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ABUNDANCE AND SCARCITY IN CALIFORNIA DEER[1]

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INTRODUCTION

Fluctuations in abundance of animals have been of interest to wildlife managers for many decades. Success or failure of a management program is usually judged by the number of game animals it has produced for the hunter. The game manager's efforts often are obscured by sudden changes in game abundance brought about by poorly understood factors. The 10-year cycle of abundance and scarcity in northern mammals, for instance, is yet to be comprehended or controlled completely.

There is evidence that California deer populations have been undergoing marked fluctuations during the past several decades. These changes in abundance bear no apparent relationship to hunting pressure, management effort, or any other single factor that could be defined. A consideration of these changes can be of value toward understanding the behavior of animal populations in general, and can be of immediate significance in evaluating deer management programs.

Where hunting is regular and sustained, the annual kill should reflect game population abundance. In California, deer hunters have been required to report the deer they kill, by returning deer tags, since 1927. While the deer tag return may not represent total kill, there is no reason to believe that the percentage of people failing to return tags has fluctuated greatly over the years. Hunting, since 1927, has largely been confined to bucks with forked antlers. The buck kill will therefore be considered here as an index to deer abundance.

Many factors other than game abundance may affect the total kill. Most obvious is the number of hunters. This has increased markedly since 1927, and along with it has come an upward trend in bucks killed. This does not necessarily reflect an increase in deer numbers, but is at least partially the result of the buildup in hunting pressure, coupled with easier access to hunting territory. Other factors which may affect deer kill are length and time of hunting season, weather during the season, and weather cycles as they modify water and forage distribution. However, none of these factors explain the major fluctuations in the California buck kill. Changes in deer abundance appear to be the principal cause of the kill fluctuations.

[1] Submitted for publication September 1962.

THE STATEWIDE PICTURE

Based on hunting information, major peaks and troughs in the buck kill occur approximately in 10-year intervals (Figure 1).

Although deer tag sales showed a fourfold increase during the 1927-1960 period, there were sales declines during the middepression (1932-33), during World War II (1942 in particular), and in 1957-1958. These hunting-effort decreases could explain the low deer kill, were it not for the lack of correspondence in the hunting-success ratio. Thus, the 1940 peak in deer kill was followed by an increased number of hunters in 1941. In 1941, however, the hunting-success ratio and deer kill fell off, suggesting that deer had either decreased or were harder to kill. During 1942 and 1943, the much-reduced number of hunters did not find deer easier to kill. Instead, the hunting-success ratio continued to fall to a low in 1943, paralleling the low in deer kill. Reduced deer abundance is again suggested. Following the 1954 peak in deer kill and hunting success, a similar pattern is shown. The numbers of hunters increased for two more years, while the deer kill and the success ratio declined.

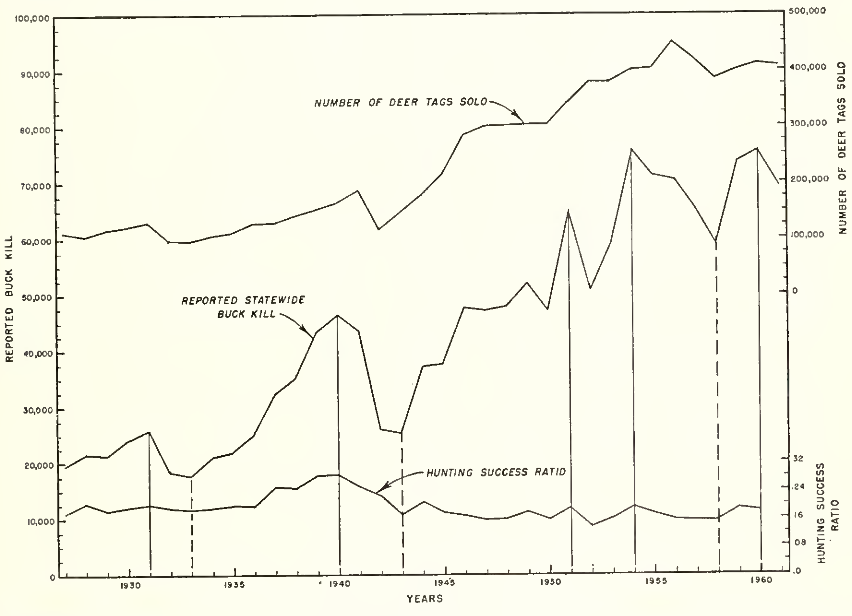

FIGURE 1. Relation of statewide buck kill with deer tag sales and hunting success ratios. Solid vertical lines show years of high kill; broken vertical lines indicate years of low kill.

However, if the statewide buck kill is examined critically, county by county, it does not show any marked synchrony throughout the various regions of California. Deer do not increase and decrease in all areas simultaneously. In the years of major statewide peaks, 1931, 1940, 1954, a high percentage of the counties did produce peak kills and most of the other counties peaked either one year before or one year after. There is thus an indication that throughout the State, conditions have favored high deer kills in certain series of years, and low deer kills in others, but local or regional exceptions occurred.

