international units per gram of oil, whereas for males greater than 155 cm. the potency increases with length to a value of over 200,000 international units per gram of oil.

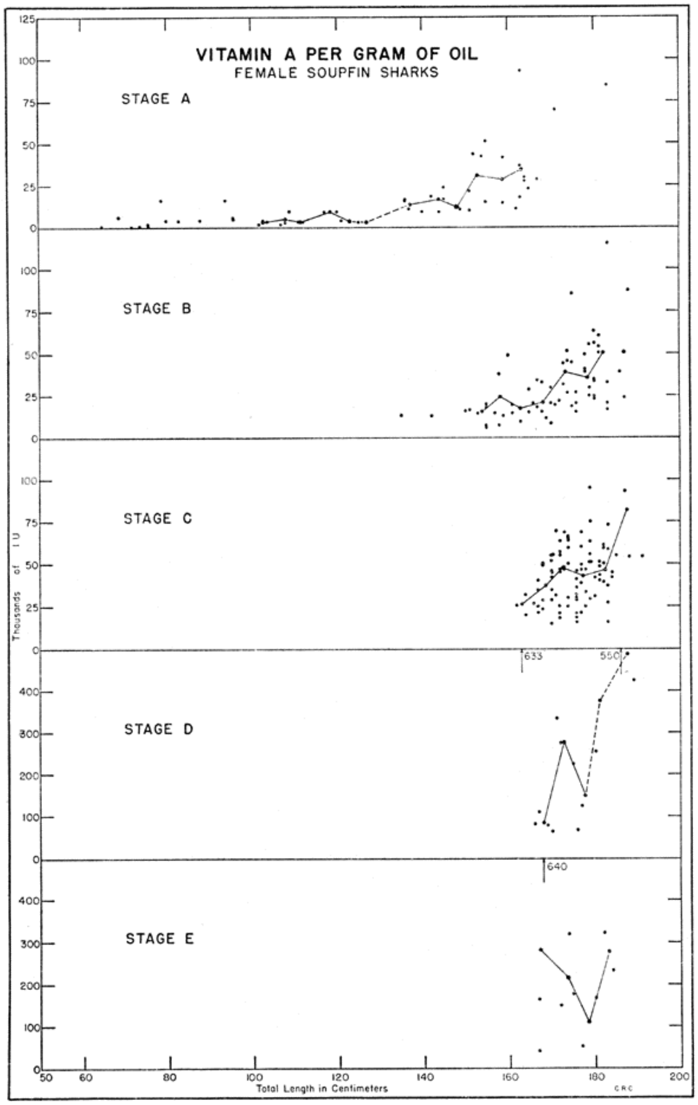

VITAMIN A PER GRAM OF OIL
FEMALE SOUPFIN SHARKS
STAGE A
STAGE B
STAGE C
STAGE D
STAGE E
Thousands of I.U.
125
100
75
50
25
0
400
300
200
100
633
550
640
50
60
80
100
120
140
160
180
200
Total Length in Centimeters
CRC

Fig. 5.

FIG. 5

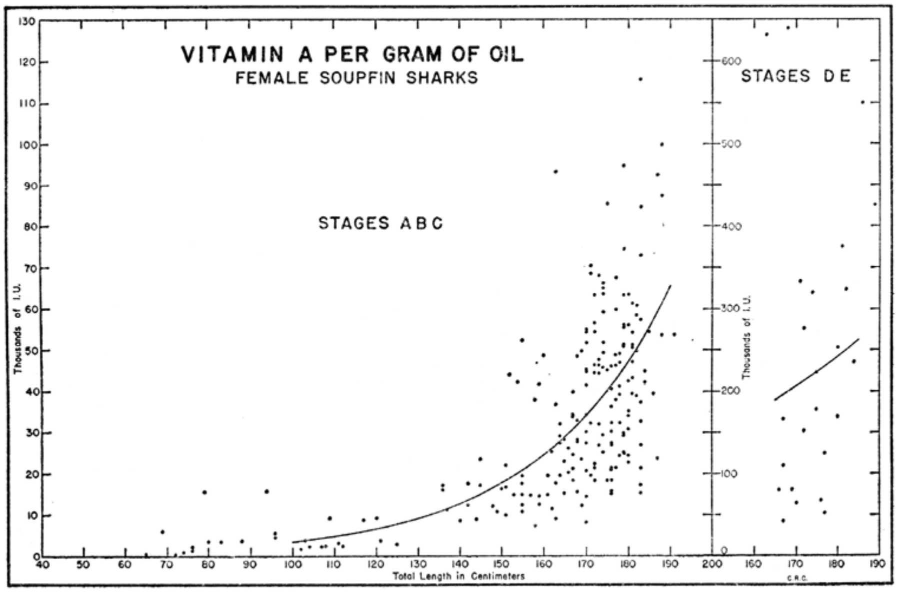


Fig. 6.

FIG. 6

Although in general the potency shows a rapid increase with length of the shark, the individual values deviate widely about the average line. The variability increases with size and shows a sudden increase above 145 cm. length. (Fig. 4 and Table 2.) For male sharks above this length, the potency ranges between 20,000 and 410,000 international units per gram of oil.

Females. As in the observation on the percentage of oil in female sharks, the vitamin A content expressed as international units per gram of oil is correlated with the sexual condition as well as with the length of the female shark (Figs. 5 and 6). Females having no eggs (Stage A) show an increase in the average potency from insignificant values for the smaller sharks to 35,000 international units of vitamin A per gram of oil for sharks 160 to 165 cm. in length (Fig. 5). For females having unfertilized eggs in their ovaries (Stage B), the average potency of vitamin A increases with length from 15,000 to 50,000 international units per gram of oil. The values for the potency of the liver oil obtained from females belonging to these three classes were combined, the line of regression calculated, and are represented as Stages ABC (Fig. 6). The standard deviation about the mean values for each size class augments with an increase in length (Table 2). The average curve

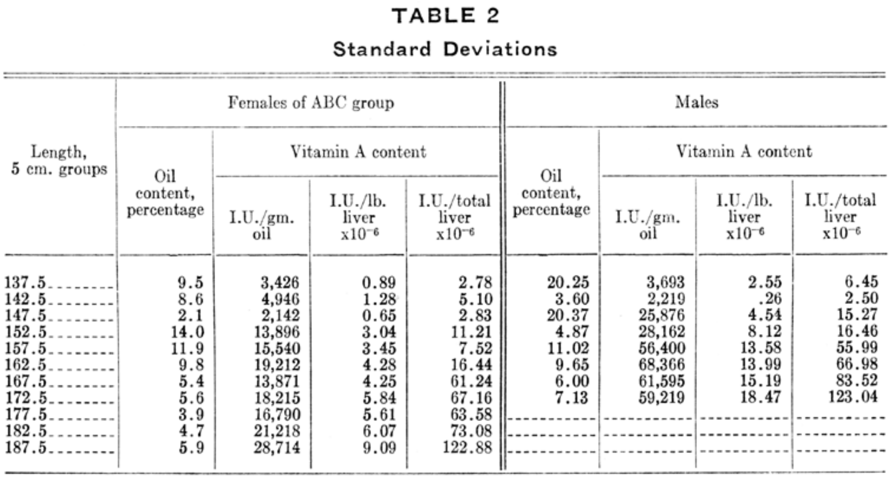


TABLE 2

Standard Deviations

Length, 5 cm. groups	Females of ABC group				Males			
	Oil content, percentage	Vitamin A content			Oil content, percentage	Vitamin A content		
		I.U./gm. oil	I.U./lb. liver x10⁻⁶	I.U./total liver x10⁻⁶		I.U./gm. oil	I.U./lb. liver x10⁻⁶	I.U./total liver x10⁻⁶
137.5	9.5	3,426	0.89	2.78	20.25	3,693	2.55	6.45
142.5	8.6	4,946	1.28	5.10	3.60	2,219	.26	2.50
147.5	2.1	2,142	0.65	2.83	20.37	25,876	4.54	15.27
152.5	14.0	13,896	3.04	11.21	4.87	28,162	8.12	16.46
157.5	11.9	15,540	3.45	7.52	11.02	56,400	13.58	55.99
162.5	9.8	19,212	4.28	16.44	9.65	68,366	13.99	66.98
167.5	5.4	13,871	4.25	61.24	6.00	61,595	15.19	83.52
172.5	5.6	18,215	5.84	67.16	7.13	59,219	18.47	123.04
177.5	3.9	16,790	5.61	63.58	----------	----------	----------	----------
182.5	4.7	21,218	6.07	73.08	----------	----------	----------	----------
187.5	5.9	28,714	9.09	122.88	----------	----------	----------	----------

TABLE 2

Standard Deviations

of Stages ABC, although it represents the trend of a fairly large sample is not representative of individual specimens.

The vitamin A potency of liver oil in females having well-developed pups in their uteri (Stage D, Fig. 5) or having recently given birth to their young (Stage E, Fig. 5), shows no distinct correlation with the length of the shark. These females are grouped together as Stages DE, figure 6. The results indicate that changes associated with the end of the reproductive cycle have a greater influence on the vitamin A content per gram of oil than does the length. This is seen not only in the wide variations of the individual values, but also in the magnitude of these values compared with those of the three other stages. (Note that the scale for DE is five times that for ABC in figure 6.) The potency range of Stages DE lies between 45,000 and 640,000 international units of vitamin A per gram of oil as contrasted with a maximum value of 116,000 international units per gram of oil for Stages ABC.

Summary. The maximum calculated average value of 212,600 international units of vitamin A per gram of oil for male sharks occurs at a length of 175 cm. This may be contrasted with a value of 65,500 international units per gram of oil for females of Stages ABC, 190 cm. long. The regression coefficient for vitamin A/gm. of oil for males was .026 and for females, Stages ABC, .014. Thus the rate of increase with length for males is 46 per cent greater than for females (Table 1). The highest individual values are 410,000 and 116,000 international units per gram of oil for males, and females of Stages ABC, respectively. The liver oils of male sharks are, therefore, on the average richer in vitamin A than are those of females of Stages ABC, but some of the female sharks of Stages DE may surpass the males in vitamin A content per gram of oil. The highest value recorded in this investigation, 640,000 international units of vitamin A per gram of oil, was found in a female of Stage E.

2.5.2. International Units of Vitamin A per Pound of Liver

A striking similarity exists between the shape of the curves demonstrating the relationship of length to potency per pound of liver (Figs. 7 8 9) on the one hand and to the potency per gram of oil (Figs. 1 to 3) on the other. The potency per pound of liver is a function of the percentage of oil in the liver and the concentration of vitamin A in the oil. The relationship of vitamin A per pound of liver to percentage of oil

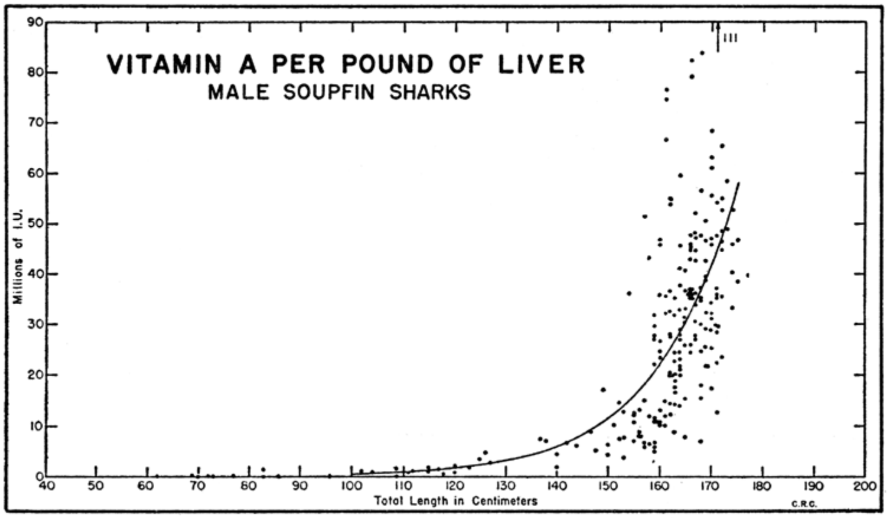


Fig. 7

FIG. 7

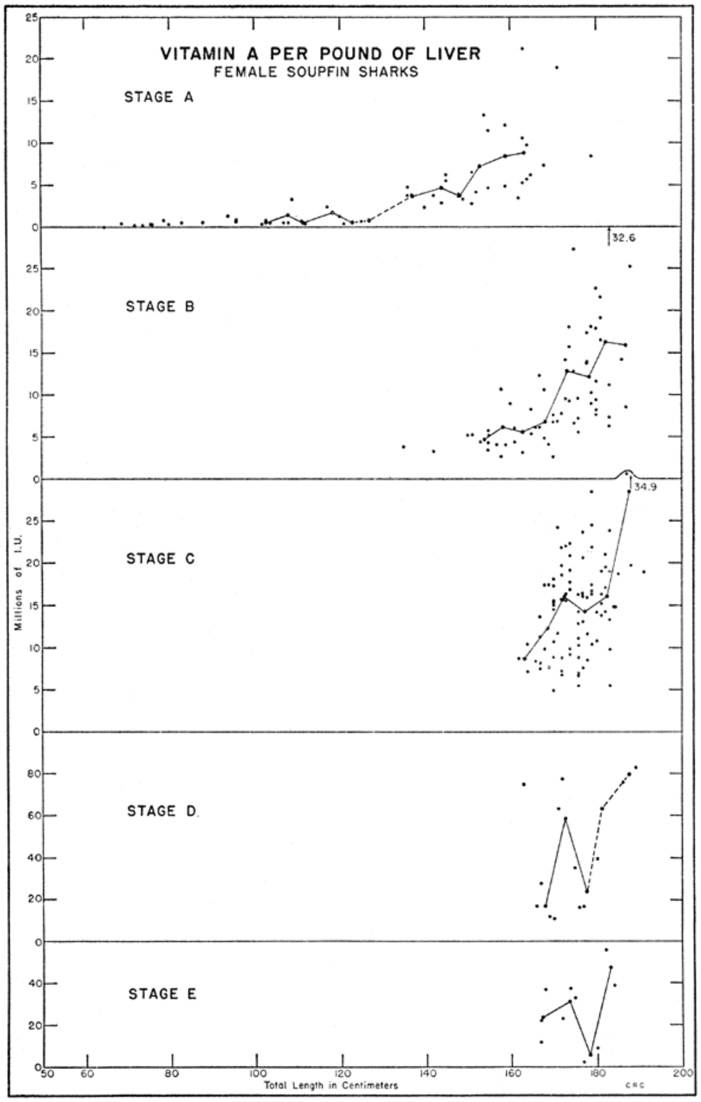

VITAMIN A PER POUND OF LIVER
FEMALE SOUPFIN SHARKS
STAGE A
STAGE B
STAGE C
STAGE D
STAGE E
Millions of I.U.
32.6
34.9
25
20
15
10
5
0
80
60
40
20
50
60
80
100
120
140
160
180
200
Total Length in Centimeters
CRC

Fig. 8.

FIG. 8

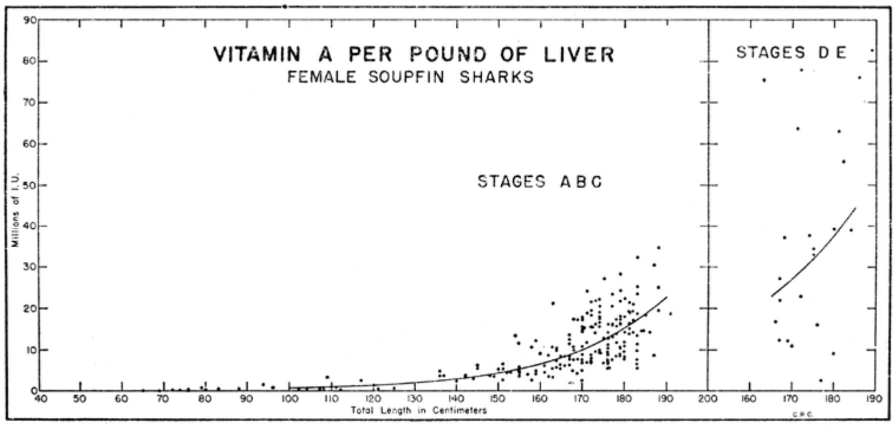


Fig. 9.

FIG. 9

and vitamin A per gram of oil can be expressed by the equation Pl = (Pg) (453.6) (Po) where Pl = Potency of vitamin A per pound of liver Pg = Potency of vitamin A per gram of oil 453.6 = Factor for converting grams to pounds Po = Percentage of oil in liver ÷ 100

Males. The potency of vitamin A per pound of liver in the males increases from insignificant values to 15,700,000 international units at a length of 155 cm. and to 58,000,000 international units at a length of 175 cm. The extreme values for the adults range from about 3,000,000 to 111,000,000 international units of vitamin A per pound of liver.

Females. Aside from the correlation of potency per pound of liver with length in the female sharks, probably the most striking comparison is that between the potency per gram of oil and the potency per pound of liver, especially insofar as the difference in magnitude between the values for Stages ABC and Stages DE is concerned. Thus female sharks of Stages DE have roughly five times the potency per gram of oil (Fig. 6) and roughly two and one-half times the potency per pound of liver (Fig. 9) of sharks of Stages ABC. Similar differences are indicated in figures 5 and 8 in which the females have been classified into their five respective sexual stages.

Whether or not any significance can be attached to the observation that the potency per pound of liver is lower for sharks of Stage E than for sharks of Stage D (Fig. 8) is hard to tell at present. Nevertheless, it may be an interesting point to study at some future date especially since this observation is not apparent when the potency per gram of oil is considered.

Summary. Male sharks 175 cm. long have a maximum average potency of 58,000,000 international units per pound of liver while females of Stages ABC attain a maximum average value of 22,600,000 international units per pound of liver at a length of 190 cm. The highest individual values are 111,000,000 and 35,000,000 international units per pound of liver for males and females of Stages ABC respectively.

2.5.3. Total International Units of Vitamin A in the Liver

The third and last potency variable to be considered is the total vitamin A content of the liver. A study of this variable offers a means of evaluating the soupfin shark in terms of total vitamin A production. The total potency of the liver is dependent not only on the potency per gram of oil and the percentage of oil but also on the size of the liver. In this case as in the correlation of the potency per gram of oil and the potency per pound of liver, the average values rise with increasing length (Fig. 10). The variation of the individual values is great and increases in magnitude from the smaller to the larger sharks.

Males. The average total potency of the liver of male sharks increases from insignificant values for the smaller sharks to 256,000,000 international units for sharks 170 cm. long. Adult males above 160 cm. in length show a maximum spread in potency ranging from 25,000,000 to 717,000,000 international units (Fig. 10).

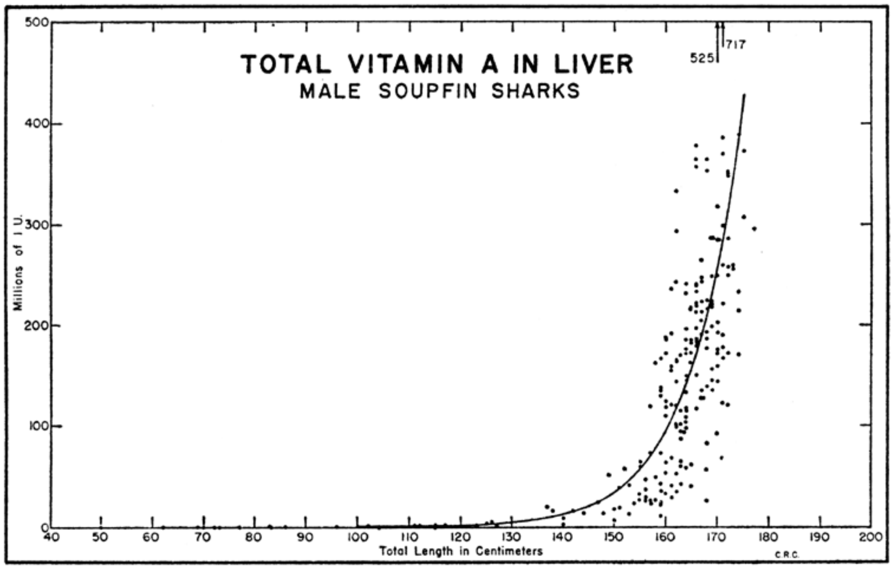


FIG. 10.

FIG. 10

Females. The average curve for the total vitamin A content of the liver of females is similar to that of males although the high potency values of females are reached in the range of 180 to 190 cm. as contrasted with the range of 165 to 175 cm. for males (Fig. 12). The average total potency of Stages AB and C female livers extends from insignificant values for the smaller sharks to about 300,000,000 international units of vitamin A at an average length of 185 cm. The spread about the mean for each 5 cm. class increases towards the longer sharks and reaches a maximum range of about 40,000,000 to 470,000,000 international units.

Unlike the correlations of length with potency per pound of liver and especially with those per gram of oil, the total vitamin A content of the liver of female sharks in Stages DE is less than that for females of comparable lengths in Stages ABC (Fig. 12). The values of Stage E (Fig. 11) are somewhat lower than those of Stage D. However, due to the lack of sufficient material in these last two stages, it cannot be stated with certainty how much decrease occurs in the total vitamin A content between the livers of females in Stages ABC and those in Stages DE.

