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LEO SHAPOVALOV, *Editor*
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SECOND PROGRESS REPORT ON THE TAGGING OF WHITE CATFISH (*ICTALURUS CATUS*) IN THE SACRAMENTO-SAN JOAQUIN DELTA[1]

DAVID E. PELGEN and GEORGE W. McCAMMON
Inland Fisheries Branch
California Department of Fish and Game

This report constitutes the second of a series on the results of tagging studies begun in 1952 on the white catfish (*Ictalurus catus*) of the Sacramento-San Joaquin Delta. The ultimate objective is to derive a valid index of the annual rate of harvest of white catfish in the Delta fishery. Such information is fundamental to the conservation of this valuable resource.

These investigations were secondarily aimed at revealing information about the movements of white catfish in the Delta. Knowledge of any regular, seasonal migrations was particularly desired.

The initial report (Pelgen, 1954) described preliminary holding experiments and presented the results of one year of tag returns from tagged white catfish released in the Delta. In summary, opercular strap tags proved unsatisfactory. The disk-dangler tag appeared promising and worthy of further tests. Tag returns from fishermen indicated only sporadic, directionless movement of fish.

The present report describes the second year's results of the initial study, and presents the preliminary results of a second experiment that was designed to compare two types of tags, to further explore movements, and to estimate the annual rate of harvest.

FIRST STUDY

The inadequacy of the opercular strap tag was confirmed by observation of experimentally tagged fish, and by tag returns during the second year of the first study.

Pelgen (1954) reported that both opercular strap tags and disk-dangler tags remained attached to white catfish held in hatchery ponds for one year, although the strap tags became hidden under a layer of opaque mucus. After the experimentally tagged fish had been held for 22 months, a check revealed that a number of strap tags had become detached. Ten were lost and most of the 31 tags that remained were very loose.

None of the 20 disk-dangler tags were missing, although several had irritated the flesh surrounding the points of attachment. Excessive netting and handling are believed primarily responsible for these irritations. The authors have rarely observed such irritations on tagged catfish in the Delta.

1 Submitted for publication June, 1955. This work was performed as part of Dingell-Johnson Project California F-2-R. "A Study of the Catfish Fishery of California", supported by Federal Aid to Fish Restoration funds.

Tag returns from catfish released in the Delta in 1952 diminished greatly during the second year. Table 1 summarizes returns from the first study for both the first and second years. The superiority of the disk-dangler tag over the opercular strap tag remains evident despite the few returns during the second year.

TABLE 1

Data on Tags at Large and Tags Returned from First Study

Study period	Tags at large at beginning of each period			Tags returned during each period		
	Strap	Disk-dangler	Total	Strap	Disk-dangler	Total
First year	2,865	601	3,466	75 (2.6%)	98 (16.3%)	173 (5.0%)
Second year	*2,790	*503	*3,293	9 (0.03%)	14 (0.3%)	23 (0.07%)

* These figures were actually lower than indicated since natural mortality, loss of tags, and nonreturn of tags were not considered.

SECOND STUDY

Methods

Two types of tags were compared in this study: the disk-dangler tag and the staple tag. These tags, with their position on the fish, are illus-

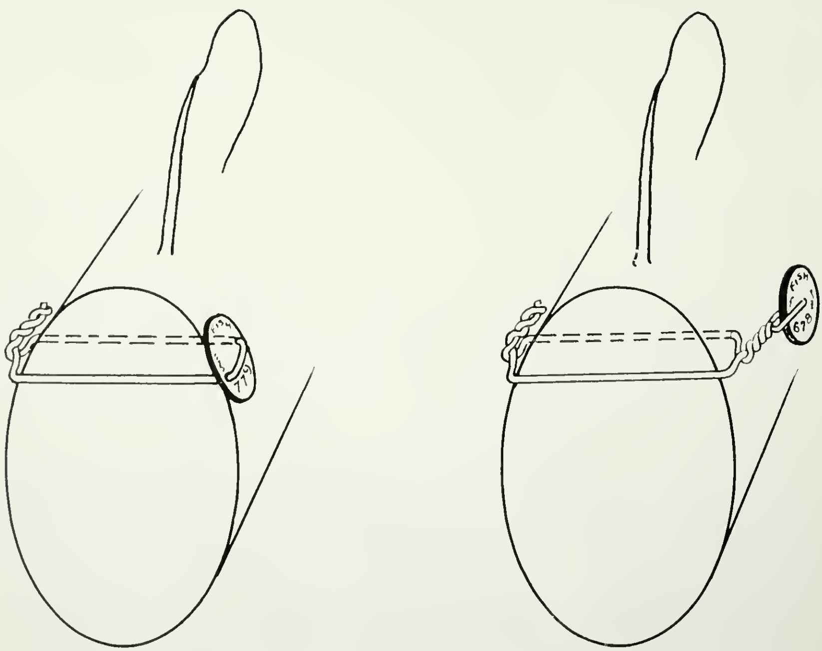

FIGURE 1. *Left:* staple tag shown in place. *Right:* disk-dangler tag shown in place.

trated in Figure 1. Both types were originally developed in connection with tagging studies on striped bass, *Roccus saxatilis* (Calhoun, 1953).

There is actually little difference between these two tags. The only distinction lies in the position of the disk in relation to the body of the fish. It was hoped that the staple tag's snug position against the fish would reduce the possibility of entanglement with gill nets, weeds, and other obstructions.

All tags were constructed of the same materials: cellulose nitrate disks, one-half inch in diameter and 0.040-inch thick, and 0.020-inch tantalum wire. The disks were supplied by Bastian Brothers Company of San Francisco.

The method of attachment of both tags to the body of the catfish was identical to that used by Pelgen (1954).

Three separate tagging stations (Figure 2) were selected to obtain an adequate distribution of tagged fish throughout the population. The results of the first study, in which six tagging stations were used, indicated that the dispersion from the point of tagging was sufficiently thorough to eliminate the necessity for more than three stations.

Fyke nets[2] similar to those used by commercial catfish fishermen (Warner, 1949) were used to capture the fish for tagging. Each net possessed seven circular iron hoops, grading from 45 inches to 28 inches in diameter from front to rear. The webbing consisted of number 15 cotton twine with 2½-inch stretched mesh. Funnels were hung from the second, third, and fifth hoops. The last funnel had an opening approximately four inches in diameter.

All nets were dipped in heated coal tar at frequent intervals to prevent rapid deterioration of the webbing. It has been observed in the past by commercial fishermen, and more recently by project personnel, that nets treated in this manner catch significantly more white catfish in the Delta than do nets treated with other preservatives.

It was originally planned to use 250 tags of each type at each of the three stations, for a total of 1,500. However, since one disk-dangler tag was not used at the Antioch Bridge station, the total was actually 1,499.

Tagging was carried out between December 16, 1952, and January 27, 1953. Winter tagging is believed to be distinctly superior to summer tagging. The reduced metabolic rate of the fish in cold weather may moderate the initial effects of the tagging operation. In addition, some disease-producing and parasitic organisms are less active and thus less likely to secure a foothold in the tag wound when water temperatures are low.

At two stations, Disappointment Slough and Cache Slough, both netting and tagging were performed at the release point. This work was done with the aid of the Department of Fish and Game research boat "Striper." Every effort was made to handle the fish carefully. Only a few fish were removed from the nets at one time and they were quickly tagged and returned to the water. Experienced workers usually require slightly less than 30 seconds to apply a tag. The procedure at the Antioch Bridge station was slightly different. White catfish were

[2] Nets with funnels but without wings are commonly called "fyke nets" in California. Such nets are frequently termed "hoop nets" in many other areas.

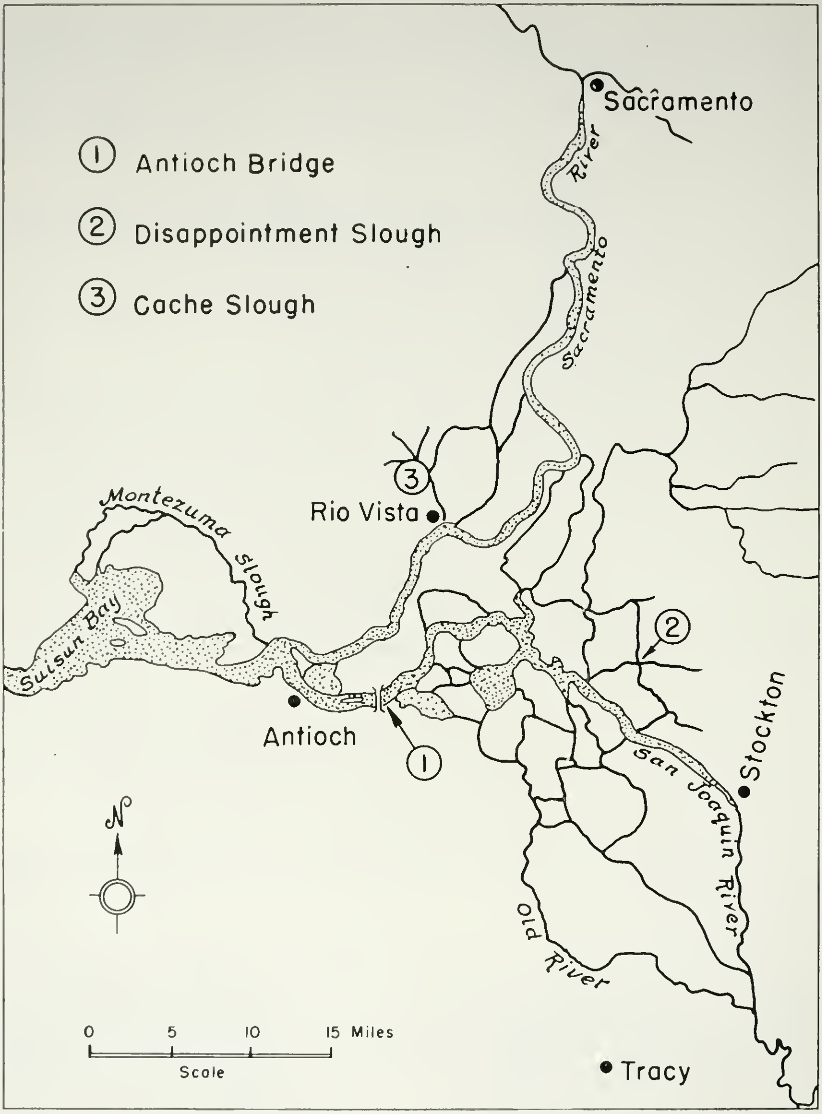

FIGURE 2. The three localities at which tagged catfish were released.

trapped in Mayberry Cut, two miles northwest of the Antioch Bridge, and transported to a field base installation at the south end of the bridge, where the fish were retained in a live box and tagged from a dock.

The fork length of each catfish was measured to the nearest tenth of an inch.

After the catfish were tagged, the success of the study was entirely dependent upon the return of tags by sport and commercial fishermen.

Hence, the importance of returning tags was advertised throughout the Delta area. Posters, press releases, prize drawings, personal contact with resort owners and sportsmen's clubs, and commendation cards all played a part in the publicity campaign. The prize drawing sponsored by the Foothill Sportsmen's Club of Oakland was probably the most effective single publicity method. An annual prize of $100, together with numerous awards of fishing equipment, was generously donated by that group.

Tag Returns

Table 2 summarizes tag return data during the first 12 months of the study. The total return from both sport and commercial fishermen was 15.1 percent. The largest number of tags was recovered from catfish released at the Antioch Bridge, where the return was 21.0 percent. The Disappointment Slough and Cache Slough stations yielded returns of 11.2 percent and 13.2 percent, respectively.

TABLE 2

Data on Tags Attached and Tags Returned During First Year

Tagging station	Tags attached			Tags returned		
	Disk-dangler	Staple	Total	Disk-dangler	Staple	Total
Antioch Bridge	249	250	499	54 (21.7%)	51 (20.4%)	105 (21.0%)
Disappointment Slough	250	250	500	33 (13.2%)	23 (9.2%)	56 (11.2%)
Cache Slough	250	250	500	35 (14.0%)	31 (12.4%)	66 (13.2%)
Totals	749	750	1,499	122 (16.3%)	105 (14.0%)	227 (15.1%)

The range in size of the fish tagged was 6.1 to 12.4 inches, fork length. The mean length was 8.2 inches. The size range at the time of tagging of the catfish from which tags were returned was 6.3 to 12.0 inches and the mean length was 8.3 inches. A chi-square test revealed that a statistically significant difference exists between the size of catfish tagged and the size of catfish from which tags were returned ($P<0.003$). The actual number of returns from catfish under 8.5 inches fork length was less than would be expected were the return of tags independent of the size of the fish tagged, while returns from catfish over 8.5 inches were greater than would be expected. No explanation for this difference is available at the present time.

Suitability of Tags

As shown in Table 2, 16.3 percent of the disk-dangler tags and 14.0 percent of the staple tags were returned. The difference is not statistically significant at the 5-percent level. At no time during the second study did any evidence appear that definitely demonstrated the superiority of either tag. Comparative tests of the suitability of both tags on other species of fish are under way in other projects, and they may disclose advantages of one tag over the other that are not now apparent. One such test has shown that the staple tag beneath the dorsal fin is unsatisfactory for use on large steelhead rainbow trout (*Salmo gairdneri gairdneri*).

The shedding of unsatisfactory tags can often be detected by observing the time of recovery of tags. Table 3 presents the number of returns in this study by monthly intervals following time of tagging.

TABLE 3

Tag Returns by Monthly Intervals During First Year

Elapsed time in months	Tags returned					
	Staple tags		Disk-dangler tags		Totals	
	Number	Percentage	Number	Percentage	Number	Percentage
0- 1	11	10.5	6	4.9	17	7.5
1- 2	8	7.6	3	2.5	11	4.8
2- 3	14	13.3	9	7.4	23	10.1
3- 4	12	11.4	18	14.8	30	13.2
4- 5	14	13.3	13	10.7	27	11.9
5- 6	10	9.5	16	13.1	26	11.5
6- 7	8	7.6	13	10.7	21	9.7
7- 8	8	7.6	21	17.2	29	12.8
8- 9	9	8.6	6	4.9	15	6.6
9-10	5	4.8	10	8.2	15	6.6
10-11	5	4.8	1	0.8	6	2.6
11-12	1	1.0	6	4.9	7	3.1
Totals	105	—	122	—	227	—

From these data it is not evident that either type of tag was becoming detached in significant numbers. It is believed that the variation in number of returns is largely governed by changes in angling effort. The periods when the most tags were returned coincide with the periods of greatest angling intensity in the Delta.

Harvest

Until September, 1953, the Delta white catfish population was the object of both a commercial and a sport fishery.

The commercial fishery was relatively small in terms of the number of fishermen involved and gross income. For instance, in 1952, approximately 20 licensed commercial fishermen reported landing 174,452 [3] pounds of catfish with a total value to the fishermen of $35,763 (Pelgen, 1952). The actual commercial landings were undoubtedly larger than the record indicates, since there was good evidence that some of the marketed catch was not reported as required by law.

Sport fishing for catfish is fairly important in California. In 1953, an estimated 225,000 anglers (19 percent of all license holders) caught approximately 7,500,000 catfish (Skinner, 1955).

Evidence of a decline in the Delta catfish fishery (Pelgen, 1952) led to the elimination of the commercial fishery by the California Legisla-

[3] Poundage corrected to cover cleaning loss of 50 percent.

ture in September, 1953. For all practical purposes, commercial fishing in the Delta during 1953 was limited to the months of January, February, March, and April, since the commercial closed season extended from May 1st to August 31st.

Thus, both the commercial and sport fisheries were active during the first four months of the tagging study. In this period, a total of 107 tags was recovered. Sport fishermen turned in 75 tags, commercial fishermen returned 28 tags, and project personnel accounted for four tags.

It is believed that very few sport fishermen failed to return tags. Undoubtedly there were instances in which anglers captured tagged catfish but did not return the tags for various reasons. No basis exists for estimating the percentage of nonreturn by sport fishermen; however, the absence of any indication of tag nonreturn of significant proportions leads the authors to presume that nearly all tags were returned.

In contrast, it is believed that a number of commercial fishermen failed to return a substantial number of tags. During the four-month period when the commercial fishery was active, only seven of approximately 20 licensed commercial men returned any tags at all. These seven fishermen reported a total catch of 12,544 pounds. The total catch by all fishermen during the same four months was 28,314 pounds. Thus, the seven cooperative fishermen, who were responsible for all of the 28 commercial returns, caught about 44 percent of the total 1953 landings. It is surmised that the remaining 56 percent of the 1953 commercial catch was taken by individuals who were either disinterested or unsympathetic toward the tagging program. The evidence that some commercial fishermen were not inclined to return tags was verified by personal contact in several instances.

The effect of nonreturn of tags by the commercial fishery upon the estimate of annual harvest is difficult to assess. If it is assumed that the catch of the seven fishermen who returned tags was representative of the total commercial catch, then a correction can be made to compensate for tags not returned. On this basis, it is estimated by simple proportion that the commercial fishery recovered 63 instead of 28 tags during the first year.

Addition of the corrected commercial tag returns to the 195 returns from anglers increases the total number of tag returns from 223 to 258. The four tags recovered by project personnel are not included in this total. The revised sum represents a total return of 17.2 percent.

With the correction for commercial nonreturn of tags, a minimal harvest of approximately 17.2 percent of the available white catfish in the Delta is indicated for 1953. The harvest by sport fishermen alone is estimated to be at least 13.0 percent. These estimates are tentative, pending the results of further studies in progress.

Following the elimination of the commercial fishery in 1953, a third experiment was begun, using only disk-dangler tags. The results of this study should provide a valid index of the annual harvest of white catfish by the sport fishery. A subsequent report will describe the findings.

Movement of Tagged Catfish

It was possible to determine accurately the movements of 194 of the 227 white catfish from which tags were returned. Sixty-eight fish traveled upstream, averaging 10.4 miles; 76 fish traveled downstream, averaging 8.7 miles. Fifty individuals were recaptured in the immediate vicinity of their point of release.

The movements of the tagged catfish in both the first and second studies were surprisingly similar. Table 4 summarizes movement data from both studies. The only noticeable difference lies in the large number of fish captured near the point of release in the second study. Only 20 catfish were recovered near their release point in the first study.

TABLE 4

Movement of Tagged White Catfish in the First and Second Sacramento-San Joaquin Delta Tagging Studies

Tagging study	Number of fish for which movement was determined	No movement	Movement			
			Upstream		Downstream	
			Number fish	Average distance	Number fish	Average distance
First Delta study (First year's returns)	158	20	85	9.8	53	8.6
Second Delta study (First year's returns)	194	50	68	10.4	76	8.7
Totals	352	70	153	*10.1	129	*8.7

* Mean distance.

The earlier evidence that the movement of white catfish in the Delta is sporadic and without apparent direction (Pelgen, 1954) is corroborated by these results.

ACKNOWLEDGMENTS

Acknowledgment is due Alex Calhoun, under whose guidance the tagging studies were conducted. We are also grateful to William E. Rowley, Jr., who assisted in the tagging of the fish, and to Vincent Catania, who assisted in their capture. Special thanks are due the Foothill Sportsmen's Club of Oakland, particularly Mr. Ed Busalak, who generously sponsored the prize drawings, which stimulated so much public interest in the project.

SUMMARY

Tagging studies of the white catfish (*Ictalurus catus*) in the Sacramento-San Joaquin Delta area of California were begun in 1952, in order to obtain data on annual harvest and migration. This is the second progress report on the findings of these studies.

All disk-dangler tags on white catfish held in hatchery ponds remained in place for 22 months, while a significant number of opercular strap tags were shed.

Very few tags were returned during the second year from 3,466 tagged white catfish released in the Delta in the spring of 1952. However, the percentage of return for disk-dangler tags was 10 times that for strap tags.

In the winter of 1952-53, 1,499 white catfish were tagged with disk-dangler tags and staple tags in equal numbers and released at three localities.

The total return of both types of tags from all sources was 15.1 percent during the first 12 months. The Antioch Bridge tagging station produced a high return of 21.0 percent.

A significant difference was noted between size of fish tagged and size of fish from which tags were returned. Fewer tags were returned from fish under 8.5 inches than would theoretically be expected.

Fourteen percent of the staple tags and 16.3 percent of the disk-dangler tags were returned. The difference was not statistically significant.

It is estimated that a minimum of 17 percent of the available white catfish was harvested by sport and commercial fishermen in the Delta in 1953. The true figure is undoubtedly somewhat larger, because of failure to return tags.

No evidence of any regular, seasonal migration of white catfish in the Sacramento-San Joaquin Delta was found.

LITERATURE CITED

Calhoun, A. J.
1953. Aquarium tests of tags on striped bass. Calif. Fish and Game, vol. 39, no. 2, p. 209-218.

Pelgen, David E.
1952. A preliminary analysis of the catfish fishery of the Sacramento-San Joaquin Delta. Calif. Dept. Fish and Game, Inland Fisheries Branch, Admin. Rept. No. 52-23. 10 p. (Mimeo.)

1954. Progress report on the tagging of white catfish (*Ictalurus catus*) in the Sacramento-San Joaquin Delta. Calif. Fish and Game, vol. 40, no. 3, p. 313-321.

Skinner, John E.
1955. California state-wide angling estimates for 1953. Calif. Fish and Game, vol. 41, no. 1, p. 19-32.

Warner, George H.
1949. Catfish. *In:* The commercial fish catch of California for the year 1947 with an historical review 1916-1947. Calif. Div. Fish and Game, Fish Bull. 74, p. 53-57.

FLUCTUATIONS IN ABUNDANCE OF CERTAIN FISHES IN SOUTH SAN FRANCISCO BAY AS INDICATED BY SAMPLING AT A TRASH SCREEN[1]

EARL S. HERALD and DONALD A. SIMPSON
Steinhart Aquarium, California Academy of Sciences,
San Francisco

The presence of a fixed fish-collecting device on the west shore of south San Francisco Bay has been a considerable asset to Steinhart Aquarium over the past years. In addition to providing fishes for display and as food for aquarium fishes, the records of the catches have provided valuable information about some of the population dynamics within the bay.

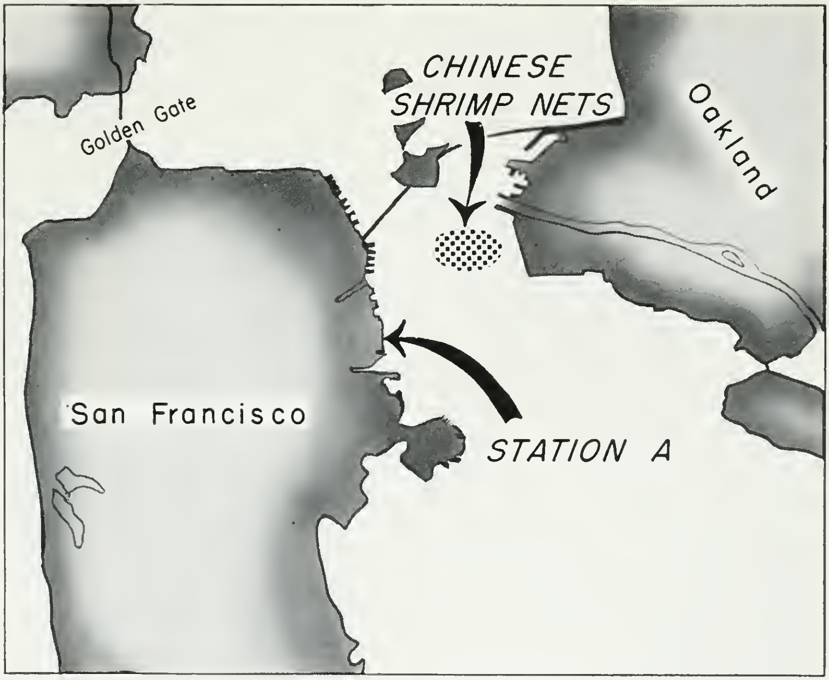

FIGURE 1. Map of a section of San Francisco Bay, showing location of the Station A pumping plant of the Pacific Gas and Electric Company and its relation to the fishing area of the Chinese shrimp nets.

[1] Submitted for publication May, 1955. Data for this report have been taken by the various collectors at Steinhart Aquarium, but chiefly by the junior author and Mr. Walter Schneebeli. We wish to thank Mr. W. I. Follett and Mrs. Lillian Dempster of the academy's department of ichthyology for their assistance in identification and in checking records. Also, our thanks are extended to the Pacific Gas and Electric Company for having made the trash screens available as a collecting device over the past years.

This fish-collecting device is the revolving trash screens of the Station A power plant of the Pacific Gas and Electric Company, located at Third and Twenty-third Streets in San Francisco (Figure 1).

The station draws cooling water from the bay through two concrete tubes 10 feet in diameter, extending outward for about 30 yards from shore. At high tide the top of each is about seven feet under water. Thus, at low tide the open ends of the tubes extend from 2 to 12 feet beneath the surface and at high tide from 7 to 17 feet. It should be noted that all of our samples were taken at high tide. The bayside openings of the tubes are protected by guards of perpendicular flat bars ($\frac{3}{8}$ inches x $2\frac{1}{2}$ inches) which are placed so that there is a $5\frac{3}{4}$-inch opening between adjacent bars. These guards prohibit the entrance of the larger fishes. When the plant is pumping at its normal rate of 100,000 gallons per minute, the water travels through the tubes at about $1\frac{1}{2}$ mph. This sucks many small fishes into the openings, and they pass subsequently through to the well in front of the revolving trash screens (Figure 2). The plant pumps continuously through both tubes and does not alternate.

FIGURE 2. The junior author hauling up the collecting net from the sump in front of the revolving trash screen. *Photograph by Toshio Asaeda, November, 1954.*

The monel wire screens are 9⅓ feet wide and 33 feet high, with ½-inch square mesh. They rotate vertically, passing over sprockets 3⅓ feet in diameter at the top and bottom. At intervals of two feet the screens are hinged and equipped with a metal strip or baffle four inches wide, which extends outwardly from the face of the screen in the form of a flat scoop. As the screen moves upward, these baffles catch debris and fish which have been pinioned against the mesh by the force of the incoming water. This material is then lifted over the top of the revolving screen and deposited in a trough of running water, whence it is washed back into the bay.

During the summer months fish yield at the screens is small. A haul of 10 pounds during any day of this period is a good catch, and as little as one or two pounds is not unusual. By contrast, in the winter we have often taken as much as 150 to 200 pounds of fish from the screen sump. The largest amount, 270 pounds, was taken on February 8, 1951. However, these amounts seem insignificant when compared with the two to four tons that have been taken from the Southern California Edison Company's power plant intakes at Hermosa Beach, California (verbal communication, Mr. Ross McBride).[2]

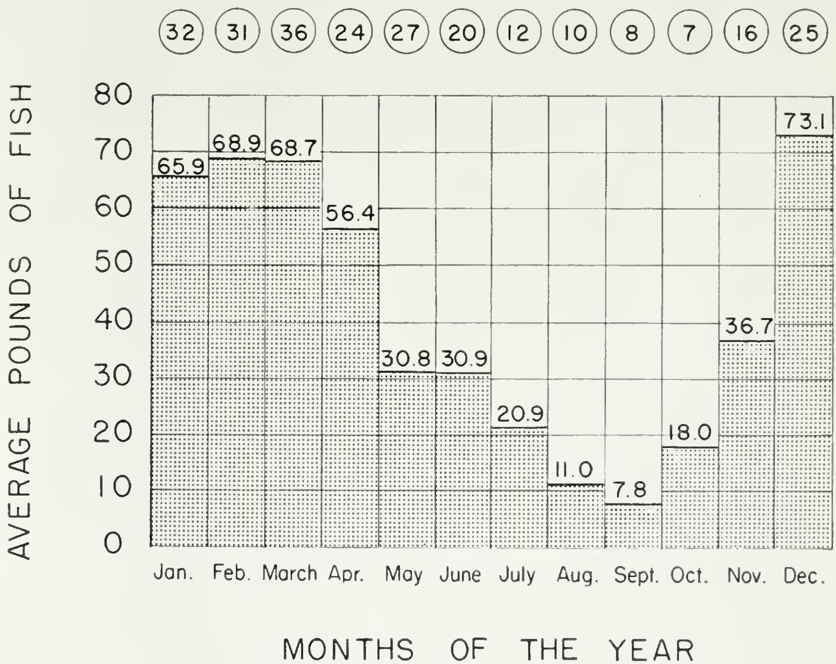

FIGURE 3. Average number of pounds of fish taken per month from the revolving trash screens at the Station A pumping plant of the Pacific Gas and Electric Company during the six years 1945-1950. Figures in circles above each histogram indicate the number of trips during the six-year period upon which each average month is based. A total of 248 collections and 14,935 pounds of fish is represented.