Vegetation, climate and conditions for deer vary too greatly throughout California to permit more detailed analysis of the statewide kill. In order to carry this consideration further, a group of counties was selected in the north coastal region of the State within which climate, vegetation and hunting conditions are generally similar.

DESCRIPTION OF AREA AND DEER

The area selected embraces Marin, Napa, Sonoma, Lake and Mendocino Counties lying just north of San Francisco Bay. Two other counties, Humboldt and Del Norte, lie between Mendocino and the Oregon border. All of the counties lie within the coastal mountain ranges and are characterized by fairly large valleys (mostly devoted to agriculture), rolling foothills, and rather steep mountains rising to elevations up to 7,500 feet. Vegetation ranges through grassland, savannah and oak woodland in the valleys and low foothills. Chaparral brush species grow on higher foothills and a conifer cover is found in the mountains. Redwood (*Sequoia sempervirens*) stands occur on north slopes and in some of the more humid bottoms.

The deer in north coastal California belong to the Columbian black-tailed race of mule deer (*Odocoileus hemionus columbianus*). Those found in Marin, Napa, Sonoma, southern Lake and western Mendocino Counties tend to be nonmigratory, although some may move up to a mile or so between summer and winter ranges. In northern Lake and eastern Mendocino Counties, where more mountainous terrain and higher elevations occur, definite migratory patterns exist. Here, population ceilings for the separate herds may be set by their more limited seasonal ranges.

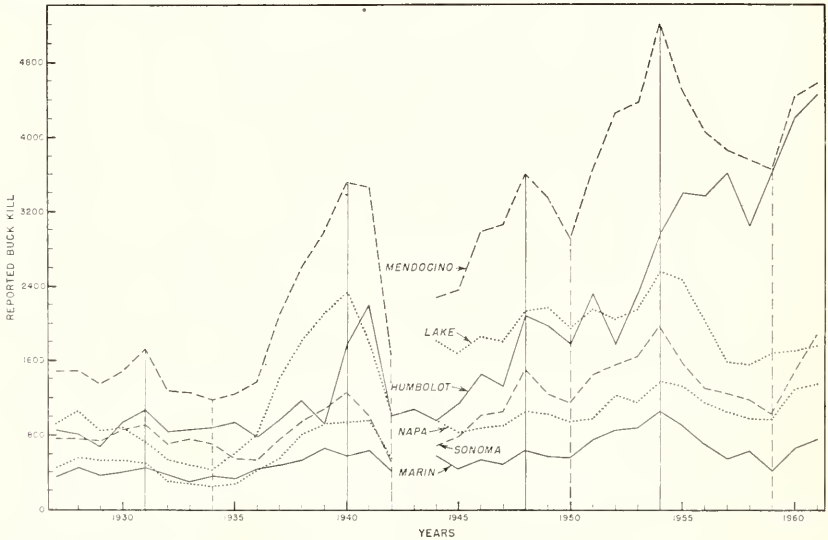

FIGURE 2. Comparison of deer kills in six north coastal counties. Solid vertical lines show years of general high kill; broken vertical lines indicate years of general low kill. There was no open season in Lake, Marin, Mendocino, Napa or Sonoma Counties during 1943.

TABLE 1

Reported Buck Kill *

Six Counties in Northwestern California

Year	*Marin*	*Sonoma*	*Lake*	*Mendocino*	*Napa*	*Total*	*Humboldt*	*Status*
1927	367	751	901	1,475	442	3,936	821	
1928	444	753	1,038	1,468	569	4,272	777	
1929	394	732	841	1,355	523	3,845	689	
1930	403	865	885	1,483	536	4,172	917	
1931	449	903	726	1,706	488	4,272	1,069	High
1932	376	709	524	1,273	304	3,186	807	
1933	301	748	481	1,234	285	3,049	842	
1934	341	704	419	1,185	288	2,937	877	Low
1935	328	554	570	1,207	278	2,937	921	
1936	411	536	757	1,372	415	3,491	796	
1937	482	744	1,418	2,072	544	5,260	940	
1938	534	948	1,803	2,700	795	3,780	1,284	
1939	649	1,094	2,103	2,967	927	7,740	932	
1940	581	1,242	2,328	3,517	907	8,575	1,791	High
1941	615	1,005	1,805	3,460	962	7,847	2,200	
1942	403	489	1,042	1,652	557	4,143	1,101	Low
1943—No open season							1,068	
1944	579	685	1,787	2,297	932	6,280	945	
1945	438	787	1,674	2,365	809	6,073	1,133	
1946	520	1,102	1,768	2,980	887	7,257	1,459	
1947	488	1,151	1,835	3,067	899	7,440	1,335	
1948	634	1,505	2,120	3,627	1,027	8,913	2,083	High
1949	597	1,269	2,182	3,354	1,020	8,422	1,962	
1950	544	1,138	1,942	2,927	952	7,513	1,770	Low
1951	767	1,447	2,155	3,665	983	9,017	2,313	
1952	832	1,553	2,056	4,252	1,220	9,913	1,792	
1953	885	1,679	2,146	4,394	1,161	10,265	2,323	
1954	1,048	1,979	2,549	5,232	1,386	12,194	3,055	High
1955	901	1,586	2,479	4,587	1,329	10,882	3,408	
1956	707	1,303	2,030	4,051	1,144	9,235	3,393	
1957	548	1,267	1,585	3,847	1,045	8,292	3,631	
1958	613	1,172	1,568	3,754	994	8,101	3,047	
1959	407	1,016	1,684	3,655	997	7,759	3,649	Low
1960	659	1,483	1,706	4,426	1,306	9,580	4,214	
1961	749	1,883	1,763	4,585	1,356	10,336	4,486	

* From Game Management Handbook, California Department of Fish and Game.