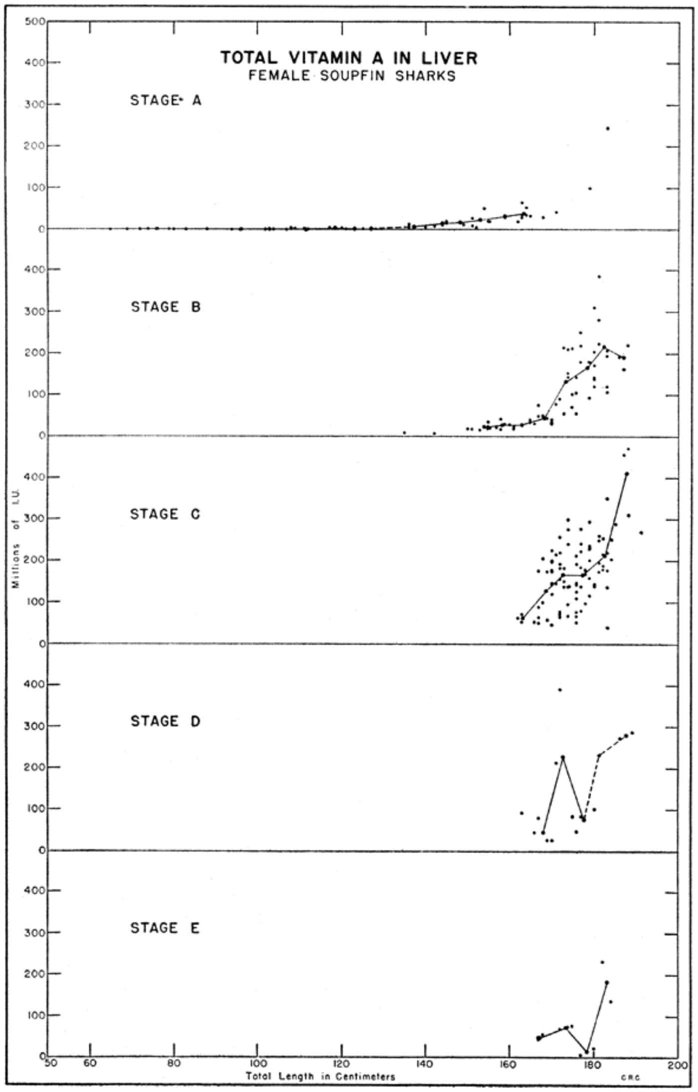

TOTAL VITAMIN A IN LIVER
FEMALE SOUPFIN SHARKS
STAGE A
STAGE B
STAGE C
STAGE D
STAGE E
Millions of I.U.
500
400
300
200
100
0
50
60
80
100
120
140
160
180
200
Total Length in Centimeters
CRC

Fig. 11.

FIG. 11

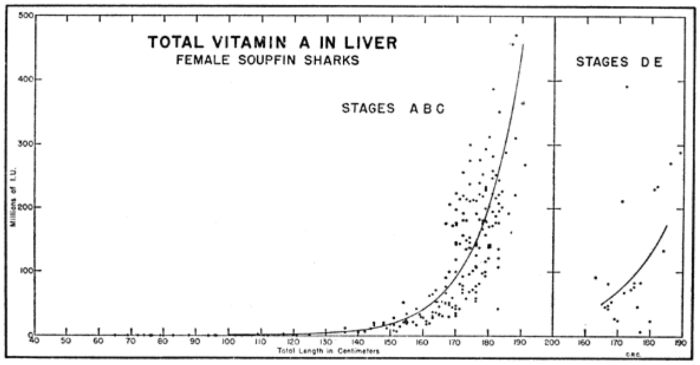


FIG. 12.

FIG. 12

Summary. Male sharks have between two and three times more total vitamin A in their livers than do females of comparable lengths, but the highest average values are approximately the same at the maximum length of each sex. The regression coefficient for the total potency of vitamin A with length was 20 per cent greater for males than for females.

2.6. THE EFFECT OF MISCELLANEOUS INDEPENDENT VARIABLES ON THE OIL AND VITAMIN CONTENT

It is apparent from the preceding discussion that the oil and vitamin A content are correlated with the total length of the shark and with sexual condition in the females. However it is equally obvious from the wide variations in the individual values that variables other than length exert considerable influence upon the oil and potency content of the liver. Some of these are the total weight of the shark, the liver weight, and geographic location and season of capture.

2.6.1. Total Weight

Correlations of body weight with total length for both males and females were made in "The Soupfin Shark and the Fishery." From these correlations it could be assumed that the oil yield and vitamin potencies are related to the body weight as they are to the total length. This expectation is actually realized; however, the weight relationships are not as well defined as they are in the length correlations. The potency does not increase as rapidly with weight as it does with length which is to be expected since both weight and potency have an exponential relationship to length. Figures 13 and 14 show the dependence of potency per pound of liver on the total weight for males and females, respectively. The average curve was obtained by plotting the mean values for each five-pound class against the average total weight of each class.

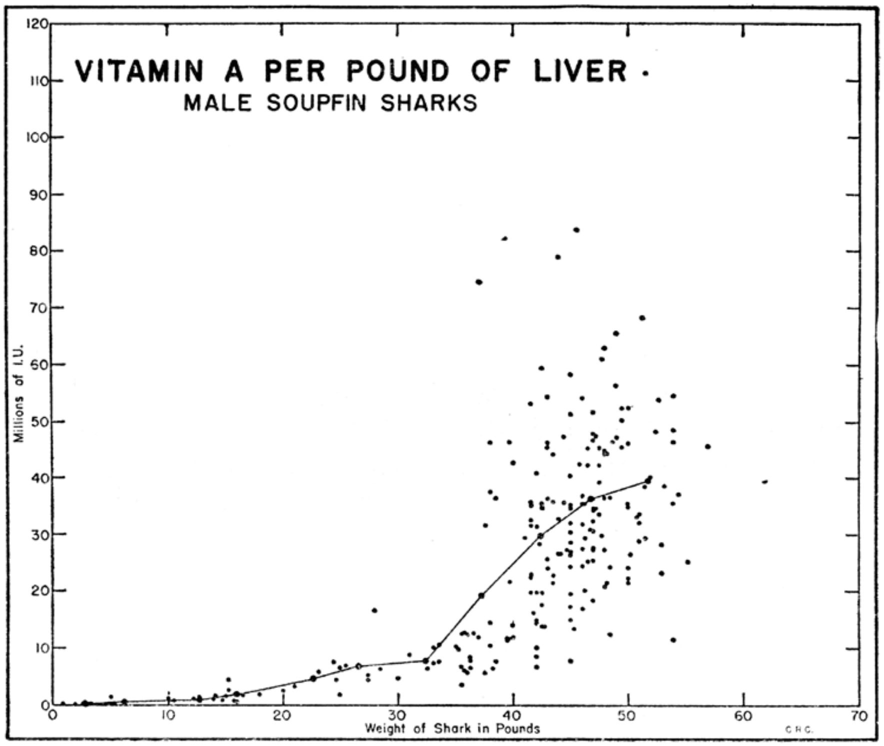


FIG. 13.
FIG. 13

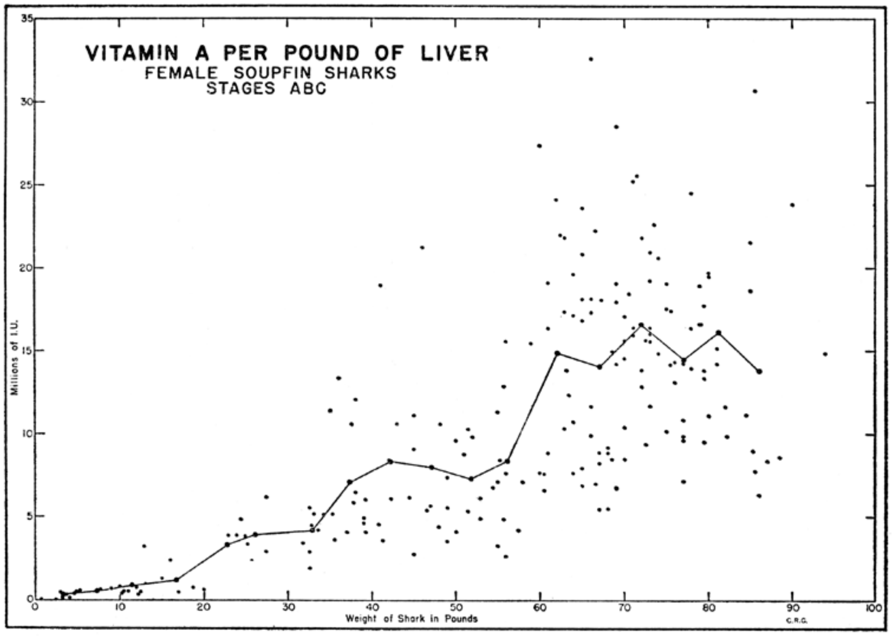


FIG. 14.
FIG. 14

2.6.2. Influence of Geographic and Seasonal Factors

The soupfin shark fishery in any given locality is largely a seasonal occupation as may be seen by consulting the first paper in this bulletin. Liver sampling was performed in only one locality at a time. Since the effect of length upon the oil and the vitamin A content of the liver is so pronounced this variable must be included in the regional and seasonal correlations. Classifying the data in this manner results in a number of groups which do not contain sufficient cases to be statistically valid. For this reason no figures representing this phase of the study are included in this paper. The original data are given in Appendix I. However, there is no indication that the mean values for the dependent variables for any given length fluctuated greatly with geographical or seasonal factors in the males. The wide variations in the individual values at any given length demonstrated in the previous discussions can not be explained on the basis of these variables. This was also true for females of Stages ABC.

2.7. INTERPRETATION OF THE DATA

From the foregoing observations a number of recommendations and questions become apparent. However, before attempting to interpret the data it should be kept in mind that, although some 450 specimens have been analyzed both for oil and for vitamin A, the size of this sample of the soupfin population of the Pacific Coast is small compared to that required for a thorough understanding of the biological and physical factors that influence the oil and vitamin A content of the livers.

The wide variation in the percentage of oil in the liver of sharks and an oil content as high as 84 per cent are points that demand some explanation. As in the case of males, the percentage of oil in the livers of females of Stages ABC increases with length. Females of Stages A, B, and C that are longer than 160 cm. have an average percentage of oil ranging between 65 and 75 while females of the same size but in Stages D and E have average values that are less than 40 per cent. In other words, there is a drop in the percentage of oil in the liver of females approaching term. Various postulates have been advanced in an attempt to explain this phenomenon. One of these is that the oil content of the liver of females in the later stages of pregnancy is drawn upon to nourish the growing embryos. This postulate seems highly improbable, since the soupfin shark egg is macrolecithal and contains sufficient yolk to nourish the embryos to the time of birth. Moreover, as there is no placental membrane, the transfer of such food from the mother to the embryos would be an inefficient and difficult process. It would seem, therefore, that a more probable postulate explaining this decrease in oil content is that of the utilization of reserve fat by the mother during pregnancy. Although food has been found in the stomachs of pregnant sharks near term, the procurement of food is probably a difficult task for females in this condition. A reserve of oil such as that stored in the liver could be utilized to make up a deficiency in the quantitative food intake. The lowest percentage of oil encountered in the liver of adult female sharks is found in females that have recently liberated their young (Stage E). This is an observation that lends support to the present postulate and offers a satisfactory explanation for the great variation in the percentage of oil in the liver of females of Stages D and E. If the postulate is correct that the liver oil is a food reserve, it may account in part for the wide variation of oil content in adult sharks of either sex.

The low percentage of oil in the livers of smaller sharks of either sex may be due to the fact that the young soupfin are extremely active and that they are in a period of rapid growth demanding food not only to replace the catabolized tissue, but also to build up new tissue. Observations were made on nine male and two female embryos just approaching term. The average percentage of oil in the livers of these embryos was close to 30 per cent. This value is somewhat higher than that found in soupfin sharks smaller than 70 cm. Sanford (personal communication) has made a similar observation on the oil content of unborn and of immature dogfish. However, the number of samples so far considered, both in the soupfin and the dogfish, is small.

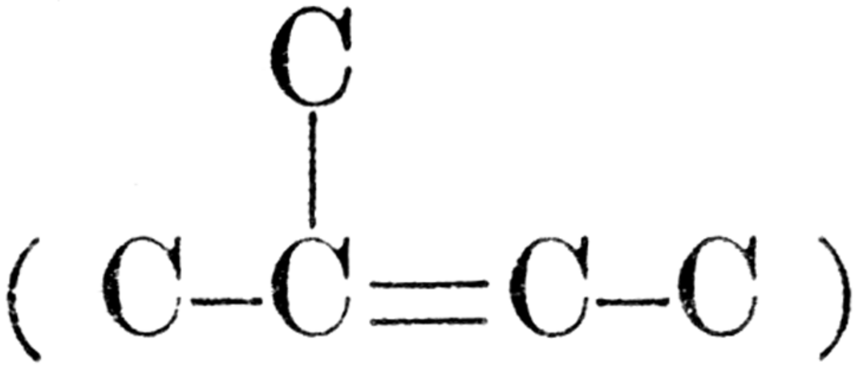
It was noted above that the percentage of oil in the liver of adult female sharks drops considerably as they reach the later stages of pregnancy. The vitamin A potency per gram of oil, moreover, tends to be considerably higher for females of Stages D and E than for those of Stages A, B and C of comparable lengths. In addition to these observations we have noted that the total vitamin A content of the liver of adult females of comparable lengths is apparently not seriously affected as pregnancy approaches its later stages since the differences are not of major magnitude between the total vitamin A values of the livers of females in Stages A, B and C and Stage DE. This indicates that the vitamin A of the shark liver is not utilized as rapidly as is the oil; and therefore, as the liver oil content of females in the later stages of pregnancy drops, the vitamin A concentration in the oil increases. Thus it becomes apparent that at least part of the variation in the individual values for the vitamin A potency per gram of oil is dependent on variations in the oil content of the liver.

That the above discussion can be offered only as a partial explanation for the wide variations in the oil potencies is seen from the fact that it does not explain the variations in the total vitamin A content of the livers of sharks of comparable lengths; it does not explain the increase in the average vitamin A content in terms of the shark length, nor does it account for the fact that the vitamin A in the oil from male livers tends to be considerably higher than that of females in Stages A, B, and C. While it is true that the percentage of oil in the livers of adult males is somewhat lower than that of females of comparable lengths, this difference is not sufficient to account for the fact that the oil obtained from adult male livers has about three times more vitamin A than that obtained from the livers of adult females.

Two hypotheses may be advanced to explain the means by which the shark obtains its vitamin A; namely, the vitamin A may be derived from the food as such and stored in the liver or it may be synthesized from some other food constituent.

If the vitamin A in the soupfin liver is entirely derived as such from ingested food and is accumulated in the liver, we have a simple explanation of the fact that the vitamin A content of the liver increases with the age of the shark as measured by total length. The wide variations in the vitamin A content of the livers of the soupfin sharks of comparable lengths may be explained in part by the differences in rate of growth, rate of vitamin A absorption from the alimentary tract, vitamin A content of the food, and rate of vitamin A utilization by the shark.

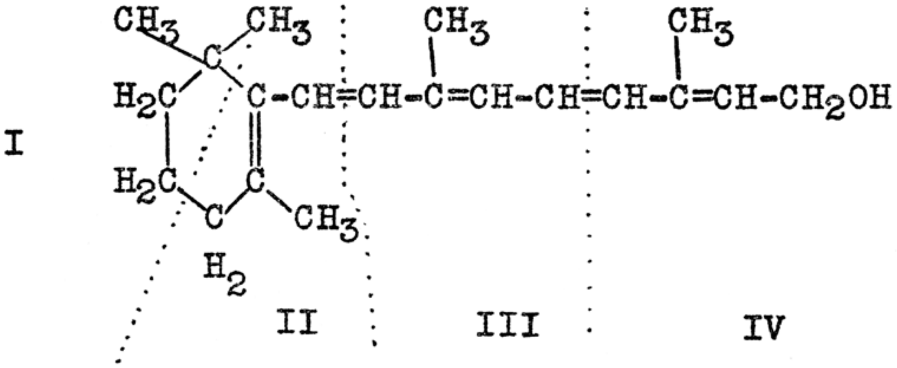
The synthesis of vitamin A in the soupfin shark has not been investigated but theoretically it would seem possible. Vitamin A is a diterpenoid and in this respect belongs to a large class of compounds that are very widely distributed in nature. Carotenes, squalene, kitol, and sterols are examples of polyterpenoids found in fish liver oils. These compounds are made up of a series of isoprene units combined in a variety of ways to give the desired structure. For example the carbon skeleton of vitamin A may be represented by four isoprene units



$$\left(C-\overset{\overset{\displaystyle C}{|}}{C}=C-C \right)$$

FORMULA

to give the structure:



FORMULA

It is not inconceivable that vitamin A could be formed from the precursors of terpenoids, or from other terpenoids. A well known example is the *in vivo* conversion of one molecule of [B]-carotene into two molecules of vitamin A. This reaction occurs in practically all forms of animal life. It is possible, therefore, that vitamin A may be synthesized in the soupfin shark. The function of vitamin A in the soupfin has not been indicated in this investigation.

SUMMARY

1. The percentage of oil and the vitamin A content expressed in international units per gram of oil, international units per pound of liver and total international units in the liver increase with the length of the shark.

2. The livers of adult female sharks of Stages ABC, namely, those without eggs, those with unfertilized eggs in their ovary, and those with fertilized eggs in their uteri have a higher percentage of oil than do the livers of adult males. The average percentage of oil in the liver is about 75 per cent for adult female sharks of Stages ABC and about 60 per cent for adult males.

3. The percentage of oil for females of Stages DE, namely, those with well-developed pups in their uteri and those that have recently spent their pups, is considerably lower than that of females in

Stages ABC. The values of Stages DE can not be related to the length of the shark.

4. The oil derived from adult male livers on the average has about three times more vitamin A than that derived from adult females.
5. Females of Stages DE (those having near term embryos in their uteri and those having recently liberated their young) average between 190,000 to 260,000 international units per gram of liver oil with a range from 45,000 to 640,000 units. The average values are considerably higher than those obtained for females of Stages ABC.
6. The livers of adult male sharks contain on the average about two and one-half times more vitamin A per pound of liver than do adult females.
7. Females of Stages DE have from 2,000,000 to 83,000,000 international units of vitamin A per pound of liver and have on the average over two and one-half times more vitamin A per pound of liver than do females of Stages ABC.
8. The average total vitamin A content of the liver of adult male sharks is about the same as that found in the livers of females of Stages ABC.
9. The total vitamin A content of the liver of females of Stages DE is indicated to be somewhat less than that for the adult females of Stages ABC.
10. In both the males and in the females of Stages ABC the percentage of oil, the vitamin A potency per gram of oil, the vitamin A potency per pound of liver, and the total vitamin potency of the liver increase with increase of total weight.
11. There was no indication that the region and the season of capture influenced the wide variations in the individual values of the dependent variables. The study of these independent variables is, however, incomplete due to the paucity of the available data.
12. Males below 155 cm. and females below 165 cm. do not appear to be sufficiently valuable in terms of vitamin A content to be exploited. Sharks of either sex larger than these respective lengths are, however, very rich sources of vitamin A. This is especially true in the case of the males.
13. The means by which vitamin A is accumulated in the liver, and the functions of vitamin A in the soupfin shark remain unanswered.