[2] This amount of fish was usually taken only after a buildup period of one to three weeks. The most abundant fish was the queenfish, *Seriphus politus*, followed by the white croaker, *Genyonemus lineatus*. Many other species were present in lesser numbers, but tabulations are not available.

Unfortunately for public aquaria, this ready source of fish food and live specimen appears to be doomed by the changing design of screens at these installations. Studies such as that by Kerr (1953) on fish screening devices for power plants have implemented the redesign of older installations to provide for more efficient fish diversion.

Figure 3 presents the average catch in pounds per month for the six years 1945 through 1950. This represents a total of 248 collecting trips, from which 14,415 living fishes were returned to Steinhart Aquarium for display, with an additional 14,835 pounds of dead fish for food. The live fish have not been included in the data for Figure 3.

Identical months in different years are sometimes quite variable. For example, in February, 1949, the largest catch was 10 pounds of fish, whereas in February, 1950, it was 150 pounds, and in February, 1951, 270 pounds. However, on an annual basis the monthly variations tend to smooth out and a fairly representative histogram results (Figure 3).

The question immediately arises regarding the reason for high production during winter months and low production during summer months. Temperature does not appear to provide the answer, but storms, prevailing winds, and the phenomenal fecundity of the viviparous surfperches do furnish a part of the solution. During and immediately after a storm the yield at the screens is increased several fold,

TABLE 1

Comparison of Representative Winter and Summer Catch Samples From the Trash Screens of the South San Francisco Bay Station A Power Plant of the Pacific Gas and Electric Company

Species	February 19, 1951			August 13, 1951		
	Number specimens	Weight in pounds	Weight percentage of total catch	Number specimens	Weight in pounds	Weight percentage of total catch
Shiner seaperch, *Cymatogaster aggregata*	2,217	81.80	87.53	242	2.66	19.00
Pileperch, *Rhacochilus vacca*	28	2.50	2.68	93	2.81	20.07
Walleye surfperch, *Hyperprosopon argenteum*	11	2.20	2.35	88	1.31	9.36
Striped seaperch, *Embiotoca lateralis*	10	0.75	0.80	2	0.07	0.50
Bay blackperch, *Embiotoca jacksoni*	10	0.75	0.80	11	0.75	5.36
Dwarfperch, *Micrometrus minimus*	12	0.50	0.54	1	0.07	0.50
White seaperch, *Phanerodon furcatus*	4	0.25	0.27	4	0.56	4.00
Rainbow seaperch, *Hypsurus caryi*	1	0.03	0.03			
Rubberlip seaperch, *Rhacochilus toxotes*			----	7	3.19	22.79
Boccacio, *Sebastodes paucispinis*	1	0.22	0.23	10	0.44	3.14
Black rockfish, *Sebastodes melanops*	2	0.37	0.40	7	0.50	3.57
Lingcod, *Ophiodon elongatus*	1	0.03	0.03	1	0.09	0.64
Striped bass, *Roccus saxatilis*	21	0.40	0.43			
English sole, *Parophrys vetulus*	8	0.50	0.54			
San Francisco topsmelt, *Atherinops affinis affinis*	2	0.18	0.19			
Sacramento smelt, *Spirinchus thaleichthys*	9	0.25	0.27			
Tomcod, *Microgadus proximus*	2	0.09	0.10			
Northern anchovy, *Engraulis mordax*				7	0.12	0.86
Staghorn sculpin, *Leptocottus armatus armatus*	12	1.50	1.60	7	0.56	1.00
Leopard shark, *Triakis semifasciata*	1	0.50	0.54			
California skate, *Raja inornata*				1	0.31	2.21
Detritus and isopods		0.63	0.67		0.56	4.00
Totals	2,352	93.45	100.00	481	14.00	100.00

perhaps in large part a result of the storm winds blowing fish toward the intake tubes. During the spring and summer months, when the female surfperch drop their young, there are a great many small juveniles in the catch. The surfperch population during the winter is made up mostly of large juveniles and adults.

In order to determine accurately the composition of the catches, 14 of the 248 collections, covering 9 of the 12 months (July through March, inclusive), were broken down and detailed analyses made. Since the basic pattern seems to be approximately the same in all of the months during which samples were taken, we present in Table 1 the two extremes—a winter sample (February 19, 1951), contrasted with a summer sample taken six months later (August 13, 1951). As shown by the total weight of each collection (88 pounds vs. 14 pounds), the winter and spring is the period of maximum abundance and the summer and early fall is the period of minimum abundance (see also Figure 2). The shiner seaperch is usually the most abundant species. In the fall the number of juveniles drops considerably, so that the total poundage of this species is much less than in the spring. By contrast, the numbers of some of the other species of surfperches, most of which are adult fish, e.g., pileperch, rubberlip, and walleye, increase in the late fall. From Table 2 it will be noted that the number of shiner seaperch

TABLE 2

Shiner Seaperch, Cymatogaster aggregata, Contained in 14 Catches From the Trash Screens of the South San Francisco Bay Station A Power Plant of the Pacific Gas and Electric Company

Date	Weight of catch (pounds)	Number of shiners	Weight of shiners (pounds)	Shiner weight as percentage of total catch weight
March 11, 1949	140.00	2,130	97.00	69.28
January 10, 1951	82.00	338	12.00	14.63
February 19, 1951	93.45	2,217	81.80	87.53
July 31, 1951	14.00	670	4.81	34.36
August 13, 1951	14.00	242	2.66	19.00
September 11, 1951	1.87	1 (juvenile)	0.002	0.01
October 4, 1951	1.50	2	0.02	1.33
November 30, 1951	145.16	189	7.62	5.25
December 26, 1951	111.44	553	23.43	21.02
February 8, 1952	50.49	722	24.19	47.91
March 25, 1952	150.50	289	17.25	11.16
July 22, 1952	16.82	459	4.62	27.47
August 29, 1952	14.44	219	5.56	38.50
January 30, 1953	11.00	138	4.80	43.64

in the 14 collections critically analyzed ranged from 1 (total catch weight of 1.87 pounds; September 11, 1951) to 2,217 (total catch weight of 93.45 pounds; February 19, 1951). The weight of the shiners expressed as a percentage of the total catch weight for these same two collections ranged from 0.01 to 87.53.

The minimum number of species of fishes in the collections was usually 7 and the maximum 18, with the usual number 10-14. The total of all species is 61, as indicated by Table 3. Since the two-foot diameter net (21-foot handle) used in collecting at the trash screens is made of ⅞-inch stretched mesh, many of the smaller fishes are not taken in their true proportion. For example, the slender bay goby,

TABLE 3

Species List and Approximate Number of Fishes Taken in the 248 Collections Made at the Trash Screens of the South San Francisco Bay Station A Power Plant of the Pacific Gas and Electric Company During the Six Years 1945-1950

Species	Number of specimens	Species	Number of specimens
Pacific lamprey, *Entosphenus tridentatus*	7	Pile perch, *Rhacochilus vacca*	383
Sevengill cowshark, *Notorynchus maculatum*	1	Rubberlip seaperch, *Rhacochilus toxotes*	192
Leopard shark, *Triakis semifasciata*	140	Shiner seaperch, *Cymatogaster aggregata*	Many 1,000
Brown smoothhound, *Rhinotriacis henlei*	27		
Dogfish, *Squalus suckleyi*	2	Dwarfperch, *Micrometrus minimus*	558
California skate, *Raja inornata*	15	Bocaccio, *Sebastodes paucispinis*	689
Longnose skate, *Raja rhina rhina*	5	Yellowtail rockfish, *Sebastodes flavidus*	2
Bat ray, *Myliobatis californicus*	3	Black rockfish, *Sebastodes melanops*	252
Electric ray, *Torpedo californica*	23	Brown rockfish, *Sebastodes auriculatus*	1
Pacific herring, *Clupea pallasi*	701	Grass rockfish, *Sebastodes rastrelliger*	3
Sardine, *Sardinops caerulea*	11	Black-and-yellow rockfish, *Sebastodes chrysomelas*	4
Northern anchovy, *Engraulis mordax*	100		
Whitebait smelt, *Allosmerus elongatus*	17	Kelp greenling, *Hexagrammos decagrammus*	16
Sacramento smelt, *Spirinchus thaleichthys*	1	Lingcod, *Ophiodon elongatus*	322
Surf smelt, *Hypomesus pretiosus*	1	Cabezon, *Scorpaenichthys marmoratus*	12
King salmon, *Oncorhynchus tshawytscha*	2	Reef irishlord, *Hemilepidotus spinosus*	1
Tomcod, *Microgadus proximus*	354	Buffalo sculpin, *Enophrys bison*	38
Pacific sanddab, *Citharichthys sordidus*	1	Northern staghorn sculpin, *Leptocottus armatus armatus*	< 1,000
Curlfin turbot, *Pleuronichthys decurrens*	34		
English sole, *Parophrys vetulus*	22		
Starry flounder, *Platichthys stellatus*	22	Slipskin snailfish, *Liparis fucensis*	3
Striped bass, *Roccus saxatilis*	168	Showy snailfish, *Liparis pulchellus*	1
Jacksmelt, *Atherinopsis californiensis*	1	Northern threespine stickleback, *Gasterosteus aculeatus aculeatus*	1
San Francisco topsmelt, *Atherinopsis affinis affinis*	386	Tube-nose, *Aulorhynchus flavidum*	1
Jackmackerel, *Trachurus symmetricus*	5	Northern bay pipefish, *Syngnathus griseolineata griseolineata*	88
Pompano, *Palometa simillima*	2		
White croaker, *Genyonemus lineatus*	18	Bay goby, *Lepidogobius lepidus*	1
Redtail surfperch, *Amphistichus rhodoterus*	7	Mudsucker, *Gillichthys mirabilis*	1
Walleye surfperch, *Hyperprosopon argenteum*	510	Northern midshipman, *Porichthys notatus*	280
		Wolf-eel, *Anarrhichthys ocellatus*	4
Bay blackperch, *Embiotoca jacksoni*	399	Rock-eel, *Xiphister mucosus*	1
Striped seaperch, *Embiotoca lateralis*	344	Saddleback gunnel, *Pholis ornata*	1
Rainbow perch, *Hypsurus caryi*	9	Spotted cusk-eel, *Otophidium taylori*	2
White seaperch, *Phanerodon furcatus*	194		

which is quite common in many parts of the bay, has a maximum length of about 2½ inches; thus, it generally slips through the dip net.

The occurrence of some of the less common fishes has been surprising. Of nine specimens of slipskin snailfish *(Liparis fucensis)* known from San Francisco Bay, three were taken at Station A. In contrast with this, Station A has yielded only one specimen of the fairly common showy snailfish *(Liparis pulchellus)*. In the south bay the brown smoothhound is usually twice as abundant as the leopard shark; the dogfish is rather erratic in appearance; and the sevengill and soupfin usually form 5 to 16 percent of the elasmobranch population (Herald and Ripley, 1951, p. 317; Herald, 1952, p. 241). At Station A we find a reversal of this condition, for during the six years there occurred more leopards (140) than brown smoothhounds (27), while the dogfish (2), and sevengill (1) were both poorly represented, and the soupfin was entirely absent.

Table 4 presents a listing by months of certain fishes whose total numbers for the six-year period ranged between 50 and 1,000. In most cases these fishes were returned to Steinhart Aquarium alive and so do

TABLE 4

Occurrence of Certain Fishes as Demonstrated by the Total Numbers Contained in 248 Collections Made at the Trash Screens of the South San Francisco Bay Station A Power Plant of the Pacific Gas and Electric Company During the Six Years 1945-1950

Species / Month / Trips	Jan. 32	Feb. 31	March 36	April 24	May 27	June 20	July 12	Aug. 10	Sept. 8	Oct. 7	Nov. 16	Dec. 25	Totals 248
Herring, *Clupea pallasi*	222	210	4	14	28	18	--	130	14	2	1	58	701
Bocaccio, *Sebastodes paucispinis*	59	21	51	40	58	224	53	85	32	17	30	19	689
Lingcod, *Ophiodon elongatus*	--	--	--	36	233	32	1	--	1	1	18	--	322
Tomcod, *Microgadus proximus*	106	39	71	64	20	--	--	--	--	1	--	53	354
San Francisco topsmelt, *Atherinops a. affinis*	280	16	8	13	--	1		--	--	6	32	30	386
Midshipman, *Porichthys notatus*	--	4	6	11	29	120	110	--	--	--	--	--	280
Black rockfish, *Sebastodes melanops*	27	23	28	23	31	30	12	16	22	3	13	24	252
Striped bass, *Roccus saxatilis*	118	19	7	2	--	--	--	--	--	--	4	18	168
Leopard shark, *Triakis semifasciata*	14	14	39	7	4	--	--	--	5	11	5	41	140
Northern anchovy, *Engraulis mordax*	--	--	--	12	42	1	1	15	4	14	9	2	100
Northern Bay pipefish, *Syngnathus g. griseolineata*	16	20	10	5	19	2	--	--	1	2	6	7	88
Totals	842	366	224	227	464	428	177	246	79	57	118	252	3,480

not appear in the data of Figure 3. Of the species listed in Table 4, only two, the black rockfish and the boccacio, occurred during every month of the year. These were invariably young born a few months earlier. Three species, the brown rockfish, lingcod, and herring, occurred during 11 months of the year. The fact that San Francisco Bay is a nursery ground for two of these species, boccacio and lingcod, has generally been overlooked. Most of the species in Table 4 follow the abundance histogram of Figure 1. However, some exceptions are (a) the absence of midshipmen for six months, August through January, which is undoubtedly correlated with the spawning cycle, and (b) the absence of the northern anchovy during the three months January through March.

In total numbers the 61 fish species from Station A compare favorably with the 60 species which our as yet-unpublished records show for the Chinese shrimp nets fishing in deeper water (45-60 feet) about two and one-half miles northeast. From the north bay shrimp trawlers who fish in water of 8 to 35 feet we have records of 47 species. Detailed comparative analyses of the catches made in these three areas will be included in a subsequent paper on the shrimp fisheries and associated organisms.

Suffice to say for the present that the list of 61 species from Station A includes 11 that have not been taken in the Chinese shrimp nets. These are: jackmackerel, grass rockfish, yellowtail rockfish, black-and-yellow rockfish, longnose skate, California skate, tubenose, king salmon, rock-eel, northern stickleback, and redtail surfperch. From the Chinese nets, however, there are 11 species that are not known from Station A. These are: bonehead sculpin, *Artedius notospilotus;* padded sculpin, *Artedius fenestralis;* arrow goby, *Clevelandia ios;* river lamprey, *Lampetra fluviatilis;* thresher, *Alopias vulpinus;* hake, *Merluccius productus;* dover sole, *Microstomus pacificus;* sandlance, *Ammodytes tobianus personatus;* angelshark, *Squatina californica;* pit-head poacher, *Odontopyxis trispinosa*, and the rubber sculpin, *Ascelichthys rhodorus.* Inasmuch as these records of presence and absence deal with species that are not abundant in the catches, their significance is not very great, except as an indication of difference between the two sampling sites. The Chinese nets fish only on incoming tides and from a fairly central position in the south bay. Thus, these nets should be expected to catch some fishes from offshore and deeper water. By contrast, Station A operates continually, and we believe that many of the fishes appearing here are brought by shore currents along the south side rather than through the center of the Golden Gate. Whether or not this tentative explanation for some of the differences in the catches is valid must await further studies.

REFERENCES

Herald, Earl S.
1953. The 1952 shark derbies at Elkhorn Slough, Monterey Bay, and at Coyote Point, San Francisco Bay. Calif. Fish and Game, vol. 39, no. 2, p. 237-243.

Herald, Earl S., and Wm. Ellis Ripley
1951. The relative abundance of sharks and bat stingrays in San Francisco Bay. Calif. Fish and Game, vol. 37, no. 3., p. 315-329.

Kerr, James E.
1953. Studies on fish preservation at the Contra Costa steam plant of the Pacific Gas and Electric Company. Calif. Dept. Fish and Game, Fish Bull. 92, 66 p.

TOLERANCE OF THE SAN FRANCISCO TOPSMELT, *ATHERINOPS AFFINIS AFFINIS*, TO CONDITIONS IN SALT-PRODUCING PONDS BORDERING SAN FRANCISCO BAY[1]

LARS H. CARPELAN
University of California, Los Angeles

INTRODUCTION

The topsmelt, *Atherinops affinis*, is tolerant to a wide range of salinity: it lives in fresh and brackish water, in the sea, and in salt concentrations greater than in the ocean. During a year-round ecological study of five salt-producing ponds bordering San Francisco Bay, the San Francisco topsmelt, *Atherinops affinis affinis* (Ayres), was observed to spawn in water with twice the salinity of the ocean. Since it does not live the year around in ponds of such high salinity, concurrent records were made of the development of the young fish, and of the seasonal changes that took place in certain factors of the environment. These factors were: pH, concentration of dissolved oxygen, temperature, and salinity.

From the data obtained, it is not possible to determine the exact upper limits of tolerance to the factors measured. However, since there seem to be few records of the actual environmental conditions that prove limiting to fish, this is presented as an account of the extreme conditions under which a school of *Atherinops* developed, and existed until conditions exceeded the upper limits of its tolerance.

The ponds under study are located near Alviso, at the southern end of San Francisco Bay. These Alviso ponds are early in the evaporative series. *Atherinops* lives the year around in the first three ponds; in these the mean salinity ranges from 27.5 parts per thousand in the first to 45 parts per thousand in the third. In the fifth pond, which has an annual range of salinity from 61 parts per thousand in the winter to as high as 150 parts per thousand in the fall, *Atherinops* does not live throughout the year. It may, however, spawn there in the spring.

Concurrent data were recorded on the growth of fish in a school spawned at the inlet of the fifth pond, and on seasonal changes in certain environmental factors. The young fish lived from April until August. The school then disappeared, presumably because of intolerance to the seasonal change in some factor or factors of the environment.

[1] Submitted for publication February, 1955. The work was done at the Hopkins Marine Station of Stanford University and was aided by a fellowship from the Leslie Salt Company.

METHOD OF FISH SAMPLING

During the course of the ecological study, plankton collections were made at weekly intervals, using a net of nine inch diameter, No. 12 silk bolting cloth, 125 meshes per inch. Fish taken by this means were incidental to the main study. The method was not well adapted to the collection of fish, and did not take the faster-moving, larger fish.

The fish of the salt ponds were not intensively studied. It also seems necessary to point out that the samples enumerated below were taken from a school of fish, so that the number per volume are not representative of the fish population throughout the pond.

BIOLOGY OF *ATHERINOPS*

From March to August, plankton collections from all stations in the ponds contained young topsmelt. Eggs were collected as early as March. Spawning thus seemed to begin in March and to reach a peak in April and May, when many larval fish were taken. However, the presence of fish 5 mm. long as late as August indicates a long spawning season.

During the long spawning season, there was considerable range in size of fish at most collection stations in the Alviso ponds. For example, the following is a tabulation of collections taken in the third pond:

Atherinops Collected in Midpond No. 3, 1951

Month	*Size range in mm.*	*Average number per ¼ M^3*
February	--	0
March	8	1
April	5–12	9
May	5–18	26
June	10–30	39
July	15–30	37
August	5–25	2
September	--	0

However, topsmelt apparently spawned over a shorter time interval at the inlet of the fifth pond:

Atherinops Collected at Pond No. 5 Inlet, 1951

Month	*Size range in mm.*
April	5–10
May	10–30
June	25–40
July	35–55
August	30 (one fish)

According to Schultz (1933) the various subspecies of *Atherinops affinis* on the Pacific Coast are from 65 to 100 mm. long by the end of their first year, the greatest size being attained by the most northern subspecies. The growth of the *Atherinops* in the salt ponds under study seems more rapid than that reported by Schultz for *A. affinis affinis*, presumably the subspecies in the ponds. Schultz reported 70 mm. as the average length reached by the end of the first year. In the salt ponds that length was attained by August. Fish in August collections in the first of the Alviso ponds ranged from 60 to 80 mm. By the end of the year the average length was from 90 to 100 mm.

Topsmelt of the salt ponds reached sexual maturity when in their second year; that is, fish hatched in April spawned the following April, when one year old. Their total length when mature was 100 to 110 mm. Fish larger than this were not observed in the ponds.

MORTALITY OF *ATHERINOPS* IN POND NO. 5

Although topsmelt are present throughout the year in the first three of the Alviso ponds, they are not present in later ponds during winter. Beginning in April or May, when the water levels of the ponds fall due to evaporation, water is pumped from pond No. 3 into the later ponds.

When pumping operations began, in early April of 1951, mature fish, about 100-110 mm. in length, which had wintered in the third pond, found their way into the fourth and into the inlet of the fifth pond.

At the inlet of pond No. 5, gravid females spawned in water which then had a salinity of 72 parts per thousand. The eggs hatched, giving rise to a large school of fish which persisted at the inlet of the pond from April until July, with the increase in size shown previously.

Tabulated below are data showing the size of the population, and some of the changing environmental conditions to which these fish were subjected at the inlet of the fifth pond.

Month	*Atherinops (average no. per ¼ M³)*	*Mean salinity (p.p. 1000)*	*Mean pH (P.M.)*	*Mean water temperature (P.M.)*
March	0	63.2	8.8	19° C
April	36	72.3	9.0	21° C
May	95	73.1	8.5	23° C
June	112	80.9	8.3	24° C
July	48	90.9	8.5	27° C
August	1	93.1	8.3	26° C
September	0	92.2	8.3	25° C

The data above and the size range of the fish are illustrated in Figure 1.

The tabulation above is of monthly means, based on weekly collections and samples. A great change, not apparent in the table, was the number of fish collected during the first two weeks in July. The number decreased from 227 per quarter cubic meter on July 2d to five per quarter cubic meter on July 9th. The large school of fish virtually disappeared.

DISCUSSION OF FACTORS CONCERNED

Various environmental factors (Figure 1) in the ponds change seasonally; one of the following, or some combination of them, may be implicated in the disappearance of the fish.

Salinity. The eggs hatched in water with a total salt content of 72 parts per thousand. The salinity increased gradually until it was 85.5 parts per thousand on July 2d. During the week from July 2d to 9th, it increased greatly—to 90.2 parts per thousand. This could be interpreted to mean that somewhere in the range between 80 and 90 parts per thousand conditions became intolerable for *Atherinops*. However, it is impossible to estimate the exact upper limit of salt tolerance

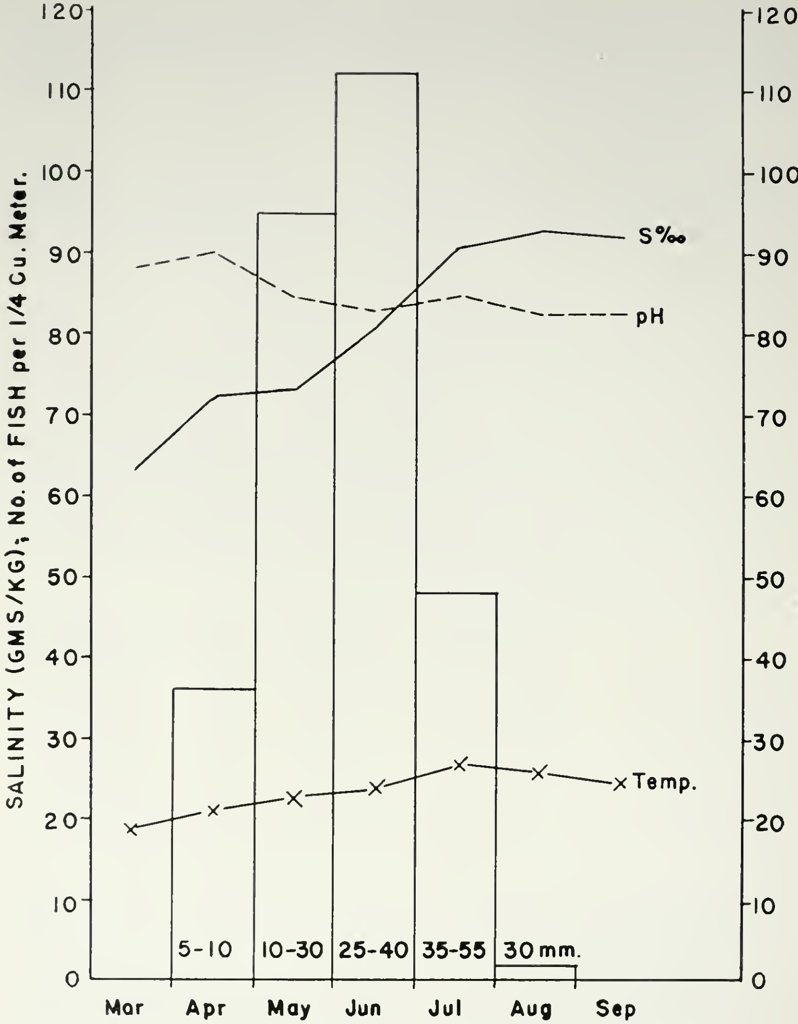

FIGURE 1. Histogram: Average number and size of *Atherinops* in collections from Alviso pond No. 5 (inlet), 1951.
Graphs: Seasonal changes in $S^0/_{00}$, pH, and temperature.

from the data. Furthermore, increase in osmotic pressure due to salt concentration is probably not the only factor involved.

Hydrogen Ion Concentration. The table and the figure show the decrease in pH that took place during the period concerned. The peak in April was associated with uptake of carbon dioxide during a spring bloom of the alga *Stichococcus*. After this bloom, the pH decreased to a value more nearly like that of the oceans, but in this case, the decrease indicates a loss of carbonate. In the salt ponds, the increasing salt concentrations eventually lead to the precipitation of salts (the purpose for which the ponds are maintained). Calcium carbonate is the first salt to precipitate; it begins to come out of solution at salinities above about 80 parts per thousand. Loss of carbonate not only increases the hydrogen ion concentration, but creates an upset in the ratio of ions present in sea water. Calcium as well as carbonate is lost from solution. This change in ionic proportions may, in some way, be responsible for the inability of *Atherinops* to tolerate salinities beyond 80 parts per thousand.

Temperature. The temperature of the water, though rising during this period, was no higher than in the other ponds, in which *Atherinops* continued to live. *Atherinops* is remarkable in its tolerance to temperature changes. The use of means in the table covers up great diurnal temperature ranges. For example, the extreme diurnal range observed in the ponds was 12° C., from a morning low of 21° (69.8° F.) to an afternoon high of 33° (91.4° F.); this occurred in August. *Atherinops* must also withstand an annual range of 25° C.: from a low of 8° (46.4° F.) in January to as high as 33° (91.4° F.) in July and August.

Dissolved Oxygen. Not tabulated is another factor that should be considered. The concentration of dissolved oxygen may become a limiting factor because of the increased salt concentration. Water with a salt content two and one-half times that of ocean water can hold only about one-half as much oxygen, at saturation in equilibrium with air, as can be held by sea water of ocean salinity. Because of the oxygen evolved by algae during photosynthesis, evening values for dissolved oxygen in pond No. 5 are above saturation. (There may be as much as six or seven milliliters of oxygen per liter of water.) However, morning values are below saturation, due to the respiration of all the organisms present, without compensating oxygen production by the algae at night. Very low concentrations of dissolved oxygen at dawn may limit the continued existence of *Atherinops* in pond No. 5.

Combination of Factors. No single factor can be isolated as *the* factor limiting *Atherinops* to salinities below 80 parts per thousand. But the combination of factors (high temperatures, high osmotic pressure, an upset in the ionic ratio, variable oxygen concentrations) finally becomes too much for even so hardy an organism as the topsmelt.

Differences in Tolerance With Age. There is at least one other factor that might be considered. The school of fish was of uniform age. It may be that these young topsmelt are more tolerant than older ones, and that the disappearance of the school might be due, not to changes in the environmental factors described, but rather to attainment of a certain age or size at which the fish may become less able to withstand the environment. However, the fish have not been studied physiologically for such differences, nor have they been studied for possible morphological changes which might have been induced by the extremes of the environment to which they were exposed during their development.

SUMMARY

Atherinops, the topsmelt, is the most salt tolerant fish observed living in ponds used for the production of salt by evaporation of sea water.

It lives throughout the year in ponds with a salt content as great as one and one-half times that of ocean water. It has been observed to spawn in salinities double that of the ocean (72 parts per thousand) and to exist in still higher salt concentrations.