The deer kill in five of the California north coastal counties (Table 1) shows a marked upward trend related to the increase in hunters, and also a marked periodicity. The high and low kills occur simultaneously over a broad area, although sometimes parts of the area will reach a high or low one year before or after the balance. A review of the data reveals that low kills have occurred every eight or nine years and high kills at six- to nine-year intervals (Figure 2).

HUNTING PRESSURE

We have no way of knowing how many people hunted annually in the five counties during the 35-year period, 1927-1961, under consideration. We can only assume that the number of hunters seeking deer in this part of California yearly was proportional to the total people purchasing deer tags in the State. Accepting the assumption that state deer tag sales are indicative of annual hunting pressure in the five

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counties, these figures are compared with the total five-county deer kill in Figure 3.

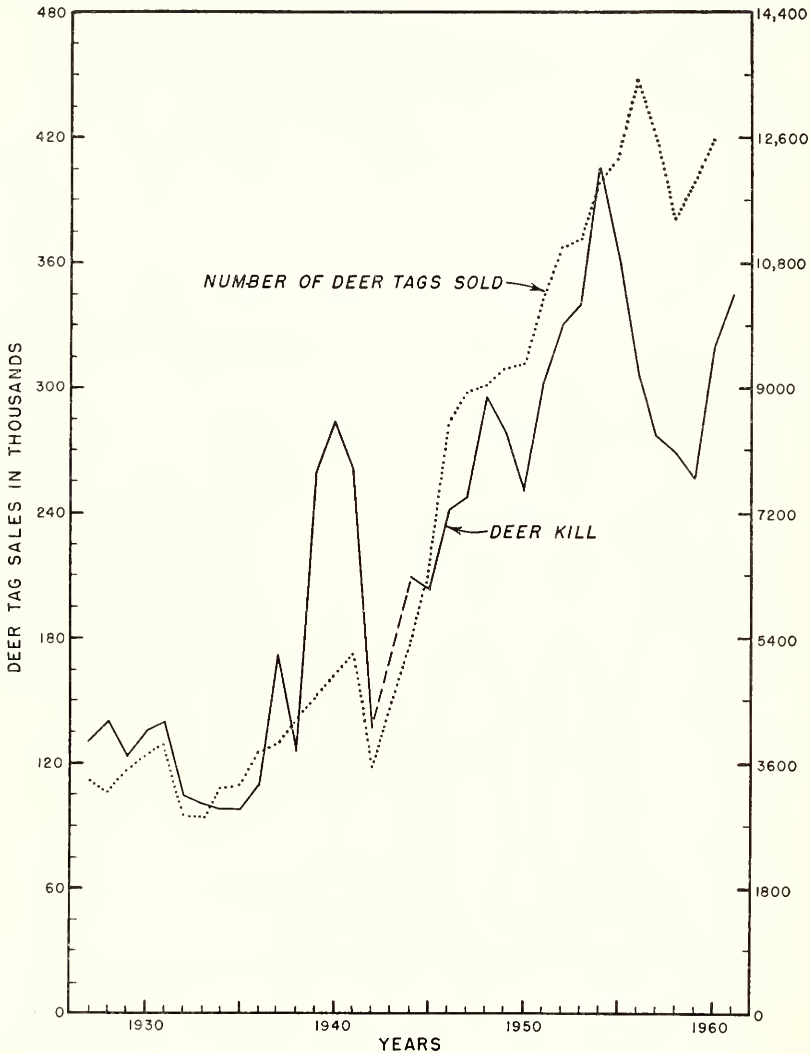

FIGURE 3. The relation of buck kill to hunting pressure in the five counties under study.

The immediate reaction is that a close correlation between the ups and downs of kill and of hunting pressure has existed. However, a closer inspection will show, with the exception of 1931, the decline in hunting pressure has followed the reduction in deer kill by one or more years. It is suggested that the news deer are in a decline results in fewer people purchasing tags. It would also appear that preseason information spurs tag sales once the deer population shows signs of recovery.

Legal hunting in the five counties has been confined to bucks, forkedhorn or better, throughout the 35-year period, with two exceptions. In 1955, 452 antlerless deer were taken in Napa County during a special hunt (Ferrel, 1956) and in 1956 when that county was open for three days to either-sex deer hunting, 461 antlerless deer were removed (Dasmann *et al.*, 1958). Removing these antlerless deer appears to have been insufficient to affect the kill cycle in Napa County. This continued to behave in close correlation with other counties where no antlerless deer removals were made.