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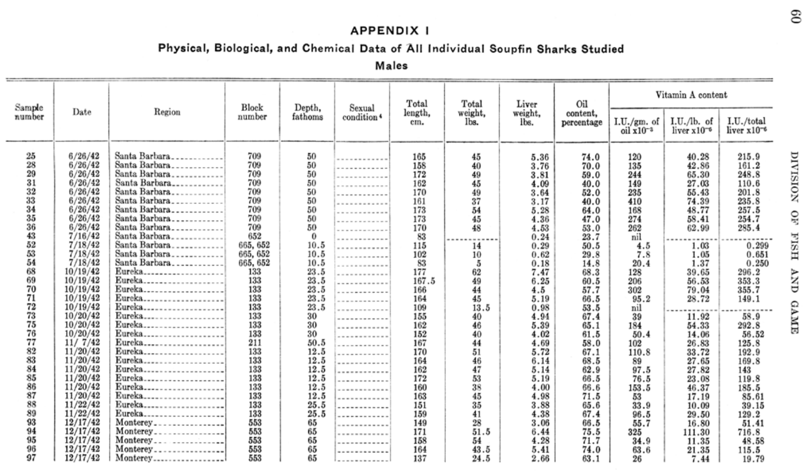


APPENDIX I

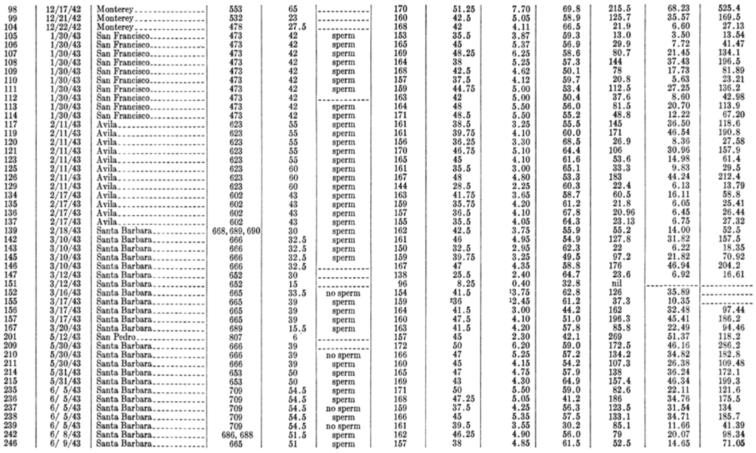
Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

Males

Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition [4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil x10⁻³	I.U./lb. of liver x10⁻⁶	I.U./total liver x10⁻⁶
25	6/26/42	Santa Barbara	709	50	----------	165	45	5.36	74.0	120	40.28	215.9
28	6/26/42	Santa Barbara	709	50	----------	158	40	3.76	70.0	135	42.86	161.2
29	6/26/42	Santa Barbara	709	50	----------	172	49	3.81	59.0	244	65.30	248.8
31	6/26/42	Santa Barbara	709	50	----------	162	45	4.09	40.0	149	27.03	110.6
32	6/26/42	Santa Barbara	709	50	----------	170	49	3.64	52.0	235	55.43	201.8
33	6/26/42	Santa Barbara	709	50	----------	161	37	3.17	40.0	410	74.39	235.8
34	6/26/42	Santa Barbara	709	50	----------	173	54	5.28	64.0	168	48.77	257.5
35	6/26/42	Santa Barbara	709	50	----------	173	45	4.36	47.0	274	58.41	254.7
36	6/26/42	Santa Barbara	709	50	----------	170	48	4.53	53.0	262	62.99	285.4
43	7/16/42	Santa Barbara	652	0	----------	83	----------	0.24	23.7	nil	----------	----------
52	7/18/42	Santa Barbara	665, 652	10.5	----------	115	14	0.29	50.5	4.5	1.03	0.299
53	7/18/42	Santa Barbara	665, 652	10.5	----------	102	10	0.62	29.8	7.8	1.05	0.651
54	7/18/42	Santa Barbara	665, 652	10.5	----------	83	5	0.18	14.8	20.4	1.37	0.250
68	10/19/42	Eureka	133	23.5	----------	177	62	7.47	68.3	128	39.65	296.2
69	10/19/42	Eureka	133	23.5	----------	167.5	49	6.25	60.5	206	56.53	353.3
70	10/19/42	Eureka	133	23.5	----------	166	44	4.5	57.7	302	79.04	355.7
71	10/19/42	Eureka	133	23.5	----------	164	45	5.19	66.5	95.2	28.72	149.1
72	10/19/42	Eureka	133	23.5	----------	109	13.5	0.98	53.5	nil	----------	----------
73	10/20/42	Eureka	133	30	----------	155	40	4.94	67.4	39	11.92	58.9
75	10/20/42	Eureka	133	30	----------	162	46	5.39	65.1	184	54.33	292.8
76	10/20/42	Eureka	133	30	----------	152	40	4.02	61.5	50.4	14.06	56.52
77	11/ 7/42	Eureka	211	50.5	----------	167	44	4.69	58.0	102	26.83	125.8
82	11/20/42	Eureka	133	12.5	----------	170	51	5.72	67.1	110.8	33.72	192.9
83	11/20/42	Eureka	133	12.5	----------	164	46	6.14	68.5	89	27.65	169.8
84	11/20/42	Eureka	133	12.5	----------	162	47	5.14	62.9	97.5	27.82	143
85	11/20/42	Eureka	133	12.5	----------	172	53	5.19	66.5	76.5	23.08	119.8
86	11/20/42	Eureka	133	12.5	----------	160	38	4.00	66.6	153.5	46.37	185.5
87	11/20/42	Eureka	133	12.5	----------	163	45	4.98	71.5	53	17.19	85.61
88	11/22/42	Eureka	133	25.5	----------	151	35	3.88	65.6	33.9	10.09	39.15
89	11/22/42	Eureka	133	25.5	----------	159	41	4.38	67.4	96.5	29.50	129.2
93	12/17/42	Monterey	553	65	----------	149	28	3.06	66.5	55.7	16.80	51.41
94	12/17/42	Monterey	553	65	----------	171	51.5	6.44	75.5	325	111.30	716.8
95	12/17/42	Monterey	553	65	----------	158	54	4.28	71.7	34.9	11.35	48.58
96	12/17/42	Monterey	553	65	----------	164	43.5	5.41	74.0	63.6	21.35	115.5
97	12/17/42	Monterey	553	65	----------	137	24.5	2.66	63.1	26	7.44	19.79

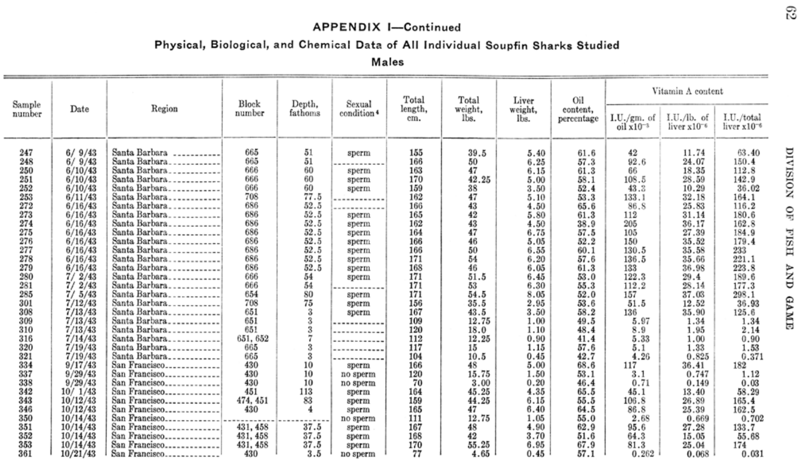
APPENDIX I

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied



98	12/17/42	Monterey	553	65	----------	170	51.25	7.70	69.8	215.5	68.23	525.4
99	12/21/42	Monterey	532	23	----------	160	42.5	5.05	58.9	125.7	35.57	169.5
104	12/22/42	Monterey	478	27.5	----------	168	42	4.11	66.5	21.9	6.60	27.13
105	1/30/43	San Francisco	473	42	sperm	153	35.5	3.87	59.3	13.0	3.50	13.54
106	1/30/43	San Francisco	473	42	sperm	165	45	5.37	56.9	29.9	7.72	41.47
107	1/30/43	San Francisco	473	42	sperm	169	48.25	6.25	58.6	80.7	21.45	134.1
108	1/30/43	San Francisco	473	42	sperm	164	38	5.25	57.3	144	37.43	196.5
109	1/30/43	San Francisco	473	42	sperm	168	42.5	4.62	50.1	78	17.73	81.89
110	1/30/43	San Francisco	473	42	sperm	157	37.5	4.12	59.7	20.8	5.63	23.21
111	1/30/43	San Francisco	473	42	sperm	159	44.75	5.00	53.4	112.5	27.25	136.2
112	1/30/43	San Francisco	473	42	----------	163	42	5.00	50.4	37.6	8.60	42.98
113	1/30/43	San Francisco	473	42	sperm	164	48	5.50	56.0	81.5	20.70	113.9
114	1/30/43	San Francisco	473	42	sperm	171	48.5	5.50	55.2	48.8	12.22	67.20
117	2/11/43	Avila	623	55	sperm	161	38.5	3.25	55.5	145	36.50	118.6
119	2/11/43	Avila	623	55	sperm	161	39.75	4.10	60.0	171	46.54	190.8
120	2/11/43	Avila	623	55	sperm	156	36.25	3.30	68.5	26.9	8.36	27.58
121	2/11/43	Avila	623	55	sperm	170	46.75	5.10	64.4	106	30.96	157.9
123	2/11/43	Avila	623	55	sperm	165	45	4.10	61.6	53.6	14.98	61.4
125	2/11/43	Avila	623	60	sperm	161	35.5	3.00	65.1	33.3	9.83	29.5
126	2/11/43	Avila	623	60	sperm	167	48	4.80	53.3	183	44.24	212.4
129	2/11/43	Avila	623	60	sperm	144	28.5	2.25	60.3	22.4	6.13	13.79
134	2/17/43	Avila	602	43	sperm	163	41.75	3.65	58.7	60.5	16.11	58.8
135	2/17/43	Avila	602	43	sperm	159	35.75	4.20	61.2	21.8	6.05	25.41
136	2/17/43	Avila	602	43	sperm	157	36.5	4.10	67.8	20.96	6.45	26.44
137	2/17/43	Avila	602	43	sperm	155	35.5	4.05	64.3	23.13	6.75	27.32
139	2/18/43	Santa Barbara	668, 689, 690	30	sperm	162	42.5	3.75	55.9	55.2	14.00	52.5
142	3/10/43	Santa Barbara	666	32.5	sperm	161	46	4.95	54.9	127.8	31.82	157.5
143	3/10/43	Santa Barbara	666	32.5	sperm	150	32.5	2.95	62.3	22	6.22	18.35
145	3/10/43	Santa Barbara	666	32.5	sperm	159	39.75	3.25	49.5	97.2	21.82	70.92
146	3/10/43	Santa Barbara	666	32.5	----------	167	47	4.35	58.8	176	46.94	204.2
147	3/12/43	Santa Barbara	652	30	----------	138	25.5	2.40	64.7	23.6	6.92	16.61
151	3/12/43	Santa Barbara	652	15	----------	96	8.25	0.40	32.8	nil	----------	----------
152	3/16/43	Santa Barbara	665	33.5	no sperm	154	41.5	[1]3.75	62.8	126	35.89	----------
155	3/17/43	Santa Barbara	665	39	sperm	159	[2]36	[1]2.45	61.2	37.3	10.35	----------
156	3/17/43	Santa Barbara	665	39	sperm	164	41.5	3.00	44.2	162	32.48	97.44
157	3/17/43	Santa Barbara	665	39	sperm	160	47.5	4.10	51.0	196.3	45.41	186.2
167	3/20/43	Santa Barbara	689	15.5	sperm	163	41.5	4.20	57.8	85.8	22.49	94.46
201	5/12/43	San Pedro	807	6	----------	157	45	2.30	42.1	269	51.37	118.2
209	5/30/43	Santa Barbara	666	39	----------	172	50	6.20	59.0	172.5	46.16	286.2
210	5/30/43	Santa Barbara	666	39	no sperm	166	47	5.25	57.2	134.2	34.82	182.8
211	5/30/43	Santa Barbara	666	39	sperm	160	45	4.15	54.2	107.3	26.38	109.48
214	5/31/43	Santa Barbara	653	50	sperm	165	47	4.75	57.9	138	36.24	172.1
215	5/31/43	Santa Barbara	653	50	sperm	169	43	4.30	64.9	157.4	46.34	199.3
235	6/ 5/43	Santa Barbara	709	54.5	sperm	171	50	5.50	59.0	82.6	22.11	121.6
236	6/ 5/43	Santa Barbara	709	54.5	sperm	168	47.25	5.05	41.2	186	34.76	175.5
237	6/ 5/43	Santa Barbara	709	54.5	no sperm	159	37.5	4.25	56.3	123.5	31.54	134
238	6/ 5/43	Santa Barbara	709	54.5	sperm	166	45	5.35	57.5	133.1	34.71	185.7
239	6/ 5/43	Santa Barbara	709	54.5	no sperm	161	39.5	3.55	30.2	85.1	11.66	41.39
242	6/ 8/43	Santa Barbara	686, 688	51.5	sperm	162	46.25	4.90	56.0	79	20.07	98.34
246	6/ 9/43	Santa Barbara	665	51	sperm	157	38	4.85	61.5	52.5	14.65	71.05

APPENDIX I—Cont'd.



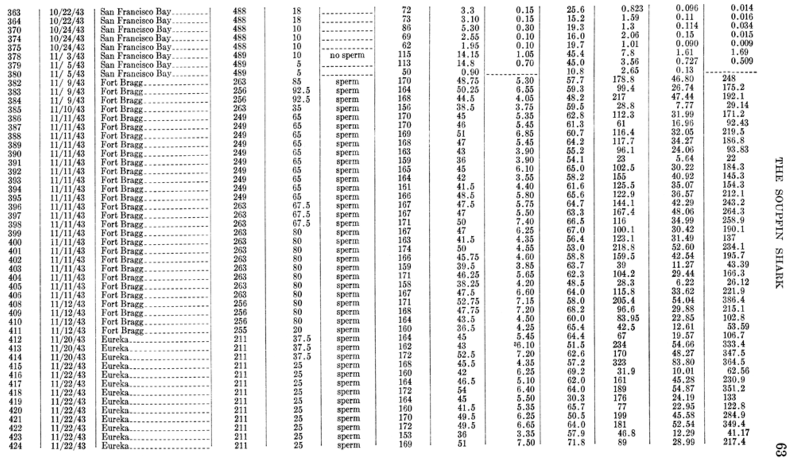
APPENDIX I—Continued

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

Males

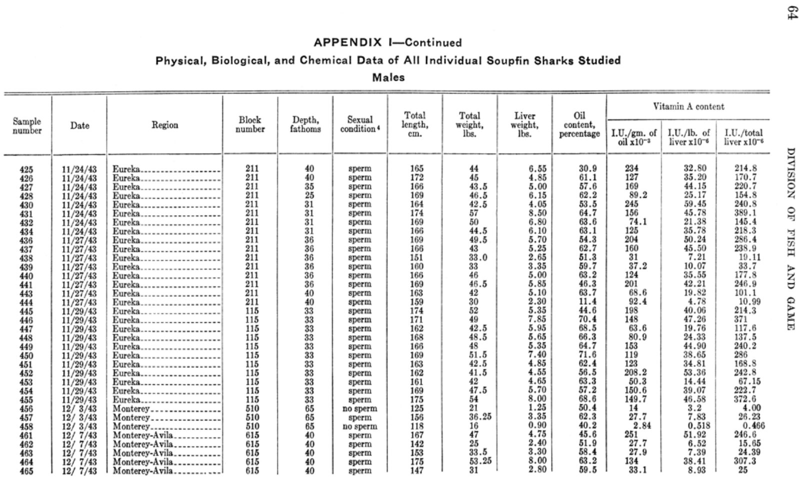
Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition[4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil x10^{-3}	I.U./lb. of liver x10^{-6}	I.U./total liver x10^{-6}
247	6/ 9/43	Santa Barbara	665	51	sperm	155	39.5	5.40	61.6	42	11.74	63.40
248	6/ 9/43	Santa Barbara	665	51	-----------	166	50	6.25	57.3	92.6	24.07	150.4
250	6/10/43	Santa Barbara	666	60	sperm	163	47	6.15	61.3	66	18.35	112.8
251	6/10/43	Santa Barbara	666	60	sperm	170	42.25	5.00	58.1	108.5	28.59	142.9
252	6/10/43	Santa Barbara	666	60	sperm	159	38	3.50	52.4	43.3	10.29	36.02
253	6/11/43	Santa Barbara	708	77.5	-----------	162	47	5.10	53.3	133.1	32.18	164.1
272	6/16/43	Santa Barbara	686	52.5	-----------	166	43	4.50	65.6	86.8	25.83	116.2
273	6/16/43	Santa Barbara	686	52.5	sperm	165	42	5.80	61.3	112	31.14	180.6
274	6/16/43	Santa Barbara	686	52.5	sperm	162	43	4.50	38.9	205	36.17	162.8
275	6/16/43	Santa Barbara	686	52.5	sperm	164	47	6.75	57.5	105	27.39	184.9
276	6/16/43	Santa Barbara	686	52.5	sperm	166	46	5.05	52.2	150	35.52	179.4
277	6/16/43	Santa Barbara	686	52.5	sperm	166	50	6.55	60.1	130.5	35.58	233
278	6/16/43	Santa Barbara	686	52.5	sperm	171	54	6.20	57.6	136.5	35.66	221.1
279	6/16/43	Santa Barbara	686	52.5	sperm	168	46	6.05	61.3	133	36.98	223.8
280	7/ 2/43	Santa Barbara	666	54	sperm	171	51.5	6.45	53.0	122.3	29.4	189.6
281	7/ 2/43	Santa Barbara	666	54	-----------	171	53	6.30	55.3	112.2	28.14	177.3
285	7/ 5/43	Santa Barbara	654	80	sperm	171	54.5	8.05	52.0	157	37.03	298.1
301	7/12/43	Santa Barbara	708	75	sperm	156	35.5	2.95	53.6	51.5	12.52	36.93
308	7/13/43	Santa Barbara	651	3	sperm	167	43.5	3.50	58.2	136	35.90	125.6
309	7/13/43	Santa Barbara	651	3	-----------	109	12.75	1.00	49.5	5.97	1.34	1.34
310	7/13/43	Santa Barbara	651	3	-----------	120	18.0	1.10	48.4	8.9	1.95	2.14
316	7/14/43	Santa Barbara	651, 652	7	-----------	112	12.25	0.90	41.4	5.33	1.00	0.90
320	7/19/43	Santa Barbara	665	3	-----------	117	15	1.15	57.6	5.1	1.33	1.53
321	7/19/43	Santa Barbara	665	3	-----------	104	10.5	0.45	42.7	4.26	0.825	0.371
334	9/17/43	San Francisco	430	10	sperm	166	48	5.00	68.6	117	36.41	182
337	9/29/43	San Francisco	430	10	no sperm	120	15.75	1.50	53.1	3.1	0.747	1.12
338	9/29/43	San Francisco	430	10	no sperm	70	3.00	0.20	46.4	0.71	0.149	0.03
342	10/ 1/43	San Francisco	451	113	sperm	164	45.25	4.35	65.5	45.1	13.40	58.29
343	10/12/43	San Francisco	474, 451	83	sperm	159	44.25	6.15	55.5	106.8	26.89	165.4
346	10/12/43	San Francisco	430	4	sperm	165	47	6.40	64.5	86.8	25.39	162.5
350	10/14/43	San Francisco	-----------	-----------	no sperm	111	12.75	1.05	55.0	2.68	0.669	0.702
351	10/14/43	San Francisco	431, 458	37.5	sperm	167	48	4.90	62.9	95.6	27.28	133.7
352	10/14/43	San Francisco	431, 458	37.5	sperm	168	42	3.70	51.6	64.3	15.05	55.68
353	10/14/43	San Francisco	431, 458	37.5	sperm	170	55.25	6.95	67.9	81.3	25.04	174
361	10/21/43	San Francisco	430	3.5	no sperm	77	4.65	0.45	57.1	0.262	0.068	0.031

APPENDIX I—Cont'd.



363	10/22/43	San Francisco Bay	488	18	------------	72	3.3	0.15	25.6	0.823	0.096	0.014
364	10/22/43	San Francisco Bay	488	18	------------	73	3.10	0.15	15.2	1.59	0.11	0.016
370	10/24/43	San Francisco Bay	488	10	------------	86	5.30	0.30	19.3	1.3	0.114	0.034
374	10/24/43	San Francisco Bay	488	10	------------	69	2.55	0.10	16.0	2.06	0.15	0.015
375	10/24/43	San Francisco Bay	488	10	------------	62	1.95	0.10	19.7	1.01	0.090	0.009
378	11/ 3/43	San Francisco Bay	489	10	no sperm	115	14.15	1.05	45.4	7.8	1.61	1.69
379	11/ 5/43	San Francisco Bay	489	5	------------	113	14.8	0.70	45.0	3.56	0.727	0.509
380	11/ 5/43	San Francisco Bay	489	5	------------	50	0.90	------------	10.8	2.65	0.13	------------
382	11/ 9/43	Fort Bragg	263	85	sperm	170	48.75	5.30	57.7	178.8	46.80	248
383	11/ 9/43	Fort Bragg	256	92.5	sperm	164	50.25	6.55	59.3	99.4	26.74	175.2
384	11/ 9/43	Fort Bragg	256	92.5	sperm	168	44.5	4.05	48.2	217	47.44	192.1
385	11/10/43	Fort Bragg	263	35	sperm	156	38.5	3.75	59.5	28.8	7.77	29.14
386	11/11/43	Fort Bragg	249	65	sperm	170	45	5.35	62.8	112.3	31.99	171.2
387	11/11/43	Fort Bragg	249	65	sperm	170	46	5.45	61.3	61	16.96	92.43
388	11/11/43	Fort Bragg	249	65	sperm	169	51	6.85	60.7	116.4	32.05	219.5
389	11/11/43	Fort Bragg	249	65	sperm	168	47	5.45	64.2	117.7	34.27	186.8
390	11/11/43	Fort Bragg	249	65	sperm	163	43	3.90	55.2	96.1	24.06	93.83
391	11/11/43	Fort Bragg	249	65	sperm	159	36	3.90	54.1	23	5.64	22
392	11/11/43	Fort Bragg	249	65	sperm	165	45	6.10	65.0	102.5	30.22	184.3
393	11/11/43	Fort Bragg	249	65	sperm	164	42	3.55	58.2	155	40.92	145.3
394	11/11/43	Fort Bragg	249	65	sperm	161	41.5	4.40	61.6	125.5	35.07	154.3
395	11/11/43	Fort Bragg	249	65	sperm	166	48.5	5.80	65.6	122.9	36.57	212.1
396	11/11/43	Fort Bragg	263	67.5	sperm	167	47.5	5.75	64.7	144.1	42.29	243.2
397	11/11/43	Fort Bragg	263	67.5	sperm	167	47	5.50	63.3	167.4	48.06	264.3
398	11/11/43	Fort Bragg	263	67.5	sperm	171	50	7.40	66.5	116	34.99	258.9
399	11/11/43	Fort Bragg	263	80	sperm	167	47	6.25	67.0	100.1	30.42	190.1
400	11/11/43	Fort Bragg	263	80	sperm	163	41.5	4.35	56.4	123.1	31.49	137
401	11/11/43	Fort Bragg	263	80	sperm	174	50	4.55	53.0	218.8	52.60	234.1
402	11/11/43	Fort Bragg	263	80	sperm	166	45.75	4.60	58.8	159.5	42.54	195.7
403	11/11/43	Fort Bragg	263	80	sperm	159	39.5	3.85	63.7	39	11.27	43.39
404	11/11/43	Fort Bragg	263	80	sperm	171	46.25	5.65	62.3	104.2	29.44	166.3
405	11/11/43	Fort Bragg	263	80	sperm	158	38.25	4.20	48.5	28.3	6.22	26.12
406	11/11/43	Fort Bragg	263	80	sperm	167	47.5	6.60	64.0	115.8	33.62	221.9
408	11/12/43	Fort Bragg	256	80	sperm	171	52.75	7.15	58.0	205.4	54.04	386.4
409	11/12/43	Fort Bragg	256	80	sperm	168	47.75	7.20	68.2	96.6	29.88	215.1
410	11/12/43	Fort Bragg	256	80	sperm	164	43.5	4.50	60.0	83.95	22.85	102.8
411	11/12/43	Fort Bragg	255	20	sperm	160	36.5	4.25	65.4	42.5	12.61	53.59
412	11/20/43	Eureka	211	37.5	sperm	164	45	5.45	64.4	67	19.57	106.7
413	11/20/43	Eureka	211	37.5	sperm	162	43	[3]6.10	51.5	234	54.66	333.4
414	11/20/43	Eureka	211	37.5	sperm	172	52.5	7.20	62.6	170	48.27	347.5
415	11/22/43	Eureka	211	25	sperm	168	45.5	4.35	57.2	323	83.80	364.5
416	11/22/43	Eureka	211	25	sperm	160	42	6.25	69.2	31.9	10.01	62.56
417	11/22/43	Eureka	211	25	sperm	164	46.5	5.10	62.0	161	45.28	230.9
418	11/22/43	Eureka	211	25	sperm	172	54	6.40	64.0	189	54.87	351.2
419	11/22/43	Eureka	211	25	sperm	164	45	5.50	30.3	176	24.19	133
420	11/22/43	Eureka	211	25	sperm	160	41.5	5.35	65.7	77	22.95	122.8
421	11/22/43	Eureka	211	25	sperm	170	49.5	6.25	50.5	199	45.58	284.9
422	11/22/43	Eureka	211	25	sperm	172	49.5	6.65	64.0	181	52.54	349.4
423	11/22/43	Eureka	211	25	sperm	153	36	3.35	57.9	46.8	12.29	41.17
424	11/22/43	Eureka	211	25	sperm	169	51	7.50	71.8	89	28.99	217.4

APPENDIX I—Cont'd.