In addition to high salinities, *Atherinops* in the salt ponds must also withstand other environmental extremes, including high summer temperatures (with a great diurnal range), high pH values, and variable concentrations of dissolved oxygen.

LITERATURE CITED

Schultz, Leonard P.
1933. The age and growth of *Atherinops affinis oregonia* Jordan and Snyder and of other subspecies of baysmelt along the Pacific coast of the United States. Wash. Univ., Publ. Biol., vol. 2, no. 3, p. 45-102.

AGE AND LENGTH COMPOSITION OF THE SARDINE CATCH OFF THE PACIFIC COAST OF THE UNITED STATES AND MEXICO IN 1954-55[1]

FRANCES E. FELIN and JOHN MacGREGOR
United States Fish and Wildlife Service
and
ANITA E. DAUGHERTY and DANIEL J. MILLER
Marine Fisheries Branch
California Department of Fish and Game

This report on age and length composition of the catch of sardines *(Sardinops caerulea)* off the Pacific Coast of North America is the ninth of a series which gives similar data from 1941-42 to the present season (Felin et al., 1954).

During the 1954-55 season, 65,918 tons were landed in the San Pedro region; this included fish landed at Santa Barbara, Port Hueneme, Santa Monica, Los Angeles-Long Beach Harbor, and Newport. Fish from some of these points were trucked to Monterey, Moss Landing, and San Francisco for processing during October, November, and December. At San Diego 510 tons were landed and trucked to the Los Angeles area for processing. In August and September, 830 tons were landed at Avila and trucked to Monterey and Moss Landing for processing. No fish were landed at Monterey, Moss Landing, or San Francisco.

The fishing season at San Pedro and San Diego, as for the several preceding years, extended from October 1st to February 1st; that in the Monterey region extended from August 1st to January 15th. For Ensenada, Baja California, where fishing is carried on throughout the year, data for a period approximating the California canning season only were used—in this case, July 30th to January 7th.

Sampling was carried on, as described for recent preceding seasons, at Monterey, San Pedro, San Diego, and Ensenada. Sampling and age determinations were continued by personnel of the California Department of Fish and Game and the U. S. Fish and Wildlife Service.

Tables 1-5 show, by sex and area of catch, the length-frequency distributions of sardines of each year class as taken in the 1954-55 random scale samples.

Table 6 gives calendar dates for the lunar months included in Table 7.

Table 7 gives total tonnages and numbers of fish of each age caught in each region, estimated in the same manner as described for preceding seasons.

[1] Submitted for publication April, 1955.

Table 8 gives, by sex and region of catch, the mean length and standard error of the mean for each year class sampled in the 1954-55 season. These are based on the random scale samples.

REFERENCE

Felin, Frances E., John MacGregor, Anita E. Daugherty, and Daniel J. Miller. 1954. Age and length composition of the sardine catch off the Pacific Coast of the United States and Mexico in 1953-54. Calif. Fish and Game, vol. 40, no. 4, p. 423-431. (See this report for preceding references.)

TABLE 1

Length Composition of the 1954, 1953, and 1952 Year Classes in 1954-55

Standard length mm.	1954 year class, age 0 San Pedro	1953 year class, age 1									1952 year class, age 2																		
		San Pedro			Ensenada			Grand total			Monterey			San Pedro			San Diego			California total			Ensenada			Grand total		
	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
134	1																											
136	3																											
138	5																											
140	3																											
142	10																											
144	4																											
146	3																											
148	1																											
186																												
188														1		1				1		1				1		1
190																							1		1	1		1
192			1	1					1	1				5		5	1		1	6		6	2		2	8		8
194														9	4	13		1	1	9	5	14		1	1	9	6	15
196						1	1		1	1				11	6	17	1		1	12	6	18	2	2	4	14	8	22
198			2	2					2	2				13	2	15	1	1	2	14	3	17	3	3	6	17	6	23
200														19	8	27	2		2	21	8	29		2	2	21	10	31
202														16	18	34	2	2	4	18	20	38	2	2	4	20	22	42
204														14	11	25		1	1	14	12	26	1	2	3	15	14	29
206														9	22	31				9	22	31				9	22	31
208														3	16	19				3	16	19		1	1	3	17	20
210											1		1	3	6	9				4	6	10				4	6	10
212														2	7	9				2	7	9		1	1	2	8	10
214														1	2	3		1	1	1	3	4				1	3	4
216														1	1	2				1	1	2				1	1	2
218														1	2	3				1	2	3				1	2	3
220															1	1					1	1					1	1
222																												
224																												
226																							1		1	1		1
Totals	30*		3	3		1	1		4	4	1		1	108	106	211	7	6	13	116	112	228	12	14	26	128	126	254

* Includes 30 young sardines of undetermined sex.

TABLE 2

Length Composition of the 1951 Year Class in 1954-55

Standard length mm.	1951 year class, age 3																	
	Monterey			San Pedro			San Diego			California total			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
186				1		1				1		1				1		1
188				2		2				2		2				2		2
190				3		3				3		3				3		3
192				4	2	6				4	2	6				4	2	6
194				11	3	14	1		1	12	3	15		1	1	12	4	16
196				14	2	16	1		1	15	2	17	1		1	16	2	18
198				10	4	14	1		1	11	4	15	3	4	7	14	8	22
200				17	11	28				17	11	28	1		1	18	11	29
202		1	1	16	13	29				16	14	30	1	3	4	17	17	34
204				8	8	16				8	8	16				8	8	16
206				11	17	28	2	1	3	13	18	31	3	1	4	16	19	35
208	1	2	3	7	12	19	1		1	9	14	23		1	1	9	15	24
210				6	10	16				6	10	16	1	1	2	7	11	18
212	1	1	2	7	8	15		1	1	8	10	18	1	1	2	9	11	20
214		2	2	5	3	8	1		1	6	5	11				6	5	11
216		1	1	2	5	7				2	6	8		1	1	2	7	9
218		1	1	1	7	8		1	1	1	9	10				1	9	10
220				2	6	8		1	1	2	7	9				2	7	9
222		1	1	1	2	3		1	1	1	4	5				1	4	5
224					1	1					1	1					1	1
226					1	1					1	1		1	1		2	2
Totals	2	9	11	128	115	243	7	5	12	137	129	266	11	14	25	148	143	291

TABLE 3

Length Composition of the 1950 Year Class in 1954-55

Standard length mm.	1950 year class, age 4																	
	Monterey			San Pedro			San Diego			California total			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
190				1		1				1		1				1		1
192																		
194				2		2				2		2				2		2
196				1		1				1		1				1		1
198				2		2		1	1	2	1	3				2	1	3
200				2	1	3				2	1	3				2	1	3
202					2	2					2	2					2	2
204				3	1	4				3	1	4		1	1	3	2	5
206				3	1	4				3	1	4	1		1	4	1	5
208				4	1	5				4	1	5	1		1	5	1	6
210				6	1	7				6	1	7	1	1	2	7	2	9
212	2	1	3	2	4	6				4	5	9	1		1	5	5	10
214				5	3	8				5	3	8	2		2	7	3	10
216	3		3	2	2	4				5	2	7	1		1	6	2	8
218				3	5	8				3	5	8	1		1	4	5	9
220				4	5	9				4	5	9				4	5	9
222		1	1	1	2	3				1	3	4				1	3	4
224					4	4					4	4		1	1		5	5
226					4	4					4	4					4	4
228					1	1					1	1					1	1
230				1	1	2				1	1	2				1	1	2
232														1	1		1	1
234																		
236																		
238					1	1					1	1					1	1
240																		
Totals	5	2	7	42	39	81		1	1	47	42	89	8	4	12	55	46	101

TABLE 4

Length Composition of the 1949 Year Class in 1954-55

Standard length mm.	1949 year class, age 5																	
	Monterey			San Pedro			San Diego			California total			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
190																		
192																		
194																		
196				1		1				1		1				1		1
198																		
200				1		1				1		1		1	1	1	1	2
202				1		1				1		1				1		1
204				1		1				1		1				1		1
206				2		2				2		2				2		2
208	1		1	2		2				3		3				3		3
210				4		4				4		4				4		4
212	1	1	2	3	2	5				4	3	7	1	1	2	5	4	9
214		1	1	4	1	5				1	2	6	1		1	5	2	7
216				1	2	3				1	2	3	1	2	3	2	4	6
218				2		2				2		2		1	1	2	1	3
220				1	2	3		1	1	1	3	4	1	1	2	2	4	6
222				2	1	3		1	1	2	2	4		1	1	2	3	5
224					1	1					1	1	1		1	1	1	2
226		1	1		1	1					2	2					2	2
228					1	1					1	1					1	1
230				1	1	2				1	1	2				1	1	2
244				1		1				1		1				1		1
258					1	1					1	1					1	1
Totals	2	3	5	27	13	40		2	2	29	18	47	5	7	12	34	25	59

TABLE 5

Length Composition of the 1948 and 1947 Year Classes in 1954-55

Standard length mm.	1948 year class, age 6																		1947 year class, age 7								
	Monterey			San Pedro			San Diego			California total			Ensenada			Grand total			San Pedro			Ensenada			Grand total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
198				2	1	3				2	1	3				2	1	3									
200				1		1				1		1				1		1									
202				4		4				4		4		1	1	4	1	5									
204					1	1					1	1					1	1									
206				1		1				1		1				1		1									
208				7	2	9				7	2	9				7	2	9				1		1	1		1
210	1		1	3	3	6				4	3	7				4	3	7	1		1				1		1
212	1		1	8	3	11				9	3	12	1		1	10	3	13		1	1					1	1
214				3	4	7				3	4	7	1	1	2	4	5	9	1		1				1		1
216	2		2	5	4	9				7	4	11	1	1	2	8	5	13	1		1				1		1
218		1	1	8	3	11		2	2	8	6	14		2	2	8	8	16				1		1	1		1
220				4	9	13				4	9	13				4	9	13	2		2				2		2
222				2	1	3				2	1	3	1	1	2	3	2	5		1	1					1	1
224				2	4	6				2	4	6				2	4	6	1		1				1		1
226					1	1					1	1					1	1		1	1					1	1
228					1	1					1	1		1	1		2	2									
230																											
232																											
234					1	1					1	1					1	1									
236					1	1					1	1					1	1									
Totals	4	1	5	50	39	89		2	2	54	42	96	4	7	11	58	49	107	6	3	9	2		2	8	3	11

TABLE 6

Calendar Dates of Lunar Months for the 1954-55 Season

"July"	July 15-August 13
"August"	August 14-September 11
"September"	September 12-October 11
"October"	October 12-November 9
"November"	November 10-December 9
"December"	December 10-January 7
"January"	January 8-February 7

TABLE 7

Age (Year Class) Composition of the Sardine Catch in the 1954-55 Season (Numbers of fish are given in thousands, i.e., 000 omitted)

	Catch		Number of fish by age (year class)							
	Tons	Nos.	0	1	2	3	4	5	6	7
			1954	1953	1952	1951	1950	1949	1948	1947
Monterey										
"July"[1]	29	181	--	--	6	71	42	33	29	--
"August"	579	3,642	--	--	121	1,433	850	655	583	--
"September"	220	1,375	--	--	46	541	321	247	220	--
"October"	1	5	--	--	--	2	1	1	1	--
"November"	1	4	--	--	--	1	1	1	1	--
Totals Monterey	830	5,207	--	--	173	2,048	1,215	937	834	--
San Pedro										
"September"[2]	4,110	30,473	--	--	8,229	10,208	4,723	3,961	2,895	457
"October"	35,026	270,390	--	--	91,067	101,235	30,716	16,656	29,202	1,514
"November"	22,296	179,184	--	2,294	61,209	68,663	17,202	11,754	15,625	2,437
"December"	4,309	34,065	--	--	11,947	11,173	3,134	1,455	5,859	497
"January"	177	3,766	3,766	--	--	--	--	--	--	--
Totals San Pedro	65,918	517,878	3,766	2,294	172,452	191,279	55,775	33,826	53,581	4,905
San Diego[3]										
"October"	42	326	--	--	110	122	37	20	35	2
"November"	267	2,047	--	26	700	785	196	134	178	28
"December"	201	1,610	--	--	565	528	148	69	277	23
Totals San Diego	510	3,983	--	26	1,375	1,435	381	223	490	53
Totals California	67,258	527,068	3,766	2,320	174,000	194,762	57,371	34,986	54,905	4,958
Ensenada[4]										
"July"[1]	865	6,539	--	--	2,747	2,223	--	1,569	--	--
"August"	1,394	10,541	--	--	3,560	2,328	547	1,916	2,190	--
"September"	993	7,510	--	484	2,907	--	2,666	969	484	--
"October"	1,112	8,407	--	--	2,018	2,690	2,354	336	1,009	--
"November"	3,664	27,699	--	--	6,833	13,110	1,246	1,108	1,848	554
"December"	679	5,133	--	--	1,266	2,430	787	205	342	103
Totals Baja California	8,707	65,829	--	484	19,331	22,781	10,600	6,103	5,873	657
Grand totals	75,965	592,897	3,766	2,804	193,331	217,543	67,971	41,089	60,778	5,615

[1] Includes deliveries August 1-13 only.
[2] Includes deliveries October 1-11 only.
[3] Numbers of fish in the San Diego catch were prorated at the same ratio as the San Pedro catch for the comparable months.
[4] Numbers of fish were prorated according to the average weight of fish taken November 3-23.

TABLE 8

Number of Fish, Mean Length, and Standard Error of the Mean for Each Year Class in the 1954-55 Season, by Region of Catch

Year Class	Monterey			San Pedro			San Diego			Ensenada		
	No.	M.	S.E.	No.	M.	S.E.	No.	M.	S.E.	No.	M.	S.E.
1954												
Male	--		--	--	--	--	--	--	--		--	--
Female	--	--	--	--		--	--	--	--	--	--	--
Total	--	--	--	30	141	4.81	--	--	--	--	--	--
1953												
Male	--	--	--	0			--	--	--	0		--
Female	--	--		3	196	2.00	--	--		1	--	--
Total	--	--	--	3	196	2.00		--	--	1	--	--
1952												
Male	1		--	108	201	0.52	7	199	1.36	12	200	2.70
Female	0	--	--	106	205	0.51	6	202	2.76	14	201	1.32
Total	1	--	--	214	203	0.39	13	200	1.50	26	200	1.41
1951												
Male	2	--	--	128	202	0.65	7	203	3.02	11	203	1.63
Female	9	213	2.00	115	208	0.69	5	216	2.92	14	205	2.34
Total	11	212	1.67	243	205	0.50	12	208	2.68	25	204	1.48
1950												
Male	5	214	0.98	42	210	1.33	0	--		8	212	1.44
Female	2	--	--	39	218	1.33	1	--		1	218	6.40
Total	7	215	1.37	81	213	1.04	1	--		12	214	2.26
1949												
Male	2	--	--	27	213	1.84	0	--	--	5	217	2.16
Female	3	217	4.38	13	223	3.34	2	--	--	7	215	2.76
Total	5	214	3.06	40	216	1.79	2	--	--	12	216	1.80
1948												
Male	4	214	1.50	50	213	0.95	0	--	--	4	216	2.16
Female	1	--	--	39	217	1.19	2	--	--	7	217	3.02
Total	5	214	1.47	89	215	0.78	2	--	--	11	217	2.00
1947												
Male	--	--	--	6	217	2.04	--	--	--	2	--	--
Female		--	--	3	220	4.16	--	--	--	0		--
Total		--	--	9	218	1.84	--	--		2	--	--

NESTING STUDIES OF DUCKS AND COOTS IN HONEY LAKE VALLEY[1]

E. G. HUNT and A. E. NAYLOR
Game Management Branch
California Department of Fish and Game

INTRODUCTION

During the spring of 1951 and 1953 studies were made to determine the status of nesting ducks and coots in Honey Lake Valley, Lassen County, California.

The main objectives of the studies were to obtain information on nesting populations, nesting density, preferred nesting habitat, nesting success, and the production derived from successful nesting. The 1951 study was the first survey made on nesting ducks and coots in the valley. The 1953 study determined what changes had occurred in nesting activities and also supplied data additional to those obtained in 1951.

Sample areas were established and utilized during each study, and nest histories were completed on all nests found in these areas.

The results obtained in both years were similar in most cases. The most apparent difference was a shift in the bulk of nesting from dry upland areas in 1951 to marshy areas in 1953. The average nesting success for both years was approximately 50 percent for ducks and 96 percent for coots.

Brood data showed a slight reduction in the brood size of ducks and an extensive reduction in the brood size of coots during the first week of life.

ACKNOWLEDGMENTS

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LOCALE OF THE STUDIES

The study areas were located in Honey Lake Valley in southeastern Lassen County (Figure 1). Most of the preferred waterfowl nesting habitat in this valley was in an area along the lower reaches of the Susan River, from the mouth of Willow Creek to the river's entrance

[1] Submitted for publication March, 1955. Federal Aid in Wildlife Restoration Act, California Project 30-R, "A Study of Waterfowl in California."

into Honey Lake. During the wet cycles, when Honey Lake is filled to capacity or near capacity, suitable nesting habitat is available from the mouth of the Susan River west along the lakeshore for approximately five miles. A further description of waterfowl nesting areas in the valley has been published previously (Naylor, 1953; Naylor and Hunt, 1954).

Approximately 80 percent of the nesting population of ducks and coots in the Honey Lake Valley was found along the Susan River and its diversions from Litchfield to Honey Lake. It was in this area that the studies were located.

The 1951 study was conducted by Naylor on the Fleming unit of the state-owned Honey Lake Waterfowl Management area. The second study was conducted by Hunt in 1953 on the Fleming unit and on privately owned land.

HISTORY

The water level of Honey Lake throughout the years has been characterized by fluctuation, determined mainly by wet and dry climatic cycles. The lake has contained water several years after filling, but at times reverts to a dry alkaline lake bed. When full the lake covers approximately 100 square miles and has an average depth of 18 inches.

The main source of water for Honey Lake is the Susan River drainage. The water in this drainage is either stored for domestic use and irrigation or allowed to flow into the lake. The amount of water that eventually enters the lake is determined by the amount of spring runoff and the demand on the water supply. Only during the years of extremely large spring runoff does an appreciable amount of water enter Honey Lake. Some water enters the lake from Long Valley Creek and several other small streams, but the volume is small and is not considered an important source for Honey Lake.

Honey Lake filled during 1937 and then gradually receded until it became dry in the late 1940's. Above normal winter rains and snowfall combined to fill the lake partially during the winter of 1950-51. Water was abundant in the vicinity of the lake until late spring (May, 1951), at which time the water level of the lake receded rapidly until fall, when little or no water remained. The abundant spring water supply enabled dormant emergent vegetation to attain some growth before the water level dropped in the fall. However, with the continuation of heavy winter precipitation during the winters of 1951-52 and 1952-53, the emergent vegetation became abundant. In 1953 growth was considered to have reached a maximum. Vegetative growth along the lakeshore, excluding the large area at the mouth of the Susan River, was not appreciably increased during 1952 and 1953, when water was abundant.

In general, drier conditions prevailed during the nesting season of 1951 than was the case in 1953. In 1953 the vegetation had become rank and ideal for nesting in the area at the mouth of the Susan River.

Land use practices in Honey Lake Valley have remained relatively stable during the last few years. The chief agricultural activities are concerned with pasturing livestock and raising cereal crops.

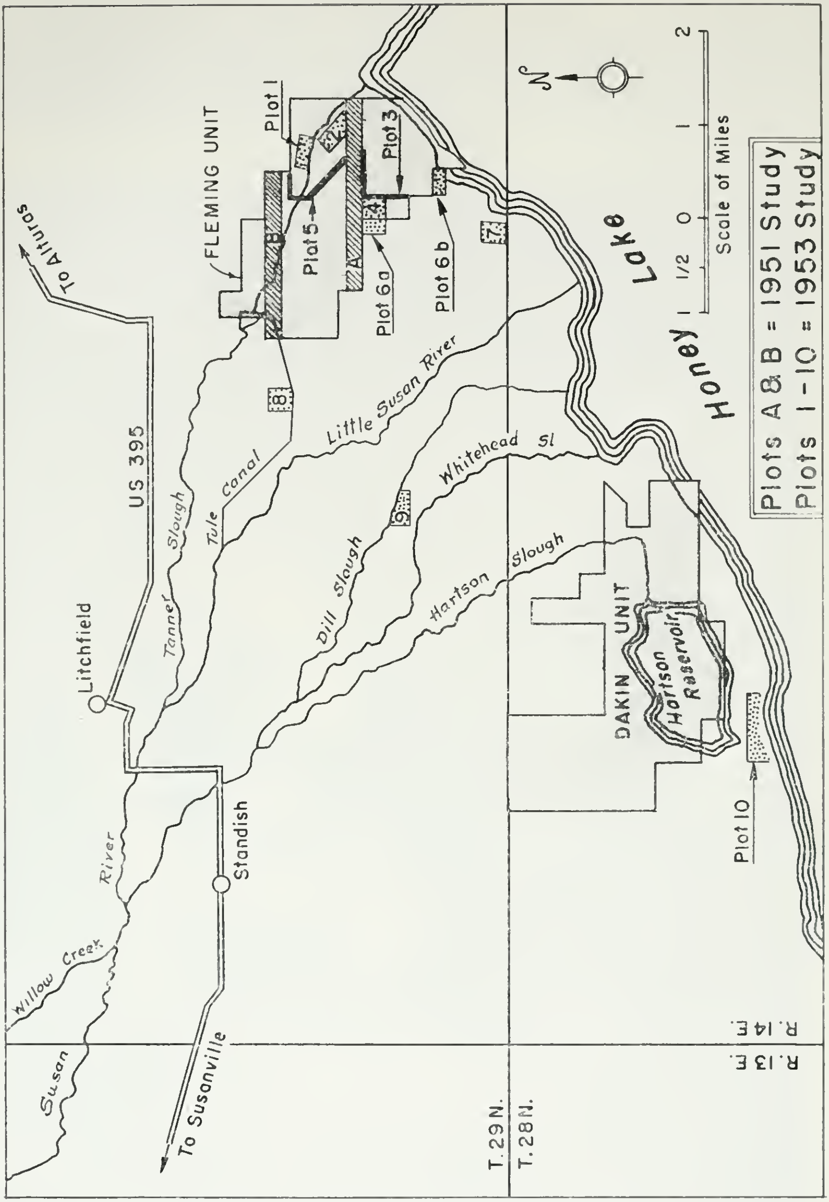

FIGURE 1. Map of study areas in Haney Lake Valley.

METHODS

Because of the large size of the study area, plots were used to sample the nesting activities. The methods used in locating and marking the nests differed slightly in the two studies. None of the differences was of great significance, and methods utilized in both studies obtained satisfactory results.

FIGURE 2. Field recording of nest history data on a unisort analysis card. *Photograph by C. V. Oglesby.*

Each plot was visited at least every 10 days. A rope was dragged several times on plots to flush the nesting birds when the nature of the vegetation made this practice possible. As each nest was found it was assigned a number and marked by placing a willow marker several feet from the nest to facilitate location on return visits. The marker was aligned with the nest and a fixed object, a mountain peak easily seen from any spot on all study plots. The distance between the marker and nest varied from 3 feet in very dense cover to 15 feet in sparse cover. The markers were placed away from the nests to reduce the chance of predators being attracted to the nests. The top of each willow marker was cut on an angle, and the number assigned to the nest was written on the cut surface. In the 1953 study a white specimen tag was tied to the top of each willow marker that was placed in dense cover and to some markers that were placed in sparse cover. The flashing of this white tag facilitated the finding of nests in all types and colors of vegetation. It was found that little or no increase in the amount of predation occurred in areas where the white tags were used.

At each visit to a nest all necessary information was recorded on a nest card. A nest card was assigned to each nest, and all data gathered during subsequent visits to the nest were recorded on the same card (Figure 2).

Table 1 gives the species composition of the nests found during both studies.

TABLE 1

Species Composition of Nests Found

Species	Total nests		Percentage of total	
	1951	1953	1951	1953
Mallard	63	143	31.2	39.8
Pintail	15	53	22.3	14.8
Cinnamon teal	22	125	10.9	34.8
Gadwall	18	13	8.9	3.6
Shoveller	17	7	8.4	2.0
Baldpate	--	1	0.0	0.3
Ruddy duck	--	6	0.0	1.7
Redhead	3	11	1.5	3.0
Unclassified	2	--	1.0	0.0
Unclassified, destroyed when found	15	--	7.4	0.0
Unclassified, hatched when found	17	--	8.4	0.0
Total ducks	202	359	100.0	100.0
Coot	20	143	9.0	28.0

An attempt was made to find as many of the nests as possible, but on the densely vegetated plots all could not be found. In 1951 it was estimated that the percentage of nests found in relation to the actual number on each plot ranged from approximately 60 percent in the densely covered plots to 100 percent in some of the sparsely vegetated plots. In 1953 an estimated 75 percent of the nests in the densely covered plots were found and 100 percent of those in some of the sparsely vegetated plots.

The scientific names of all birds, mammals, and plants referred to in this study are given in Appendix A.

SELECTION OF STUDY PLOTS

Because most of the nesting in Honey Lake Valley in 1951 was confined to the Fleming Unit of the Honey Lake Waterfowl Management Area, the 1951 study was made on this unit. In 1953 nesting activity was more widespread, and the study was conducted on both the Fleming Unit and private land. Data on the number of breeding pairs of ducks and coots are given in Table 2.

TABLE 2

Breeding Pairs of Ducks and Coots in Honey Lake Valley 1951-53 *

Species	1951†	1952	1953
Mallard	734	1,214	1,010
Pintail	364	201	220
Cinnamon teal	266	262	283
Gadwall	668	714	294
Shoveller	173	110	68
Redhead	323	129	212
Scaup	5	1	8
Ruddy duck	40	28	10
Other	6	18	3
Total ducks	2,579	2,677	2,108
Coot	126	398	620

* Population numbers taken from California breeding ground surveys of 1951-1953.
† Part of the 1951 breeding ground survey was taken from the ground and is not completely comparable to 1952-53, when all figures were made from aerial counts.

Two strip plots were used in 1951. These plots included all cover types present on the area. The combined area of the two strip plots was approximately 300 acres, or 15 percent of the total area of the Fleming Unit.

In 1953 eleven study plots were established to sample nesting on approximately 20,000 acres. They contained 328 acres, or approximately 1.6 percent of the total acreage in the study area.

Description of the 1951 Study

Practically all the open water and marsh area in northeastern Honey Lake Valley existed on the Fleming Unit of the Honey Lake Waterfowl Management Area. Water was impounded in artificial ponds during the nesting season and early summer. As a result of the availability of this water and marsh area, most of the waterfowl nesting in the valley was believed to have been confined to the Waterfowl Management Area.

The information gathered during the 1951 study was compiled from nests found on the two strip plots located on the Fleming Unit which were representative of the cover types found on the unit. Plot A contained the following cover types: pasture grasses, volunteer barley, cultivated wheat, five-hooked bassia, rye grass, Baltic rush, hardstem bulrush and others. Plot B contained five-hooked bassia, rye grass, Baltic rush, hardstem bulrush, sagebrush, greasewood, and other cover types.

Description of the 1953 Study Plots

Eleven study plots were established in nine different cover types representing the general cover types used most extensively by nesting waterfowl in the Honey Lake Valley in 1953. Seven plots of 40 acres each, two plots of 20 acres each, and two plots 1 mile long by 30 feet wide were used. The two one-mile plots were along a ditchbank and a levee and were both approximately four acres in area. In order to sample 40 acres of cover growing on ditchbanks and levees it would have taken 10 miles of ditchbank and levee, a factor not feasible in that study. The two 20-acre plots were of Baltic rush cover type. The seven 40-acre plots were established to include samples of the following major cover types: hardstem bulrush, river bulrush, sagebrush and greasewood, five-hooked bassia, rye grass, salt grass, cereal crops, and other cover types.

NEST SITES AND COVER TYPES

In compiling data on both studies, two broad headings were used in describing the locations of waterfowl nests. These headings or classifications were nest sites and cover types. The nest site classification described the physical characteristics of the terrain where the nest was located; e.g., in a marsh, on an island, or on a dike. The most abundant species of vegetation in the immediate vicinity of the nest was used to designate the cover type found at each site. As an example of cover type and nest site relationship, most of the duck nests found in 1953 were constructed in marsh nest sites and the dominant cover type around the nests was Baltic rush.