Since deer are polygamous, removing a portion of the males should not affect annual production. At least half of the buck deer taken from coastal ranges in California are more than two years old and many are not taken until four or five years old (California Department of Fish and Game, 1955). When such a high percentage of males escapes the gun each year, hunting removals cannot prevent a deer population from increasing. There are more than enough left for breeding. We can safely assume heavy buck removal in peak years has not been the cause of subsequent prolonged declines in the take.

HUNTING SEASONS

All five counties have enjoyed the mixed blessing of one of the earliest deer seasons in the United States. Deer are hunted in midsummer, when temperatures may reach 100° F. or more, and successful nimrods perspire in efforts to prevent meat spoilage. During the time hunting seasons were established by the State Legislature (1927-1945), the season for Marin, Napa and Sonoma Counties invariably was set for August 1 to September 14 or 15. In Lake and Mendocino Counties, however, the season was periodically reshuffled. Occasionally, these two counties were open to hunting at the same time as the others, but often, northern Lake County and eastern Mendocino were opened two weeks later (August 16) yet were closed on September 15. For a four-year period (1935-38), deer were hunted in Lake County a full six weeks later than the other four counties. During this period, it was included with the largest part of California, and with Humboldt and Del Norte Counties to the north, in a September 16 to October 15 hunting season.

After the authority to establish hunting seasons was granted to the Fish and Game Commission, the five counties, along with a considerable block to the south and east, were opened and closed at the same time. The area still has an early season, but the opening dates have ranged from July 25 to August 11, and the closing dates from September 12 to 25.

The tradition of the midsummer hunt has developed from the belief that deer meat will be tainted and bucks will become too vulnerable, if the hunting season extends into the period of rut. It is true that the breeding season is quite early in parts of some counties immediately adjacent to the seacoast and most notably in Marin (Cook *et al.*, 1949). Here, breeding may start in September or early October, and neck swelling in bucks occurs a week or two before that. But on most of the blacktailed deer range, the breeding periods, according to Bischoff (1957) occur from late October to early January. The shifting of the hunting seasons in the five counties concerned, and particularly the late season in Lake County during the 1939-1942 period, does not appear to have affected the periodicity of high and low kills. In fact, the Lake County kill reached a high simultaneously with other counties in 1940, and a low in 1942 apparently without respect to the placement of the hunting season.

EFFECT OF WEATHER

August and the first half of September are normally hot and dry in the five counties. A check was made to determine if the occasional rain in August might show a correlation with high and low deer kills. Some rain occurred in one or more of the counties in 18 out of the 35 years. Usually only a trace occurred, but in eight years measurable precipitation fell. When these years of rainfall were compared with years of high and low kill, the following lack of relationships was revealed:

1929—Kill lower than that of the year preceding or following.
1935—Kill at a low part of the cycle.
1941—Kill relatively high, but lower than the peak.
1951—Kill just starting up from a low to a peak which occurred three years later.
1953—Kill at a high level, but lower than peak.
1954—Kill at a record peak.
1959—Kill at a low.
1961—Kill at a high level.

No general rains occurred during the other years of peak kill. One general rain occurred in 1935, an extended low, and one in 1959, but none in the other years of low kill. To have the most effect on deer take, rain must occur just prior to and during the opening days of the season when most hunters are afield and a large part of the total kill is made. Because of the lack of correlation shown above, and because a similar comparison of July rainfalls was equally nonproductive, we decided not to pursue the matter further. The occurrence of rain during the opening month of the hunting season apparently has no significant effect on either the peaks or the troughs of kill fluctuations.

WEATHER CYCLES

Weather cycles may influence deer abundance and kill through their effect on forage production and water distribution. Because the data for Mendocino County are incomplete, the averages in Figure 4 are for the other four counties. Precipitation trends in Mendocino County, as indicated by the partial record, were in conformity with the four-county trends.

One would expect a comparison of precipitation with deer kill from a stable population to show higher kills during drought periods when deer tend to concentrate around permanent water than during wet periods when they are scattered. But the opposite generally has occurred in the five counties.

The coincidence of peaks and troughs of precipitation with high and low buck kills was fairly close from 1927 to 1949. Major and minor peaks for both kill and precipitation occurred in 1931, 1937, 1940 and 1948, and lows for both elements occurred simultaneously in 1929, 1934 and 1943. However, the relationship loosened after 1949. The