APPENDIX I—Continued

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

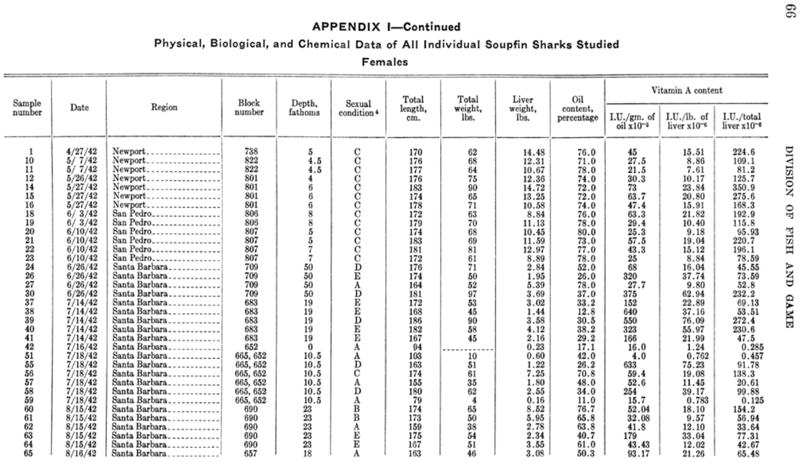
Males

Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition[4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil $x10^{-3}$	I.U./lb. of liver $x10^{-6}$	I.U./total liver $x10^{-6}$
425	11/24/43	Eureka	211	40	sperm	165	44	6.55	30.9	234	32.80	214.8
426	11/24/43	Eureka	211	40	sperm	172	45	4.85	61.1	127	35.20	170.7
427	11/24/43	Eureka	211	35	sperm	166	43.5	5.00	57.6	169	44.15	220.7
428	11/24/43	Eureka	211	25	sperm	169	46.5	6.15	62.2	89.2	25.17	154.8
430	11/24/43	Eureka	211	31	sperm	164	42.5	4.05	53.5	245	59.45	240.8
431	11/24/43	Eureka	211	31	sperm	174	57	8.50	64.7	156	45.78	389.1
432	11/24/43	Eureka	211	31	sperm	169	50	6.80	63.6	74.1	21.38	145.4
434	11/24/43	Eureka	211	31	sperm	166	44.5	6.10	63.1	125	35.78	218.3
436	11/27/43	Eureka	211	36	sperm	169	49.5	5.70	54.3	204	50.24	286.4
437	11/27/43	Eureka	211	36	sperm	166	43	5.25	62.7	160	45.50	238.9
438	11/27/43	Eureka	211	36	sperm	151	33.0	2.65	51.3	31	7.21	19.11
439	11/27/43	Eureka	211	36	sperm	160	33	3.35	59.7	37.2	10.07	33.7
440	11/27/43	Eureka	211	36	sperm	166	46	5.00	63.2	124	35.55	177.8
441	11/27/43	Eureka	211	36	sperm	169	46.5	5.85	46.3	201	42.21	246.9
443	11/27/43	Eureka	211	40	sperm	163	42	5.10	63.7	68.6	19.82	101.1
444	11/27/43	Eureka	211	40	sperm	159	30	2.30	11.4	92.4	4.78	10.99
445	11/29/43	Eureka	115	33	sperm	174	52	5.35	44.6	198	40.06	214.3
446	11/29/43	Eureka	115	33	sperm	171	49	7.85	70.4	148	47.26	371
447	11/29/43	Eureka	115	33	sperm	162	42.5	5.95	68.5	63.6	19.76	117.6
448	11/29/43	Eureka	115	33	sperm	168	48.5	5.65	66.3	80.9	24.33	137.5
449	11/29/43	Eureka	115	33	sperm	166	48	5.35	64.7	153	44.90	240.2
450	11/29/43	Eureka	115	33	sperm	169	51.5	7.40	71.6	119	38.65	286
451	11/29/43	Eureka	115	33	sperm	163	42.5	4.85	62.4	123	34.81	168.8
452	11/29/43	Eureka	115	33	sperm	162	41.5	4.55	56.5	208.2	53.36	242.8
453	11/29/43	Eureka	115	33	sperm	161	42	4.65	63.3	50.3	14.44	67.15
454	11/29/43	Eureka	115	33	sperm	169	47.5	5.70	57.2	150.6	39.07	222.7
455	11/29/43	Eureka	115	33	sperm	175	54	8.00	68.6	149.7	46.58	372.6
456	12/ 3/43	Monterey	510	65	no sperm	125	21	1.25	50.4	14	3.2	4.00
457	12/ 3/43	Monterey	510	65	sperm	156	36.25	3.35	62.3	27.7	7.83	26.23
458	12/ 3/43	Monterey	510	65	no sperm	118	16	0.90	40.2	2.84	0.518	0.466
461	12/ 7/43	Monterey-Avila	615	40	sperm	167	47	4.75	45.6	251	51.92	246.6
462	12/ 7/43	Monterey-Avila	615	40	sperm	142	25	2.40	51.9	27.7	6.52	15.65
463	12/ 7/43	Monterey-Avila	615	40	sperm	153	33.5	3.30	58.4	27.9	7.39	24.39
464	12/ 7/43	Monterey-Avila	615	40	sperm	175	53.25	8.00	63.2	134	38.41	307.3
465	12/ 7/43	Monterey-Avila	615	40	sperm	147	31	2.80	59.5	33.1	8.93	25

APPENDIX I—Cont'd.

466	12/ 7/43	Monterey-Avila	615	40	sperm	162	37	2.95	45.7	57.6	11.94	35.22
467	12/ 7/43	Monterey-Avila	615	40	sperm	174	50.75	5.15	57.4	126.9	33.04	170.2
468	12/ 7/43	Monterey-Avila	615	40	sperm	163	42.75	4.60	61.2	50.3	13.96	64.22
469	12/ 7/43	Monterey-Avila	615	40	sperm	160	46	4.80	58.9	91.5	24.45	117.4
470	12/ 7/43	Monterey-Avila	615	40	sperm	162	41.5	5.10	54.9	79.2	19.72	100.6
471	12/ 8/43	Monterey	539	75	sperm	143	23.25	1.65	53.8	24	5.86	9.67
472	12/ 8/43	Monterey	539	75	no sperm	126	15.25	1.15	67.8	13.83	4.25	4.89
473	12/ 8/43	Monterey	539	75	no sperm	127	15.25	0.85	35.4	16.63	2.67	2.27
474	12/ 8/43	Monterey	539	75	no sperm	133	20	1.65	56.6	9.95	2.55	4.21
475	12/ 8/43	Monterey	539	75	sperm	140	24.75	2.00	56.4	17	4.35	8.70
476	12/ 8/43	Monterey	539	75	no sperm	123	16.5	1.10	23.5	17	1.81	1.99
477	12/ 8/43	Monterey	539	75	sperm	156	35.75	3.65	62.0	45.6	12.82	46.79
478	12/ 8/43	Monterey	539	75	sperm	170	47.75	5.20	59.9	224.5	61.00	317.2
479	12/ 8/43	Monterey	539	75	sperm	172	48.25	5.80	61.0	160	44.27	256.8
480	12/ 8/43	Monterey	539	75	sperm	155	33.5	3.20	52.2	44.1	10.44	33.41
481	12/ 8/43	Monterey	508	80	sperm	166	39.25	4.45	57.3	316	82.13	365.5
482	12/ 8/43	Monterey	508	80	sperm	150	27.5	1.65	10.6	89.7	4.31	7.11
483	12/ 8/43	Monterey	508	80	sperm	140	25	1.90	15.2	26.05	1.80	3.42
484	12/ 8/43	Monterey	508	80	sperm	166	47.25	7.95	66.4	158.1	47.62	378.6
485	12/ 8/43	Monterey	508	80	sperm	148	27.5	2.75	53.0	21.19	5.09	14.0

APPENDIX I—Cont'd.



APPENDIX I—Continued

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

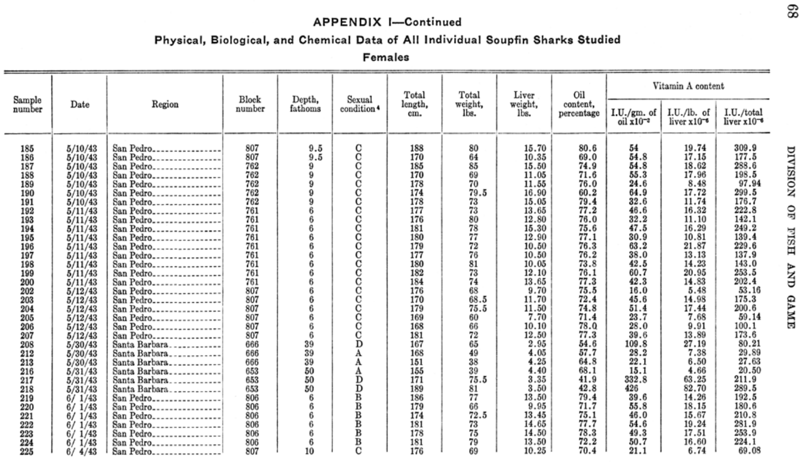
Females

Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition[4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil x10^{-3}	I.U./lb. of liver x10^{-6}	I.U./total liver x10^{-6}
1	4/27/42	Newport	738	5	C	170	62	14.48	76.0	45	15.51	224.6
10	5/ 7/42	Newport	822	4.5	C	176	68	12.31	71.0	27.5	8.86	109.1
11	5/ 7/42	Newport	822	4.5	C	177	64	10.67	78.0	21.5	7.61	81.2
12	5/26/42	Newport	801	4	C	176	75	12.36	74.0	30.3	10.17	125.7
14	5/27/42	Newport	801	6	C	183	90	14.72	72.0	73	23.84	350.9
15	5/27/42	Newport	801	6	C	174	65	13.25	72.0	63.7	20.80	275.6
16	5/27/42	Newport	801	6	C	178	71	10.58	74.0	47.4	15.91	168.3
18	6/ 3/42	San Pedro	806	8	C	172	63	8.84	76.0	63.3	21.82	192.9
19	6/ 3/42	San Pedro	806	8	C	179	70	11.13	78.0	29.4	10.40	115.8
20	6/10/42	San Pedro	807	5	C	174	68	10.45	80.0	25.3	9.18	95.93
21	6/10/42	San Pedro	807	5	C	183	69	11.59	73.0	57.5	19.04	220.7
22	6/10/42	San Pedro	807	7	C	181	81	12.97	77.0	43.3	15.12	196.1
23	6/10/42	San Pedro	807	7	C	172	61	8.89	78.0	25	8.84	78.59
24	6/26/42	Santa Barbara	709	50	D	176	71	2.84	52.0	68	16.04	45.55
26	6/26/42	Santa Barbara	709	50	E	174	50	1.95	26.0	320	37.74	73.59
27	6/26/42	Santa Barbara	709	50	A	164	52	5.39	78.0	27.7	9.80	52.8
30	6/26/42	Santa Barbara	709	50	D	181	97	3.69	37.0	375	62.94	232.2
37	7/14/42	Santa Barbara	683	19	E	172	53	3.02	33.2	152	22.89	69.13
38	7/14/42	Santa Barbara	683	19	E	168	45	1.44	12.8	640	37.16	53.51
39	7/14/42	Santa Barbara	683	19	D	186	90	3.58	30.5	550	76.09	272.4
40	7/14/42	Santa Barbara	683	19	E	182	58	4.12	38.2	323	55.97	230.6
41	7/14/42	Santa Barbara	683	19	E	167	45	2.16	29.2	166	21.99	47.5
42	7/16/42	Santa Barbara	652	0	A	94	----------	0.23	17.1	16.0	1.24	0.285
51	7/18/42	Santa Barbara	665, 652	10.5	A	103	10	0.60	42.0	4.0	0.762	0.457
55	7/18/42	Santa Barbara	665, 652	10.5	D	163	51	1.22	26.2	633	75.23	91.78
56	7/18/42	Santa Barbara	665, 652	10.5	C	174	61	7.25	70.8	59.4	19.08	138.3
57	7/18/42	Santa Barbara	665, 652	10.5	A	155	35	1.80	48.0	52.6	11.45	20.61
58	7/18/42	Santa Barbara	665, 652	10.5	D	180	62	2.55	34.0	254	39.17	99.88
59	7/18/42	Santa Barbara	665, 652	10.5	A	79	4	0.16	11.0	15.7	0.783	0.125
60	8/15/42	Santa Barbara	690	23	B	174	65	8.52	76.7	52.04	18.10	154.2
61	8/15/42	Santa Barbara	690	23	B	173	50	5.95	65.8	32.08	9.57	56.94
62	8/15/42	Santa Barbara	690	23	A	159	38	2.78	63.8	41.8	12.10	33.64
63	8/15/42	Santa Barbara	690	23	E	175	54	2.34	40.7	179	33.04	77.31
64	8/15/42	Santa Barbara	690	23	E	167	51	3.55	61.0	43.43	12.02	42.67
65	8/16/42	Santa Barbara	657	18	A	163	46	3.08	50.3	93.17	21.26	65.48

APPENDIX I—Cont'd.

66	8/16/42	Santa Barbara	657	18	D	172	68	5.03	61.9	277.1	77.79	391.3
67	8/16/42	Santa Barbara	657	18	A	171	41	2.19	59.3	70.52	18.96	41.52
74	10/22/42	Eureka	133	20.5	B	170	56	4.64	55.5	30.2	7.60	35.26
90	12/17/42	Monterey	553	65	A	154	36	3.78	69.5	42.5	13.40	50.65
91	12/17/42	Monterey	553	65	B	167	45	6.20	79.0	34.5	12.36	76.65
92	12/17/42	Monterey	553	65	A	117	16	1.12	57.9	8.98	2.36	2.64
100	12/21/42	Monterey	532	23	B	187	88.5	19.14	79.4	23.85	8.59	164.4
101	12/22/42	Monterey	478	27.5	B	170	54.5	6.27	71.9	20.75	6.77	42.45
102	12/22/42	Monterey	478	27.5	B	183	66	6.39	62.0	115.9	32.61	208.4
103	12/22/42	Monterey	478	27.5	B	158	45	6.45	80.9	7.39	2.71	17.48
115	1/30/43	San Francisco	473	42	A	148	35.5	4.75	66.1	12.2	3.66	17.38
116	1/30/43	San Francisco	473	42	B	180	79.5	14.62	61.3	34.2	9.51	139
118	2/11/43	Avila	623	55	B	175	60.5	10.80	79.3	18.5	6.65	71.87
122	2/11/43	Avila	623	55	B	168	48.25	4.80	70.6	33	10.57	50.73
124	2/11/43	Avila	623	55	A	145	32.5	3.65	70.3	17.3	5.52	20.14
127	2/11/43	Avila	623	60	B	179	63	9.10	75.7	30	10.30	93.74
128	2/11/43	Avila	623	60	B	175	60	7.75	70.8	85.4	27.43	212.6
130	2/13/43	Monterey	554	50	B	180	67.25	9.50	70.7	56.3	18.05	171.5
138	2/18/43	Santa Barbara	688, 689, 690	30	B	168	55.75	10.00	67.6	15.85	4.86	48.6
140	2/18/43	Santa Barbara	688, 689, 690	30	B	180	87	17.15	74.5	24.62	8.32	142.7
141	2/18/43	Santa Barbara	688, 689, 690	30	B	176	77	14.80	73.5	21.5	7.17	106.1
144	3/10/43	Santa Barbara	666	32.5	A	144	32.5	3.80	69.5	9.1	2.87	10.91
148	3/12/43	Santa Barbara	652	15	A	163	46.5	5.70	65.4	18.0	5.34	30.44
149	3.12.43	Santa Barbara	652	15	B	181	85	17.95	77.5	61.3	21.55	386.8
150	3/12/43	Santa Barbara	652	15	B	163	55	8.60	76.8	9.3	3.24	27.86
154	3/17/43	Santa Barbara	665	39	B	176	67	10.60	77.1	15.6	5.46	57.88
158	3/17/43	Santa Barbara	665	39	A	108	12.5	0.85	38.2	2.68	0.464	0.394
159	3/20/43	Santa Barbara	689	15.5	B	178	78	15.70	75.1	41.1	14.00	219.8
160	3/20/43	Santa Barbara	689	15.5	B	174	72.5	15.60	76.6	27.0	9.38	146.3
161	3/20/43	Santa Barbara	689	15.5	B	180	73.5	13.75	78.5	63.5	22.61	310.9
162	3/20/43	Santa Barbara	689	15.5	B	172	65	11.80	77.2	22.6	7.91	93.34
163	3/20/43	Santa Barbara	689	15.5	B	169	57.5	10.75	76.0	12.2	4.20	45.15
164	3/20/43	Santa Barbara	689	15.5	B	176	77	15.05	78.0	27.1	9.59	144.3
165	3/20/43	Santa Barbara	689	15.5	B	171	65	11.70	76.6	19.8	6.88	80.50
166	3/20/43	Santa Barbara	689	15.5	B	180	85.5	15.65	74.5	22.9	7.74	121.1
168	3/25/43	Santa Barbara	652	4	B	183	82.25	16.45	76.5	21.2	7.36	121.1
169	3/25/43	Santa Barbara	652	4	B	165	51.5	7.70	74.5	15.6	5.27	40.58
170	3/25/43	Santa Barbara	652	4	A	88	5.25	10.35	29.7	3.9	0.526	----------
172	5/ 6/43	San Pedro	761	13	C	191	79	14.25	77.3	54.0	18.93	269.8
173	5/ 6/43	San Pedro	761	13	C	176	74	11.35	77.9	36.4	12.86	146
174	5/ 6/43	San Pedro	761	13	C	167	79.5	12.70	76.4	39.9	13.83	175.6
175	5/ 6/43	San Pedro	761	13	C	183	79.5	13.30	79.1	37.4	13.42	178.5
176	5/ 6/43	San Pedro	761	13	C	164	58	10.10	78.9	19.9	7.12	71.91
177	5/ 6/43	San Pedro	761	13	B	155	48	7.75	77.2	12.6	4.41	34.18
178	5/ 6/43	San Pedro	761	13	B	173	69	15.10	70.5	44.5	14.23	214.9
179	5/ 6/43	San Pedro	761	13	B	159	50	7.35	70.3	12.8	4.08	30
180	5/ 6/43	San Pedro	761	13	C	172	70.5	13.90	74.3	54.8	18.47	256.7
182	5/10/43	San Pedro	807	9.5	C	181	75	13.65	81.7	51.4	19.05	260
183	5/10/43	San Pedro	807	9.5	C	168	66	11.90	78.0	48.9	17.30	205.9
184	5/10/43	San Pedro	807	9.5	B	167	53	8.15	73.1	18.5	6.13	49.96

APPENDIX I—Cont'd.