A description of the different nest sites used during the studies follows:

Dike or Ditchbank. Elevated margins of any slough, creek, river, irrigation ditch, or dam embankment were classified as dike nest sites.

Marsh. Areas such as lakeshores, artificial ponds, and all semiwet land were recorded as marsh-type sites.

Island. Any sizable piece of land completely surrounded by water was considered to be an island nest site.

Agricultural Land. All land used for agricultural purposes was listed as agricultural nest sites. During both studies most of the agricultural land was either in irrigated pasture or in cereal crops.

Uncultivated Land. Dry upland-type areas not under cultivation were classified as uncultivated land nest sites.

A difference was shown in the location of nest sites by ducks in 1951 and 1953. In 1951 nests were located primarily in dry upland areas. Dikes and uncultivated fields were the most common nest sites used by ducks that year. Results of the 1953 study showed an over-all change of location to the marsh type site. The change was attributed to the increased proportion of marsh nest sites available to the nesting waterfowl. The marsh nest sites contained 14.7 percent of all duck nests found in 1951 and 67.4 percent of all duck nests found in 1953. All coot nests found in 1951 and 98.6 percent of the coot nests found during the 1953 study were located in marsh nest sites. Location of nest sites by species is shown in Table 3.

TABLE 3

Nest Sites (Percentage in Each Site)

Species	Dike	Island	Marsh	Uncultivated	Agricultural	Total
Mallard						
1951	39.7	1.6	23.8	19.0	15.9	100.0
1953	18.9	0.0	62.9	15.4	2.8	100.0
Pintail						
1951	26.7	4.4	4.4	22.2	42.3	100.0
1953	22.6	0.0	37.7	34.0	5.7	100.0
Cinnamon teal						
1951	59.0	9.2	9.2	18.1	4.5	100.0
1953	1.6	0.0	89.6	8.0	0.8	100.0
Gadwall						
1951	44.4	0.0	0.0	27.8	27.8	100.0
1953	7.7	0.0	23.1	69.2	0.0	100.0
Shoveller						
1951	29.4	0.0	17.7	23.5	29.4	100.0
1953	0.0	0.0	0.0	85.7	14.3	100.0
Baldpate						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	0.0	100.0	0.0	100.0
Ruddy duck						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	0.0	0.0	100.0	0.0	0.0	100.0
Redhead						
1951	0.0	0.0	100.0	0.0	0.0	100.0
1953	0.0	0.0	100.0	0.0	0.0	100.0
Unclassified						
1951	50.0	0.0	0.0	0.0	50.0	100.0
Average for ducks						
1951	37.7	2.9	14.7	20.6	24.1	100.0
1953	11.7	0.0	67.4	18.4	2.5	100.0
Coot						
1951	0.0	0.0	100.0	0.0	0.0	100.0
1953	0.7	0.0	98.6	0.7	0.0	100.0

The change in nest sites between 1951 and 1953 was accompanied by a change in cover types. The cover utilized most often by nesting ducks in 1951 was rye grass, five-hooked bassia and salt grass. These three plant species provided cover for 60.6 percent of all duck nests found that year. In 1953, 59.7 percent of all duck nests found were in Baltic rush. Emergent plants were the preferred cover types utilized by coots during both studies. During 1951, 95 percent of the coot nests found were in hardstem bulrush. Baltic rush, river bulrush, and hardstem bulrush provided cover for 98.6 percent of the coot nests found in 1953. The utilization of the different cover types during both studies is presented in Table 4.

TABLE 4

Cover Types Utilized (Percentage in Each Type)

Cover type	Mallard	Pintail	Cinnamon teal	Gadwall	Shoveller	Baldpate	Ruddy duck	Redhead	Unclassified	Average ducks	Coots
Baltic rush											
1951	7.8	6.6	9.0	5.6	29.4	0.0	0.0	66.7	0.0	10.6	0.0
1953	35.7	51.0	96.0	69.2	57.1	0.0	16.6	18.2	0.0	59.7	42.0
Hardstem bulrush											
1951	22.2	8.9	0.0	0.0	0.0	0.0	0.0	33.3	0.0	11.2	95.0
1953	31.4	7.5	0.8	0.0	0.0	0.0	83.4	72.7	0.0	17.6	23.8
River bulrush											
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1953	1.4	1.9	0.0	0.0	0.0	0.0	0.0	9.1	0.0	1.1	32.8
Sagebrush-rye grass											
1951	7.8	1.4	4.5	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0
1953	8.4	13.2	0.8	23.1	14.3	100.0	0.0	0.0	0.0	6.9	0.0
Bassia											
1951	25.5	17.8	4.5	22.2	5.9	0.0	0.0	0.0	50.0	18.2	0.0
1953	7.7	11.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0
Rye grass											
1951	23.8	33.3	55.0	38.8	23.5	0.0	0.0	0.0	0.0	31.2	0.0
1953	7.7	5.7	0.0	7.7	0.0	0.0	0.0	0.0	0.0	4.2	0.0
Salt grass											
1951	3.3	13.4	18.0	5.6	29.1	0.0	0.0	0.0	50.0	11.2	0.0
1953	2.8	0.0	1.6	0.0	28.6	0.0	0.0	0.0	0.0	2.2	0.0
Cereal crops											
1951	4.8	15.6	0.0	11.2	11.8	0.0	0.0	0.0	0.0	8.2	0.0
1953	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Other											
1951	4.8	0.0	9.0	16.6	0.0	0.0	0.0	0.0	0.0	4.7	5.0
1953	4.2	9.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1.4
Total											
1951	100.0	100.0	100.0	100.0	100.0	0.0	0.0	100.0	100.0	100.0	100.0
1953	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	100.0	100.0

In order to get the over-all trend of the preferred nesting sites and cover types, information from these two classifications was combined in Table 5.

TABLE 5

Nest Site—Cover Type Relationships

	Nest site *		Cover type	
Species	1951	1953	1951	1953
Mallard	General	General	Bassia Rye grass Hardstem bulrush	Baltic rush Hardstem bulrush
Pintail	General	General	Rye grass Bassia	Baltic rush
Cinnamon teal	General	Marsh	Rye grass	Baltic rush
Gadwall	Dike	Uncultivated	Rye grass Bassia	Baltic rush
Shoveller	Dike	Uncultivated	Salt grass Baltic rush	Baltic rush Grasses
Baldpate	--	Uncultivated	--	Sagebrush-greasewood
Ruddy duck	--	Marsh	--	Hardstem bulrush
Redhead	Marsh	Marsh	Baltic rush Hardstem bulrush	Hardstem bulrush
Average duck	Dike	Marsh	Rye grass Hardstem bulrush Bassia	Baltic rush Hardstem bulrush
Coot	Marsh	Marsh	Hardstem bulrush	Baltic rush River bulrush Hardstem bulrush

* Where the term "general" is used, there was no definite preference for a nest site, and nesting occurred in the nest sites with about the same frequency.

NESTING PERIODS

The springs of 1951 and 1953 were considered favorable for nesting waterfowl in Honey Lake Valley. Although a change in location of nest sites and cover types was found in the two studies, the nesting periods and hatching dates were quite similar. The first nest found in 1951 was on April 19; in 1953 the first nest was found on April 22. The last nest history in 1951 was completed on July 25 and in 1953 on July 17. Nesting continued in the valley after these dates during both years, but it is believed that the number of nests hatched after July 25 was nominal and had little or no effect on the peak of hatch.

Nesting periods similar to those shown above were recorded at the Tule Lake and Lower Klamath National Wildlife Refuges in Siskiyou County (Miller and Collins, 1954).

Information concerning peak of hatch for both ducks and coots is illustrated (Figure 3).

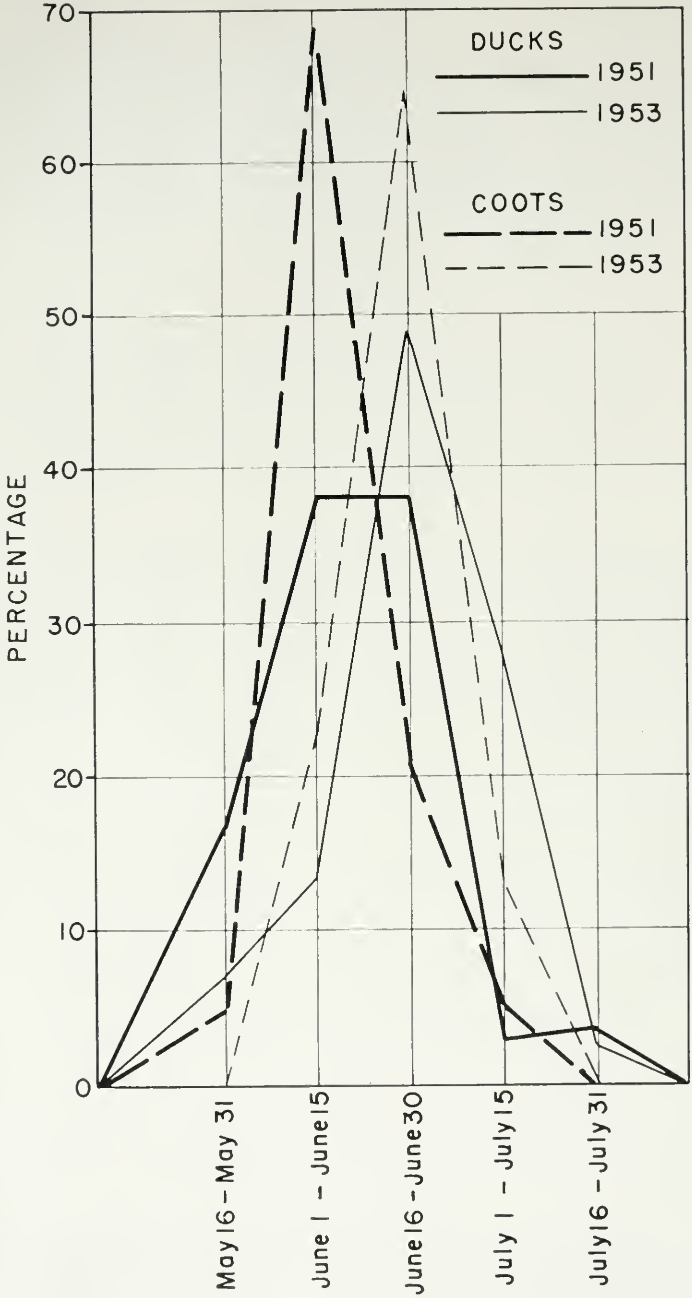

FIGURE 3. Hatching periods and peak of hatch for duck and coot nests in Honey Lake Valley.

FATE OF NESTS

The categories used in classifying fates of nests were the same as those used in several other nesting studies in California. The fate of nest classification used was as follows: (1) hatched nests, (2) deserted nests, (3) flooded nests, (4) destroyed nests and (5) fate unknown nests. A definition of these categories has been published by Miller and Collins (1953). Table 6 shows the fate of all nests found during the studies.

TABLE 6

Fate of Nests *

Species	Number of nests	Percentage nests hatched	Percentage nests destroyed	Percentage nests deserted	Percentage nests flooded	Total
Mallard						
1951	63	60.4	28.5	7.9	3.2	100.0
1953	143	47.6	36.4	14.0	2.0	100.0
Pintail						
1951	45	33.3	57.8	4.5	4.4	100.0
1953	53	45.3	45.3	9.4	0.0	100.0
Cinnamon teal						
1951	22	54.6	13.6	31.8	0.0	100.0
1953	125	56.0	28.8	13.6	1.6	100.0
Gadwall						
1951	18	66.7	22.1	5.6	5.6	100.0
1953	13	38.5	46.1	15.4	0.0	100.0
Shoveller						
1951	17	58.8	41.2	0.0	0.0	100.0
1953	7	28.6	42.8	28.6	0.0	100.0
Ruddy duck						
1951	--	0.0	0.0	0.0	0.0	0.0
1953	6	66.7	0.0	33.3	0.0	100.0
Redhead						
1951	3	33.3	66.7	0.0	0.0	100.0
1953	11	54.5	9.1	36.4	0.0	100.0
Total ducks						
1951	168	52.5	35.0	9.5	3.0	100.0
1953	359	50.1	34.3	14.2	1.4	100.
Coot						
1951	20	95.0	5.0	0.0	0.0	100.0
1953	143	97.2	2.1	0.7	0.0	100.0

* 34 nests not shown from the 1951 study were: 2 unclassified, 15 destroyed when found, 17 hatched when found. One nest not shown from the 1953 study was a baldpate nest that was destroyed.

Successful Nests

The average nesting success for the duck nests found on study plots during both years was similar. In 1951, 52.5 percent of the duck nests hatched, while in 1953 success rate dropped slightly, with a hatch of 50.1 percent.

The over-all hatching success of dabbling ducks was lower in 1953 than in 1951. The pintail was the only dabbling duck that showed any appreciable gain in nesting success in 1953. The rate of success found in cinnamon teal nesting was relatively constant during both studies. In 1951 gadwall, mallard, and shoveler were the most successful nesters of the dabbling ducks, with success rates of 66.7, 60.4, and 58.8 percent, respectively. In 1953 the three species of dabbling ducks that were the most successful nesters were the cinnamon teal, mallard, and pintail. The success rates for these species were 56.0, 47.6, and 45.3 percent, respectively. The success rates of the nests of diving ducks found during the studies were 33.3 percent for redheads in 1951 and 54.5 percent in 1953. The hatching success of ruddy duck nests was 66.7 percent in 1953. No ruddy duck nests were found in 1951.

All recent duck and coot nesting surveys in northeastern California have indicated that the coot is the most successful nester with respect to hatching success and hatchability of eggs. The success rate for coots at Honey Lake was 95.0 percent in 1951 and 97.2 percent in 1953. The success rate for coots at the Tule Lake and Lower Klamath National Wildlife Refuges was 94.6 percent in 1952 (Miller and Collins, 1954).

Unsuccessful Nests

Destruction. Predation on nests of both ducks and coots was the greatest single cause of nesting failures during both studies. The amount of destruction attributed to predation was relatively constant during both studies. Of all the duck nests that were found, 35.0 percent were destroyed in 1951, while 34.3 percent were destroyed in 1953. The amount of predation on coot nests was light, with 5.0 percent of the nests destroyed in 1951 and 2.1 percent destroyed in 1953.

The cause of nest destruction was difficult to determine in many cases. The lack of sufficient evidence to establish definitely the cause

TABLE 7
Percentage of Destroyed Duck Nests Found in Each Nest Site

	Dike	Island	Marsh	Uncultivated land	Agricultural land	Total
Destroyed by mammal						
1951	64.0	0.0	33.3	85.7	38.9	55.4
1953	25.7	0.0	40.0	45.3	16.7	36.6
Destroyed by bird						
1951	12.0	0.0	50.0	0.0	5.5	12.5
1953	20.0	0.0	27.5	11.9	16.7	19.5
Destroyed by unknown causes						
1951	24.0	0.0	16.7	14.3	27.8	23.2
1953	54.3	0.0	32.5	42.8	66.6	43.9
Destroyed by unnatural causes						
1951	0.0	0.0	0.0	0.0	27.8	8.9
1953	0.0	0.0	0.0	0.0	0.0	0.0
Total						
1951	100.0	0.0	100.0	100.0	100.0	100.0
1953	100.0	0.0	100.0	100.0	100.0	100.0

One coot nest was destroyed in 1951 and three coot nests were destroyed in 1953 in marsh nest sites and are not shown in the table.

of predation was responsible for the large number of nests attributed to destruction by unknown causes (Table 7). If there was any doubt as to the identity of the predator a nest was listed as destroyed by unknown causes. Mammalian predators known to occur in the area were the striped skunk, coyote, house cat, badger, bobcat, and weasel; the avian species which prey on nests were the California and ring-billed gulls, the black-billed magpie, the crow, and the raven. An instance of nest destruction by unnatural causes occurred during 1951, when five nests were destroyed by land-leveling operations.

Preseason trapping of predators by a State trapper on the Honey Lake Waterfowl Management Area resulted in the capture of 23 striped skunks, 4 coyotes, 9 house cats, and 2 bobcats in 1951 and 31 striped skunks, 1 coyote, and 5 house cats in 1953.

Desertion. The amount of desertion found in duck nests was 9.5 percent in 1951 and 14.2 percent in 1953. This higher rate of desertion was the greatest difference found in comparing the results of the fate of nests in the two studies.

Competition for preferred nest sites among the ducks probably accounted for some desertion. However, data concerning desertion

FIGURE 4. Mallard duck nest parasitized by a pheasant. The six pheasant eggs show darker and smaller than the five duck eggs. *Photograph by E. G. Hunt.*

due to competition for preferred nest sites were inconsistent, and no definite statement can be made on this subject.

Parasitism occurred in 2.7 percent of the total duck nests found in 1951 and in 6.2 percent of the total duck nests found in 1953. Any nest containing eggs laid by two species of ducks or a duck and a pheasant was considered parasitized (Figure 4). There were no instances of a duck nest being parasitized by another species of duck during the 1951 study. In 1953, 13 (42 percent) of the duck nests parasitized contained eggs laid by another species of duck. Parasitism of duck nests by pheasants occurred in all five of the parasitized nests found in 1951 and in 18 (58 percent) of the duck nests parasitized in 1953. Some desertion resulting directly from parasitism in duck nests probably occurred, but data gathered during both studies showed that parasitism was not an important cause of desertion. No instance of parasitism was found in coot nests during either study.

Only one coot nest was recorded as deserted during the 1953 study, and none was deserted during the 1951 study. It was believed that overcrowding in preferred nest sites and parasitism that may exist in duck nests were not factors that affected coot nesting. The pugnacity

TABLE 8

Clutch Size and Average Hatch Per Clutch

Species	Successful nests	Total eggs	Average clutch	Average hatch per clutch
Mallard				
1951	38	339	8.9	8.3
1953	64	529	8.3	6.9
Pintail				
1951	15	111	7.4	6.8
1953	25	176	7.0	5.9
Cinnamon teal				
1951	12	125	10.4	9.7
1953	61	583	9.1	7.8
Gadwall				
1951	12	126	10.5	9.6
1953	5	50	10.0	7.4
Shoveller				
1951	10	109	10.9	10.1
1953	2	20	10.0	10.0
Ruddy duck				
1951	0	0	0.0	0.0
1953	3	15	5.0	5.0
Redhead				
1951	1	14	11.0	4.0
1953	5	42	8.1	5.4
All ducks				
1951	88	824	9.1	8.1
1953	168	1,115	8.4	7.1
Coot				
1951	19	154	8.1	7.9
1953	123	913	7.4	7.4

with which the coot defends a nesting territory might be a reason for such a low desertion rate.

Flooding. The flooding of nests was of minor significance in the success of duck and coot nesting. Five duck nests were found flooded during each of the studies. No instance of a coot nest being flooded was recorded. Stable or receding water levels during the nesting season accounted for the low incidence of flooded nests.

FATE OF EGGS AND CLUTCH SIZE OF SUCCESSFUL NESTS

The information collected from successful nests was used to determine the average clutch and fate of eggs. The average clutch size of both ducks and coots was found to be slightly lower in 1953 than in 1951 (Table 8).

All available data concerning the fate of eggs were recorded in the following categories: (1) number of eggs hatched, (2) number of eggs destroyed, (3) number of eggs infertile, (4) number of eggs containing dead embryos, (5) number of eggs missing, and (6) number of dead in nest. The fate of eggs in successful nests is shown in Table 9. The number of dead young in nests were included in the percentage of eggs hatched.

TABLE 9

Fate of Eggs Expressed in Percentages

Species	Hatched	Dead embryo	Infertile	Destroyed	Missing	Total
Mallard						
1951	93.5	5.0	0.0	0.0	1.5	100.0
1953	83.5	12.8	0.2	1.3	2.2	100.0
Pintail						
1951	91.9	7.2	0.9	0.0	0.0	100.0
1953	84.2	10.7	1.1	0.6	3.4	100.0
Cinnamo teal						
1951	92.8	0.8	0.8	0.0	5.6	100.0
1953	85.5	11.2	0.0	1.0	2.3	100.0
Gadwall						
1951	91.2	3.2	1.6	0.0	4.0	100.0
1953	74.0	16.0	0.0	4.0	6.0	100.0
Shoveller						
1951	92.7	4.6	0.9	0.0	1.8	100.0
1953	100.0	0.0	0.0	0.0	0.0	100.0
Ruddy duck						
1951	0.0	0.0	0.0	0.0	0.0	0.0
1953	100.0	0.0	0.0	0.0	0.0	100.0
Redhead						
1951	28.6	71.4	0.0	0.0	0.0	100.0
1953	61.9	26.2	11.9	0.0	0.0	100.0
Average of all ducks						
1951	91.7	5.4	0.6	0.0	2.3	100.0
1953	83.9	12.0	0.6	1.0	2.5	100.0
Coot						
1951	97.5	0.0	0.6	0.0	1.9	100.0
1953	99.3	0.3	0.0	0.4	0.0	100.0

The successful duck nests produced 824 eggs in the 1951 study and 1,415 eggs in the 1953 study, of which 755 hatched in 1951 and 1,187 hatched in 1953. The hatching success of the duck eggs in 1951 was 91.7 percent; in 1953 it was 83.9 percent. The hatching success of coot eggs was 97.5 percent in 1951 and 99.3 percent in 1953. Only four coot eggs out of 154 in 1951 and seven out of 913 in 1953 did not hatch.

The total number of eggs attributed to parasitism in successfully hatched duck nests was 26 in 1953 and two in 1951. Of the 26 eggs found in 1953, 16 were duck eggs and 10 were pheasant eggs; both of the eggs found in 1951 were pheasant eggs. The small number of eggs resulting from parasitism made little difference in the total number of eggs in the successfully hatched nests and was not computed in the fate of eggs or average clutch.

Infertile eggs and eggs containing dead embryos that were found in successfully hatched nests were classified by the method described by Kossack (1950). An egg was considered infertile if the yolk was suspended in the albumen and no indication of development was present. Any egg that contained a dead embryo in any stage of development or contained yellow custard-like material was classified as a dead embryo.

In all, 45 eggs containing dead embryos and five infertile eggs were found in successfully hatched duck nests in 1951, and 172 eggs containing dead embryos and eight infertile eggs were found in 1953. In all the successfully hatched coot nests only three eggs containing dead embryos and no infertile eggs were found in 1953, and no dead embryos and one infertile egg were found in 1951.

A total of 50 eggs was either destroyed or missing from the successfully hatched duck nests in 1953, while in 1951 there were 19 eggs missing from successful duck nests, but no eggs were destroyed. Successful coot nests contained four destroyed eggs and had no eggs missing in 1953; there were no destroyed eggs and four eggs were missing in 1951.

BROOD DATA

The number of duck brood counts taken during the two studies was 132 in 1951 and 151 in 1953. Most of the duck broods counted were either one or two weeks old. Only 30.1 percent of the duck broods counted during 1951 and 44.3 percent of the duck broods counted during 1953 were over two weeks old. Losses in broods during the first week of life averaged 0.1 bird in 1951 and 0.7 bird in 1953.

No coot broods were counted during 1951, and only 24 coot broods were counted during 1953. Since a pair of coots will often split the brood between them, brood counts may not accurately reflect the actual brood size. Therefore, observers tallied only those broods that could be considered complete. An average loss of 3.0 coots per brood during the first week of life occurred in the few coot broods taken. This loss was undoubtedly due to the general helplessness of young coots during their first few days of life (Gullion, 1954).

DISCUSSION

The amount of water in Honey Lake has a definite bearing on the number of waterfowl utilizing the valley throughout the year. The lake in wet years provides an adequate resting place for the spring migrants and attracts breeding pairs that remain to nest in the area. Fall migrating waterfowl feed and rest in the vicinity of the lake and, together with the waterfowl produced in the valley, provide hunting during the waterfowl season.

In 1951 most of the duck nesting occurred in dry, upland-type habitat that was adjacent to artificial ponds. These nesting areas provided a combination of good nesting cover and sufficient water for rearing broods. The preferred nesting cover under 1951 conditions was rye grass, five-hooked bassia, and salt grass. These plant species grew in clumps and provided cover that was relatively low and dense. In 1953 there was not only an abundant growth of upland plant species, including rye grass, five hooked bassia, and salt grass, but also an abundant growth of emergent plant species, such as Baltic rush. The Baltic rush offered the same concealment factors as the rye grass, five-hooked bassia, and salt grass and was usually growing in or near water. Approximately the same percentage of duck nests was found in the Baltic rush in 1953 as was found in rye grass, five-hooked bassia, and salt grass in 1951. Apparently the conditions that prevailed at the nest location, such as concealment and proximity to water, were more important to the nesting ducks than the selection of a certain plant species in which to build a nest. The coot nesting during both studies was confined to areas that grew emergent plant species.

From observations made of coots it appears that both parents participate in incubation of the eggs. A further observation is that the coot often commences incubation at some interval after the first egg is laid and before the final egg of the clutch is laid. This would enable the coot to hatch several of the young and allow one parent to take the young from the nest and the other parent to continue incubating until all eggs in the clutch were hatched. These observations followed the coot nesting behavior described by Gullion (1954) and others. As an example of the frequency of this behavior, 83 of the 139 coot nests hatched during the 1953 study were hatched in this manner. The early start in incubation would also give the coot eggs more protection than that received by duck eggs.

The most frequent cause of nest failure was predation. Approximately one-third of all nests found during both studies were destroyed by predators. The species of ducks that nested in the dry upland locations sustained the majority of the nest destruction in each study. Many of the ducks nesting in the upland areas preferred ditch banks and dikes for a nest location. Mammalian predators, principally the striped skunk, seemed to hunt these areas extensively in search of food. Nest destruction in the marsh area was very limited, apparently because of protection afforded by standing water. Undoubtedly the absence of such aquatic predators as the mink was also a factor in the low incidence of predation in the marsh area. The rate of nest destruction by avian predators was low in marshy areas and moderate in the upland areas during both studies.

Since coots habitually built their nests over water they were protected from most mammalian predators, and thus were the most successful nesters studied. Another factor which may have contributed to the high rate of nesting success of coots was the participation of both parents in guarding the nest.

An insufficient number of broods was counted to determine accurately brood regression during either study. The utilization of dense escape cover by the duck and coot broods made brood counting difficult. The one- and two-week-old broods were the only age classes that were counted frequently. Information taken from the brood cards regarding week-old duck broods indicated that there was a slight reduction in brood size during the first week of life. The coot broods that were counted showed a loss of approximately 40 percent of the number of hatched young during the first week of life.

SUMMARY

1. Studies on nesting ducks and coots were conducted during the spring of 1951 and 1953 in Honey Lake Valley, Lassen County, California.

2. Two sample strips with a total area of 300 acres were studied during 1951; 11 study plots with a total area of 328 acres were studied during 1953.

3. Nest histories were completed on 202 duck nests and 20 coot nests during 1951. In 1953 nest histories were completed on 359 duck nests and 143 coot nests.

4. The peak of hatch for coot nests was between June 1 and June 15 during 1951; for duck nests, between June 1 and June 30. The peak of hatch for both ducks and coots during 1953 was between June 16 and June 30.

5. The nesting success for all nests found in 1951 was 52.5 percent for ducks and 95.0 percent for coots; in 1953 the nesting success for all nests found was 50.1 percent for ducks and 97.2 percent for coots.

6. Predation was the most important cause of unsuccessful nesting of ducks and coots during both studies.

7. The hatching success of eggs in the successful nests in 1951 was 91.7 percent for ducks and 97.5 percent for coots; in 1953 the hatching success was 83.9 percent for ducks and 99.3 percent for coots.

8. In 1951, 132 duck broods were counted, while in 1953, 151 duck broods were tallied. The brood count data showed that on the average less than one duck per brood was lost during the first week of life. The 24 coot broods counted in 1953 revealed an average reduction of 3 coots per brood during the first week of life.

REFERENCES

Gullion, Gordon W.
1954. The reproductive cycle of American coots in California. Auk, vol. 71, no. 4, p. 366-412.

Kossack, Charles W.
1950. Breeding habits of Canada geese under refuge conditions. Amer. Midl. Nat., vol. 43, no. 3, p. 627-649.

Miller, A. W., and B. D. Collins
1953. A nesting study of Canada geese on Tule Lake and Lower Klamath National Wildlife Refuges, Siskiyou County, California. Calif. Fish and Game, vol. 39, no. 3, p. 385-396.
1954. A nesting study of ducks and coots on Tule Lake and Lower Klamath National Wildlife Refuges. Calif. Fish and Game, vol. 40, no. 1, p. 17-37.