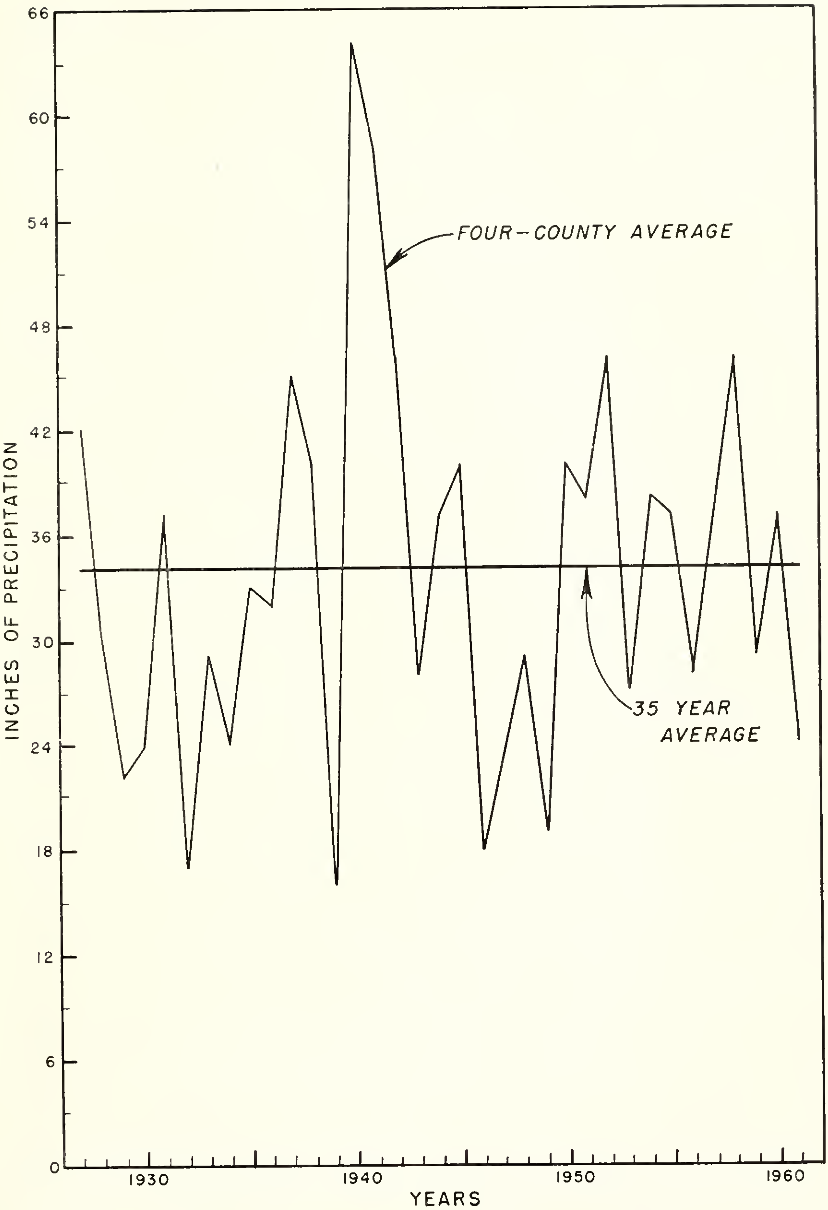

FIGURE 4. Annual precipitation in the five-county area.

record kill of 1954 was coincident with a minor precipitation peak and the low kill of 1959 occurred simultaneously with a moderate precipitation low. Otherwise, a close relationship is not evident after 1949. No explanation for the change from a close to loose relationship is offered; however, the earlier period of close relationship was one of rather violent fluctuation in precipitation. Both the wettest and the driest years fell within this period. In contrast, the period since 1949 has been one of relatively moderate fluctuation and characterized by a higher average annual rainfall (36 inches). If the deer kill is a reflection of population abundance, one could expect fairly close relationship of kill to precipitation if deer are crowding the upper limits of range carrying capacity, particularly during a period of extremes. Such a relationship appears to have occurred within the five counties.

DEER POPULATION FLUCTUATIONS

Because the periodicity of deer-kill highs and lows in the five counties appear unrelated to the various factors we have considered, except precipitation, it is believed they reflect animal abundance. Possibly the population cycles reflected in these kills are a product of habitat supply and deer demand. Starting in a period of high habitat supply and low animal demand, with no shortages to affect health, thrift or reproduction, the deer multiply. After a period of years, the animals more fully occupy the range and reach a population peak imposed by the habitat ceiling. Now there is a high animal demand for a short habitat supply. Depressant factors are brought into play. Only the strongest are able to fill their needs, and one animal must die to make room for another. The deer are living along the margin of disaster. A drop in food production, appearance of disease, spread of parasites among unthrifty animals, accumulating stress of competition for proper food, water, cover and living space—any or all of these factors may be the cause of snowballing mortality, resulting in a sharp population decline. With deer numbers once again at a low, the cycle repeats itself.

That some such mechanism may be fundamental to population fluctuations in the five counties is indicated by the record of what has happened in the sixth county, i.e. Humboldt. The deer in Humboldt County showed close relationship with the other five counties from 1927 to 1950 (Figure 2). After 1950, this kill showed general correspondence with that of Lake County until 1954, when it broke away from the general pattern and started a sustained climb. In an effort to discover a possible cause of this phenomenon, lumber production records of the counties were examined (Figure 5).

Humboldt County supports largely a conifer cover. Areas having unbroken mature stands of conifers usually make poor deer habitat, because of the low volume and poor quality of herbaceous and shrubby cover growing in the shade beneath them (Einarsen, 1946). But when the forests are opened by logging, a profusion of palatable undergrowth will often appear on the site and good-quality deer habitat is created.