APPENDIX I—Continued

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

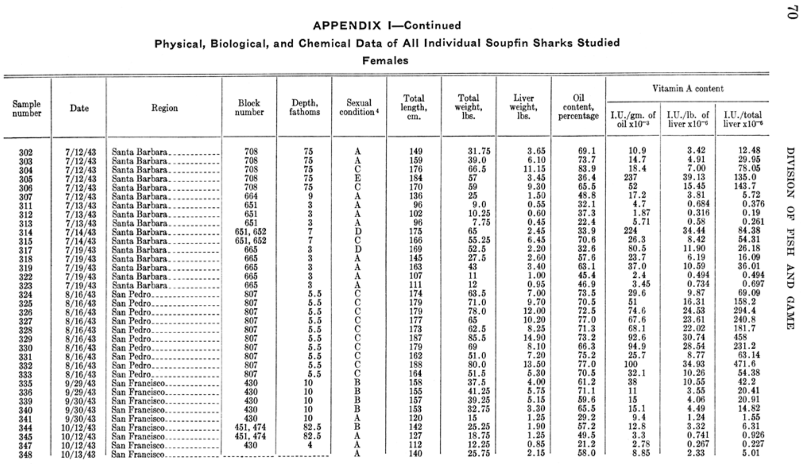
Females

Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition[4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil x10^{-2}	I.U./lb. of liver x10^{-6}	I.U./total liver x10^{-6}
185	5/10/43	San Pedro	807	9.5	C	188	80	15.70	80.6	54	19.74	309.9
186	5/10/43	San Pedro	807	9.5	C	170	64	10.35	69.0	54.8	17.15	177.5
187	5/10/43	San Pedro	762	9	C	185	85	15.50	74.9	54.8	18.62	288.6
188	5/10/43	San Pedro	762	9	C	170	69	11.05	71.6	55.3	17.96	198.5
189	5/10/43	San Pedro	762	9	C	178	70	11.55	76.0	24.6	8.48	97.94
190	5/10/43	San Pedro	762	9	C	174	79.5	16.90	60.2	64.9	17.72	299.5
191	5/10/43	San Pedro	762	9	C	178	73	15.05	79.4	32.6	11.74	176.7
192	5/11/43	San Pedro	761	6	C	177	73	13.65	77.2	46.6	16.32	222.8
193	5/11/43	San Pedro	761	6	C	176	80	12.80	76.0	32.2	11.10	142.1
194	5/11/43	San Pedro	761	6	C	181	78	15.30	75.6	47.5	16.29	249.2
195	5/11/43	San Pedro	761	6	C	180	77	12.90	77.1	30.9	10.81	139.4
196	5/11/43	San Pedro	761	6	C	179	72	10.50	76.3	63.2	21.87	229.6
197	5/11/43	San Pedro	761	6	C	177	76	10.50	76.2	38.0	13.13	137.9
198	5/11/43	San Pedro	761	6	C	180	81	10.05	73.8	42.5	14.23	143.0
199	5/11/43	San Pedro	761	6	C	182	73	12.10	76.1	60.7	20.95	253.5
200	5/11/43	San Pedro	761	6	C	184	74	13.65	77.3	42.3	14.83	202.4
202	5/12/43	San Pedro	807	6	C	176	68	9.70	75.5	16.0	5.48	53.16
203	5/12/43	San Pedro	807	6	C	170	68.5	11.70	72.4	45.6	14.98	175.3
204	5/12/43	San Pedro	807	6	C	179	75.5	11.50	74.8	51.4	17.44	200.6
205	5/12/43	San Pedro	807	6	C	169	60	7.70	71.4	23.7	7.68	59.14
206	5/12/43	San Pedro	807	6	C	168	66	10.10	78.0	28.0	9.91	100.1
207	5/12/43	San Pedro	807	6	C	181	72	12.50	77.3	39.6	13.89	173.6
208	5/30/43	Santa Barbara	666	39	D	167	65	2.95	54.6	109.8	27.19	80.21
212	5/30/43	Santa Barbara	666	39	A	168	49	4.05	57.7	28.2	7.38	29.89
213	5/30/43	Santa Barbara	666	39	A	151	38	4.25	64.8	22.1	6.50	27.63
216	5/31/43	Santa Barbara	653	50	A	155	39	4.40	68.1	15.1	4.66	20.50
217	5/31/43	Santa Barbara	653	50	D	171	75.5	3.35	41.9	332.8	63.25	211.9
218	5/31/43	Santa Barbara	653	50	D	189	81	3.50	42.8	426	82.70	289.5
219	6/ 1/43	San Pedro	806	6	B	186	77	13.50	79.4	39.6	14.26	192.5
220	6/ 1/43	San Pedro	806	6	B	179	66	9.95	71.7	55.8	18.15	180.6
221	6/ 1/43	San Pedro	806	6	B	174	72.5	13.45	75.1	46.0	15.67	210.8
222	6/ 1/43	San Pedro	806	6	B	181	73	14.65	77.7	54.6	19.24	281.9
223	6/ 1/43	San Pedro	806	6	B	178	75	14.50	78.3	49.3	17.51	253.9
224	6/ 1/43	San Pedro	806	6	B	181	79	13.50	72.2	50.7	16.60	224.1
225	6/ 4/43	San Pedro	807	10	C	176	69	10.25	70.4	21.1	6.74	69.08

APPENDIX I—Cont'd.

226	6/ 4/43	San Pedro	807	10	C	174	66.5	10.75	74.3	66.1	22.28	239.5
227	6/ 4/43	San Pedro	807	10	C	173	56	8.80	73.5	46.6	15.54	136.8
228	6/ 4/43	San Pedro	807	10	C	182	75.5	12.60	80.4	39.0	14.22	179.2
229	6/ 4/43	San Pedro	807	10	C	183	77	13.85	80.0	27.1	9.83	136.2
230	6/ 4/43	San Pedro	807	10	C	182	70	11.10	75.2	50.0	17.05	189.3
231	6/ 4/43	San Pedro	807	10	C	177	73	11.50	71.8	49.1	15.99	183.9
232	6/ 4/43	San Pedro	807	10	C	169	63	10.05	76.4	50.0	17.33	174.2
233	6/ 4/43	San Pedro	807	10	C	173	61	9.20	74.8	48.0	16.29	149.9
234	6/ 4/43	San Pedro	807	10	C	172	69	10.70	80.9	18.49	6.78	72.55
240	6/ 8/43	Santa Barbara	686, 688	51.5	D	166	54.75	2.70	45.6	81.3	16.82	45.41
241	6/ 8/43	Santa Barbara	686, 688	51.5	E	180	53	2.60	11.7	170	9.02	23.45
243	6/ 8/43	Santa Barbara	686, 688	51.5	A	165	44.5	5.30	58.9	23.1	6.17	32.7
244	6/ 8/43	Santa Barbara	686, 688	51.5	A	162	49	5.60	67.0	11.6	3.53	19.77
245	6/ 8/43	Santa Barbara	686, 688	51.5	D	170	55.75	2.30	36.3	64.9	10.69	24.59
249	6/ 9/43	Santa Barbara	665	51	A	151	32.5	3.15	61.5	10.1	2.82	8.88
254	6/14/43	San Pedro	761	22.5	C	183	49	7.45	78.5	15.5	5.52	41.12
255	6/14/43	San Pedro	761	22.5	C	170	53	9.60	73.3	14.7	4.89	46.94
256	6/14/43	San Pedro	761	22.5	C	167	67	6.35	73.5	24.7	8.23	52.26
257	6/14/43	San Pedro	761	22.5	C	171	66	12.35	80.4	32.2	11.74	145
258	6/14/43	San Pedro	761	22.5	C	172	70	10.00	77.2	44.7	15.65	156.5
259	6/14/43	San Pedro	761	22.5	C	176	----------	13.10	77.2	46.3	16.21	212.4
260	6/14/43	San Pedro	761	22.5	C	172	55	9.40	73.6	21.3	7.11	66.83
261	6/14/43	San Pedro	761	22.5	C	177	74	13.45	75.7	60	20.60	277.1
262	6/14/43	San Pedro	761	22.5	C	174	65	8.25	74.4	49.7	16.77	138.4
263	6/14/43	San Pedro	761	22.5	C	184	94	17.05	72.5	45	14.80	252.3
264	6/15/43	San Pedro	806, 807	5	C	170	67	13.50	70.6	27.7	8.87	119.7
265	6/15/43	San Pedro	806, 807	5	C	167	55	8.00	73.4	34	11.32	90.56
266	6/15/43	San Pedro	806, 807	5	C	172	73	14.15	73.3	46.8	15.56	220.2
267	6/15/43	San Pedro	806, 807	5	C	170	70	10.00	77.1	41.6	14.55	145.5
268	6/15/43	San Pedro	806, 807	5	C	176	76	13.40	77.6	40.7	14.33	192
269	6/15/43	San Pedro	806, 807	5	C	170	64	9.30	68.8	34.4	10.74	99.88
270	6/15/43	San Pedro	806, 807	5	C	171	62	8.90	77.5	68.8	24.19	215.3
271	6/15/43	San Pedro	806, 807	5	C	179	79	14.20	64.6	56.5	16.56	235.2
282	7/ 2/43	Santa Barbara	666	54	A	137	23	1.85	74.6	11.4	3.86	7.14
283	7/ 2/43	Santa Barbara	666	54	A	125	20	1.85	43.5	3.14	0.62	1.147
284	7/ 5/43	Santa Barbara	654	80	A	121	17	1.25	23.7	3.98	0.428	0.535
286	7/ 5/43	Santa Barbara	654	80	A	152	33.5	1.45	21.0	44.1	4.20	6.09
288	7/ 8/43	Santa Barbara	689	10	A	179	68.5	11.75	75.0	25	8.50	99.88
289	7/ 8/43	Santa Barbara	689	10	A	142	27.5	2.15	47.3	17.9	3.84	8.26
290	7/ 8/43	Santa Barbara	689	10	B	160	45	3.15	40.7	49	9.05	28.51
291	7/ 8/43	Santa Barbara	689	10	A	148	37	5.00	72.0	12.4	4.05	20.25
292	7/ 8/43	Santa Barbara	689	10	A	183	71.5	9.60	66.5	84.8	25.58	245.6
293	7/ 8/43	Santa Barbara	689	10	D	177	80	5.15	28.7	125.3	16.31	84.0
294	7/ 8/43	Santa Barbara	689	10	E	177	54	2.65	9.8	52.3	2.32	6.15
295	7/ 8/43	Santa Barbara	689	10	C	167	60.5	8.80	78.0	21.3	7.54	66.35
296	7/ 8/43	Santa Barbara	689	10	B	183	86	17.10	80.0	17.3	6.28	107.4
297	7/ 9/43	Santa Barbara	707	60	A	136	24.5	2.50	65.5	16.2	4.81	12.02
298	7/ 9/43	Santa Barbara	707	60	A	164	47.0	6.20	42.6	29.3	5.66	35.09
299	7/ 9/43	Santa Barbara	707	60	C	172	64	9.25	76.4	56.8	19.68	182
300	7/ 9/43	Santa Barbara	707	60	C	182	80	11.10	73.1	58.8	19.50	216.5

APPENDIX I—Cont'd.



APPENDIX I—Continued

Physical, Biological, and Chemical Data of All Individual Soupfin Sharks Studied

Females

Sample number	Date	Region	Block number	Depth, fathoms	Sexual condition[4]	Total length, cm.	Total weight, lbs.	Liver weight, lbs.	Oil content, percentage	Vitamin A content		
										I.U./gm. of oil x10⁻³	I.U./lb. of liver x10⁻⁶	I.U./total liver x10⁻⁶
302	7/12/43	Santa Barbara	708	75	A	149	31.75	3.65	69.1	10.9	3.42	12.48
303	7/12/43	Santa Barbara	708	75	A	159	39.0	6.10	73.7	14.7	4.91	29.95
304	7/12/43	Santa Barbara	708	75	C	176	66.5	11.15	83.9	18.4	7.00	78.05
305	7/12/43	Santa Barbara	708	75	E	184	57	3.45	36.4	237	39.13	135.0
306	7/12/43	Santa Barbara	708	75	C	170	59	9.30	65.5	52	15.45	143.7
307	7/12/43	Santa Barbara	664	9	A	136	25	1.50	48.8	17.2	3.81	5.72
311	7/13/43	Santa Barbara	651	3	A	96	9.0	0.55	32.1	4.7	0.684	0.376
312	7/13/43	Santa Barbara	651	3	A	102	10.25	0.60	37.3	1.87	0.316	0.19
313	7/13/43	Santa Barbara	651	3	A	96	7.75	0.45	22.4	5.71	0.58	0.261
314	7/14/43	Santa Barbara	651, 652	7	D	175	65	2.45	33.9	224	34.44	84.38
315	7/14/43	Santa Barbara	651, 652	7	C	166	55.25	6.45	70.6	26.3	8.42	54.31
317	7/19/43	Santa Barbara	665	3	D	169	52.5	2.20	32.6	80.5	11.90	26.18
318	7/19/43	Santa Barbara	665	3	A	145	27.5	2.60	57.6	23.7	6.19	16.09
319	7/19/43	Santa Barbara	665	3	A	163	43	3.40	63.1	37.0	10.59	36.01
322	7/19/43	Santa Barbara	665	3	A	107	11	1.00	45.4	2.4	0.494	0.494
323	7/19/43	Santa Barbara	665	3	A	111	12	0.95	46.9	3.45	0.734	0.697
324	8/16/43	San Pedro	807	5.5	C	174	63.5	7.00	73.5	29.6	9.87	69.09
325	8/16/43	San Pedro	807	5.5	C	179	71.0	9.70	70.5	51	16.31	158.2
326	8/16/43	San Pedro	807	5.5	C	179	78.0	12.00	72.5	74.6	24.53	294.4
327	8/16/43	San Pedro	807	5.5	C	177	65	10.20	77.0	67.6	23.61	240.8
328	8/16/43	San Pedro	807	5.5	C	173	62.5	8.25	71.3	68.1	22.02	181.7
329	8/16/43	San Pedro	807	5.5	C	187	85.5	14.90	73.2	92.6	30.74	458
330	8/16/43	San Pedro	807	5.5	C	179	69	8.10	66.3	94.9	28.54	231.2
331	8/16/43	San Pedro	807	5.5	C	162	51.0	7.20	75.2	25.7	8.77	63.14
332	8/16/43	San Pedro	807	5.5	C	188	80.0	13.50	77.0	100	34.93	471.6
333	8/16/43	San Pedro	807	5.5	C	164	51.5	5.30	70.5	32.1	10.26	54.38
335	9/29/43	San Francisco	430	10	B	158	37.5	4.00	61.2	38	10.55	42.2
336	9/29/43	San Francisco	430	10	B	155	41.25	5.75	71.1	11	3.55	20.41
339	9/30/43	San Francisco	430	10	B	157	39.25	5.15	59.6	15	4.06	20.91
340	9/30/43	San Francisco	430	10	B	153	32.75	3.30	65.5	15.1	4.49	14.82
341	9/30/43	San Francisco	430	10	A	120	15	1.25	29.2	9.4	1.24	1.55
344	10/12/43	San Francisco	451, 474	82.5	B	142	25.25	1.90	57.2	12.8	3.32	6.31
345	10/12/43	San Francisco	451, 474	82.5	A	127	18.75	1.25	49.5	3.3	0.741	0.926
347	10/12/43	San Francisco	430	4	A	112	12.25	0.85	21.2	2.78	0.267	0.227
348	10/13/43	San Francisco	----------	----------	A	140	25.75	2.15	58.0	8.85	2.33	5.01

APPENDIX I—Cont'd.

354	10/14/43	San Francisco	489	15	B	161	39.25	3.90	67.3	19.68	6.01	23.44
355	10/14/43	San Francisco	489	15	B	155	37.75	4.15	65.1	19.8	5.85	24.28
356	10/15/43	San Francisco	488	7	B	151	33	3.45	67.0	17	5.17	17.84
357	10/15/43	San Francisco	488	7	B	150	34.25	3.50	68.1	16.6	5.13	17.96
358	10/21/43	San Francisco	458	101	B	166	42.25	5.15	65.7	20.4	6.08	31.31
359	10/21/43	San Francisco	430	3.5	A	109	13	0.70	75.5	9.35	3.20	2.24
360	10/21/43	San Francisco	430	3.5	A	76	3.55	0.25	41.1	1.36	0.254	0.064
362	10/22/43	San Francisco Bay	488	18	A	76	3.55	0.20	24.1	2.33	0.255	0.051
365	10/23/43	San Francisco Bay	430	10	B	179	85.25	20.00	79.1	25.1	9.00	180
366	10/23/43	San Francisco Bay	430	10	A	72	3.10	0.25	46.8	0.569	0.121	0.030
367	10/24/43	San Francisco Bay	488	5	B	161	40.75	4.25	66.0	15.1	4.52	19.21
368	10/24/43	San Francisco Bay	488	10	A	80	4.55	0.20	19.1	3.79	0.328	0.066
369	10/24/43	San Francisco Bay	488	10	A	74	3.15	0.15	18.8	0.94	0.077	0.012
371	10/24/43	San Francisco Bay	488	10	A	83	4.80	0.20	27.4	3.85	0.478	0.096
372	10/24/43	San Francisco Bay	488	10	A	69	2.90	0.15	14.3	6.1	0.396	0.059
373	10/24/43	San Francisco Bay	488	10	A	65	2.40	0.15	15.1	0.676	0.046	0.007
376	11/ 1/43	San Francisco	430	10	B	178	63.25	13.00	77.9	39.3	13.89	180.6
377	11/ 3/43	San Francisco Bay	489	10	A	104	10.45	0.65	43.1	2.56	0.50	0.325
381	11/ 5/43	San Francisco Bay	489	5.2	A	46	0.60	----------	9.0	0.908	0.037	----------
429	11/24/43	Eureka	211	31	B	188	71	8.80	63.5	87.6	25.23	222
433	11/24/43	Eureka	211	31	B	180	82	17.40	73.3	35.2	11.70	203.6
435	11/27/43	Eureka	211	36	B	183	84.5	17.55	75.0	32.9	11.19	196.4
442	11/27/43	Eureka	211	40	B	170	56.0	11.90	68.9	8.25	2.58	30.70
459	12/ 3/43	Monterey	510	65	B	155	35.25	4.05	63.5	17.9	5.16	20.90
460	12/ 3/43	Monterey	510	65	B	165	42.00	4.05	64.9	28.6	8.42	34.10
486	12/ 8/43	Monterey	508	80	B	175	55.75	7.85	62.9	45.2	12.90	101.3
487	12/ 8/43	Monterey	508	80	B	135	24.00	2.05	64.0	13.45	3.90	8.00

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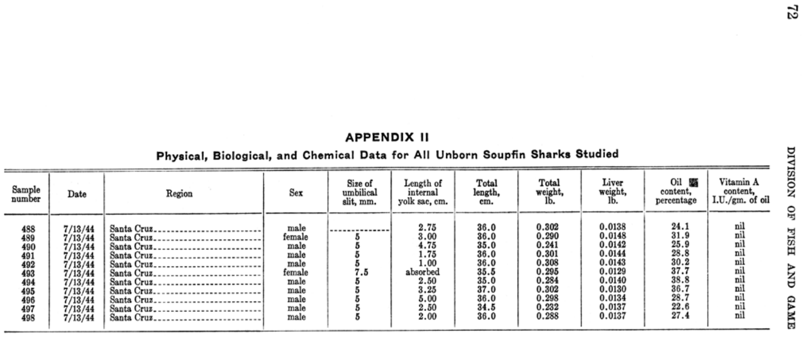
[1] Liver partly eaten by Hag fish.
[2] Carcass partly eaten by Hag fish.
[3] Cancerous growth on anterior distal shoulder of right lobe of liver.
[4] Sexual condition as defined in text.

APPENDIX I—Cont'd.



APPENDIX II

Physical, Biological, and Chemical Data for All Unborn Soupfin Sharks Studied

Sample number	Date	Region	Sex	Size of umbilical slit, mm.	Length of internal yolk sac, cm.	Total length, cm.	Total weight, lb.	Liver weight, lb.	Oil content, percentage	Vitamin A content, I.U./gm. of oil
488	7/13/44	Santa Cruz	male	------	2.75	36.0	0.302	0.0138	24.1	nil
489	7/13/44	Santa Cruz	female	5	3.00	36.0	0.290	0.0148	31.9	nil
490	7/13/44	Santa Cruz	male	5	4.75	35.0	0.241	0.0142	25.9	nil
491	7/13/44	Santa Cruz	male	5	1.75	36.0	0.301	0.0144	28.8	nil
492	7/13/44	Santa Cruz	male	5	1.00	36.0	0.308	0.0143	30.2	nil
493	7/13/44	Santa Cruz	female	7.5	absorbed	35.5	0.295	0.0129	37.7	nil
494	7/13/44	Santa Cruz	male	5	2.50	35.0	0.284	0.0140	38.8	nil
495	7/13/44	Santa Cruz	male	5	3.25	37.0	0.302	0.0130	36.7	nil
496	7/13/44	Santa Cruz	male	5	5.00	36.0	0.298	0.0134	28.7	nil
497	7/13/44	Santa Cruz	male	5	2.50	34.5	0.232	0.0137	22.6	nil
498	7/13/44	Santa Cruz	male	5	2.00	36.0	0.288	0.0137	27.4	nil

APPENDIX II
Physical, Biological, and Chemical Data for All Unborn Soupfin Shark Studied

3. DETERMINATION OF THE PERCENTAGE OF OIL IN SOUPFIN SHARK LIVERS

3.1. INTRODUCTION

In the extraction of oil from natural substances the solvent as well as the extraction procedure must be considered. Peroxide-free diethyl ether is generally employed in the extraction of vitamin A-containing oils from fish livers. Since this solvent has a low boiling point little time is required to concentrate an extract; hence, it is widely used in continuous extractors of the Soxhlet and liquid-liquid types. However, when diethyl ether is applied to single extraction procedures a great deal of care is required to prevent loss of the solvent during the extraction and subsequent manipulations.