Naylor, Albert E.
1953. Production of the Canada goose on Honey Lake Refuge, Lassen County, California. Calif. Fish and Game, vol. 39, no. 1, p. 83-94.

Naylor, A. E., and E. G. Hunt
1954. A nesting study and population survey of Canada geese on the Susan River, Lassen County, California. Calif. Fish and Game, vol. 40, no. 1, p. 5-16.

APPENDIX

Scientific Names of Animals and Plants Listed in the Text

Birds

Mallard—*Anas platyrhynchos*
Pintail—*Anas acuta tzitzihoa*
Cinnamon Teal—*Anas cyanoptera*
Gadwall—*Anas strepera*
Shoveller—*Spatula clypeata*
Baldpate—*Mareca americana*
Ruddy Duck—*Oxyura jamaicensis rubida*
Redhead—*Athya americana*
Coot—*Fulica americana*
California Gull—*Larus californicus*
Ring-billed Gull—*Larus delawarensis*
Black-billed Magpie—*Pica pica hudsonia*
Western Crow—*Corvus brachyrhynchos hesperis*
Raven—*Corvus corax*

Mammals

Great Basin Striped Skunk—*Mephitis mephitis major*
Mountain Coyote—*Canis latrans lestes*
Pallid Bobcat—*Lynx rufus pallescens*
California Badger—*Taxidea taxus neglecta*
Weasel—*Mustela* sp.
Housecat—*Felis domesticus*

Plants

Grasses—*Gramineae*
Cultivated Barley—*Hordeum vulgare*
Cultivated Wheat—*Triticum aestivum*
Black Greasewood—*Sarcobatus vermiculatus*
Sagebrush—*Artemisia tridentata*
Five-hooked Bassia—*Bassia hyssopifolia*
Rye Grass—*Elymus* sp.
Baltic Rush—*Juncus balticus*
Hardstem Bulrush—*Scirpus acutus*
River Bulrush—*Scirpus fluviatilis*
Alkali Bulrush—*Scirpus paludosus*
Salt grass—*Distichlis spicata*
Alfalfa—*Medicago sativa*

NESTING AND REPRODUCTION OF THE BAND-TAILED PIGEON IN CALIFORNIA[1]

WALLACE G. MACGREGOR and WALTON M. SMITH
Game Management Branch
California Department of Fish and Game

INTRODUCTION

The State of California is the principal wintering area of the band-tailed pigeon (*Columba fasciata monilis*), which is one of the important migratory game birds of the Pacific Coast. Hunting pressure is exerted on this species not only in California, but also in Oregon and Washington. Past fluctuations in population due to one cause or another have been reflected in crop depredation complaints and hunting closures.

In order to determine the status of this species and secure adequate data on which to base recommendations for management, a Pittman-Robertson research project was set up in 1950. This paper reports on the results of a part of this study.

PRODUCTIVITY

The band-tailed pigeon has been credited with having the lowest breeding potential of any game bird in the United States. Ever since Grinnell (1913) wrote, "it seems impossible that, at least as far as our knowledge of the species on the Pacific Coast is concerned, more than one brood can be raised each year by a single pair of birds * * *," authorities have assumed that pigeons rear only one brood per year. Glover (1953) states that "there is no reliable evidence that the band-tail nests more than once each year in California, except when its first nesting is disturbed. Within the confines of this study, no data was obtained to the contrary."

The authors first began to suspect that the reproductive potential was higher than one squab per year while conducting checks of pigeon hunters in 1952. Age ratios were obtained at that time which would be possible only if there was a higher reproductive rate, or a differential migration of young and old birds. These age ratios were obtained by examining the bursa of Fabricius in birds killed by hunters. Although imature birds can be distinguished from adult birds by plumage this characteristic is not completely valid during the fall hunting period, as some of the earlier hatched birds have completed the moult and have full adult plumage. The presence of the bursa of Fabricius as described by Riddle (1928) is the best method of telling immature from adult birds.

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Table 1 gives age ratios of birds in Oregon and California from 1950 through 1954. All of these ratios were based on examination of the bursa in birds killed during the hunting season.

TABLE 1

Band-tailed Pigeon Age Ratios Obtained From Hunter Killed Birds

Locality	Date	Adult: Immature	Number in sample
Oregon*	September, 1950	1:0.25	439
Oregon*	September, 1951	1:0.41	356
Shasta County	September, 1952	1:0.26	77
Monterey County	December, 1952	1:0.79	171
Kern County	December, 1952	1:2.00	161
Monterey County	December, 1953	1:0.97	146
Monterey County	December, 1954	1:0.81	352

* Morse (1951).

It will be noted that the age ratios obtained in September, both from Oregon and California, are below 0.5 immature bird per adult. In contrast, the ratios obtained during December range from 0.79 immature per adult up to 2.00 immature per adult. As a ratio of 0.5 would be the maximum expected ratio if the production were one squab per season, there must have been higher production or differential migration of young and old birds.

NESTING

In 1952 a nesting study was initiated in the Carmel area of Monterey County. This area was chosen because of its accessibility and high density of nesting birds. During the period from July, 1952, to May, 1955, a total of 26 pigeon nests and 33 nestings was observed. Although this is a fairly small number of nests, it equals the number of all the other pigeon nests found in California and recorded in the literature to date.

Grinnell, Bryant, and Storer (1918) gave data on 17 nests recorded in the literature or known to them from 1877 to 1918. More recently Glover (1953) reported on five nests from northwestern California.

Table 2 summarizes the nesting data obtained by this study. The locations of the nests are shown in Figures 1 and 2.

Nest Location

All the nests were located in trees. The nests were found at heights from 12 to 95 feet, with an average height of 36 feet. Sixty-two percent (16) of the nests were found in Monterey pine (*Pinus radiata*); 19 percent (5) in coast live oak (*Quercus agrifolia*); 15 percent (4) in acacia (*Acacia* sp.); and 4 percent (1) in hawthorn (*Crataegus* sp.). The pine and oak are native species and the acacia and hawthorn are cultivated exotics. Most nests were constructed of a flimsy aggregation of twigs placed in the fork of a limb. In the case of a nest located next to the Carmel Police Station, with each new nesting additional material was added on top of the preceding nest, until it became quite a substantial structure.

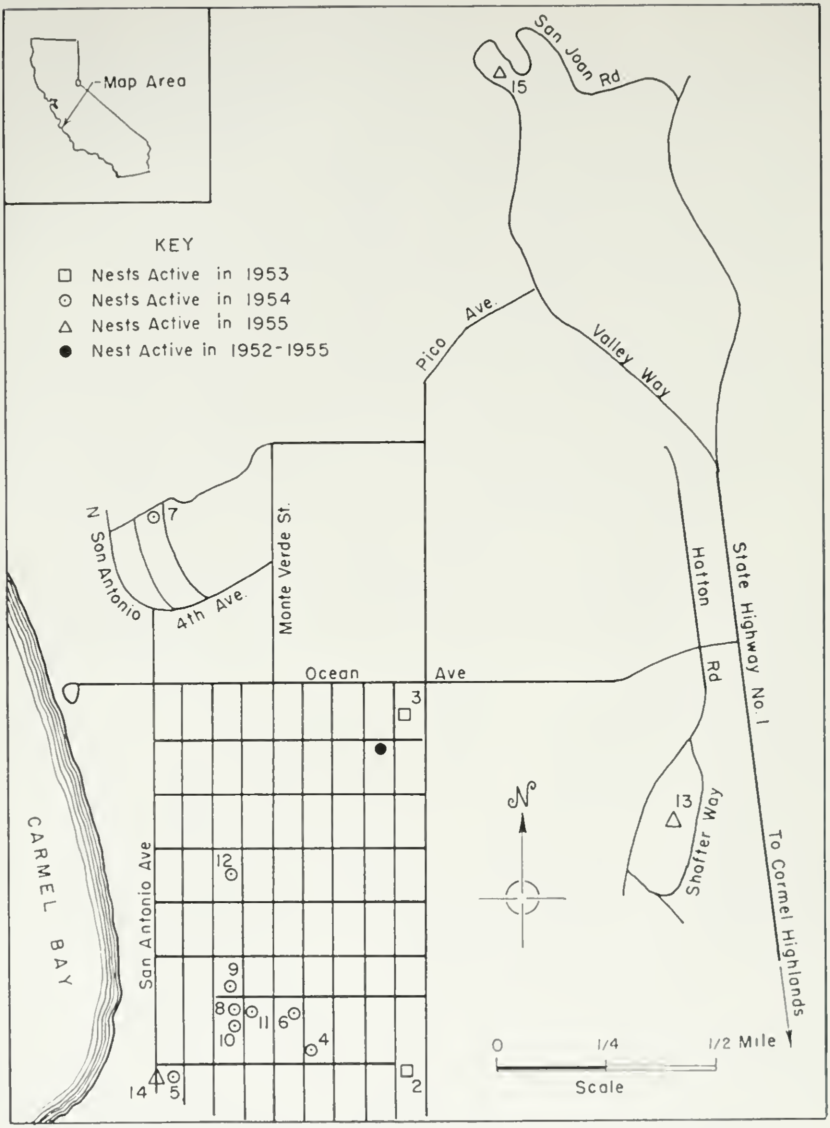

FIGURE 1. Map of band-tailed pigeon nests in Carmel, 1953-1955. *Drawn by Cliffa Corson.*

Number of Eggs

Due to the height of some of the nests and other factors it was possible to observe the contents of only 26 nests. Twenty-five (96 percent) of the nests contained one egg or squab and one nest contained two eggs.

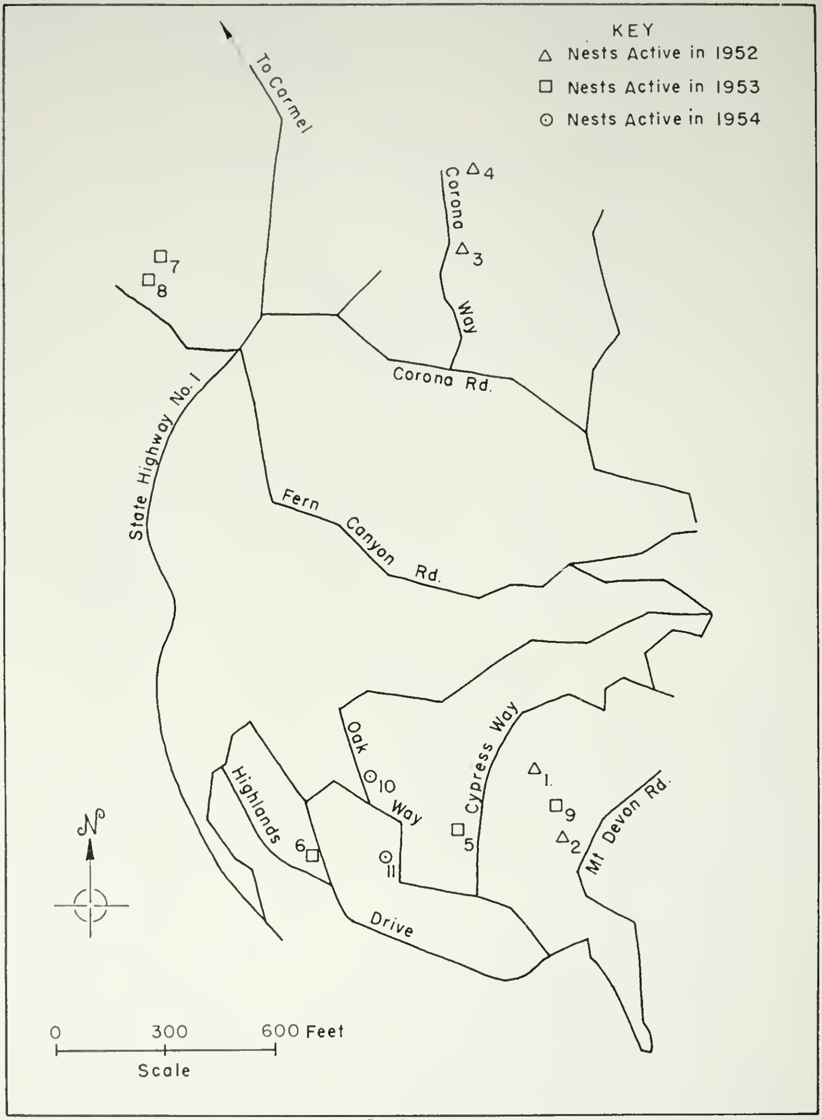

FIGURE 2. Map of band-tailed pigeon nests in Carmel Highlands, 1952-1954. *Drawn by Cliffa Corson.*

Nesting Period

The earliest date of egg laying noted in this study was February 1. A squab was observed in a nest as late as October 13th. Although later observations were not made, this squab probably remained in the nest until the end of October.

Nesting Success

Of the 26 nestings where observations were made, 17 (65 percent) were considered successful in fledging the squabs, five (20 percent) were unsuccessful, and the fate of four (15 percent) was unknown. Of the unsuccessful nests, two were destroyed by avian predation (jays and ravens); two were destroyed by unknown causes; one by man; and one contained a dead embryo. Mr. Laidlaw Williams, of Carmel Highlands, who for many years has been engaged in ornithological studies in this area, has kindly given the authors additional information on mortality factors. Mr. Williams observed a sharp-shinned hawk (*Accipter striatus*) devouring a young squab in the nest, July 7, 1940.

Conversations with Mr. Williams and other residents in the Carmel area have brought out the fact that the combination of flimsily constructed nests and high winds is responsible for considerable losses of eggs and young birds. Mr. Williams has hand reared two young squabs that have fallen out of nests by feeding them Pablum. Almost every nesting season young birds are found that have fallen from the nests due to either wind or the young bird overstepping the nest.

Multiple Nesting

Of unusual interest is the nest designated as Number 1 in Figure 1 and B-1 in Table 2. This nest was found on May 22, 1953. At that time it contained many droppings, indicating that a squab had been raised in the nest earlier that year. This nest is located in an acacia tree about 15 feet from the ground. The tree is in a strip between the sidewalk and street opposite the Carmel Police Station. Members of the Police Department had observed the nest in 1951 and 1952. The officers stated that at least one brood was reared in 1951 and two broods in 1952.

This nest was rechecked on June 5, 1953, when it contained one egg. When the nest was checked on June 8 it contained a downy nestling. On June 16 the adult bird was marked on the back feathers with white airplane dope to enable sight recognition. On June 21, the squab fell from the nest and was banded and weighed. The squab weighed 165 grams and was kept until the following day to see if it was injured and then returned to the nest. The squab was last observed in the nest on June 29.

On July 21, the marked adult bird was again on the nest, but the nest was empty. The nest contained one egg on July 24 and the adult was recognized as the bird marked on June 16. Due to other work it was not possible to follow this nestling closely, but the officers said the squab was successfully fledged.

On February 18, 1954, an adult bird was on the nest and the nest contained one egg that appeared to be pipped. On February 19 the nest was again checked and the egg proved to be broken rather than pipped and contained a dead embroyo in an advanced state of development. On March 12, the adult bird was seen rearranging the nest. The adult was on the nest incubating one egg on March 17 and March 23. On April 1 the nest contained one squab. This nestling was banded on April 7, and left the nest on April 19. The adult was on the nest.

TABLE 2

Nesting Data Summary

Nest No.	Area	Date found	Location	Height	Status when found	Date hatched	Date fledged	Fate	Remarks
A-1	Carmel Highlands	7/ 9/52	Monterey Pine	35′	Building	7/31/52	8/28/52	Successful	Egg laid 7/31/52
A-2	Carmel Highlands	9/ 2/52	Monterey Pine	40′	Incubating	--	--	Unsuccessful	Egg found on ground 9/ 5/52.
A-3	Carmel Highlands	8/ 4/52	Monterey Pine	30′	Brooding	--	8/18/52	Successful	Adult reported first seen on nest 6/1, squab 2 weeks old when nest found.
A-4	Carmel Highlands	8/19/52	Acacia	12′	Brooding	--	8/22/52	Successful	Squab 2 weeks old when nest found.
A-5	Carmel Highlands	5/ 7/53	Monterey Pine	40′	Incubating	--	6/16/53	Successful	
A-6	Carmel Highlands	6/ 3/53	Monterey Pine	95′	Incubating	--	--	Unknown	Adult incubating 6/16/53.
A-7	Carmel Highlands	6/ 3/53	Monterey Pine	20′	Incubating	6/12/53	7/10/53	Successful	
A-8	Carmel Highlands	6/16/53	Monterey Pine	80′	Building	7/10/53	--	Unsuccessful	Nestling partially consumed by raven? 7/23/53.
A-9	Carmel Highlands	7/23/53	Monterey Pine	35′	Incubating	7/25/53	--	Successful	Nestling banded 9/6/53.
A-10	Carmel Highlands	5/13/54	Monterey Pine	95′	Incubating	--	--	Unknown	Adult incubating 5/18, 5/21.
A-11	Carmel Higlnads	5/13/54	Monterey Pine	18′	Brooding	--	5/31	Successful	
B-1a	Carmel	5/22/53	Acacia	15′	Incubating	6/ 8/53	7/ 1/53	Successful	Adult marked 6/16, squab fell from nest. 6/22 weighed 165 gm.
1b	Carmel	7/21/53	Acacia	15′	Incubating	--	--	Successful	Adult same as 1-A.
1c	Carmel	2/18/54	Acacia	15′	Incubating	--	--	Unsuccessful	Egg broken, contained embryo in advanced state of development, 2/19/54.
1d	Carmel	3/12/54	Acacia	15′	Building	4/ 1/54	4/19/54	Successful	
1e	Carmel	7/ 8/54	Acacia	15′	Incubating	7/12/54	--	Successful	
1f	Carmel	9/27/54	Acacia	15′	Incubating	--	--	Successful	Adult & squab in nest 10/13, same adult as marked 6/16.
1g	Carmel	2/ 9/55	Acacia	15′	Building	3/ 1/55	--	Unsuccessful	Egg laid 2/11/55, nestling killed by jays 3/22/55.
B-2	Carmel	5/18/53	Coast Live Oak	12′	Incubating	--	--	Unsucessful	Nest empty 5/21/53, nest reportedly destroyed by boys.
B-3a	Carmel	9/ 2/53	Monterey Pine	45′	?	--	--	Unknown	Adult on nest, unable to observe contents.
3B	Carmel	4/19/54	Monterey Pine	45′	?	--	--	Unknown	Adult on nest, unable to observe contents.
B-4	Carmel	2/24/54	Monterey Pine	85′	Incubating	--	--	Unknown	Adult incubating 2 eggs; nest empty 4/7/54.
B-5	Carmel	3/23/54	Monterey Pine	36′	?	--	--	Unknown	Unable to observe contents.
B-6	Carmel	4/ 1/54	Monterey Pine	50′	?	--	--	Unknown	Unable to oblserve contents.
B-7	Carmel	5/ 5/54	Coast Live Oak	25′	Incubating	5/21/54	--	Unknown	
B-8	Carmel	5/19/54	Hawthorn	20′	Building	6/4 /54	--	Successful	
B-9	Carmel	5/19/54	Coast Live Oak	24′	Brooding	--	6/12	Successful	
B-10	Carmel	5/19/54	Acacia	18′	Brooding	--	5/25	Successful	
B-11	Carmel	5/24/54	Acacia	16′	Incubating	5/31	--	Successful	
B-12	Carmel	5/24/54	Coast Live Oak	15′	Building	--	--	Unsuccessful	
B-13	Carmel	7/12/54	Coast Live Oak	25′	?	--	--	Unknown	Unable to observe.
B-14	Carmel	3/ 2/55	Monterey Pine	18′	Incubating	3/22/55	4/ 6/55	Successful	
B-15	Carmel	3/23/55	Monterey Pine	60′	?	--	--	Unknown	Unable to observe.

which contained one egg again, on July 8. The squab hatched on July 12 and was banded on July 16.

On September 27 and 29 an adult with one egg was on the nest. On October 13, the adult was brooding a squab.

Throughout all of these observations it was possible to tell that it was the same marked pair which was nesting and caring for the young. From these observations it will be seen that a single pair of pigeons in one season made four nesting attempts and successfully fledged three birds.

In 1955 an adult bird was seen on the nest for the first time February 9. Some of the marking applied in 1954 was still visible. No

FIGURE 3. Adult male incubating. Nest located in Monterey pine.
Photograph by Wallace G. Macgregor.

egg was in the nest. An egg was laid on February 11 and this egg hatched March 1. The nestling was banded on March 15, but was killed by scrub jays *(Aphelocoma californica)* on March 22. No further activity has been recorded at this nest.

FIGURE 4. Adult male feeding a day-old squab. *Photograph by Wallace G. Macgregor.*

Incubation

There appears to be no information on the incubation period of the band-tail since Bendire's (1892) statement that "incubation lasts from 18 to 20 days, both sexes assisting." Observations of nests in this study indicate that the incubation period averages 19 days.

Figure 3 shows an adult male incubating a nest in a Monterey pine. Observations made of incubating birds confirm the work of earlier workers who state that the incubation duties are shared by the sexes, the male incubating during the day and the female at night.

Growth of Young

The young squabs when hatched are covered with orange-yellow down. The squabs are fed pigeon milk by both parents. The following is an account of this feeding from the senior author's field notes. "The adult would take the beak of the young bird near the base and grasp it in a crosswise position; the adult would then gulp up and down 18 to 25 times. During the observations the bird fed five times with the feedings lasting from 30 seconds to two minutes. Three feedings took place 10 minutes apart." Figure 4 shows an adult male feeding a day-old squab. The squabs grow rapidly and by five days they are almost three times as large as at birth (Figure 5). At two weeks the squab weighs half as much as an adult bird and is nearly

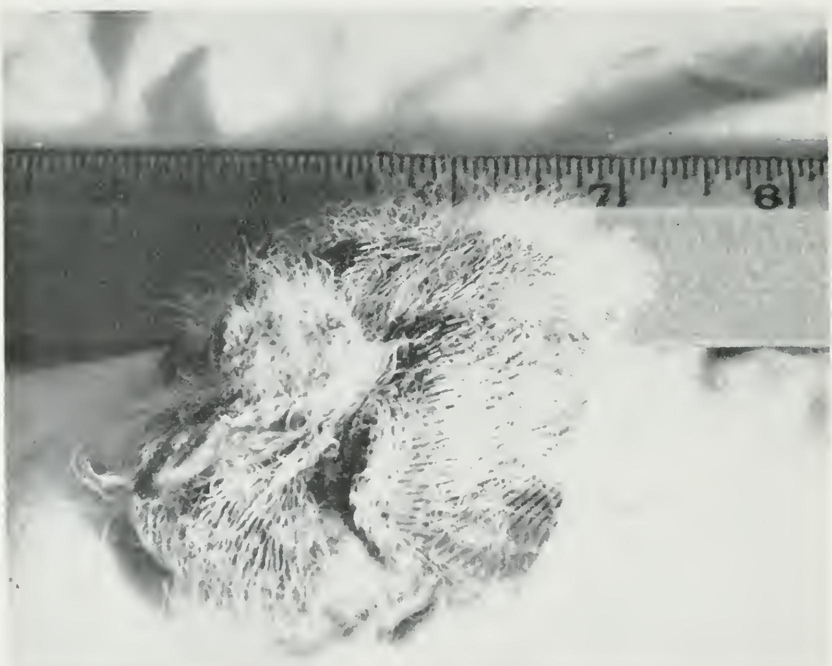

FIGURE 5. Squab, age five days. *Photograph by Wallace G. Macgregar.*

FIGURE 6. Squab, age 14 days. *Photograph by Wallace G. Macgregor.*

full feathered (Figure 6). Some birds leave the nest at 15 days, but others have been observed to remain in the nest up to 28 days. Even after the birds leave the nest they are fed at least some of the time by the adults.

The young birds are fed pigeon milk for the first few days and then a mixture of pigeon milk and whatever the adults may be eating. By the time the birds are fledged they are getting almost straight regurgitated adult food and the milk glands have started to resorb. Thus, by the time the young birds are independent the adults have little or no evidence of having milk glands.

In conducting checks of pigeon hunters in northern California during the September season of 1952, approximately 60 percent of the adult birds had active milk glands, indicating that many young squabs would die in the nest if both parents were shot. At this time California had a split season for pigeons, with the first half of the season running from September 16 through September 30 and the second half from December 17 through December 31.

The information listed above and the fact that birds were found nesting in Monterey County into late October resulted in a recommendation that the State be divided into a northern and southern zone, with an October season in the northern zone and a December season in the southern zone. This recommendation has since been put into effect.

SUMMARY

A nesting study of band-tailed pigeons was conducted in the Carmel area of Monterey County, California, from 1952 into 1955. A total of 26 nests was observed, all in tree locations. In all but one nest, clutch size was one egg. Nesting occurred as early as February and as late as October. Observations on a single pair of birds revealed three broods successfully fledged during the 1954 nesting season.

REFERENCES

Bendire, Charles
1892. Life histories of North American birds with special reference to their breeding habits and eggs. U. S. Nat. Mus., Spec. Bull. 1, p. 122-127.

Glover, Fred A.
1953. A nesting study of the band-tailed pigeon *(Columba f. fasciata)* in Northwestern California. Calif. Fish and Game, vol. 39, no. 3, p. 397-407.

Grinnell, Joseph
1913. The outlook for conserving the band-tailed pigeon as a game bird of California. Condor, vol. 15, no. 1, p. 25-40.

Grinnell, Joseph, Harold C. Bryant, and Tracy I. Storer
1918. The game birds of California. Berkeley, Univ. Calif. Press, p. 575-588.

Leopold, Aldo
1933. Game maangement. New York, Charles Scribner's Sons, 481 p.

Morse, William B.
1949. The band-tailed pigeon. Oregon St. Game Comm. Bull., vol. 4, no. 7. p. 1, 5, 7.
1951. Special report band-tailed pigeon season. Oregon St. Game Comm., 7 p.

Naether, Carl A.
1939. The book of the pigeon. Phila., David McKay Co., 258 p.

Neff, Johnson A.
1947. Habits, food, and economic status of the band-tailed pigeon. U. S. Fish Wildl. Serv., No. Amer. Fauna 58, 76 p.

Riddle, Oscar
1928. Studies on the physiology and reproduction in birds. Amer. Jour. Physiol., vol. 86, no. 2, p. 248-265.

Whitman, Charles Otis
1919. The behavior of pigeons. *In:* Carnegie Inst. of Wash., Publ. 257, vol. 3, 161 p.

SKELETAL DIFFERENCES BETWEEN DEER, SHEEP, AND GOATS[1]

MILTON HILDEBRAND
Department of Zoology
University of California, Davis

INTRODUCTION

Agencies charged with the enforcement of game laws occasionally must identify frozen, canned, or fresh dressed meat which is believed to be from illegal deer, but which is claimed by a defendant to be from domestic sheep or goat. New methods of blood analysis provide reliable identification in many instances, but determinations must sometimes be made from the skeleton. Only osteologists with access to an adequate collection of skeletons have been able to make the identifications. This paper has been written to enable any individual familiar with the skeleton and the fundamentals of statistics to distinguish bones of deer from those of sheep or goats without known skeletons for comparison.

Archaeologists have found it difficult to distinguish these domestic animals by pieces of broken bones. I have discovered no characteristic which separates all domestic sheep from all domestic goats, but the skeletons of the two animals differ significantly in the average form of many characters. Single features serve to identify many individuals, while combinations of characters make it possible to discriminate nearly any skeleton.

This study makes only a small contribution to the broader problem of finding generic differences between the postcranial skeletons of *Ovis* and *Capra*. A search for generic characters is in progress by Barbara Lawrence and one of her students.

I have drawn freely upon the paper on the skeletons of deer, sheep-goat, and several other animals published by Lawrence (1951) to assist archaeologists in the identification of bone fragments. My study, based on nearly twice as many skeletons, adds criteria not included in her paper, omits others found to be unreliable, and restates all criteria so that identifications can be made without comparative material.

Skeletons of 10 deer (*Odocoileus hemionus columbianus*), 8 sheep (*Ovis aries*), and 9 goats were examined. Most of the sheep were of the Corriedale breed, but the breed of several was not known; the goats included Angora (*Capra falconeri*) and one or more breeds of *Capra hirca*. Each sample included animals of both sexes and several age classes. Unless otherwise qualified, the ratios and descriptions presented apply to any animal old enough commonly to become a hunter's target, whether fully mature or not.