Dasmann and Hines (1959) found that virgin redwood and mixed coniferous forests supported few deer. During the first five years after logging, these animals increased to a level 7 times greater, and in the next five years to a peak population over 20 times greater than existed in the virgin forests. Deer population densities of 11 to 66 animals per square mile were found in one cutover area 10 to 13 years after logging. About 10 years after logging, deer numbers began to decline and after 20 years the population was not significantly higher than before logging.

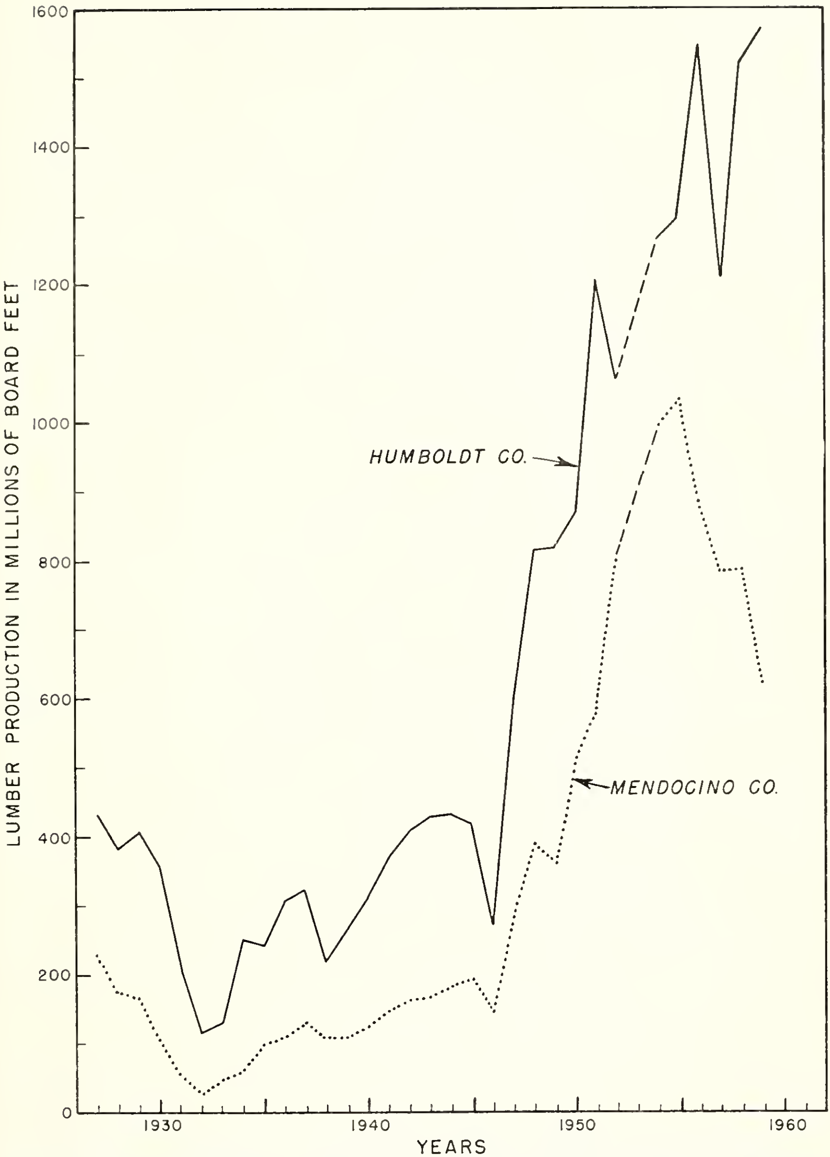

FIGURE 5. Lumber production in Humboldt and Mendocino Counties 1927-1959. (Data taken from May 1953; May et al., 1957; California Division of Forestry notes 1950-61.)

The lumber production in Humboldt County made a phenomenal and continued growth starting in 1947 (Figure 5). This accelerated and widespread logging in the Humboldt forests probably improved deer habitat and increased the carrying capacity of the range much faster than the rather low deer population was able to fill it. It is postulated that here we can observe the behavior of a deer population whose numbers were (and may still be) below the carrying capacity of their range.

With the population ceiling lifted and general conditions all in favor, rapid population expansion followed. The impulse of this expansion was strong enough to carry through the general period of decline in deer kill (1954-1959), with the exception of a moderate setback in 1958.

A different situation exists in Mendocino County where there is more interspersion of cover types. In many areas of conifer type, south slopes support a partial chapparal brush cover. The pine stands offer fair deer habitat even in virgin condition. All of this accounts for the fact that a rather high deer population existed in Mendocino County prior to the period of accelerated logging.

We believe that in Mendocino County, the rather high deer population was able to expand rapidly enough to keep up with the increasing acreage of cutover timberlands and to fill out the increased carrying capacity. Hence, it has remained chained to the general fluctuation pattern.