An oil determination could be greatly simplified by using, in conjunction with a single extraction method, a solvent having a lower rate of evaporation than that of ether. Methylene chloride and xylene possess this quality and as solvents for the simultaneous determination of oil and vitamin A have been critically studied in this laboratory for use in routine analysis.

3.2. EXPERIMENTAL

In order to determine the reliability of the various procedures two or more methods were compared in duplicate on the same sample. In addition to this, the standard deviation of the values about the mean percentage discrepancy of duplicates was calculated for those methods that showed promise.

Preparation of the reagents.—Peroxide-free diethyl ether was prepared by washing a good grade of ether twice with a 10 to 20 per cent solution of sodium bisulfite, once with 10 per cent sodium hydroxide, and twice with distilled water. The ether layer was then dried over anhydrous sodium sulfate.

Methylene chloride "refrigeration grade" was used without purification.

Xylene was treated with concentrated sulfuric acid until no further charring occurred. It was then washed with distilled water and treated with a 10 to 20 per cent solution of sodium bisulfite, washed with distilled water, dried over anhydrous sodium sulfate and distilled in an all-glass still. The fraction boiling at 134 to 142°C. with a yield of 75 to 80 per cent was used for the oil extraction.

Soxhlet extraction.—An aliquot of approximately 5 gm. of homogenized soupfin liver was ground with anhydrous sodium sulfate and quantitatively transferred to the thimble which was then inserted in the extractor. Sufficient peroxide-free diethyl ether was added and the receiving flask was submerged in a water bath held at 50 to 60°C. for eighteen hours. At the end of this period the tared receiving flask was detached from the rest of the apparatus and the ether was evaporated in vacuo or in the atmosphere of an inert gas such as nitrogen or carbon dioxide. When the removal of the solvent was complete and the flask and its contents were equilibrated to room temperature, the percentage of oil in the sample was then calculated according to the formula:

$$\text{percentage of oil} = \frac{W_o \times 100}{W}$$

FORMULA

where W_o is the weight of extracted oil and W is the weight of the liver sample.

Liquid-liquid extraction.—An aliquot of 25 to 30 gm. of homogenized soupfin liver was blended with sufficient water to bring the volume to 250 ml. A 25 ml. aliquot of this emulsion was transferred to the extractor and sufficient saturated aqueous sodium sulfate was added to bring the volume to the ¾ mark of the extractor. Peroxide-free diethyl ether was then added and the receiving flask was submerged in a water bath held at 50 to 60° C. for five hours. At the end of this period, the receiving flask was detached and the extract was dried over anhydrous sodium sulfate, evaporated to dryness in an atmosphere of nitrogen or carbon dioxide and weighed. The percentage of oil was calculated by the formula:

$$\text{percentage of oil} = \frac{W_o \times 100}{W}$$

FORMULA

where W_o is the weight of extracted oil and W is the weight of liver in the 25 ml. aliquot.

Short filtration method.—A 2 to 3 gm. aliquot of homogenized liver was shaken in a mechanical shaker with 100 ml. of methylene chloride (Tompkins and Bolomey, 1943) for one hour in a glass-stoppered Erlenmeyer flask. At the end of this period, about 10 to 20 ml. of the supernatant were filtered through Whatman No. 1 filter paper into a 25 ml. flask. The funnel was covered with a watch glass to minimize evaporation of the solvent. A 5 to 10 ml. aliquot of the filtrate was evaporated to dryness in a tared 50 ml. beaker and the percentage of oil in the original sample was calculated according to the following formula:

$$\text{percentage of oil} = \frac{W_o \times 100}{V_s} \times \frac{100}{W}$$

FORMULA

where $V_s = V_a - W_o/D$, V_a being the aliquot volume, W_o the weight of oil in V_a, D the average density of the oil (0.92), and W the weight of the liver sample.

Short centrifuge method.—A 0.2 to 0.5 gm. aliquot of homogenized liver was quickly transferred to a tared 15 ml. graduated conical centrifuge tube and weighed to the nearest milligram. Ten ml. of purified solvent (diethyl ether (Stansby and Lemon, 1937) or xylene (Sycheff, 1944)) were then added and the tube was vigorously shaken. The mass was centrifuged at 2,500 r. p. m. The total volume of liver residue plus solvent and the volume of the residue were recorded. A 5 ml. aliquot of the supernatant was evaporated to dryness under atmospheric pressure. The percentage of oil in the liver was obtained from the following relation:

$$\text{percentage of oil} = \frac{100W_o\,(V_t - V_r)}{5W}$$

FORMULA

where W_o is the weight of oil, W is the weight of the liver sample, V_t is the total volume of solvent plus liver residue, and V_r is the volume of the residue.

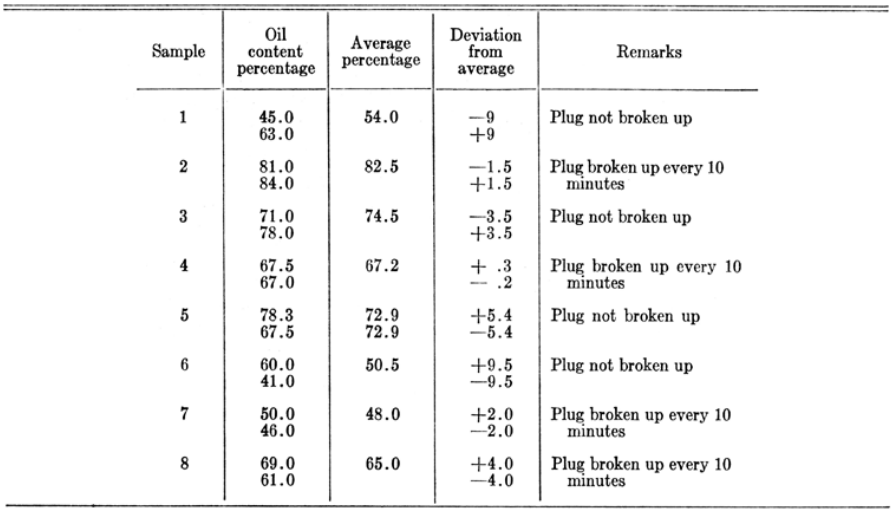
3.3. DISCUSSION

The efficiency of continuous extractors depends not only upon the frequency with which the solvent comes in contact with the tissue, but also upon the degree of dispersion and the ease of filtration of the solvent through the partially extracted residue. In order to insure complete extraction, several hours of operation are necessary and the tissue must be uniformly distributed.

After eighteen hours of extraction in a Soxhlet apparatus with diethyl ether, the standard deviation about the mean percentage discrepancy calculated on 21 samples analyzed in duplicate was ± 1.4 per cent with an extreme range of 4.2 per cent. The range of percentage of oil employed for this calculation extended from 24 to 75 per cent.

TABLE 1

Variations In the Percentage of Oil as Determined by the Liquid-Liquid Method



Sample	Oil content percentage	Average percentage	Deviation from average	Remarks
1	45.0 63.0	54.0	—9 +9	Plug not broken up
2	81.0 84.0	82.5	—1.5 +1.5	Plug broken up every 10 minutes
3	71.0 78.0	74.5	—3.5 +3.5	Plug not broken up
4	67.5 67.0	67.2	+ .3 — .2	Plug broken up every 10 minutes
5	78.3 67.5	72.9 72.9	+5.4 —5.4	Plug not broken up
6	60.0 41.0	50.5	+9.5 —9.5	Plug not broken up
7	50.0 46.0	48.0	+2.0 —2.0	Plug broken up every 10 minutes
8	69.0 61.0	65.0	+4.0 —4.0	Plug broken up every 10 minutes

TABLE 1
Variations In the Percentage of Oil as Determined by the Liquid-Liquid Method

The time consumed by this method and the lack of sufficient extractors were factors which discouraged its use in mass routine analysis. The precision of the method, however, provided us with dependable data until more rapid methods could be developed.

The liquid-liquid type of extractor has found extensive use in many laboratories. However, its application to the extraction of shark liver oils was unsatisfactory due to the nature of the tissue. Table 1 shows the results of a preliminary experiment on duplicate oil determinations in various samples. It was observed that a tissue plug formed at the interface of the ether-water layer. This plug was rather tough and provided an excellent medium in which ether channeled its way without diffusing through the whole plug. Those samples whose plugs were frequently broken up by stirring gave good duplicate values, while those samples which were left undisturbed during the extraction showed poor agreement. Our extractors were not provided with a mechanical stirring device and although it is our belief that such a provision would have helped the problem, we abandoned this method for a faster one which showed good promise.

The more rapid methods of extraction depend upon the principle that in the presence of a large volume of solvent, a small volume of tissue will retain an insignificant amount of oil. Thereby, it should be possible to remove from the tissue practically all of the oil with a single extraction of rather short duration under vigorous agitation.

The short method of Stansby and Lemon, 1937, offered much promise in that vigorous shaking of the tissue with the solvent would overcome all difficulties due to channeling through a plug. The fact that diethyl ether interferes with the Carr-Price, 1926 reaction for vitamin A and its Rosenthal-Erdelyi, 1934 and Rosenthal and Weltner, 1935 modifications caused us to concentrate our attention on other solvents. Since methylene chloride and xylene showed no deleterious effects on the Rosenthal-Erdelyi reaction for vitamin A, these solvents were investigated in conjunction with the single extraction procedures.

When methylene chloride was employed as the solvent, the extracts were invariably turbid, but clear oils could be obtained by rapid filtration through Whatman No. 1 filter paper. Preliminary experiments showed that rapid filtration of about 10 to 20 ml. of the extract could be performed without loss of the solvent. With larger volumes the rate of filtration decreased considerably as the operation proceeded, thereby, enhancing the loss of solvent by evaporation. This was especially noticeable on warm days. The standard deviation about the mean percentage discrepancy calculated on 28 samples analyzed in duplicate was ± 1.0 with an extreme range of ± 3 per cent. The samples used for this calculation covered the range from 50 to 80 per cent. Table 2 shows the comparative average values between the Soxhlet method using diethyl ether and the short filtration method employing methylene chloride as the solvent.

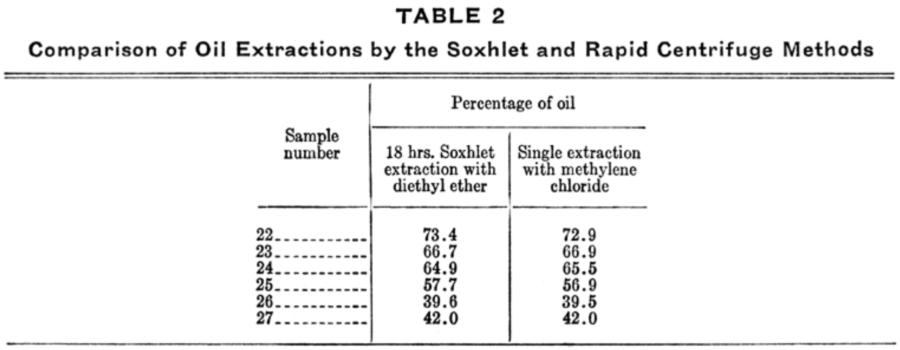


TABLE 2

Comparison of Oil Extractions by the Soxhlet and Rapid Centrifuge Methods

Sample number	Percentage of oil	
	18 hrs. Soxhlet extraction with diethyl ether	Single extraction with methylene chloride
22	73.4	72.9
23	66.7	66.9
24	64.9	65.5
25	57.7	56.9
26	39.6	39.5
27	42.0	42.0

TABLE 2

Comparison of Oil Extractions by the Soxhlet and Rapid Centrifuge Methods

The high rate of evaporation of solvents such as ether and methylene chloride requires careful manipulations when applied to single extraction procedures. During hot weather it was found necessary to conduct evaporation controls simultaneously with a set of determinations. Hence a solvent with a boiling point somewhat higher than either diethyl ether or methylene chloride was sought. The solvent should also have a low density so that centrifugal separation could be substituted for filtration, thereby reducing the number of operations to a minimum. Since this solvent had to be employed in conjunction with the Rosenthal-Erdelyi colorimetric method for vitamin A, the choice was further limited.

The boiling range of purified xylene (134 to 142° C.) is too high for continuous extraction procedures. The rate of evaporation at 65 to 85° C. is such that four hours are required at atmospheric pressure to remove the solvent completely from a 5 ml. aliquot of an oil solution. This fact may be considered a disadvantage when only a few samples are to be analyzed by the short method. However, when 10 or more livers are to be assayed simultaneously for both oil and vitamin A this disadvantage is not realized since the time required to evaporate the solvent affords ample time to determine the vitamin content of the extracts at two or more dilutions each. This is possible since xylene has no ill effect on the Rosenthal-Erdelyi modification of the Carr-Price reaction for vitamin A. Table 3 compares the xylene-centrifuge and methylene chloride filtration methods for the determination of oil in shark livers. The precision of the xylene centrifuge method is indicated by the standard deviation about the mean percentage discrepancy between duplicates; a value of ± 1.8 per cent with an extreme range of ± 4 per cent was found.

TABLE 3

Comparison of Methylene Chloride and Xylene Extraction Methods for Oil In Soupfin Shark Livers

Sample number	Percentage of oil	
	Methylene chloride filtration method	Xylene centrifuge method
C_4	53.0	50.0
C_5	54.5	51.3
C_6	74.1	74.0
119	59.8	58.8
158	39.0	36.5
171	70.8	74.9
172	77.3	74.1
173	76.3	75.8
174	76.4	78.4
180	74.3	78.8
181	73.3	76.6
216	68.1	69.0
217	41.9	37.1

TABLE 3

Comparison of Methylene Chloride and Xylene Extraction Methods for Oil In Soupfin Shark Livers

3.4. CONCLUSION AND SUMMARY

Diethyl ether, methylene chloride, and xylene have been successfully employed for the extraction of oil from soupfin shark livers. The continuous extraction procedures and the short single extraction methods have been compared from a routine analytical point of view.

Although the advantages may be many with the continuous extraction methods in certain fields of research much is to be gained by using the more rapid methods in investigations such as the present. The single extraction procedures allow one, using the same amount of equipment, to perform many more analyses per day than would be possible with continuous extraction.

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4. THE DETERMINATION OF VITAMIN A IN SOUPFIN SHARK LIVER OILS

4.1. INTRODUCTION

The choice of a method for the quantitative analysis of vitamin A depends upon a variety of factors. Thus if one is interested in the effective biological concentration of the vitamin in a given preparation one would resort to a biological method of assay. If, however, a large quantity of data is to be collected on the vitamin A content of a natural product such as soupfin shark livers one would depend on chemical or physical means of estimation since these methods are faster and more precise than the former.

The Carr and Price, 1926 colorimetric reaction for vitamin A depends on the formation of a transient blue color in the presence of a chloroform solution of antimony trichloride. Rosenthal *et al.* 1934, 1935 modified the Carr-Price reaction by heating vitamin A in the presence of guaiacol with antimony trichloride dissolved in chloroform. This treatment resulted in the formation of a stable violet color which could be readily measured by the more common instruments.

The instruments available at the start of this investigation limited us to the Rosenthal reaction for vitamin A. As time progressed, it became possible to study both the chemical and physical methods of vitamin A assay. However, since the various methods of estimation respond differently to contaminants, the Rosenthal-Erdelyi method was depended upon for the purposes of routine chemical assay,—in particular for the data reported in "Relation of the Biology of the Soupfin Shark to the Liver Yield of Vitamin A."

4.2. EXPERIMENTAL

The Carr-Price reaction and its Rosenthal-Erdelyi modification and ultra-violet absorption were used to determine the potency of pooled oils and of oils obtained from individual soupfin shark livers. Since the intensity of light absorption does not always follow Beer's law, the dilution principle advocated by Norris and Church, 1930 was applied to each case; three or more dilutions were used. The intensity of the Carr-Price blue color was determined at 620 m[u] with a Coleman 10-S spectrophotometer (5 m[u] slit width), while that of the Rosenthal-Erdelyi violet color was evaluated with a Klett-Summerson photoelectric colorimeter equipped with a green (No. 54) filter. The direct absorption was measured at 328 m[u] with a Beckman quartz prism spectrophotometer, using isopropanol as the solvent.

Each instrument was standardized against the same vitamin A concentrate. The potency of the concentrates used was determined by measuring the extinction coefficient

$$\left\{ E^{1\%}_{1\,\text{cm.}} \right\}$$

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on the Beckman spectrophotometer, and converting this value to international units per gram of oil; the conversion factor of 2000 was used. Both spectrophotometers were calibrated with potassium chromate solutions as recommended by Wilkie, 1939.

Methods.—The Carr-Price reaction for vitamin A was conducted as follows: One-half ml. of an oil solution was blown into 4.5 ml. of 30 per cent antimony trichloride in chloroform. The intensity of the resulting blue color was measured at exactly twenty seconds after the addition of the oil to the reagent. The readings were referred to a blank solution containing 0.5 ml. of the pure solvent instead of the oil solution.

The Rosenthal-Erdelyi reaction for vitamin A was performed in the following manner : One ml. of 5 per cent guaiacol in chloroform was added to three ml. of 30 per cent antimony trichloride in chloroform contained in a Klett tube. To this was added one ml. of the oil solution. The tube was then immersed in a 60° C. water bath for about one minute, and then cooled to room temperature under the tap. The intensity of the violet color was then read against the blank solution.

Partial substitution of solvents in the colorimetric methods of assay.—Several advantages may be gained by employing simple and straight-forward methods of analysis. The fewer the steps in any assay method, the less are the chances of errors due to faulty manipulation. Less time is required to perform the analysis and, therefore, the method should be well-suited to routine procedures.

The extraction of oil from fish livers with solvents other than chloroform has the advantage that more stable reagents may be selected. This should result in decreasing the chances of destroying the vitamin during the extraction procedure. However, most solvents employed for this purpose interfere with both the Carr-Price reaction for vitamin A and its Rosenthal-Erdelyi modification. This necessitates the complete removal of the solvent prior to the colorimetric analysis. In order to prevent an appreciable destruction of the vitamin during this process, these solvents must be removed in an oxygen-free atmosphere. By selecting the proper solvent Sycheff, 1944, and Tompkins and Bolomey, 1943 partial substitution of chloroform in the colorimetric reactions for vitamin A would obviate the need for removing the solvent, and hence would save time and reduce the chances of destroying the vitamin.

To attain this end, vitamin A-containing oils were dissolved in various solvents. The resulting oil solutions were then used in place of the oil-chloroform solutions prescribed in the original tests.

Methylene chloride up to a concentration of 20 per cent and xylene up to a concentration of 40 per cent in the final reaction mixture were found to have no effect on the Rosenthal-Erdelyi color intensity. Xylene appears to hasten the fading of the blue Carr-Price color to the violet Rosenthal-Erdelyi color. This effect is not observed when methylene chloride is used as the partial substituent.

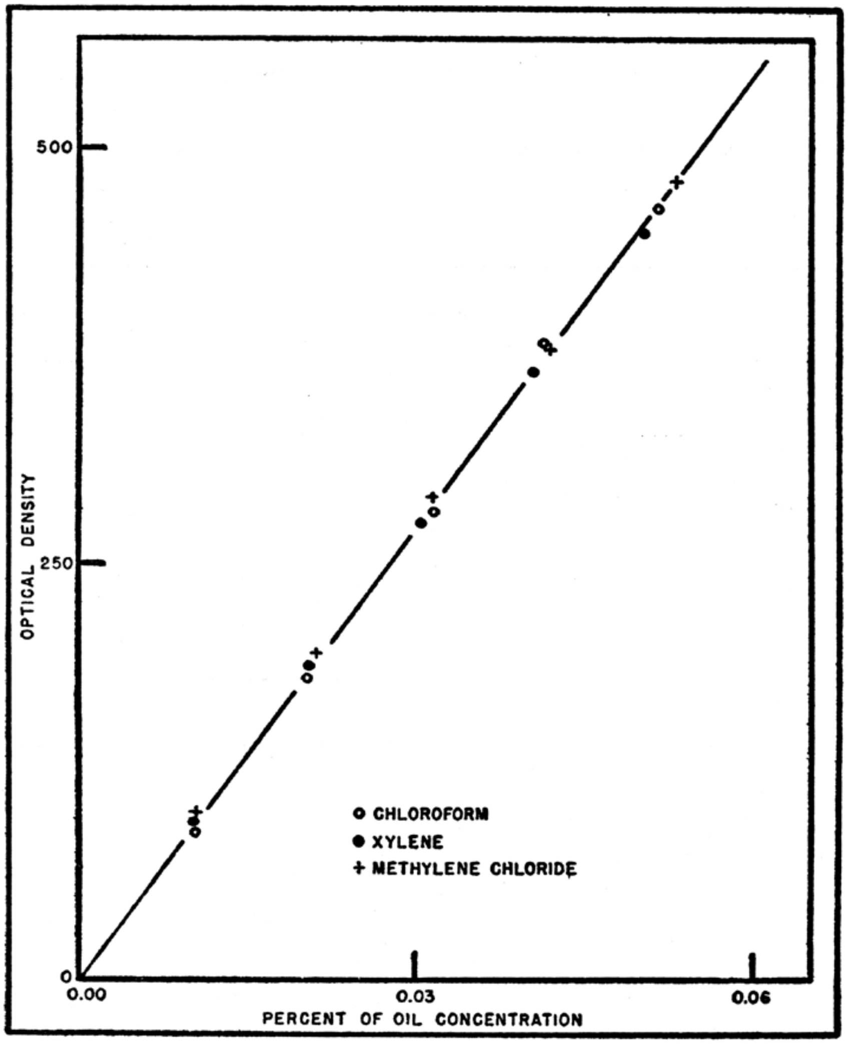

FIG. 1. Effect of partial substitution of methylene chloride and of xylene for chloroform on the dilution curves of the Rosenthal-Erdelyi color reaction for vitamin A in solution of pool 4.