The skull and the bones of the feet are omitted because they are not preserved with dressed carcasses. Skulls of these animals are not difficult

[1] Submitted for publication March, 1955.

to distinguish; Glass (1951) describes several diagnostic characters. Ribs are not distinctive. Vertebrae (except the first two and the sacrum) are omitted, because it may be difficult to assign an isolated vertebra to its correct position in the spine; comparisons might therefore be invalid.

I am indebted to the Museum of Vertebrate Zoology of the University of California for the loan of 14 skeletons. Six skeletons were borrowed from the Department of Zoology, University of California, Davis, and one from the School of Veterinary Medicine, University of California, Davis. The remainder belong to the author.

Thanks are extended to R. D. Taber, School of Forestry, University of California, Berkeley, for valuable suggestions, and, particularly, to my wife, Viola M. Hildebrand, for taking all measurements, calculating ratios, and drawing the figures.

RELIABILITY OF IDENTIFICATIONS

A bone identification which will be used as evidence in court must have a high degree of certainty. Several considerations bespeak caution. Individual variation among different skeletons of the same kind of animal is greater than commonly realized. It is helpful to compare a bone of disputed identity with an illustration or known skeleton; however, no skeleton, or even single bone, can be expected to approximate average form in all characteristics. Differences may be detected from meager material, but the reliability of differences must be determined from larger collections. Few museums have as many skeletons of deer, sheep, and goats as were available to me, yet my samples were small. Ratios usually provide a more satisfactory means of analysis than do measurements of size, because the latter do not make adequate allowance for exceptionally large specimens, and are subject to more bias resulting from discrepancies in the sex and age composition of samples.

Many differences between the skeletons of deer and those of the domestic animals, and nearly all differences between sheep and goats, may be expressed only as variations in the average or typical expression of characters for which extreme values overlap. Most size differences are of this nature. Can reliable identifications be based upon such criteria? Yes, often they can if the method of analysis is valid.

Assume we have the scapula of a deer which a defendant claims is from a sheep. Elsewhere in this paper one can find three ratios which are useful in distinguishing deer from sheep by this bone (see $\frac{B}{D}$, $\frac{E}{C}$, and $\frac{G}{H}$, Figure 1). Suppose that our bone has a value for the first ratio which is two standard deviations from the mean for sheep ($\frac{d}{\sigma} = 2$). The probability that a member of a population would differ this much from the mean of the population can be read from a table of areas of the normal curve for various values of $\frac{d}{\sigma}$ (*e.g.*, Simpson and Roe, 1939, page 137). It is found that the chance a sheep taken from a flock at random would deviate 2σ or more from the mean for sheep is 4.5 percent. Stated another way, one sheep in 22 would differ so much from the mean for sheep in general.

Now if the second ratio is calculated, and is also 2σ from the mean, the chance that a sheep taken at random would at the same time differ this much from the mean values for each ratio is reduced to one in 69. (The ratios must be independent; the same measurement may not be used in each. If one ratio expresses the slender character of a bone it might not be independent from a similar ratio for another bone, because one animal could be delicate in all its skeleton.)

If our scapula chanced to deviate from the mean by a like amount in the third independent ratio, then the chance a particular sheep would simultaneously vary so much from all three average sheep proportions would be one in 205. By combining meager odds we would have thrown serious doubt upon the defendant's claim. The odds required to establish adequate identification is, for our purposes, a legal rather than an anatomical problem, but it will often be possible to do much better than in the above example.

Suppose the disputed scapula, claimed to be a sheep bone but really from a deer, chanced to have values of the three ratios cited which were equal to the actual means for deer. These differ from the means calculated for sheep by 3.92, 2.54, and 2.38 standard deviations, respectively. The chances that a particular sheep would vary so much from mean proportions of sheep are 1 in 10,000, 1 in 91, and 1 in 59, respectively, if the ratios are considered independently. The odds for the first ratio are such that the defendant's claim is seen to be fraudulent; however, to carry our example further, let us assume that the spine of the scapula is broken so that this ratio is not available. The odds of 1 in 91 and 1 in 59 remain. Taken individually these make the defendant's claim doubtful, but one would hesitate to convict on these grounds. However, the chance that a given sheep would simultaneously differ so much from mean sheep values for both ratios is only one in 357.

This analysis indicates that the bone is not from a sheep, but does not establish it as a deer bone. To do this one must show that its proportions are typical of deer. The text and illustration also provide other characteristics of the bone which should support our conclusion.

METHOD OF ANALYSIS

The significance of the product of several independent probabilities is calculated by an application of chi square analysis as explained by Kenall (1948, pages 132-133) and Fisher (1936, pages 105-106). The last of the above examples was solved as follows. For the ratios $\frac{E}{C}$ and $\frac{G}{H}$, the means for deer differ from those of sheep by 0.33 and 0.19, respectively. Dividing by the standard deviations for sheep and expressing the quotients as percentages we derive probabilities (P) of 0.011 and 0.017. From mathematical tables the natural logarithms of these parameters are -4.07454 and -4.50986. Substituting in the equation $\chi^2 = -2\Sigma \log_e P$, we find that the χ^2 value equivalent to the desired combined probability is 17.16880. Many χ^2 tables do not include such large values, but see, for instance, Pearson and Hartley (1954, Table 8), where it is found that with four degrees of freedom (two for each variable) the desired P is between 0.001 and 0.005. By interpolation (for method see Fisher, *loc. cit.*), the required probability is 0.0028, which may be expressed as odds of about 1 to 357.

The pages which follow give for each ratio the number of specimens in the sample (N), the arithmetic mean (M), and standard deviation (σ). From these parameters the reader can calculate standard errors of the mean, probabilities, and the significance of the product of several independent probabilities.

The animals studied may be assumed to have about equal variability in regard to any given ratio. Since the samples are small, it is desirable to apply to each animal a standard deviation which is a little greater than the average of the three calculated standard deviations. Thus for the pelvis ratio $\frac{E}{F}$ of sheep, $\sigma = 0.10$, but noting that in deer $\sigma = 0.29$, and in goats $\sigma = 0.22$, it would be preferable to use a value of about 0.22 for any of the three animals.

Measurements were made to the nearest millimeter.

SCAPULA

(Figure 1)

Deer and sheep can nearly always be distinguished by the scapula, and this bone often serves to set deer apart from goats, or goats from sheep.

The ratio of the length of the spine to its depth separates most deer from sheep and goats, but does not distinguish the domestic animals. Ratio $\frac{B}{D}$; deer: $N = 8$, $M = 4.90$, $\sigma = 0.32$; sheep: $N = 8$, $M = 3.92$, $\sigma = 0.25$; goats: $N = 8$, $M = 4.00$, $\sigma = 0.20$. The ratio tends to rise slightly with advancing age.

Dividing the depth of the bone's neck by its thickness gives a ratio which often distinguishes deer from sheep, but is of less value for discriminating deer from goats, or goats from sheep. Ratio $\frac{E}{C}$; deer: $N = 10$, $M = 1.60$, $\sigma = 0.13$; sheep: $N = 8$, $M = 1.93$, $\sigma = 0.13$; goats: $N = 8$, $M = 1.79$, $\sigma = 0.14$.

The ratio between the depth and breadth of the head of the scapula separates typical sheep from both deer and goats with reasonable assurance. Not many single characteristics of the body skeleton are better for distinguishing sheep from goats; their means differ by about 2.4 standard deviations. Ratio $\frac{G}{H}$; deer: $N = 9$, $M = 1.44$, $\sigma = 0.08$; sheep: $N = 8$, $M = 1.63$, $\sigma = 0.08$; goats: $N = 8$, $M = 1.43$, $\sigma = 0.04$. The ratio tends to be lower in large animals than in small (young) ones.

The relation between the length and width of the bone is nearly identical for deer and goats, but is sufficiently different for sheep so that individual animals having particularly low or high values of the ratio can be designated sheep or not sheep. Ratio $\frac{A}{F}$; deer: $N = 10$, $M = 1.61$, $\sigma = 0.06$; sheep: $N = 8$, $M = 1.45$, $\sigma = 0.11$; goats: $N = 8$, $M = 1.57$, $\sigma = 0.07$.

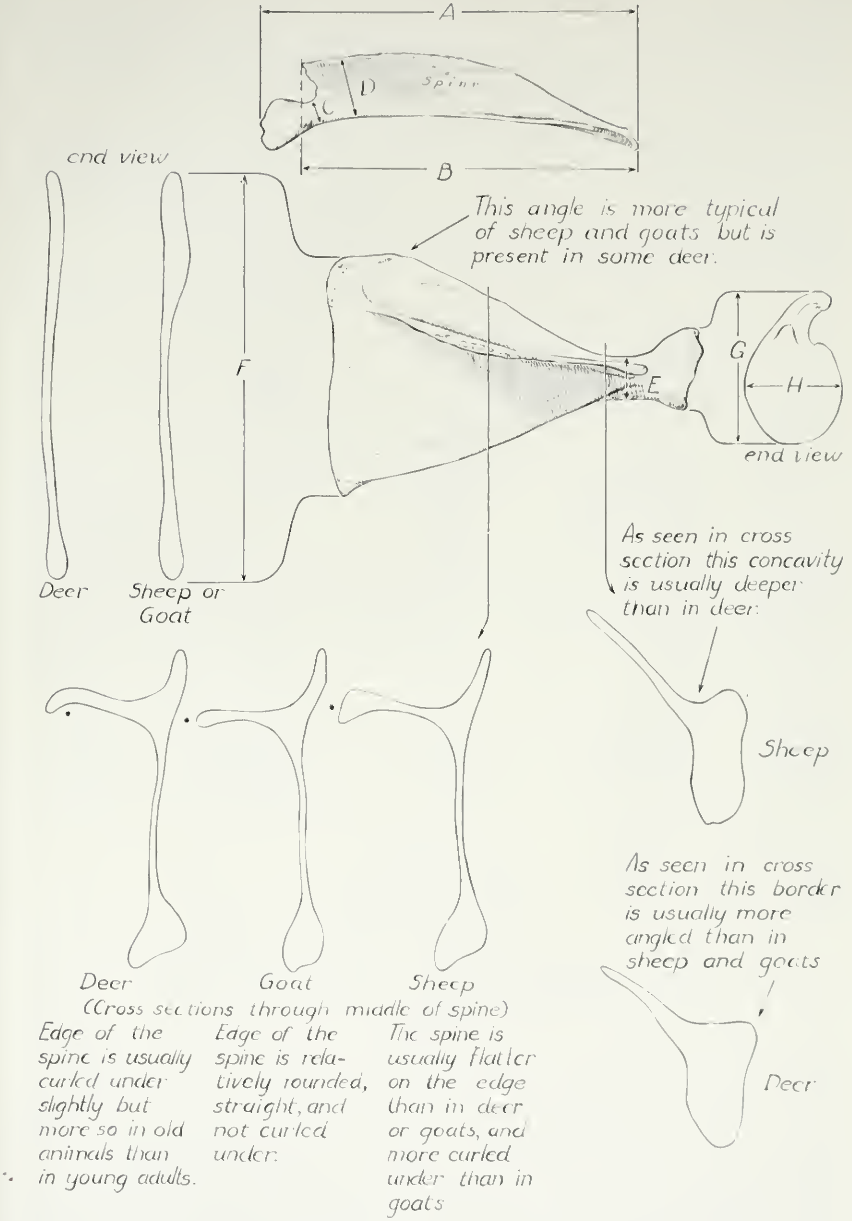

FIGURE 1. Right scapula, in lateral, anterior, and other views as indicated.

The figure illustrates differences between typical deer and sheep or goats in the form of the anterior border of the scapula, the shape of the edge of the spine near its midpoint, and the curvature and thickness of the vertebral border of the bone. Each of these characters is subject to individual variation and no one of them taken alone furnishes certain identification.

Absolute size of the shoulder blade, and straightness of its spine are not satisfactory characters for the identification of specimens.

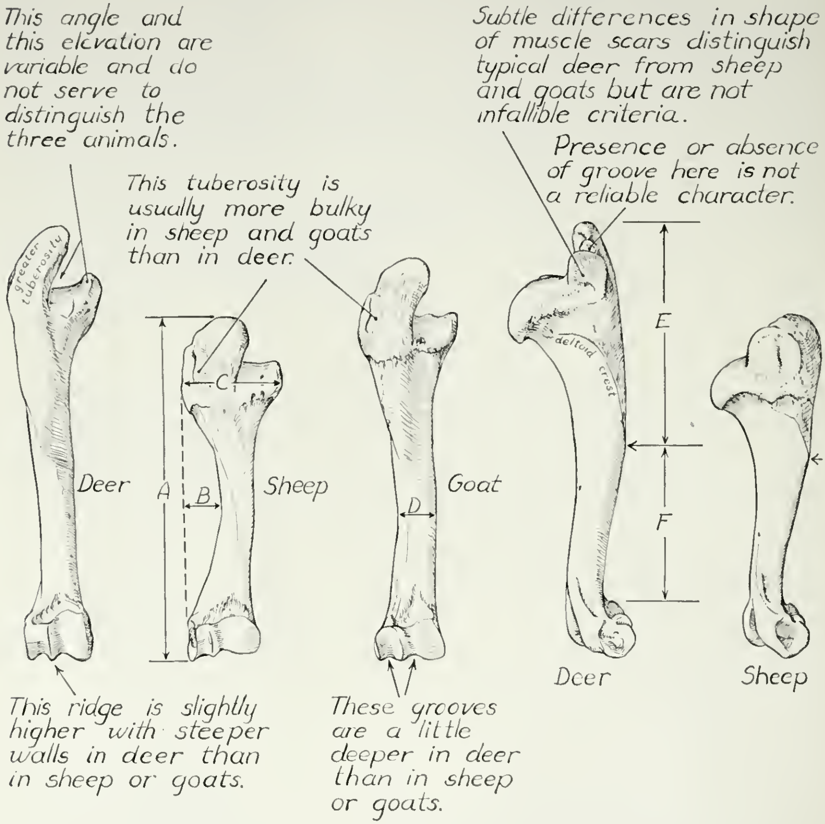

FIGURE 2. Right humerus, showing anterior and lateral aspects.

HUMERUS

(Figure 2)

It is always possible to distinguish deer from sheep by the humerus. In all characters studied the goat is intermediate between the other animals, but average values lie closer to the sheep. Goats and deer can usually be separated; sheep and goats cannot always be assigned.

The humerus is longer in adult deer than in sheep. Selecting animals old enough to have the distal epiphysis fused to the shaft, seven deer and eight sheep had bones averaging 198 and 149 mm., respectively. There was no overlap of values, but overlap would be expected in larger samples. Since the longer bones of deer are also straighter and more slender, length can be combined with other measurements to calculate very diagnostic ratios which are not dependent upon age determination, Of particular value is the ratio of over-all length to the measure of curvature shown in the figure. Ratio $\frac{A}{B}$; deer: $N = 10$, $M = 14.5$, $\sigma = 1.13$; sheep: $N = 8$, $M = 9.8$, $\sigma = 0.43$; goats: $N = 8$, $M = 11.1$, $\sigma = 0.70$. If the standard deviation for the sheep sample is taken more conservatively to be 0.9, then only about 15 sheep in 1,000 would be expected to have a ratio as high as 12.0, yet only about 12 deer in 1,000 would have so low a value.

The head of the bone, and its greater tuberosity, are heavier in sheep and goats than in deer. The difference, noticeable to the eye, can be expressed accurately by relating the breadth of the head to the length of the bone. Ratio $\frac{A}{C}$; deer: $N = 9$, $M = 4.55$, $\sigma = 0.24$; sheep: $N = 8$, $M = 3.46$, $\sigma = 0.17$; goats: $N = 8$, $M = 3.83$, $\sigma = 0.13$. Slightly higher values may be expected in young animals than in old.

Over-all length can be divided by least breadth of the shaft to provide an equally useful proportion. Ratio $\frac{A}{D}$; deer: $N = 10$, $M = 11.4$, $\sigma = 0.65$; sheep: $N = 8$, $M = 9.03$, $\sigma = 0.64$; goats: $N = 8$, $M = 9.71$, $\sigma = 0.32$.

A lateral view of the bone reveals the deltoid crest arching downward and forward under the head. The crest is related to muscle attachments and is more evident in fully mature animals. In sheep and goats it runs onto the anterior surface of the shaft relatively closer to the head of the bone than in deer, so the distance E, shown in the figure, is shorter than F; in deer E is equal to, or longer than F.

Differences in the distal articulatory surfaces, described by Lawrence (1951) and shown in Figure 2, were found reliable; others she recognized for the head of the bone were unreliable or too subtle to use with confidence in assigning the bones of my samples.

RADIUS

(Figure 3)

The radius serves to distinguish deer from sheep or goats, but does not characterize the domestic animals.

Deer have the longest radius. All adult animals in my sample had bones measuring 185 mm. or more in total length; four were 204 mm. or more. The bones of one sheep and one goat equalled 185 mm. and none reached 200 mm. Since deer do not have wider bones, a ratio of length to width of shaft is a more accurate index than actual length. Ratio $\frac{A}{B}$; deer: $N = 10$, $M = 10.85$, $\sigma = 0.62$; sheep: $N = 8$, $M = 8.59$, $\sigma = 0.41$; goats: $N = 8$, $M = 8.43$, $\sigma = 0.45$.

Lawrence (*op. cit.*) noted that the proximal head of the radius is relatively broad and flat in deer. This proportion was studied by dividing the breadth of the head by its maximum depth. The following figures show that there is so much overlap of values that only particularly low or high ratios should be considered significant. Ratio of C to depth of head; deer: $N = 9$, $M = 1.69$, $\sigma = 0.09$; sheep: $N = 8$, $M = 1.90$, $\sigma = 0.07$; goats: $N = 7$, $M = 1.81$, $\sigma = 0.08$.

Further differences between the animals are shown in Figure 3. A reliable feature is the presence in sheep and goats only of a projecting lip on the proximal end of the bone. The depth of a notch which accommodates a process of the ulna is less reliable; typical contours are

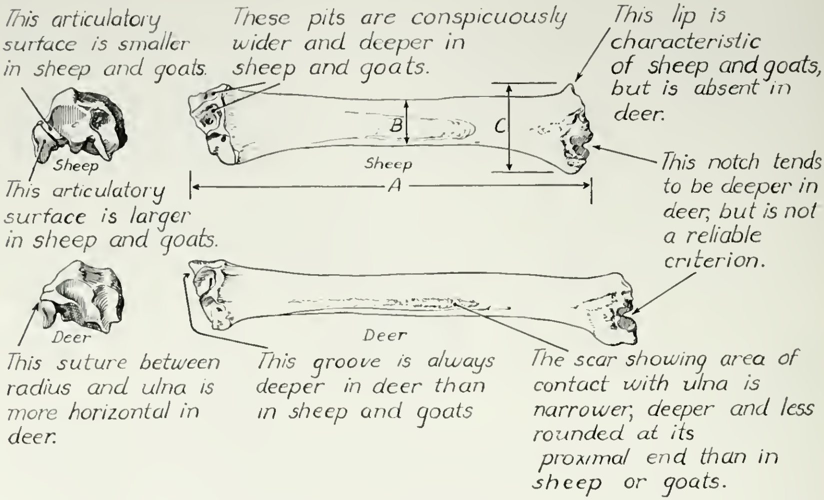

FIGURE 3. Left: distal end view of articulated right radius and ulna. Right: posterior surface of right radius.

illustrated. The characters figured at the distal head of the bone provide reliable identification of deer.

The radius and ulna remain free in all but old deer, but fuse in sub-adult sheep and goats. The area of contact between the bones, visible in disarticulated specimens as a scar on the shaft of the radius, is diagnostic.

ULNA

(Figure 4)

The ulna will nearly always set deer apart from the domestic animals. Several characters discriminate the goats of my sample from the sheep; I cannot say that these criteria would always be reliable.

Differences in proportions of the articulatory surface at the elbow joint may be expressed by relating two measurements shown in the illustration. Ratio $\frac{A}{B}$; deer: $N = 10$, $M = 0.93$, $\sigma = 0.05$; sheep: $N = 8$, $M = 1.05$, $\sigma = 0.04$. Since the mean for deer is three standard deviations from the mean for sheep, this ratio will often provide reliable identification. Measurement A could be taken on only two goats because in this animal the ulna is usually fused to the radius. Even in young specimens the suture between the bones is obscured, but the ulna seems to extend laterally farther under the radius than in sheep or deer. Values of the ratio for the two measurable goats were 1.25 and 1.39. Their mean is nearly seven standard deviations from that for sheep—a very striking difference.

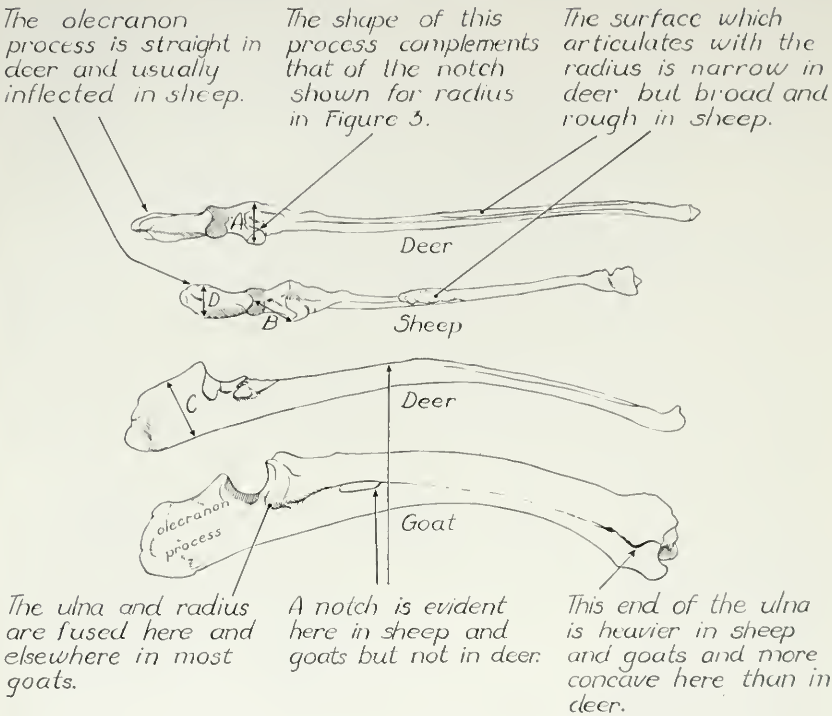

FIGURE 4. Above: anterior surface of right ulna. Below: right ulna in laterial view (ulna of goat fused to radius).

The olecranon process is deeper in relation to its thickness in deer than in the domestic animals. Ratio $\frac{C}{D}$; deer: $N = 10$, $M = 3.41$, $\sigma = 0.22$; sheep: $N = 8$, $M = 2.75$, $\sigma = 0.12$; goats: $N = 8$, $M = 2.65$, $\sigma = 0.25$. This process is in line with the shaft of the ulna in deer. It is usually straight in goats, and is usually, but not always, inflected in sheep. A bone with an inflected olecranon process could not be from a deer; one with a straight process could be from a sheep.

Diagnostic characters of the shaft are related to the greater tendency of the ulna and radius to fuse in the domestic animals. These features are shown on Figure 4, and differences seen at the distal end of the bone are illustrated there and on Figure 3.

METACARPAL

(Figure 5)

The goat is intermediate between deer and sheep in the expression of most skeletal characters, but the sheep stands between deer and goat for the most diagnostic features of the metacarpal. The bone offers sure identification of deer from goats in all but very exceptional instances, and often will distinguish sheep from the other animals.

The metacarpal and metatarsal are each formed by the fusion of two metapodials and are of similar appearance. The metacarpal is

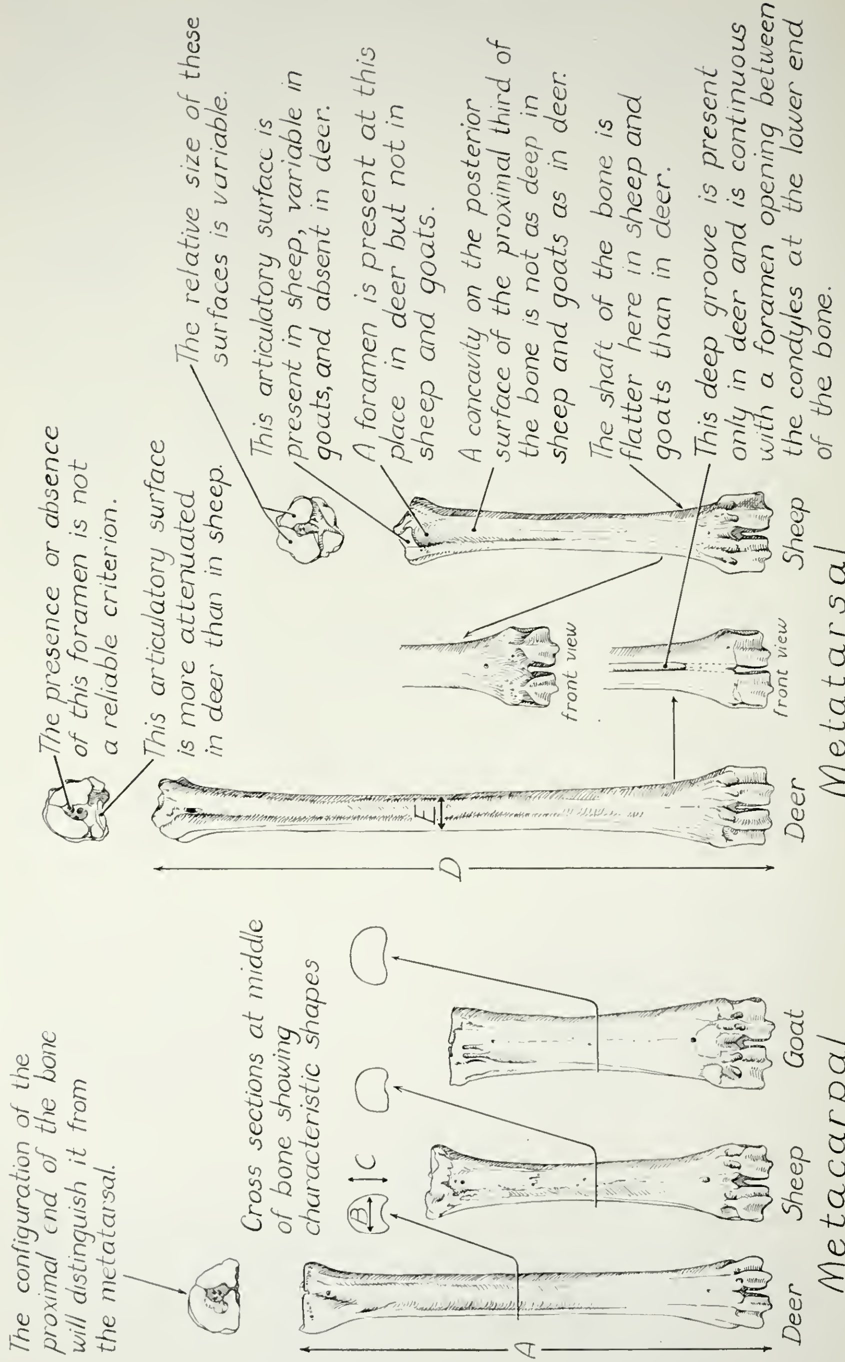

FIGURE 5. Right metapodial bones, figured in posterior and proximal end views except as noted.

recognized by its shorter length, and by the configuration of the proximal articulatory surfaces.

The metacarpal of deer is more slender than that of sheep, and this, in turn, is usually more slender than the metacarpal of goats. This proportion is analyzed by relating the length of the bone to its breadth. Ratio $\frac{A}{B}$; deer: $N = 9$, $M = 11.73$, $\sigma = 0.61$; sheep: $N = 8$, $M = 8.29$, $\sigma = 0.66$; goats: $N = 8$, $M = 6.46$, $\sigma = 0.54$.

A second proportion is equally useful. A cross section of the bone taken at the midpoint of its length shows a roughly circular outline in deer, but is compressed from front to back in sheep, and is even flatter in goats. Ratio $\frac{B}{C}$; deer: $N = 10$, $M = 1.07$, $\sigma = 0.07$; sheep: $N = 8$, $M = 1.43$, $\sigma = 0.09$; goats: $N = 8$, $M = 1.63$, $\sigma = 0.06$.

The illustration shows that at its midpoint the posterior surface of the shaft of the bone is conspicuously concave in deer, but only slightly concave in the domestic animals.

INNOMINATE

(Figure 6)

Many characteristics of the innominate distinguish deer from the other animals and often permit the distinction of sheep from goats. However, individual variation is striking and there are sexual differences, so caution must be exercised.