CONCLUSIONS

The periodicity of high and low deer kills in the five counties, and presumably throughout California, does not appear to have been a product of hunting pressure, length or time of hunting season, or kind of weather that prevailed during the opening month of the season. The relationship of the highs and lows with weather cycles appears more possibly a result of concomitant increases and decreases in habitat carrying capacity than of animal distribution. Therefore, we conclude the fluctuating kills reflect animal abundance. Such fluctuations in numbers may be expected of an unmanaged population which has expanded to the maximum carrying capacity of its habitat. With legal hunting usually limited to buck deer, forked-horn or better, and with at least half of the bucks escaping the gun for two or more years, hunting removals cannot prevent deer population increases. Hence, it can be safely assumed that throughout the five counties (and the State), deer numbers have long since expanded to the population ceilings imposed by their habitat. Where habitat conditions are improved by logging, fire, or other causes, there is room for increases to a higher ceiling. Where extensive timber harvest is carried on in areas of low deer population, these population increases may be sustained for a considerable period. In other instances they may be of short duration, and in some cases are offset by habitat declines on other parts of the range.

Deer can multiply rapidly, up to 50 percent or more per year under favorable conditions (O'Roke *et al.*, 1948). But once a deer population is extended to a level where habitat shortages of one kind or another occur, it becomes subject to decimating factors that work against further expansion, and eventually cause a decline in animal numbers.

Periodic deer population buildups and subsequent declines result in waste. Were the deer populations managed by annual (or at least occasional) removals of enough animals of either sex to hold them at an optimum level, some of the waste could be averted. Since an optimum population level is one at which the animals have all they need in order to flourish in average years, declines would occur only during the most adverse periods and never to the degree inflicted on uncontrolled populations. Under management, much of the surplus deer would be used, rather than lost, and the resource would be conserved rather than wasted.

In any event, the knowledge that unmanaged deer populations and hunting success in the five counties tend to peak and crash, can be put to use. It is usual for uninformed sportsmen to blame declines upon many unrelated factors and demand immediate action to save the deer. Recognition of natural population fluctuations will allow predictions and sensible explanations of such declines. This may help prevent unwarranted actions by governmental bodies resulting from public misunderstanding of such pheuomena.

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TROUT SURVIVAL IN TAYLOR CREEK, A TRIBUTARY OF LAKE TAHOE, CALIFORNIA[1]

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INTRODUCTION

During the summer of 1940, I was employed as a student biologist by the California Division (now Department) of Fish and Game, and assigned to study hatchery trout survival in Taylor Creek, El Dorado County, a tributary of Lake Tahoe. Increased interest in Lake Tahoe and tributaries in recent years and the fact that the study contributed to our knowledge of the Tahoe area ecology make it desirable to publish my report at this time.

THE STUDY AREA

Taylor Creek is one of the more important tributaries of Lake Tahoe which it enters at the southwest end. Immediately before its confluence with Tahoe, the section in which my study was made, it is a meandering meadow stream, with no shade and with no bottom shelter other than its slightly undercut, grassy banks. Its average current speed in 1940 (summer) was about 0.4 feet per second.

Except for a wide, shallow, gravelly stretch just below the head end, the test section was a uniform channel with no deep pools. The stream bed there was 10 percent sand and gravel and 90 percent mud. The experimental section was 295 feet long and averaged 10.3 feet wide. A typical depth was 20 inches in the middle and 11 on the sides. The volume of flow on August 8, 1940, was 5.2 cubic feet per second. On September 2 it was 2.5 cubic feet per second. The water temperature averaged about 68° F. during August, ranging from 56° F. to 72° F. These relatively high temperatures were the result of warming in the shallow end of Fallen Leaf Lake, the source of Taylor Creek.

METHODS

Bottom samples were taken with a 0.25-square-foot Ekman dredge.

To measure fish movement, the experimental section was screened at both ends and two-way traps installed. After placement of the screens, the section was partially seined to make room for 500 hatchery-reared rainbow trout, *Salmo gairdneri*, fingerlings (17 per ounce) with their left pelvic fins removed. Records were kept of all fish moving in and out of the section. All trout were fin-clipped as they entered. On September 3, after one month's operation, the stream was diverted and the section again seined. This seining was quite thorough because the only water present was a few inches backed up from the lake and the bottom was smooth and regular.

[1] Submitted for publication August 1962.

RESULTS AND DISCUSSION

Invertebrate Fauna

Three samples taken in mud, sand, and gravel indicated the stream bottom supported a rich fauna (Table 1). Caddisfly larvae were extremely abundant the first of August, but were much scarcer at the end of August. Also present, but not showing in the bottom samples, were snails, small clams, and dragonfly naiads.

TABLE 1

Taylor Creek Bottom Samples

Organism	*Sample 1: Gravel bottom, velocity 0.8 ft./sec.*	*Sample 2: Sand bottom, velocity 0.5 ft./sec.*	*Sample 3: Mud bottom, velocity 0.2 ft./sec.*
Diptera larvae, other than *Chironomus*	142	150	112
Mites	68	1	3
Chironomus	40	202	5
Nemertineans	1		
Caddisfly larvae	30	1	
Annelid worms	1		
Nematode worms	1		

In addition to feeding on these bottom organisms, fish were often observed rising to take insects, which were extremely abundant on the surface toward evening.

Fish

During the first seining (partial) 641 trout averaging 48.7 mm long and 439 rough fish averaging 66.0 mm long were removed (Table 2).