FIG. 1. Effect of partial substitution of methylene chloride and of xylene for chloroform on the dilution curves of the Rosenthal-Erdelyi color reaction for vitamin A in solution of pool 4

Figure 1 shows typical dilution curves obtained with these solvents on the Rosenthal-Erdelyi violet color. The concentration of methylene chloride and that of xylene in the final reaction mixture was 20 per cent in each case. From this figure it can be concluded that either methylene chloride or xylene has no effect on the colorimetric determination of vitamin A by the Rosenthal-Erdelyi reaction. Therefore, through the use of either of these solvents it is possible to determine the potency directly on the extract without previously removing the solvent.

In order to evaluate the precision of the Rosenthal-Erdelyi reaction for routine analysis, the standard deviation about the mean percentage discrepancy between duplicates or triplicates at any one dilution was calculated. For 109 samples of the extracts, run in duplicate or in triplicate, it amounted to ± 0.5 per cent. This value represents the errors of the colorimetric reaction and not those of weighing and oil extraction. The extreme deviation from the mean amounted to 2 per cent.

The standard deviation about the mean values, including all possible sources of error amounted to ± 1.5 per cent with an extreme range of 6 per cent. These values were not found to vary with the method of oil extraction, nor with the type of solvent used.

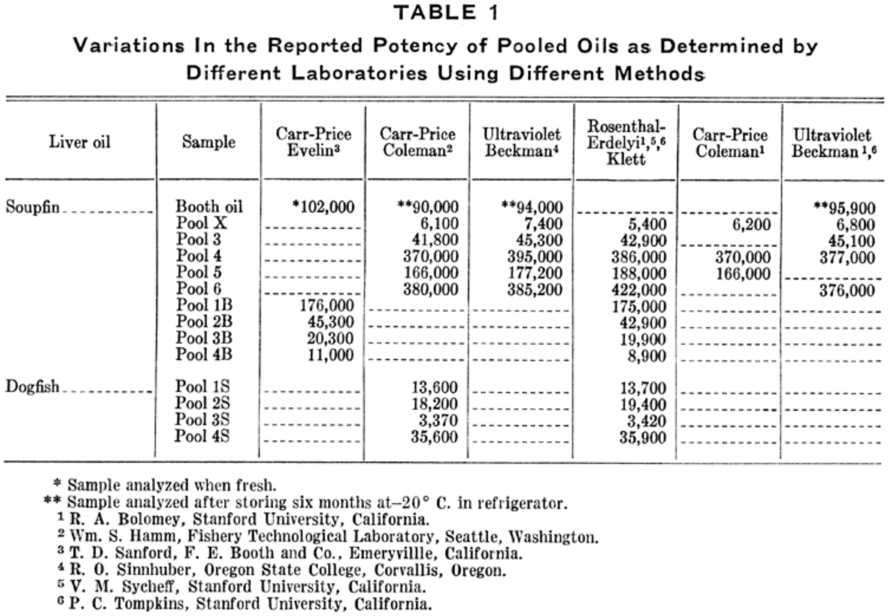

TABLE 1

Variations In the Reported Potency of Pooled Oils as Determined by Different Laboratories Using Different Methods

Liver oil	Sample	Carr-Price Evelin[3]	Carr-Price Coleman[2]	Ultraviolet Beckman[4]	Rosenthal-Erdelyi[1,5,6] Klett	Carr-Price Coleman[1]	Ultraviolet Beckman[1,6]
Soupfin	Booth oil	*102,000	**90,000	**94,000			**95,900
	Pool X		6,100	7,400	5,400	6,200	6,800
	Pool 3		41,800	45,300	42,900		45,100
	Pool 4		370,000	395,000	386,000	370,000	377,000
	Pool 5		166,000	177,200	188,000	166,000	
	Pool 6		380,000	385,200	422,000		376,000
	Pool 1B	176,000			175,000		
	Pool 2B	45,300			42,900		
	Pool 3B	20,300			19,900		
	Pool 4B	11,000			8,900		
Dogfish	Pool 1S		13,600		13,700		
	Pool 2S		18,200		19,400		
	Pool 3S		3,370		3,420		
	Pool 4S		35,600		35,900		

* Sample analyzed when fresh.

** Sample analyzed after storing six months at–20° C. in refrigerator.

[1] R. A. Bolomey, Stanford University, California.

[2] Wm. S. Hamm, Fishery Technological Laboratory, Seattle, Washington.

[3] T. D. Sanford, F. E. Booth and Co., Emeryvillle, California.

[4] R. O. Sinnhuber, Oregon State College, Corvallis, Oregon.

[5] V. M. Sycheff, Stanford University, California.

[6] P. C. Tompkins, Stanford University, California.

TABLE 1

Variations In the Reported Potency of Pooled Oils as Determined by Different Laboratories Using Different Methods

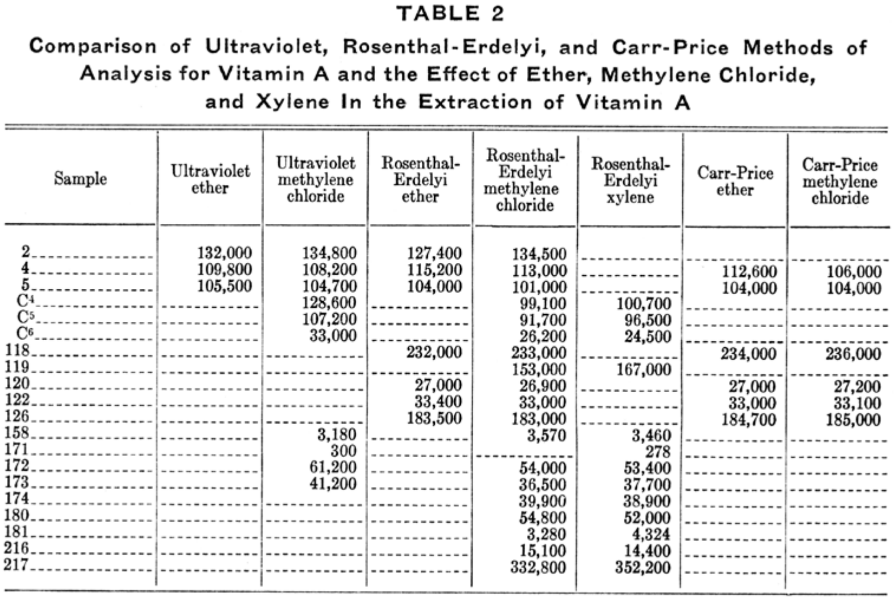

TABLE 2

Comparison of Ultraviolet, Rosenthal-Erdelyi, and Carr-Price Methods of Analysis for Vitamin A and the Effect of Ether, Methylene Chloride, and Xylene In the Extraction of Vitamin A

Sample	Ultraviolet ether	Ultraviolet methylene chloride	Rosenthal-Erdelyi ether	Rosenthal-Erdelyi methylene chloride	Rosenthal-Erdelyi xylene	Carr-Price ether	Carr-Price methylene chloride
2	132,000	134,800	127,400	134,500			
4	109,800	108,200	115,200	113,000		112,600	106,000
5	105,500	104,700	104,000	101,000		104,000	104,000
C^4		128,600		99,100	100,700		
C^5		107,200		91,700	96,500		
C^6		33,000		26,200	24,500		
118			232,000	233,000		234,000	236,000
119				153,000	167,000		
120			27,000	26,900		27,000	27,200
122			33,400	33,000		33,000	33,100
126			183,500	183,000		184,700	185,000
158		3,180		3,570	3,460		
171		300			278		
172		61,200		54,000	53,400		
173		41,200		36,500	37,700		
174				39,900	38,900		
180				54,800	52,000		
181				3,280	4,324		
216				15,100	14,400		
217				332,800	352,200		

TABLE 2

Comparison of Ultraviolet, Rosenthal-Erdelyi, and Carr-Price Methods of Analysis for Vitamin A and the Effect of Ether, Methylene Chloride, and Xylene In the Extraction of Vitamin A

In order to test further the validity of the assays, samples were analyzed collaboratively between different laboratories using different methods. These results are presented in table 1. Further correlations, table 2, were made between the Rosenthal-Erdelyi, the Carr-Price, and

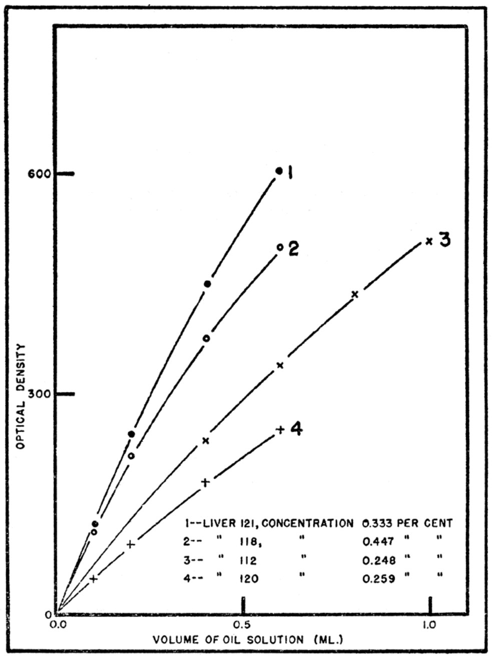

FIG. 2. Dilution curves of the Rosenthal-Erdelyi color reaction for vitamin A

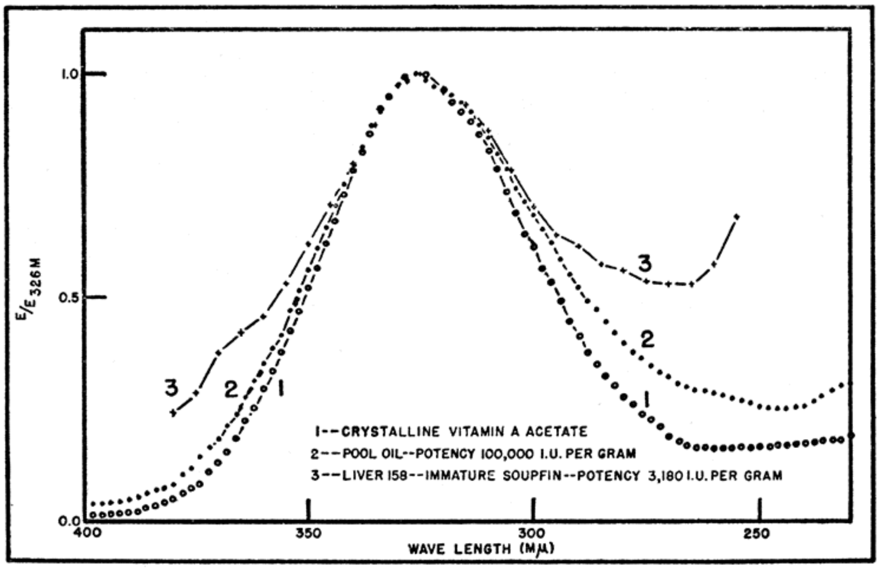

FIG. 3. Absorption curves of vitamin A acetate and of soupfin shark liver oils

the direct absorption methods of assay. Ether, methylene chloride, and xylene were employed for the extraction of vitamin-containing oils from the livers.

Most of the soupfin shark liver oils analyzed in this laboratory gave linear agreement between the potency and the oil concentration used in the determination. Some few samples (Fig. 2), however, departed from linearity to a marked extent. Other samples, (L114, L116, and L158) obeyed Beer's law, but gave brown-red Rosenthal-Erdelyi colors instead of the usual violet one. Absorption curves of L158 in isopropanol and after treatment according to the Rosenthal-Erdelyi reaction are represented as curve 3 in figures 3 and 4, respectively.

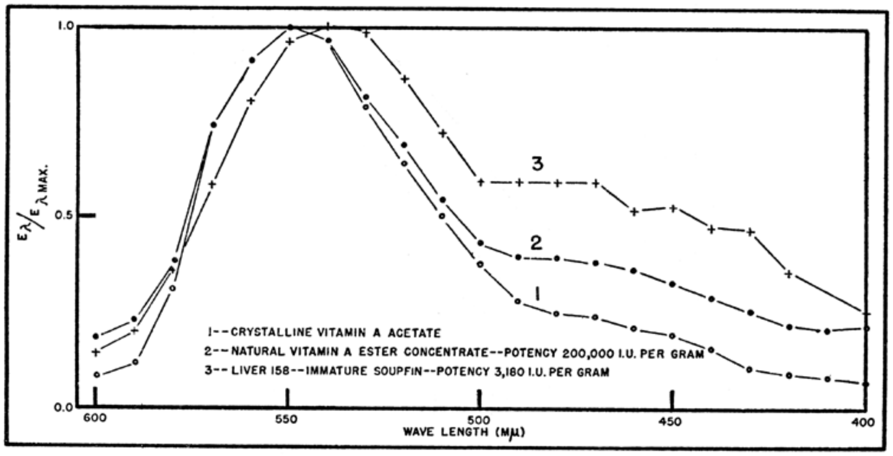

Fig. 4. Absorption curves of the Rosenthal-Erdelyi color reaction for **vitamin A.**

FIG. 4. Absorption curves of the Rosenthal-Erdelyi color reaction for vitamin A

Antimony trichloride in chloroform is known to give colors with vitamin A and carotenoids in general. This reagent produces after some time orange to red and even blue colors with some of the sterols and with the aerobic decomposition products of vitamin A. The presence of these substances can not be ignored in the physical and chemical assay of the vitamin. That substances other than vitamin A play an especially important role in the spectrophotometric analysis of the vitamin is emphasized in figure 3. The curves in this figure show that irrelevant absorption may be expected to increase as the concentration of the vitamin in a natural oil decreases. In order to bring out this point more fully, ratios of the densities to those at 326 m[u] were plotted instead of the usual extinction coefficients. This same relation applies to the Rosenthal-Erdelyi colorimetric procedure. Figure 4 was obtained by means of a Coleman 10-S spectrophotometer. Ratios of densities to those of

$$\lambda_{\text{maximum}}$$

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were plotted in order to show the relative positions of the maxima and in order to demonstrate the relative differences between the curves.

Saponification, although a help in some cases, does not entirely remedy the situation, since many of the interfering substances, especially in low potency oils, follow the unsaponifiable fraction.

4.3. SUMMARY AND CONCLUSIONS

Methylene chloride or xylene may be partially substituted for chloroform in the Rosenthal-Erdelyi colorimetric determination of vitamin A. Through the use of either of these solvents the colorimetric assay of vitamin A can be greatly simplified since the vitamin content of an oil may be determined directly on an aliquot of the extract. This precludes the necessity of removing the solvent prior to adding the antimony trichloride reagent.

The precision of the Rosenthal-Erdelyi reaction performed on a routine scale is indicated by a standard deviation of ± 3 per cent irrespective of the extraction procedure.

Sterols and oxidation products of vitamin A are some of the substances that tend to give high colorimetric and spectrophotometric values. These substances occur, for the most part, in the unsaponifiable fraction, hence it is difficult to correct for them. However, by comparing several points along the absorption curve, a fair indication regarding the quality of an oil may be obtained.

4.4. Literature Cited

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5. THE STABILITY OF VITAMIN A IN WHOLE SHARK LIVER AND IN THE EXTRACTED OIL

5.1. PROCEDURE

The procedure to be used in collecting the liver samples depended upon two major factors; namely, the stability of the vitamin in the livers kept under various storage conditions and upon the distribution of the vitamin throughout the liver. Until these factors had been studied, the entire liver was excised from the carcass at the time the sharks were caught. The livers were then frozen in dry ice and shipped whole to the laboratory for analysis. This practice was a costly one from the point of view of time and available space, both in the laboratory and on the boats. Furthermore, the size of the livers frequently made impractical the shipment of the whole organ: some livers would hardly fill a pint carton while many required a gallon container for a single lobe.

The studies reported upon in tables 1, 2, and 3, indicate respectively the effect of storage at room temperature upon the vitamin A content of whole liver, the vitamin distribution between the two lobes, and the differences in vitamin and oil distribution within a single lobe.

These distribution studies, while irrelevant to stability, are intimately related to the problems of sampling and collection of material. It is self-evident that it is necessary to ascertain whether vitamin A decreases in the whole liver after death, or whether a portion of a single lobe faithfully reflects the vitamin A content of the whole liver, and if maceration affects adversely the vitamin content of the liver when extracted and analyzed many hours later.

As revealed in table 1 whole livers or samples of ground liver may be maintained at ordinary temperatures (20° C.) up to about a month without loss of vitamin A. This conclusion leads to the premise that liver maintained in the frozen state undergoes no decrease in vitamin

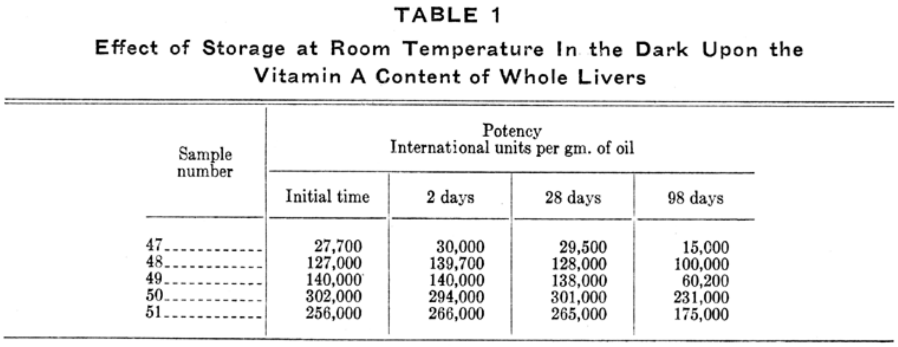

TABLE 1

Effect of Storage at Room Temperature In the Dark Upon the Vitamin A Content of Whole Livers

Sample number	Potency International units per gm. of oil			
	Initial time	2 days	28 days	98 days
47	27,700	30,000	29,500	15,000
48	127,000	139,700	128,000	100,000
49	140,000	140,000	138,000	60,200
50	302,000	294,000	301,000	231,000
51	256,000	266,000	265,000	175,000

TABLE 1

Effect of Storage at Room Temperature In the Dark Upon the Vitamin A Content of Whole Livers

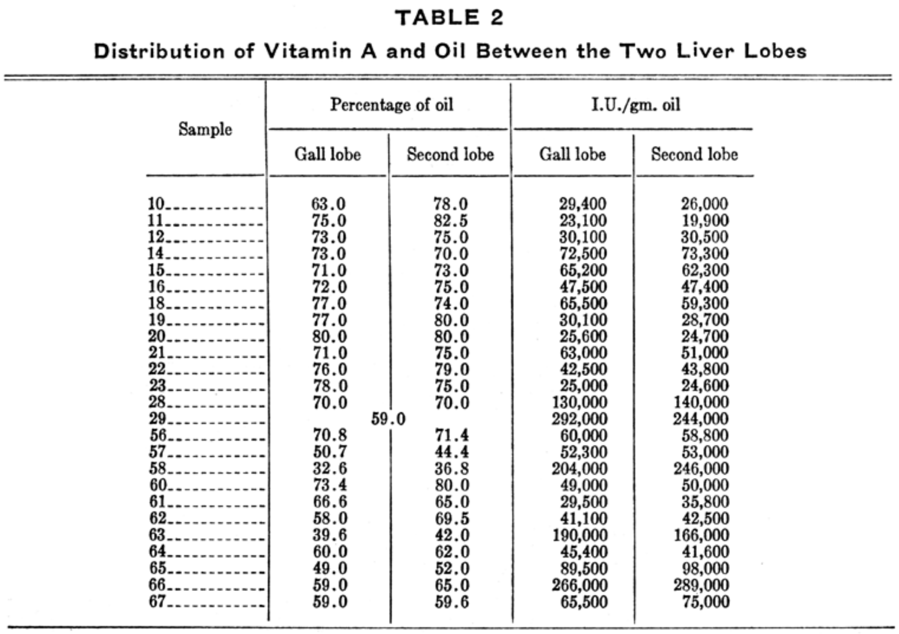

TABLE 2

Distribution of Vitamin A and Oil Between the Two Liver Lobes

Sample	Percentage of oil		I.U./gm. oil	
	Gall lobe	Second lobe	Gall lobe	Second lobe
10	63.0	78.0	29,400	26,000
11	75.0	82.5	23,100	19,900
12	73.0	75.0	30,100	30,500
14	73.0	70.0	72,500	73,300
15	71.0	73.0	65,200	62,300
16	72.0	75.0	47,500	47,400
18	77.0	74.0	65,500	59,300
19	77.0	80.0	30,100	28,700
20	80.0	80.0	25,600	24,700
21	71.0	75.0	63,000	51,000
22	76.0	79.0	42,500	43,800
23	78.0	75.0	25,000	24,600
28	70.0	70.0	130,000	140,000
29	59.0		292,000	244,000
56	70.8	71.4	60,000	58,800
57	50.7	44.4	52,300	53,000
58	32.6	36.8	204,000	246,000
60	73.4	80.0	49,000	50,000
61	66.6	65.0	29,500	35,800
62	58.0	69.5	41,100	42,500
63	39.6	42.0	190,000	166,000
64	60.0	62.0	45,400	41,600
65	49.0	52.0	89,500	98,000
66	59.0	65.0	266,000	289,000
67	59.0	59.6	65,500	75,000