The public symphysis of deer is longer, but the ischium is also longer and more slender, so the ischial arch is relatively deeper and extends anterior to a line (straightedge) joining the anterior margins of the ischial tuberosities. In the other animals the arch just reaches, or falls short of, this line. By assuming that the line joining the anterior margins of these tuberosities is about at right angles to the pubic symphysis one can apply this criterion of identification to a single innominate bone not yet fused to its fellow. It should be noted that the symphysis is not always exactly in the sagittal plane, and that its plane may be difficult to determine for young specimens lacking the wedge-shaped ossification which will form in the posterior end of the suture.

To demonstrate that the pubric symphysis is longest in deer, its length can be divided by the least breadth of the symphyseal ramus of the ischium. The ratio is higher for immature animals. The length of the symphysis cannot be determined from some disarticulated pelves for which ossification at the posterior end of the suture is incomplete. Ratio $\frac{A}{B}$; deer: $N = 6$, $M = 6.58$, $\sigma = 1.52$ (but adding 3 partly grown animals $M = 8.06$, $\sigma = 2.76$); sheep: $N = 8$, $M = 3.71$, $\sigma = 0.39$; goats: $N = 9$, $M = 5.29$, $\sigma = 2.00$.

The relationship of two measurements of the ischium serves to determine most deer from the domestic animals. Ratio $\frac{C}{D}$; deer: $N = 6$, $M = 1.85$, $\sigma = 0.16$; sheep: $N = 8$, $M = 1.03$, $\sigma = 0.14$; goats: $N = 7$, $M = 1.19$, $\sigma = 0.14$.

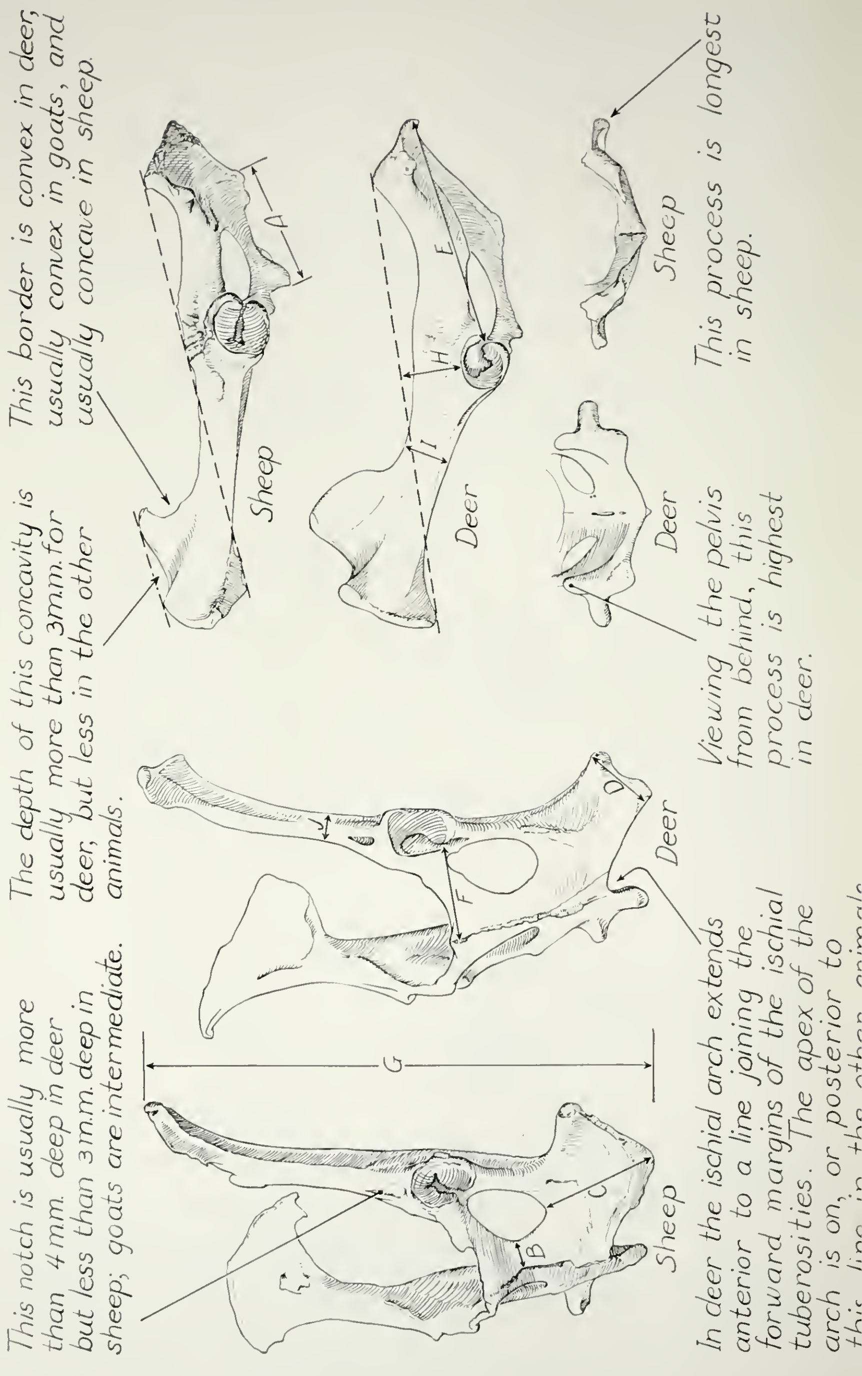

FIGURE 6. Pelvis, seen in right lateral, ventrolateral, and posterior views.

Deer have a narrower pelvis than do sheep or most goats. Measurements E and F are made from the center of the acetabular notch. Ratio $\frac{E}{F}$; deer: $N = 9$, $M = 2.72$, $\sigma = 0.29$; sheep: $N = 8$, $M = 1.74$, $\sigma = 0.10$; goats: $N = 8$, $M = 1.99$, $\sigma = 0.22$. This ratio tends to be smaller in adult females because in them the pubic bone is relatively long (R. D. Taber, MS).

When the ischial tuberosities are viewed from behind, a difference is seen between deer and sheep as illustrated; goats are intermediate.

At the level of the posterior margin of the obturator foramen the ramus of the ischium turns upward more in most deer than in the domestic animals. Measure H from the rim of the acetabulum to a straightedge placed as shown. Ratio $\frac{G}{H}$; deer: $N = 9$, $M = 9.06$, $\sigma = 1.59$; sheep: $N = 8$, $M = 18.30$, $\sigma = 3.90$; goats: $N = 8$, $M = 11.64$, $\sigma = 1.12$.

The pit on the ventral border of the ilium just anterior to the acetabulum is broader and deeper in typical deer than in sheep or goats, but there is some overlap. Measured from its inside lip the pit is usually more than 4 mm. deep in deer and may be as deep as 7 mm. In goats it is usually shallower than 4 mm., and in sheep usually less than 3 mm.

The ramus of the ilium is clearly flatter in deer than in sheep; goats are again intermediate. Ratio $\frac{I}{J}$; deer: $N = 10$, $M = 2.24$, $\sigma = 0.14$; sheep: $N = 8$, $M = 1.46$, $\sigma = 0.12$; goats: $N = 9$, $M = 1.78$, $\sigma = 0.15$.

The shape of the expanded portion of the ilium is useful in making determinations. In deer the margin is more convex on its posterior profile and more concave on its anterior profile than in the domestic animals. The anterior concavity can be measured as indicated in the illustration; its depth would rarely be less than 4.5 mm. in adult deer, or more than this in sheep or goats. Deer: $N = 7$, $M = 6.31$, $\sigma = 2.23$ (but excluding 2 immature animals $M = 7.64$, $\sigma = 0.90$); sheep: $N = 8$, $M = 0.69$, $\sigma = 0.55$; goats: $N = 8$, $M = 1.56$, $\sigma = 0.94$.

In my material a more or less evident notch marks the anterior border of the obturator foramen in deer and goats but not in sheep. This characteristic should be checked in additional specimens.

FEMUR

(Figure 7)

The femur is much less satisfactory than most of the other long bones for distinguishing the three animals. It is usually more slender in deer than in sheep. If the ratio of over-all length to breadth of shaft is less than 10.7, sheep is indicated; if it is over 12.0, deer is probable. Goat is intermediate and should not be identified on the basis of this proportion. Ratio $\frac{A}{B}$; deer: $N = 10$, $M = 12.47$, $\sigma = 0.57$; sheep: $N = 8$, $M = 10.23$, $\sigma = 0.49$; goats: $N = 9$, $M = 10.98$, $\sigma = 0.77$.

The angle between the head of the bone and its greater trochanter is usually less than 90 degrees in goats and deer, but more than 90

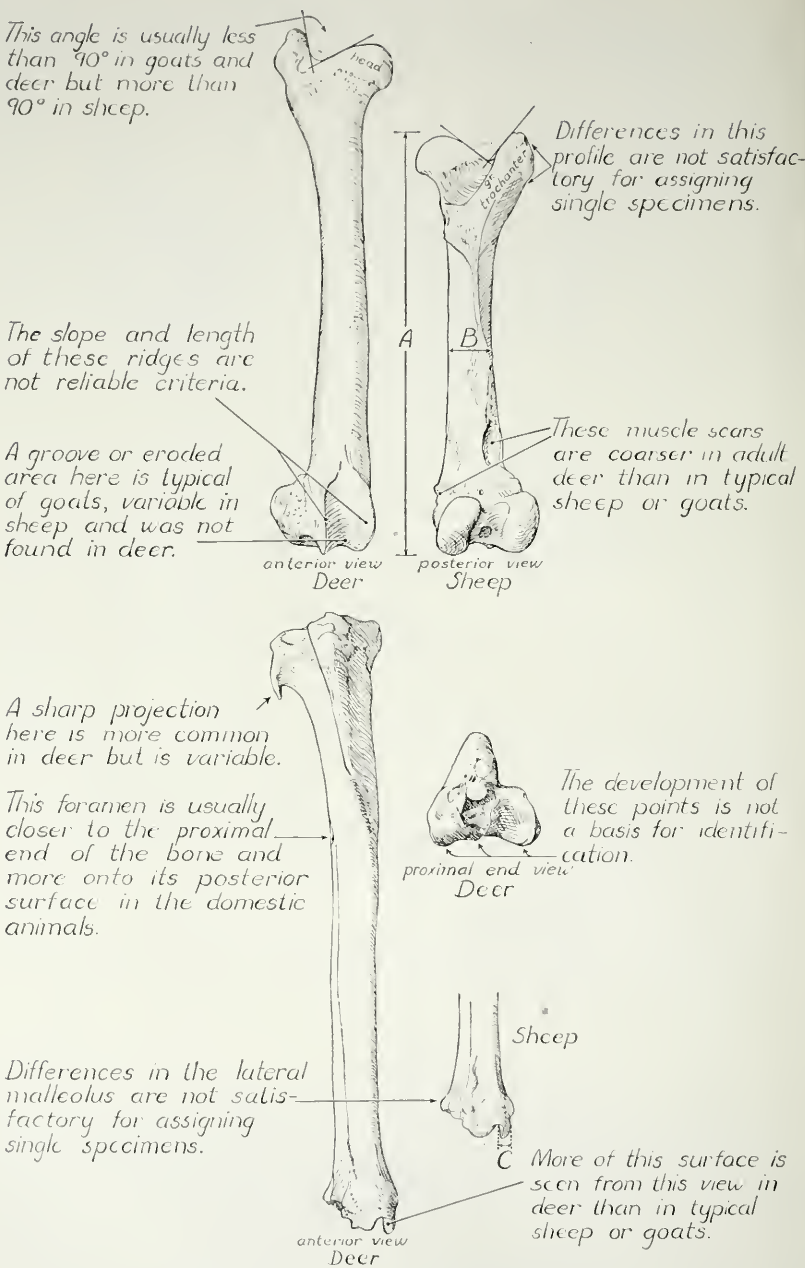

FIGURE 7. Above: right femur. Below: right tibia.

degrees in sheep. Specimens having the angle approaching 90 degrees should not be assigned on this basis.

Above the distal condyles are the supracondyloid crests which mark the origins of muscles which flex the foot. These scars, a ridge between them, and a concavity distal to the lateral scar are all more prominent in adult deer than in most sheep and goats; however, muscle scars are in general highly variable and I cannot recommend these features as a basis for identification unless age differences can be carefully considered.

All goats of my material have a crease or eroded area in the patellar groove. One sheep has a similar feature; otherwise it was absent from sheep and deer. This unexpected character may prove useful in distinguishing goats, but should be checked in more specimens.

TIBIA

(Figure 7)

Like the femur, the tibia offers few criteria for distinguishing the animals. It is usually longer in deer. If the over-all length is more than 27.5 cm. the bone is probably that of a deer (but a large goat tibia in my material measures 27.2 cm.) ; if it is less than 23 cm., and is from an adult animal (having epiphyses fused to the shaft) it is too short to be deer.

Lawrence *(op. cit.)* noted that when the tibia is seen in anterior view, the medial malleolus appears thicker in deer than in other animals (distance C in the illustration). This is true also of my material, yet its thickness correlates with, and is not appreciably more variable than, total bone length. Actual measurements for seven adult deer ranged from 4.8 to 6 mm., for eight sheep from 4 to 4.3 mm., and for eight goats from 3.7 to 4.8 mm.

Part of the smooth inner wall of the medial malleolus can be seen when the tibia is examined from in front. The extent of the surface exposed to this view differs with the animals. In no deer was less of the inner wall evident than in the specimen shown in Figure 7; selected sheep and goats show as much of the articulatory surface, but more often these animals are about as illustrated.

Unlike the other long bones, the tibia is not appreciably more slender in deer than in the other animals. The graceful curve of the shaft is more pronounced in the longer examples, and hence is more characteristic of deer than of the domestic animals.

There is a nutrient foramen on the lateral surface of the bone about one third of its length from the proximal end. In my specimens, as in those of Lawrence *(op. cit.)*, this foramen tends to be closer to the proximal end of the bone, and is also placed more onto its posterior surface in sheep and goats than in deer. However, the location of a nutrient foramen may be expected to vary and I agree that this feature does not provide reliable identification.

METATARSAL

(Figure 5)

The metatarsal of deer is so distinctive that it always sets this animal apart from sheep and goats. The domestic animals can sometimes be distinguished by this bone.

A conspicuous groove marks the anterior surface of the shaft in deer. One to one and a half inches from the distal end of the metatarsal, this groove terminates abruptly in a foramen which tunnels through the bone to emerge in the cleft between the condyles. These characters are entirely lacking in sheep and goats.

That deer have a more slender metatarsal can be demonstrated by the ratio of over-all length to breadth of shaft. Mean values for deer and goats differ by about eight standard deviations; only one animal in 10,000 would be expected to deviate from the mean for its species as much as the midpoint between the means of the two species. The sheep is intermediate in its proportions, as was true also for the corresponding metacarpal ratio. Ratio $\frac{D}{E}$; deer: $N = 9$, $M = 14.34$, $\sigma = 0.51$; sheep: $N = 8$, $M = 10.26$, $\sigma = 0.64$; goats: $N = 8$, $M = 8.30$, $\sigma = 0.74$.

The metatarsal of deer is much the longest. My material suggests that only in exceptionally large sheep or goats would the bone measure as much as 16 cm. Even juvenile deer usually have a longer metatarsal, and if the distal epiphysis has fused to the shaft the bone may be expected to exceed 18 cm.

On the posterior surface of the bone, about half an inch from its proximal end, there is an evident foramen in deer which is not found in the other animals.

The metatarsal is formed by the fusion in embryonic life of the third and fourth metatarsals of the ancestral compliment of five bones. The second has become a vestigial bone accommodated in sheep by a smooth articulatory surface on the posterior face of the head of the metatarsal (see illustration). This surface could be identified in only four of nine goats examined, and was not seen in deer.

It was shown that the shaft of the metacarpal is somewhat rounded in deer, but more compressed in sheep and, particularly, in goats; there was also a deeper concavity on the posterior surface of the shaft in deer bones. These features apply also to the metatarsal, but are here much less marked.

SACRUM

(Figure 8)

The sacrum of deer differs from that of the other animals in the typical expression of half a dozen characters.

The transverse processes of the first sacral vertebra extend anterior to the centrum in all deer, but only in few examples of sheep and goats. It may be concluded that if these processes do not extend anterior to the centrum the specimen is not deer.

If a straightedge is placed on the lower surface of the sacrum, across its long axis, and at the level of the center of the fourth vertebra, it is seen that the transverse processes extend ventral to the centrum in deer, but not in sheep or goats (see cross sectional drawings in the illustration). The ventral surface of this centrum is relatively flat in deer, and usually convex in the domestic animals.

The vertebrae of the sacrum are more solidly fused together in adults of deer than in sheep or goats. Sacral vertebra four is often free of the third, or is loosely joined to it by a partly open suture in the domestic

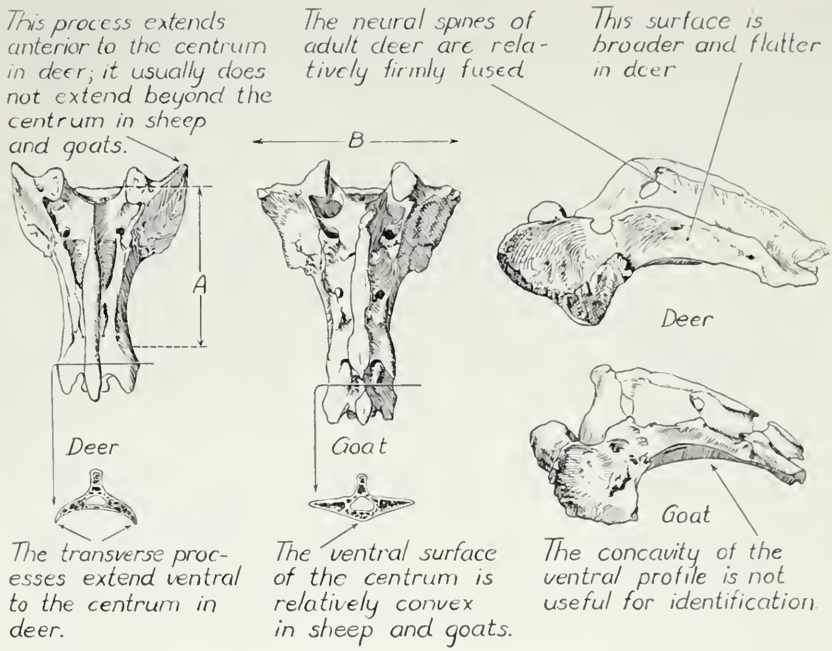

FIGURE 8. Sacrum, shown in dorsal, right lateral, and cross-sectional views.

animals. This articulation has fused in all deer old enough to have a closed suture between the second and third sacral vertebrae.

Neural spines are also more coalesced in deer than in the other animals. If the spines are joined as solidly as those figured for deer, the bone is certainly from that animal; if they are as independent (or more so) than shown for goat, then the specimen will be sheep or goat; if the degree of fusion of the spines is intermediate, identification should not be made on this basis.

Sacral vertebrae two and three tend to have their transverse processes fused into a broader and flatter surface in deer than in the other animals. The sacra figured are typical, but many specimens will be intermediate between those shown and not assignable by this character.

The bone is shorter in relation to its breadth in deer and goats than in sheep. However, caution is necessary in using this proportion because one or both ilio-sacral joints may be atypical, thus altering the width measure, and individual variations is marked. The last of the four vertebrae which usually make up the sacrum is often free of the others, and is excluded from the measure of length. Ratio $\frac{A}{B}$; deer: $N = 9$, $M = 0.93$, $\sigma = 0.08$; sheep: $N = 6$, $M = 0.83$, $\sigma = 0.03$; goats: $N = 7$, $M = 0.95$, $\sigma = 0.05$.

Wide individual variation was noted in the concavity of the ventral profile of the bone, so this is not a criterion for species identification.

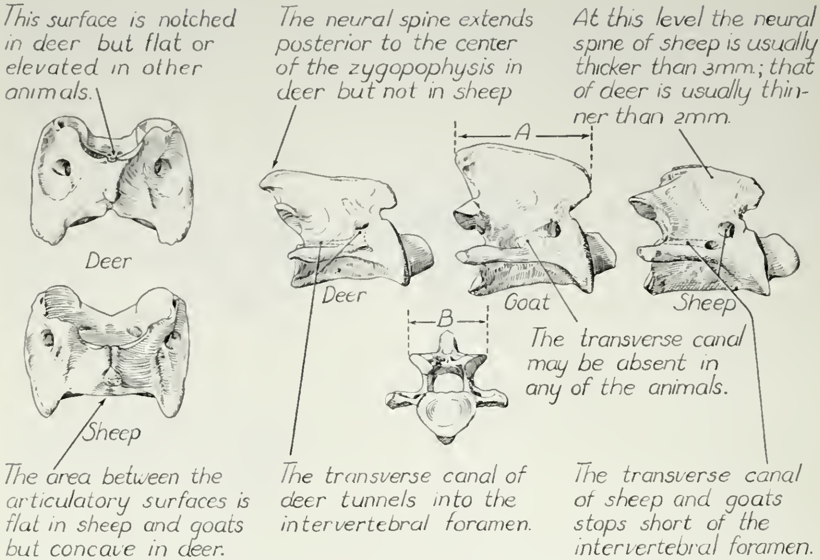

FIGURE 9. Left: ventral surface of atlas vertebra. Right: axis vertebra shown in right lateral and posterior aspects.

ATLAS

(Figure 9)

Only one character of the atlas vertebra serves to distinguish deer from the other animals. When the bone is seen in either ventral or anterior view, a distinct notch or concavity is seen between the anterior articulatory surfaces in all deer. In sheep and goats these surfaces crowd closer together and are separated by a flat area or, more often, by a distinct elevation. A notch also separates the posterior articulatory surfaces of the bone in deer; in the domestic animals this area is flat.

AXIS

(Figure 9)

With few exceptions the axis vertebra can be used to discriminate deer from sheep. The goat falls between the other animals in most features and cannot always be assigned.

Deer have the longest neural spine (anterior to posterior); sheep have the shortest. In the former, the spine extends posterior to the level of the centers of the zygopophyses, while in sheep it does not reach so far.

Dividing the length of the neural spine by the breadth across the zygopophyses provides a useful proportion. Ratio $\frac{A}{B}$; deer: $N = 8$, $M = 1.88$, $\sigma = 0.26$; sheep: $N = 8$, $M = 1.06$, $\sigma = 0.07$; goats: $N = 6$, $M = 1.37$, $\sigma = 0.48$.

The neural spine of deer is also thinner and more blade-like. At its center it is usually not over one mm. in thickness (but $4\frac{1}{2}$ mm. in one old buck). The spine of sheep is usually more than 4 mm. thick, and in my sample never less than 3 mm.; goats are intermediate but approach deer closer than sheep.

The transverse canal was absent in half of my sheep skeletons, a third of the goat bones, and was wanting on one side of one deer axis. When present it offers a reliable means of setting deer apart from the domestic animals, for in deer the canal runs forward to join the intervertebral foramen, while it terminates short of this foramen in the other animals.

SUMMARY

To enforce game laws, it is sometimes necessary to determine if certain bones at hand could be from a deer. The parts of the skeleton likely to be used as evidence of illegal hunting are those retained in a dressed carcass. Sheep and goats are most often related to deer in this way, and archaeologists sometimes have occasion to distinguish sheep from goats using only skeletal fragments. This paper describes diagnostic features of 12 bones from limbs, girdles, and spine which nearly always permit certain discrimination of deer from these domestic animals, and often set sheep apart from goats.

Clear-cut criteria for identification are best. Thus a large foramen is found in the metatarsal bone of deer which is never present on bones of the other animals. Such characters are welcome but few; differences in relative size or proportions must usually suffice. Compared to sheep, deer have a more slender femur, a thicker olecranon process, and deeper trochlea. Measurements are more concise than adjectives in describing differences of this sort, and ratios are preferable to linear measures, because they are not vitiated in exceptionally large or small animals. Individual variation is striking and many species differences can be expressed only as variations in the average form of characters for which extreme values overlap. Statistical analysis is therefore desirable to establish the reliability of determinations. By calculating the significance of the product of several independent probabilities it is often possible to combine relatively small odds to establish reasonably certain identifications. The method is described.

Deer can nearly always be distinguished from the domestic animals by the scapula, humerus, radius, and metatarsal; the axis, atlas, sacrum, and ulna are usually satisfactory. The femur and tibia are least distinctive. Goats are intermediate between the other animals in most skeletal characteristics, but differ markedly from deer in features of the metacarpal. Sheep are best set apart from goats by characters of the metacarpal, scapula, pelvis, and ulna.

REFERENCES

Fisher, Ronald Aylmer
1936. Statistical methods for research workers. 6th ed., rev. and enl. Edinburgh, Oliver and Boyd, 339 p.

Glass, B. P.
1951. A key to the skulls of North American mammals. Minneapolis, Burgess Publ. Co., 54 p.

Kendall, Maurice George
1948. The advanced theory of statistics. London, Charles Griffin and Co., Ltd., vol. 2, 521 p.

Lawrence, Barbara
1951. Post-cranial skeletal characters of deer, pronghorn, and sheep-goat, with notes on Bos and Bison. Pt. 2. Harvard Univ., Peabody Mus. Amer. Archaeol. and Ethnol. Papers, vol. 35, no. 3, p. 9-43.

Pearson, Egon Sharpe, and H. O. Hartley (eds.)
1954. Biometrika tables for statisticians. London, Cambridge Univ. Press, vol. 1, 238 p.

Simpson, George Gaylord, and Anne Roe
1939. Quantitative zoology. N. Y., McGraw-Hill Book Co., Inc., 414 p.

NOTES

WHITE STURGEON WITH SEVEN ROWS OF SCUTES

The primary diagnostic character generally given for the family Acipenseridae is the five rows of bony plates (scutes, shields) covering the body: one dorsal, two laterals, two ventrals. As a rule numerous irregularly placed stellated prickles occur between the rows of scutes but are of a different shape and also, because of their much smaller size, are rather inconspicuous.

In the course of tagging of white sturgeon (*Acipenser transmontanus*) in the Columbia River at Prescott, Oregon, during the winter of 1950 and later, a few individuals of this species which possessed not five, but seven, rows of scutes were found. The additional rows occurred on each side between the dorsal and lateral rows (Figure 1). In some individuals the additional scutes were about the same size as the lateral ones and in a few others were somewhat smaller. In the Columbia River specimens the number of scutes in the additional rows was between 20 and 30 and intermediate between the number of dorsal and lateral scutes.

At least two dozen such unusual specimens were secured by Mr. C. E. Graham, Prescott, Oregon, moorage owner, Dr. M. A. Kenney, Rainier, Oregon, and the author. Mr. Graham, an old-time sturgeon fisherman in the Columbia River, stated that he had seen seven rows of scutes on white sturgeon before. The author has examined a large specimen of white sturgeon with seven rows of perfect scutes caught

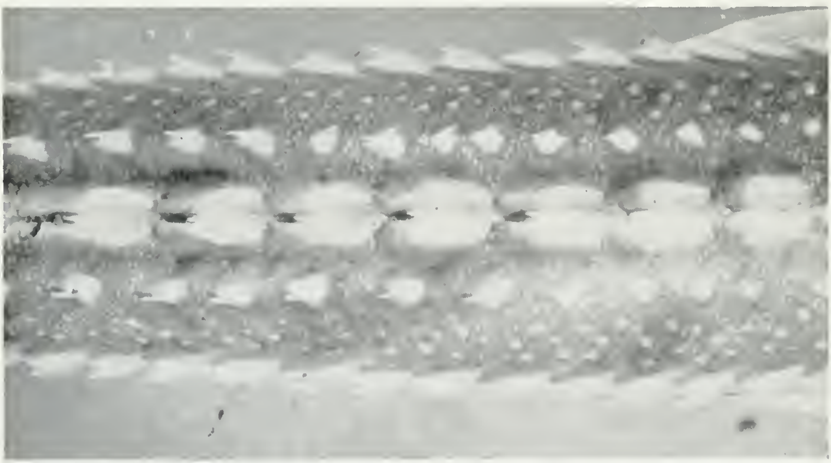

FIGURE 1. Dorsal view of a white sturgeon from the Columbia River, Oregon, showing the two extra rows of scutes between the normal dorsal and lateral rows. *Photograph by the author.*

above Bonneville Dam by Mr. John Broughton, a Columbia River commercial fisherman, who also stated that he had caught several such fish before.

Out of approximately 7,000 white sturgeon examined and tagged in the Columbia River, about 25 fish or approximately 0.3 percent possessed seven rows of scutes. During the tagging of 1,003 white sturgeon in the Sacramento-San Joaquin Delta in 1954 by the California Department of Fish and Game, one fish with seven rows of well developed scutes was found (letter from J. B. Kimsey, March 15, 1955). Whether or not such individuals occur among the other representatives of the sturgeon family is not known.—*Alexander D. Bajkov, 6820 Jennings Avenue, Milwaukie, Oregon, June, 1955.*

A RECORD OF AN ATTACK BY A LEOPARD SHARK (*TRIAKIS SEMIFASCIATA* GIRARD)

On February 10, 1955, while exploring the bottom of Trinidad Bay in Humboldt County, California, a professional diver, John Adams, was repeatedly attacked by a fish identified as a three-foot leopard shark. Adams was equipped with an Aqua-Lung and was moving slowly along the bottom when he was struck squarely on the left side of the head by the fish. Just after the first strike Adams noticed that his nose had been bleeding. Some of the blood was draining into his mouth from whence it was being exhaled through the exhaust tube of the ''lung''. These blood-tainted bubbles from the exhaust were apparently detected by the shark, since it was next observed making a pass at the rising stream of bubbles, snapping at them as it turned belly up. A few seconds later a strike, made directly at Adams' face, was warded off and the fish disappeared.

This incident should serve as a warning to divers that even small and ordinarily harmless fishes may become dangerous under circumstances when the diver assumes to the fish a suggestion of food.—*John W. DeWitt, Humboldt State College, Arcata, California, May, 1955.*

SECOND KNOWN SHARK ATTACK ON A SWIMMER IN MONTEREY BAY

On December 7, 1952, a young man swimming at Pacific Grove, California, was attacked by a large shark and died as result of his injuries (Bolin, 1954). A second attack, this fortunately not fatal, occurred at almost the same spot at about noon on February 6, 1955. The latter incident so aroused some of the citizens of Pacific Grove that a $50 reward was offered for the first man-eater (*Carcharodon carcharias*), also known as great white shark, to be taken in Monterey Bay. On March 6, one month after the second attack, Jack Daniels and Bill Tomlinson, who were hunting basking sharks off Moss Landing, shot and killed a 10½-foot *Carcharodon carcharias* which was feeding on a dead basking shark that they had anchored offshore. The fishermen received the reward when they brought the man-eater to Pacific Grove, and it was then kindly given to the Hopkins Marine Station for study.

The victim of the second attack, James F. Jacobs of Santa Cruz, California, received only minor scratches to his right foot and shin and bruises on both legs. However, the right front ankle region of his black rubber skin diving suit was torn extensively, and the foot of the garment hung only by a small piece of the heel. The left leg of his suit had two tears. In the attack, the shark removed two wool socks from Jacobs' right foot and cut two holes in the outer wool sock on the left one. The shark tore away the heavy rubber swimfin from the right foot, and Jacobs, who saw it drop, has the impression that it was cut into two pieces. The left swimfin, which was still on his foot when he was pulled from the water, received scratches and deep cuts from the animal's teeth. The deepest cut, a narrow slash with parallel marks of tooth serrations on its walls, was about three-eighths inch deep; a slightly curved gouge, about one-half inch long, was one-eighth inch wide and a little over one-eighth inch deep. These values seem small until the resilient nature of gum rubber is considered.

In attempting to reconstruct the attack from the information given by Jacobs and studying the left swimfin, it appears that the major scratches and gashes were made only by the lower teeth. The upper jaw possibly was kept from occluding with the lower by the angle of attack and the bulk of the swimfin. It is approximately 20 inches long, tapering from three and one-half inches to one-half inch in depth, and from 4 to 10 inches in width. There are three reinforcing ribs: one on each edge and one in the midline. The deepest portion of the swimfin, if it were pushed far into the angle of the jaws, could possibly keep the mouth open and the weaker posterior teeth could not cut through the heavy rubber. The right swimfin was probably cut in two by the stronger anterior teeth when the shark released its initial hold and allowed the swimfin to slide forward in the mouth to the region of greatest cutting power.

The striated markings which characterized the cut surfaces of the swimfin pointed to either *Carcharodon carcharias* or the blue shark, *Prionace glauca*, as the probable aggressor. These are the only two large, local sharks with marked serrations along the tooth margins. When the marks on the swimfin were compared to the teeth and jaws of the 10½-foot man-eater which was landed March 6, the serrated tooth edges matched closely the striations of the major gashes, and the cuts were in almost perfect alignment with the teeth of the lower jaw, the teeth being closer together than the marks, indicating that if the attacker had been a man-eater it was probably greater than 10½ feet in length. This tends to corroborate Jacobs' statement to the Pacific Grove police that the depth behind the eye was 2½ feet and the length was 15 to 20 feet. These proportions fit *C. carcharias* better than *P. glauca*, which, according to the figure in Bigelow and Schroeder (1948), would have to be about 30 feet in length to achieve the same depth behind the eye. Jacobs further stated that the shark was blue on top and whitish-gray underneath, colors which better fit the blue shark but are also a color phase (slate-blue) of the man-eater. When shown a series of plates in "California Sharks and Rays" (Roedel and Ripley, 1950) Jacobs unhesitatingly identified *C. carcharias* as his attacker. While *P. glauca* cannot be cleared completely as the culprit, the circumstantial evidence points with a fair degree of certitude to *C. carcharias* in this instance.

The attack on Jacobs took place as he was swimming in water 20 feet deep, about one-quarter mile from shore, southeast of the tip of Point Aulone (known locally as Lover's Point). A moderate surf was running, with waves to a height of five feet, the water was clear, and the day sunny with scattered clouds. Unfortunately, the water temperature was not taken after the attack; however, the temperature at the Hopkins Marine Station, approximately three-quarters of a mile to the southeast, was 52.9 degrees F. at 9 a.m., PST. The temperatures of the previous week varied between 52.0 degrees F. and 53.6 degrees F., and these temperatures are about average for the season. During the preceding week, strong northwesterly winds, not unseasonable for February, had occurred.

While the attack took place only a short distance from the one in 1952, the physical conditions do not closely approximate those described by Bolin. Then the temperature was 55.2 degrees F. at the Hopkins Marine Station, the surf reached a height of eight feet, the water was murky with phytoplankters and runoff from the land, and the day was characterized by intermittent sun. It appears that there are no strong correlative physical factors which could have induced the attacks, and the evidence seems to point to random movements of a large predator acting independently of local physical conditions.

A possible common factor in both attacks might be the presence of blood or blood serum in the water. In the case of the fatal attack, the victim had been "body surfing" (riding on the waves by the use of the outstretched body as a surfboard) and coming in over rocks. George Fraley (a former commercial diver and president of the "Sea Otters," a local skin diving club) had talked to the victim and noted that his body had numerous welts and scratches caused by this activity. Fraley warned the boy that the presence of blood in the water might lead to danger from a large predator. Bolin examined the body of the victim after the attack and found no marks other than those caused by the shark. However, the cuts of the teeth could have so marred or overshadowed any breaks in the skin present before the attack that they would not have been apparent at the time of examination.

In the case of the second assault, Jacobs had speared a two-foot cabezon (*Scorpaenichthys marmoratus*) and had placed his bleeding catch in a web-lined float. He immediately resumed fishing and scouting for another kill, when the attack took place. This was 10 to 20 minutes after he had speared his fish. He was close to his float when he felt the strike and pressure on his feet. His first thought was that a friend was playing with him, but, as the pressure increased, he looked down and saw the shark. He kicked, and the shark left, apparently content with the swimfin and the two socks from his right foot. Why the shark did not return to pursue the attack has caused some conjecture. Even though Jacobs was soon aided by other swimmers and removed from the water into a rowboat, there was still time for further assault. Possibly his complete rubber suit prevented the shark from sensing any animal odors when it made its attack, the flavor of the rubber garments being far different from the fish blood it had detected and followed to the swimmer. The victim of 1952, on the other hand, had been garbed in swimming trunks and swimfins, and the seepage of his scratches could have been the attractant. In this case, the shark returned repeatedly to slash and tear at his prey, probably lured time after time by wound seepage. It is noteworthy, in this connection, that all the wounds were concentrated on the lower extremities; no blemishes appeared above the waist.

There have been two other instances of large sharks approaching skin divers who have speared fish in the Monterey area. George Fraley told me that on two occasions in November, 1954, members of the "Sea Otters" spearfishing off the Hopkins Marine Station were approached by sharks. They identified one as the man-eater, *C. carcharias*, and the other as the salmon or mackerel shark, *Lamna ditropis*. These men have trained themselves in underwater observation, and I believe their observations to be accurate.

From these experiences and the incident mentioned by DeWitt (1955), it appears that shark attacks pose a real threat to the skin diving enthusiast. There is strong probability that with the present increase of spearfishing along our coast the number of attacks by sharks will increase. Those individuals who indulge in this sport should exercise every precaution to avoid seepage of blood, fish juices, or other attractants.

REFERENCES

Bigelow, Henry B., and William C. Schroeder
1948. Fishes of the western North Atlantic. Chapt. 3. Sharks. Sears Found. Mar. Res., Mem. 1, p. 59-546.

Bolin, Rolf L.
1954. Report on a fatal attack by a shark. Pac. Sci., vol. 8, no. 1, p. 105-108.

DeWitt, John W.
1955. A record of an attack by a leopard shark (*Triakis semifasicata* Girard). Calif. Fish and Game, vol. 41, no. 4, p. 348.

Roedel, Phil M.
1953. Common ocean fishes of the California coast. Calif. Dept. Fish and Game, Fish Bull. 91, 184 p.

Roedel, Phil M., and Wm. Ellis Ripley
1950. California sharks and rays. Calif. Div. Fish and Game, Fish Bull. 75, 88 p.

—*Thomas N. Fast, Hopkins Marine Station of Stanford University, Pacific Grove, California, May, 1955.*

REVIEWS

The Complete Book of Striped Bass Fishing

By Henry Lyman and Frank Woolner; A. S. Barnes and Company, New York, 1954; xii + 242 p., illustrated with 78 half-tone and line drawings. $4.

This volume is a welcome addition to the growing series on striped bass angling. Although the jacket claims it is the first full-length book devoted exclusively to this subject, several others have preceded it, including one on Atlantic striper fishing by Rodman (1944), and another on Pacific Coast striped bass fishing by Leon Adams (1954).

Fishing tackle of all types for every variety of Atlantic Coast striper angling is described in detail. Good photographs are generously scattered through the text, along with a series of pen and ink drawings illustrating methods of rigging tackle and using various baits.

The book is well written and well arranged. It reflects the authors' strong interest in striped bass angling in many pleasant ways.

The many details about specialized Atlantic Coast angling will be of only passing interest to most Pacific Coast anglers.

It is unfortunate, in some respects, that the authors have given so little attention to the bass themselves and to the various problems of striper management and conservation. Many of their readers would probably have welcomed more information along those lines.—*Alex Calhoun, California Department of Fish and Game.*

Homemade Fishing

By Verne E. Davison; The Stackpole Co., Harrisburg, Pa., 1953; xvii + 205 p., illus. $4.50.

The author has been closely connected with small fish pond research in his 12-year association with the Oklahoma Fish and Game Commission, and more recently in his capacity of regional biologist with the Soil Conservation Service in the Southeast. In this area he fell under the influence of Prof. Homer S. Swingle and Dr. E. V. Smith, in their application of agricultural methods to aquiculture. His pond management principles stem from the findings at the Alabama Polytechnic Institute.

Although somewhat optimistic in his stand that anyone can create "the world's best fishing pond" in his own backyard through proper management, Mr. Davison does impart some practical advice regarding pond site selection, water supply, initial stocking, the ensuing population composition changes, the fishing, and physical and chemical (through fertilization) management of the water. Basic land agricultural principles, as related to the hydrobiology of pond fish production, are clearly explained. Pond owners are encouraged to fish their ponds heavily, discourage rooted aquatic plants, fertilize with mineral compounds, and use some control over the population composition of their pond. In this latter instance the author would sanction the use of seines and derris to control this crop.

The combination of largemouth black bass and bluegill is designated as the only satisfactory one for small ponds, with words of warning against the use of crappie and bullheads. We know now that other combinations with forage minnows have been successfully tried. The writer does discuss, briefly, coldwater ponds stocked with rainbow trout. Brackishwater or saltwater pond culture is discouraged.

I think that many of Mr. Davison's recommendations to the small pond owner are exemplary, and some could be applied to other warmwater fish management practices. This is a book that will start many of us dreaming of a "fishin' hole" of our own.—*P. A. Douglas, California Department of Fish and Game.*

Ti'ap'a and Its Culture

By Pierre Chimits. *In:* FAO Fisheries Bulletin, vol. 8, no. 1, Jan.-Mar., 1955; p. ii, 1-33, illus.

Tilapia is a relative newcomer to the field of fish cultural literature. Even in the Far East, where pond culture has existed for thousands of years, this genus has been used only since about the time of World War II. Its tolerance of high temperatures and relatively high levels of salinity, and its great adaptability as a fish for pond culture, has caused its serious consideration for introduction into problem waters in this country and abroad. Only three of the approximately 90 known species have been studied extensively from the fish cultural point of view.

This annotated bibliography, with its 94 citations from the world literature, is the most complete that this writer has seen. It has extensive comments under three general headings in addition to the bibliography: I. Tilapia in Open Waters, II. Biology of the Principal Species Raised in Fish Culture, and III. Methods of Raising Tilapia.

The members of the Tilapia group are warmwater fishes that do best when temperatures range near 90 degrees F. They spawn at about 70 degrees F. and die if temperatures fall below about 50 degrees F. They are well suited for the tropics and since much of this area is in perpetual need of more protein we are destined to hear more and more of Tilapia culture. Their use in the United States will be restricted largely by their temperature requirements and sporting qualities. We have not yet reached the point where extensive pond fish industries are necessary to provide protein.

This interesting and timely paper is recommended to anyone interested in finding out more about Tilapia. A useful note by the editor of the FAO Fisheries Bulletin aids the reader further by directing him to the world's principal libraries and documentation centers where the papers listed in the bibliography may be obtained.—*J. B. Kimsey, California Department of Fish and Game.*

Streams, Lakes, Ponds

By Robert L. Coker; University of North Carolina Press, Chapel Hill, North Carolina, 1954; xviii + 327 p., illus. $6.

This is a book for which many whose major interest is in the management of our surface water resources have waited. It brings together in one concise volume a wealth of information concerning the complex picture of life existing in our streams, lakes, and ponds. The author has reflected his wide personal knowledge of and experience with the subject and has portrayed it in an interesting and readable form.

The book is written in three parts in a natural sequence—Water and Its Content, Running Water, and Still Water—each of which is a separate entity, but which together form a well coordinated and concise story of life in fresh water (as opposed to life in the sea).

The chapter on stream pollution is very interesting and points up the importance of keeping our surface waters clean, i.e., "well oxygenated, free from silt—untainted by germs of disease of man or animals or by substances toxic to man, beast, fishes or the living food of fishes."

The book is neither a textbook for students nor a reference for specialists, but is a pleasantly readable and comprehensive review of life in inland waters, recommended to those engaged in fisheries management, as well as to instructors in the field of general zoology, sanitarians, and fish culturists.—*Harry A. Hanson, California Department of Fish and Game.*

The Distribution and Abundance of Animals

By H. G. Andrewartha and L. C. Birch; University of Chicago Press, Chicago, 1954; xv + 782 p., illus. $15.

Here is a textbook of ecology which asks the fundamental questions: Why does an animal inhabit so much and no more of the earth? Why is it abundant in some parts of its distribution and rare in others? Why is it sometimes abundant and sometimes rare? In seeking answers to these questions the authors critically analyze the ways in which the environment influences an animal's chance to survive and multiply.

Both authors are Australian workers, are experienced in their field, and have accumulated and compiled, in very orderly fashion, an enormous volume of fact and theory pertinent to the field of animal ecology. They have intentionally organized their material in an unorthodox though logical manner. Rather than emphasize the traditional study of animal communities, the authors place their emphasis on species populations and the actions of the environment on these populations. An attempt is made to set up a basic pattern of inquiry which should be applicable in the study of any species.

The book is divided into five general topics each containing numerous subdivisions. The introductory part includes discussions which express some of the authors' objections to certain "principles" of ecology which they feel have been accepted dogmatically (in the past). The next two parts take up the physiological aspects of ecology and an analysis of the four basic components of the environment (weather, food, other animals, and a place in which to live). The fourth part of the book is entitled "The Numbers of Animals in Natural Populations." Here is a series of well documented, long-term population studies is analyzed according to the methods and reasoning outlined in the first three parts of the book. The last portion of the volume is devoted to the genetic aspects of ecology and their implication in evolution.

The entire book is well illustrated and amply documented. Considering the complex nature of the material, it is written in a very clear and easily followed manner. The authors have avoided the use of ponderous, complicated definitions which they feel have plagued so many works on animal ecology in the past. However, this is not a simple, easily read book—to be lightly scanned at leisure. The very nature of the material precludes this possibility. It can probably be most effectively used in group or seminar discussion. To obtain the most from the book requires considerable thought and concentration and a real desire to learn.—*David C. Joseph, California Department of Fish and Game.*

The Western End of Lake Erie and Its Ecology

By Thomas H. Langlois; J. W. Edwards, Publisher, Inc., Ann Arbor, Michigan, 1954; xx + 479 p.; 72 figs. $10.

This book, as the title indicates, is a very composite study of the interacting forces of nature in a 1,265-square-mile "key area" of Lake Erie. Its aims are to supply the basis for a fishery management program for Ohio's part of the lake. I feel very humble in reviewing a work of this magnitude, which covers some 136 years of data collections and 60 years of intensive study by the author.

It is extremely gratifying to see research starting with the basic factors affecting the welfare of the individual organisms and working up to the endpoint of the evaluation of the commercial and sport fishery. By the understanding of why the biota at the unicellular end of the food chain fluctuates, we can more easily understand the resultant fish population dynamics. The author presents adequate evidence, by inclusion of many personal observations and data on the many phases of ecology collected by other workers on Lake Erie, with which to formulate a sound fisheries management program. Some of the topics covered are climatology, bottom studies, physical and chemical character of lake water, origins of turbidifying materials, bacteria, algae, aquatic phanerogams, protozoa, annelids and other worms, mollusks, crustaceans, aquatic insects, reptiles and amphibians, fishes, birds, and mammals. The fish life of the Lake Erie drainage includes some 91 species. Notations are made on collections and life histories of many.

Under fish management methods six major headings are covered: regulated cropping, artificial propagation, pollution control, facilitation of migration of anadromous and catadromous fishes in tributary streams, improvement of land use practices, and research.

In addition to the very "meaty" material contained, some 450 references are cited, making an excellent bibliography. This book should be in the library of all warm-water fishery research workers.—*P. A. Douglas, California Department of Fish and Game.*

Water: A Study of Its Properties, Its Constitution, Its Circulation on the Earth, and Its Utilization by Man

By Cyril S. Fox; The Philosophical Library, Inc., New York, 1952; xxvii + 148 p., illus. with 4 text figs. and 25 pls. $8.75.

This book is an attempt to gather together a considerable amount of information on the subject of water. The scope of the book is not as broad as the title suggests and the principal emphasis is almost entirely on geology, rather than on the engineering or social aspects of the world's water problems. This undoubtedly reflects the author's background as Director of the Geological Survey of India and tends to reduce the usefulness of the book for readers who are interested in a more broad and basic reference book on the subject.

This book contains a considerable amount of numerical data on water, particularly on representative surface and underground waters. These analyses are interesting but lengthy and there seems to be a rather inordinate amount of repetition that could have been eliminated without loss. For example, on page 5, it states that sea water contains 3.5 percent salts and the same information can be found six other times in the book. More interest would be generated by having less emphasis on numbers and more emphasis on topics of general interest, such as irrigation development and methods of water utilization.

The book is short—only 148 pages. The review copy suffered badly as a result of rather poor printing and six pages were blank. It is hoped that this mechanical fault was corrected in the press run. Unfortunately the editing that is needed to make this a valuable, recommended reference or textbook will apparently have to wait for a new edition.—*R. M. Paul, California Department of Fish and Game.*

Analysis of Development

Edited by Benjamin H. Willier, Paul A. Weiss, and Viktor Hamburger; W. B. Saunders Company, Philadelphia, 1955; xii + 735 p., 248 text figs. $15.

One may presume that analysis is the object of a book entitled *Analysis of Development.* This is the case, but the introductory statement by the editors stresses synthesis. Although these terms are antithetical, the book approaches the subject by both methods. This is a presentation of the analysis of growth, from production of gametes, their union, and subsequent differentiation to completion of the organism prior to independent living; and this book is also a synthesis of work in the field of embryology, composing the contributions made by former workers and workers of today.

Twenty-nine papers by twenty-eight authors, guided by an editor-sponsored outline, have resulted in understandable style differences and occasional loss of unity, which are not apt to be found in a book by a single author. The editors noted this and also pointed out the impossibility of a single author writing such a book for the field of embryology. This book is a synthesis of knowledge of the principles and mechanisms of development, as the authors state; clearly it is also an analysis of the development of living organisms. The science of embryology is diverging, men must specialize, the labor must be divided. The terminology, the language of the field, grows but the opportunity for broad principles diminishes. The true synthesis seems remote.

An interesting chapter on methods and techniques poses problems that might well be considered in other fields. The problem of technique of investigation in embryology is one of observation or interference; both require the determination of natural environment. Interference with the developing embryo makes results suspect. But observation is affected by preconceptions. Normal environment is difficult to determine, since many organisms have wide ranges in environment; the embryo also has an internal as well as external environment.

Each author is a specialist and leader in his field. Only fellow workers in the author's special investigation could adequately criticize his contributory paper. The reviewer suggests, however, that a common fault seems to be an absence of broad interpretation and neglect of summation. There are exceptions to this, a notable one being the paper on teratogenesis. A paper by Weiss concludes with a thoughtful discussion of summary in developmental processes. He believes summary is not possible, for we must "clarify complex mechanisms of their operation" as well as "establish and reconfirm the validity of general laws and principles." With this it is difficult to argue; nevertheless, summarization is a standard practice in most journals and a very valuable custom it is. Technical papers are addressed to small audiences but there are workers in fields both allied and diverse who profit through the medium of summary.

The embryologists who contributed to this book are working at the limits of knowledge in their respective fields; future development, following their guidance, will be expressed in applied science. There has seldom been an exception to this in the past. This book may serve as a reference work on embryological research for workers in applied fields. To these people it will indicate the direction specialists are now taking toward understanding embryogenesis. The methods, demonstrations, and interpretations may provide stimulus to those confronted with problems in production and assist design and interpretation of their experiments. The book adds to the knowledge of the ways of living organisms.

To read this book is to be impressed once again that this is the fundamental branch of the science of living organisms. Research in this field observes development at its primary level and interrelations in their most complex state. It is not strange that therefore new problems multiply with each explanation.

Analysis of Development covers the following fields and the workers contribute papers within the framework of these section headings:

I Problems, Concepts and Their History
II Methods and Techniques
III Cellular Structure and Activity
IV The Nucleus and Cytoplasm in Development
V Embryogenesis: Preparation Phases
VI Embryogenesis: Progressive Differentiation
VII Special Vertebrate Organogenesis
VIII Energy Exchange and Enzyme Development During Embryogenesis
IX Ontogeny of Immunological Properties
X Ontogeny of Endocrine Correlation
XI Determination of Size
XII Metamorphosis
XIII Regeneration
XIV Teratogenesis

This book is a wise addition to an institution library. Although general workers in the biological sciences will have only ocasional use for it, embryologists will find it essential to their work.

Advances in experiment and thought are rapid and new summaries in the field of embryology undoubtedly will appear, although probably some time will elapse before another book of such scope and importance is published.—*Robert R. Bell, California Department of Fish and Game.*

Introducing Sea Shells

By R. Tucker Abbott; D. Van Nostrand Co., Inc., New York, 1955; vi + 64 p., 19 line drawings, 10 plates (6 in color including covers). $2.50

Popularity of shell collecting, a fast-growing American hobby, is the first subject of discussion in this little booklet. Thence, one is given an insight into the romantic pasts of some of the world's most priceless shells. Succeeding chapters are entitled "Hunting your own shells," "Exploring our color plates," "Preparing shells for the collection," "Strange seashells", and "A collector's list of shell names, dealers, and clubs."

Perhaps the most valuable information in the entire 64 pages is that contained in the chapter on preparing shells for the collection, a subject the importance of which cannot be too highly stressed. Similarly the lists of shell clubs and dealers should prove useful to those hobbyists who currently lack this knowledge.

A number of undesirable items and assorted inaccuracies tend to limit the value of the book—especially for the beginning collector who would be unable to separate the chaff from the wheat. A true conservationist would be horrified to find that the author has advocated, in at least four places, turning over stones and boulders in search of shells without once informing the reader of the need to replace these natural communities original side up. On page 23 one is led to believe that in California only the red abalone is protected by law—whereas eight species of abalones found within the borders of the State are currently regulated (from the sportsman's point of view) by such methods as: a single aggregate bag limit, four size limits depending upon species, a closed season, the need for a valid fishing license, and so on. In addition, these laws are subject to change from year to year as the need for greater or less protection is determined. The author failed to warn the amateur collector of a basic rule of thumb which should always be applied prior to field activities in any state, namely: check the latest fish and game laws of the state in question.

It is obvious from his statements on page 19 that the author is neither a skin diver himself nor is he well versed in the art of skin diving. It is doubtful if more than 1 percent of the tens of thousands of enthusiastic skin divers in the United States are physically capable of remaining submerged for more than one minute per dive, let alone "two—or even three".

A number of other errors and inconsistencies are scattered through the book. Even if one overlooked them, the paper covers, very large type, and limited information make the asking price for this booklet much too high. *John E. Fitch, California Department of Fish and Game.*

North American Moose

By Randolph L. Peterson; University of Toronto Press, Toronto, 1955; xi + 280 p., 43 photos. $12.50.

The existing literature on moose is combined with Dr. Peterson's personal work in Ontario to compose this volume. Data from the Scandinavian countries are used freely for comparative purposes.

Current knowledge of moose, including taxonomy world-wide, from prehistoric times to the present is presented. Chapters are devoted to reproduction rate; general life history; behavior; food habits; habitat ecology; relations with other animals; diseases, parasites, and insect pests; accidents; population studies; management; taxonomy; and general history.

Population data show that moose have decreased in New England and the western Great Lakes states in recent years, while encouraging increases have taken place in the western states, Canada, and Alaska.

In general, moose have a low reproductive rate, but reasons for it are poorly understood. The basic cause is probably a lack of variety of good foods. White-tailed deer competition has kept moose numbers down in many areas. Populations reach maximums in early successional stages and decrease as forests reach maturity.

Two appendices are included. One, "A Study of Mandibular Tooth-Wear as an Index to Age of Moose", by R. C. Passmore, R. L. Peterson, and A. T. Cringan, presents age classes derived from grouping jawbones of similar wear. The lack of known-age material is clearly pointed out. This aging data should be useful to technicians.

The other appendix, "Studies of Moose Antler Development in Relation to Age", by A. T. Cringan, presents little that can be put to practical use.

Animals existing in low-density populations, such as moose, compound the normal difficulties of obtaining size and age composition of herds, rate of annual production, and range carrying capacity. To a person familiar with current research efforts on such abundant big game as deer, the generally small samples referred to and the lack of much basic data in this book will be glaring. However, the work that has been done on moose is amalgamated, and profitable avenues for future investigation are clearly pointed out.—*Fred L. Jones, California Department of Fish and Game.*

M Is for Moose

By Anton Swanson; Vantage Press, Inc., New York, 1954; 64 p., 35 illustrations. $2.50.

The author is a contractor whose lifelong hobby has been the study of wildlife, his chief interest being moose. The author's experience has been mainly with moose in Sweden, where he spent his youth, and in Ontario, where he has lived for over 30 years.

This short book covers briefly the main phases of life history and management and even contains information on souvenirs which can be made from moose antlers. Of special interest to the reviewer was the section on the moose and its management in Sweden.

The professional wildlife worker will find this book lacking in detail and will feel that much has been left out in regard to life history and management. The layman who may have a general interest in the species will find this book an easily read, quick source of information on the subject.—*C. M. Ferrel, California Department of Fish and Game.*

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