TABLE 2
Distribution of Vitamin A and Oil Between the Two Liver Lobes

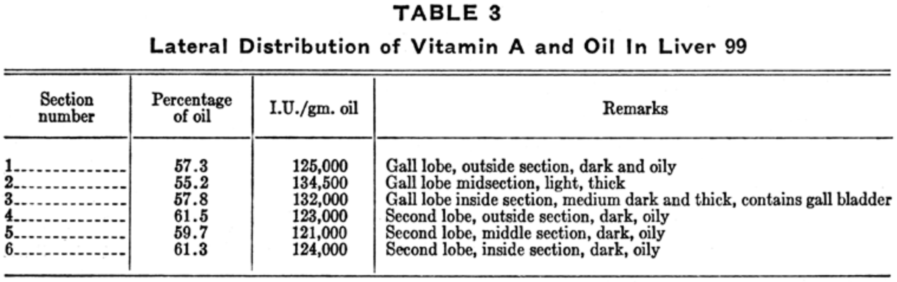

TABLE 3

Lateral Distribution of Vitamin A and Oil In Liver 99

Section number	Percentage of oil	I.U./gm. oil	Remarks
1	57.3	125,000	Gall lobe, outside section, dark and oily
2	55.2	134,500	Gall lobe midsection, light, thick
3	57.8	132,000	Gall lobe inside section, medium dark and thick, contains gall bladder
4	61.5	123,000	Second lobe, outside section, dark, oily
5	59.7	121,000	Second lobe, middle section, dark, oily
6	61.3	124,000	Second lobe, inside section, dark, oily

TABLE 3
Lateral Distribution of Vitamin A and Oil In Liver 99

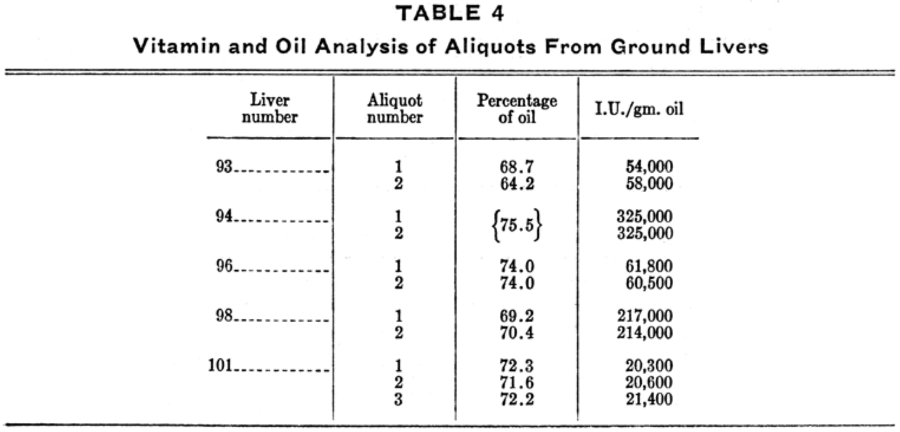

TABLE 4

Vitamin and Oil Analysis of Aliquots From Ground Livers

Liver number	Aliquot number	Percentage of oil	I.U./gm. oil
93	1	68.7	54,000
	2	64.2	58,000
94	1	{75.5}	325,000
	2		325,000
96	1	74.0	61,800
	2	74.0	60,500
98	1	69.2	217,000
	2	70.4	214,000
101	1	72.3	20,300
	2	71.6	20,600
	3	72.2	21,400

TABLE 4
Vitamin and Oil Analysis of Aliquots From Ground Livers

content and that values derived therefrom are substantially equal to those obtained from whole liver excised at the time of capture. In consequence of this observation and of those reported upon in tables 7 and 8 all subsequent analyses were made upon homogenized samples of liver obtained after grinding and sampling the organ at the landing dock. This phase of the study is reported upon further in the second paper of this publication. By way of interpretation it should be mentioned that the oil derived from ground liver after long standing at room temperature was found to have darkened considerably and to have become rancid. The vitamin A content, however, remained unchanged for long periods of time, then, suddenly decreased rapidly (Table 6).

In the next phase of the study attention was turned to the extracted oil and the effect of air upon the stability of vitamin A contained therein was investigated. About 20 ml. of the supernatant oil from homogenized soupfin livers was placed in a test tube provided with a two-hole stopper. A capillary whip was inserted in one of the holes and extended to the bottom of the test tube while the other hole was connected to the suction pump. The test tube was then immersed in a constant temperature water bath and air was aspirated through the oil at a rate of about two liters per minute. Aliquots were drawn off from time to time, weighed, diluted in isopropanol, and the optical density of the solutions was measured at 328 mμ in a Beckman quartz prism spectrophotometer. The method is essentially that used in the Fisheries Technological Laboratory, U. S. Department of Interior, Seattle, Washington (Sanford and Harrison, Personal Communication).

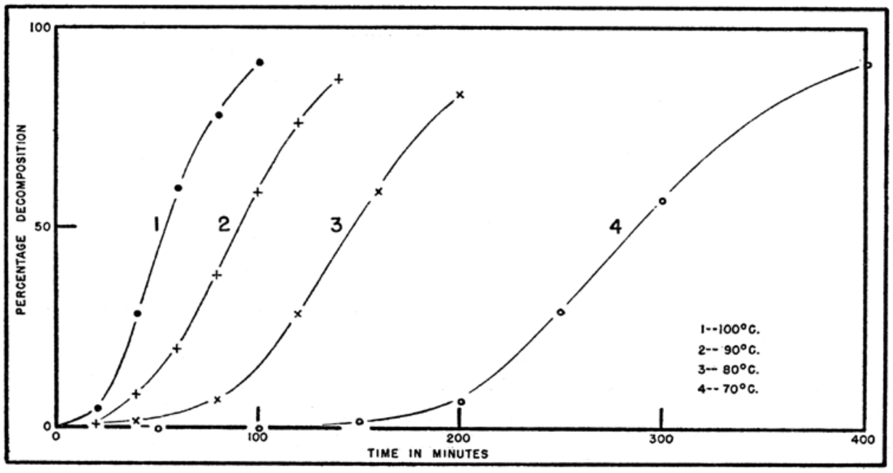

FIG. 1. Aerobic decomposition of soupfin shark liver oil Pool No. 3 at various temperatures.

FIG. 1. Aerobic decomposition of soupfin shark liver oil Pool No. 3 at various temperatures

The time required to decompose 50 per cent of the vitamin A was arbitrarily taken as a measure of the stability of the vitamin in the oil under the particular conditions of the experiment. Typical results are shown in figure 1. As a result of a similar study on three different oils decomposed at various temperatures, the temperature coefficient of the reaction was calculated and expressed in table 5. The average value is equal to about 2 for every 10° C. rise in the range studied. The experiments were conducted in diffused daylight, a fact which may account in part for the wide extremes in the results since no attempt was made to standardize the intensity of light between the various runs.

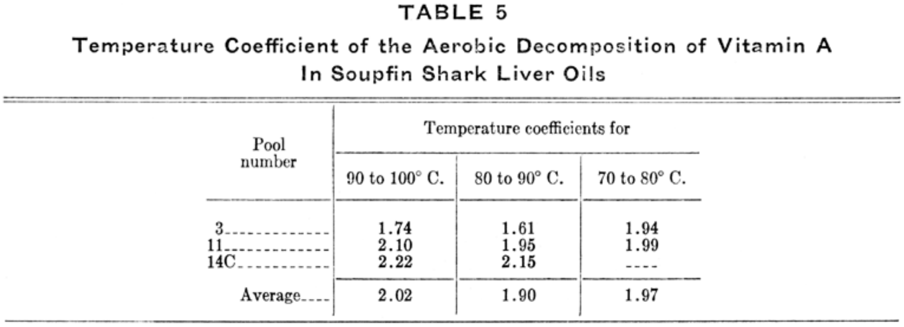

TABLE 5

Temperature Coefficient of the Aerobic Decomposition of Vitamin A In Soupfin Shark Liver Oils

Pool number	Temperature coefficients for		
	90 to 100° C.	80 to 90° C.	70 to 80° C.
3	1.74	1.61	1.94
11	2.10	1.95	1.99
14C	2.22	2.15	----
Average	2.02	1.90	1.97

TABLE 5

Temperature Coefficient of the Aerobic Decomposition of Vitamin A In Soupfin Shark Liver Oils

Typical stability values obtained on various soupfin liver oils are demonstrated in table 6. The values in the last column of this table were calculated on the assumption that the temperature coefficient of the reaction remained constant down to room temperature. Shark livers kept under commercial storage conditions would be stable for much longer periods of time, since the storage temperatures are much lower than room temperature and since livers are not kept in intimate contact with air.

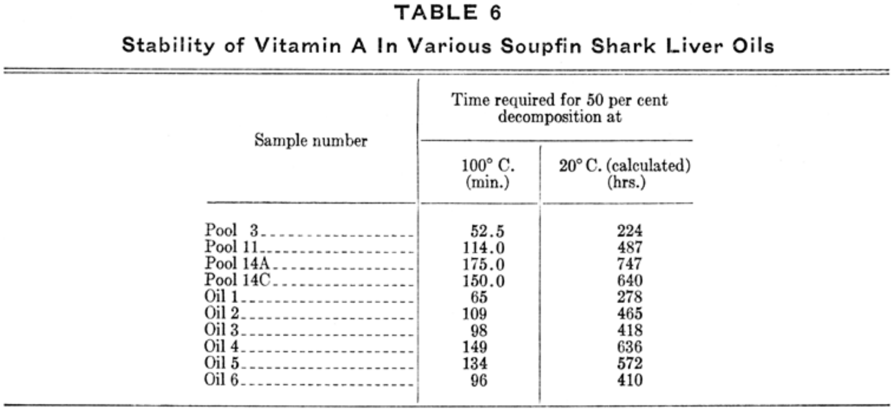

TABLE 6

Stability of Vitamin A In Various Soupfin Shark Liver Oils

Sample number	Time required for 50 per cent decomposition at	
	100° C. (min.)	20° C. (calculated) (hrs.)
Pool 3	52.5	224
Pool 11	114.0	487
Pool 14A	175.0	747
Pool 14C	150.0	640
Oil 1	65	278
Oil 2	109	465
Oil 3	98	418
Oil 4	149	636
Oil 5	134	572
Oil 6	96	410

TABLE 6

Stability of Vitamin A In Various Soupfin Shark Liver Oils

The high degree of stability of vitamin A in soupfin shark liver oils indicated by these experiments is not to be misinterpreted. Even though the oils which have been roughly treated show no loss of vitamin in the initial lag period of the decomposition, the oils have lost the greater part of their antioxidant activity. This is more clearly shown in figures 2 to 5. Oils and aliquots of whole livers were stored in the dark at 40° C. in open wide mouth bottles. The contents were regularly stirred and aliquots of the clear oils were collected at various intervals. When the liver tissue was present an aliquot sample was centrifuged at 2,500 r. p. m. Variations in the potency of the oils with time are shown in figures 2 and 3 while variations in the stability of the vitamins in these oils are demonstrated in figures 4 and 5. These results show definitely that although the potency remains the same, the stabilities are greatly altered. The color of the oils in the presence of liver darkened considerably between the 4th and 8th day. Towards the end of the experiment these oils were almost black. The increase in stability at the 6-day period in figure 4 is hard to explain. It may be due to the liberation of protective substances from the tissue. Such substances would dissolve in the oil and retard the rate of oxidative decomposition of the vitamin. On the other hand this increase in the stability may be only an artifact due to experimental error. Unfortunately, this experiment could not be repeated due to the lack of fresh samples. Curve 6 of figures 2 and 4 was obtained on a pool of livers which had been kept for some time at 10° C. This curve does not show the maximum in the stability curve. From the initial

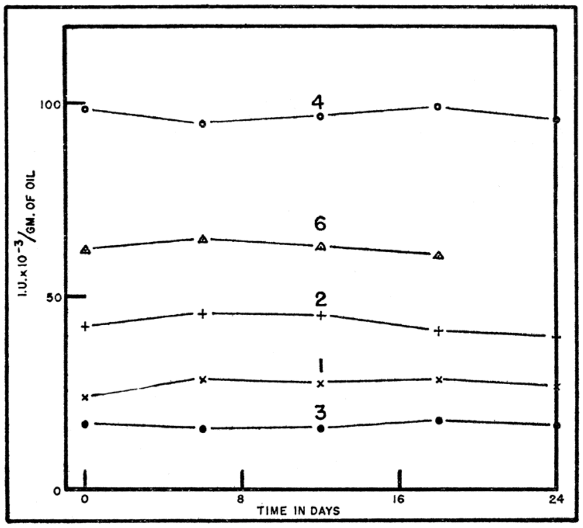

FIG. 2. Effect of incubation at 40° C. in the presence of air and of liver tissue on the potency of various soupfin liver oils

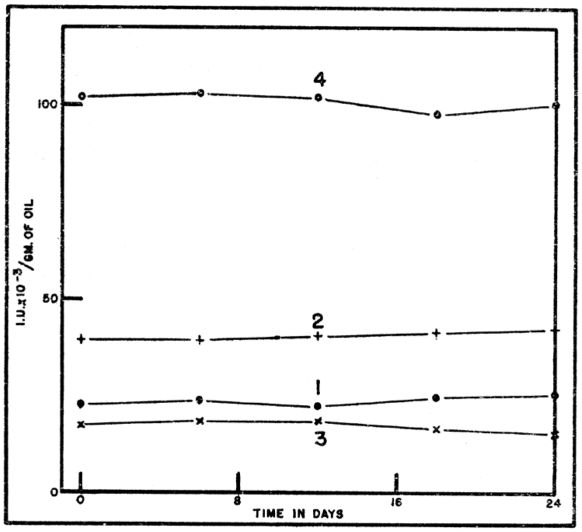

FIG. 3. Effect of incubation at 40° C. in the presence of air on the potency of various soupfin liver oils

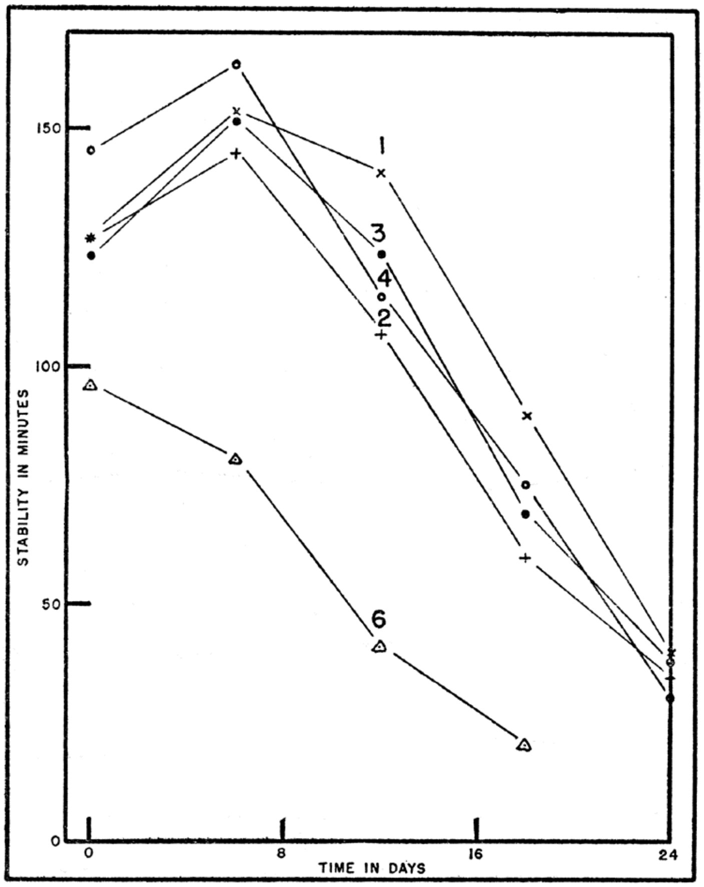

FIG. 4. Effect of incubation at 40° C. in the presence of air and of liver tissue on the stability of various soupfin liver oils

stability values and from the fact that the sample was not fresh, the results of this curve are not strictly comparable to those of the other four curves of this figure. Sanford and Harrison (Personal Communication) report a similar maximum in the stability of dogfish liver oils. Their maximum, however, occurred at a much later period in the decomposition.

From the above data it appeared that, for the biological survey, it was not essential that the livers be frozen immediately in dry ice. Hence, liver collections were made on shore. This permitted the collection of a greater number of samples than was possible by the old technique since the biologist was no longer restricted to the captures of a single boat.

5.2. EXPERIMENTAL

The vitamin potency was determined by the Rosenthal-Erdelyi (2, 3, 6) method described in section B. The percentage of oil, on the other hand, was evaluated by the methylene chloride method (Tompkins and Balomey, 1943) outlined in section A.

Whole livers, table 2, were divided into their separate lobes which were then analyzed separately for oil and vitamin content. A typical example of the results obtained on longitudinal sections of each lobe is shown in table 3. In each case the results are not consistent and can not be relied upon to determine either the oil or the vitamin content of the whole liver.

Results in table 4 were obtained on homogenized aliquots of livers previously ground in an electrically-driven grinder. Liver 101 was ground in the field before freezing while the other livers were ground in

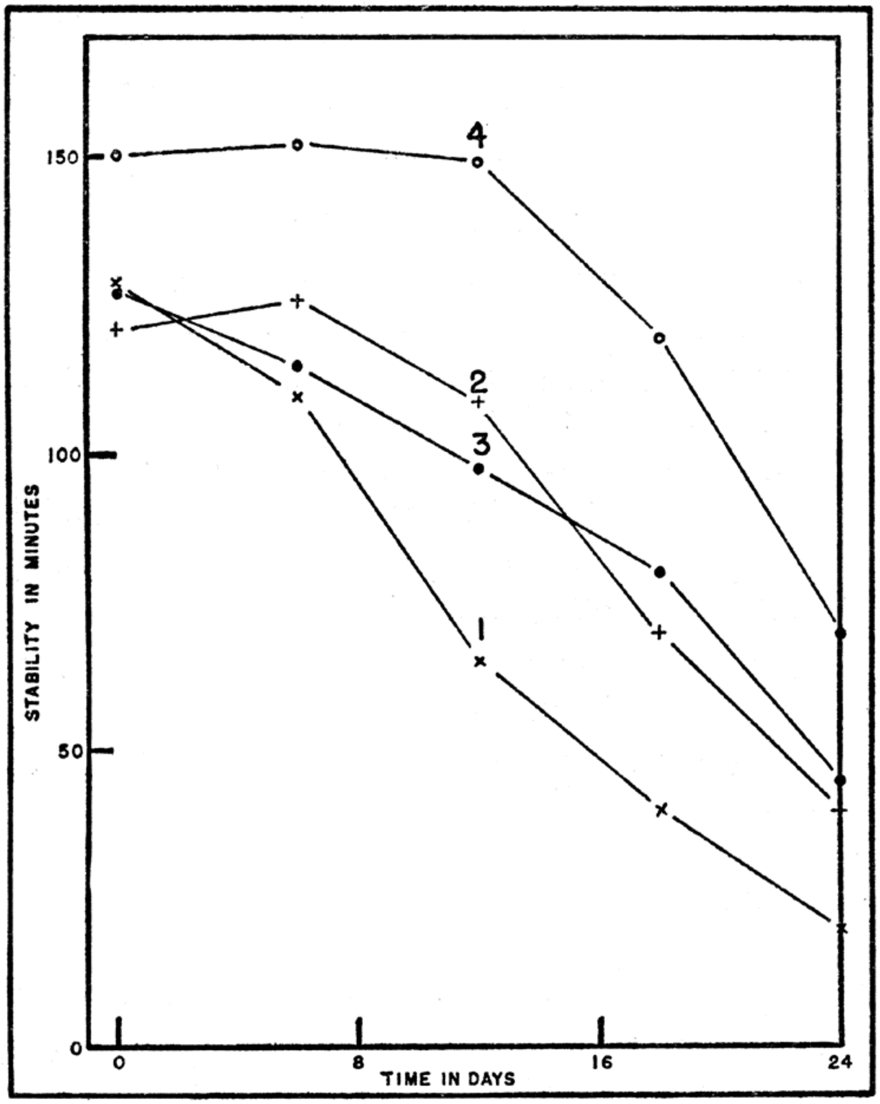

FIG. 5. Effect of incubation of 40 per cent in presence of air on the stability of various soupfin liver oils

the laboratory after freezing in dry ice, separate aliquots being homogenized. The main difference between frozen and fresh livers is that the oil in frozen livers separates out quite readily and more care is required in obtaining a representative sample. With fresh livers the greater part of the oil remains in the cellular tissue. The results expressed in table 4 indicated that aliquots of the ground livers instead of whole livers could be collected and shipped to the laboratory. By this means up to 48 samples instead of 4 per box could be sent for analysis.

5.3. CONCLUSIONS

The forced aeration of soupfin shark liver oils has been studied at temperatures ranging between 70 and 100° C. The stability of these oils measured as a function of the time required to decompose 50 per cent of the vitamin varies between 52 and 175 minutes at 100° C. The reaction has a temperature coefficient of about 2 for every 10° C. rise.

The distribution of oil and vitamin A is not uniform in the livers. Therefore, grinding the livers and thorough mixing are required to obtain representative aliquots.

Samples to be collected for the study of the oil and vitamin content of soupfin shark livers may be collected at the time the sharks are landed, although fresher samples are required for stability studies.

5.4. Literature Cited

Tompkins, P. C., and Bolomey, René A. 1943. Ind. Eng. Chem., Anal. Ed., 15, 437.