Of the 500 marked rainbow fingerlings stocked in the test section, 55 left via the traps and 47 were recovered during the September 3 seining (Table 3). Eliminating the 55 from consideration, this represented a 10.3 percent survival for the one-month period.

TABLE 2

Fish Removed From Study Section of Taylor Creek Prior to Start of Experiment

Species	*Number removed*	*Mean fork length (mm)*	*Ranges in length (mm)*
Rainbow trout	489	44.3	32 to 126
Brown trout	143	60.0	42 to 75
Eastern brook trout	19	56.8	48 to 65
Speckled dace	177	43.0	31 to 73
Lahontan sucker	1	62.0	62 to 62
Lahontan redside	261	81.7	73 to 92
Total	1,090		

TABLE 3

Fish Removed From Study Section of Taylor Creek at End of Experiment

Species	*Number removed*	*Mean fork length (mm)*	*Ranges in length (mm)*
Rainbow trout (wild)	39 *	47	33 to 60
Rainbow trout (hatchery)	47	58	47 to 69
Brown trout	22 †	61	43 to 84
Eastern brook trout	2	66	64 to 68
Speckled dace	1,176	27.7	26 to 60
Tahoe sucker	77	48.5	40 to 109
Lahontan redside	3	89	88 to 90
Total	1,366		

* Includes those which moved in and those already present.
† Does not include a 20-inch brown trout.

As previously mentioned, the wild fish moving into the section were counted and marked so it was possible to calculate their survival too. Of 263 rainbow trout-of-the-year that entered, 11.7 percent survived. This is in striking correlation with the survival of the hatchery fish. The slightly higher survival of wild fish may be partially explained by the fact that all of them did not spend the entire period in the section. While the greatest influx was in the first half of August, some moved in during the entire month.

Several facts may help explain the low survival of both groups. A 20-inch brown trout, *Salmo trutta,* was in the section during the entire period. A bittern, *Botaurus lentginosis*, habitually fed in a gravelly stretch that was a favorite of the trout. Ducks were seen occasionally and garter snakes, *Thamnophis ordinoides,* were often in the stream. The stream section afforded no shade or shelter except the slightly undercut banks.

Wild brown and eastern brook trout, *Salvelinus fontinalis,* were too few to make any survival calculations.

During the last five days of the experiment the upstream traps had to be closed, since most of the trout appeared to have a keen desire to move upstream. Had they left, no data would have been available on survival.

Rough fish were very abundant in the experimental section. The Lahontan redside, *Richardsonius egregius,* breeds all through the summer or at least to the end of August. They probably stop breeding as soon as the water cools considerably in the fall. They suffered a tremendous mortality of adults during August; scores of dead were washed against the screens on some days and many dead were on the stream bottom. Caddisfly larvae acted as scavengers, and removed them.

On August 17, numerous Tahoe sucker fry, *Catostomus tahoensis,* appeared, moving upstream only; their movements tapered off after a few days. At the end of August, many very small speckled dace, *Rhinichthys osculus,* showed up—apparently moving downstream; they averaged about 26 mm long. Lahontan suckers, *Pantosteus lahontan,* were present, but very rare.

The minimum of 1,581 wild fish in the section before the experiment began (Table 4) shows how many fish may live in a limited area. This minimum is not the sum of Tables 2 and 3; it was computed by adding the numbers in Table 2 to those in Table 3, after the fish which entered the section were subtracted and those which left were added. They are minimal because no account was taken of fish from the original population that perished during the month.

TABLE 4

Minimum Original Fish Population of the 295-foot Experimental Section of Taylor Creek

Species	*Number*	*Mean length (mm)*
Rainbow trout	656	44.3
Brown trout	165	60.0
Eastern brook trout	27	56.8
Rhinichthys osculus	177	43.0
Richardsonius egregius	555	81.7
Pantosteus lahontan	1	62.0
Total	1,581	

SUMMARY

During the summer of 1940, a short-term experiment on trout survival was conducted in a 295-foot section of Taylor Creek, tributary to the southwest end of Lake Tahoe, California. A minimum of 10.6 percent of 500 hatchery rainbow trout fingerlings survived after a month in the stream. Wild rainbow trout-of-the-year had an 11.7 percent survival. One month of one summer is not enough time to reach definite conclusions on young hatchery trout survival. However, a low survival is indicated where competition and predation are as great as they were here, and shade and shelter as limited.

Late summer and early fall seem to be extremely critical times in the life histories of many fishes. The mortality of *Richardsonius* was very high, large numbers of *Catostomus*-of-the-year suddenly moved upstream, enormous numbers of *Rhinichthys* seemed to move toward Lake Tahoe, and trout-of-the-year started to move upstream at the end of August, when the water level was dropping.

SYNONYMY, CHARACTERS, AND VARIATION OF *GILA CRASSICAUDA*, A RARE CALIFORNIAN MINNOW, WITH AN ACCOUNT OF ITS HYBRIDIZATION WITH *LAVINIA EXILICAUDA*[1]

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The thicktail chub, *Gila crassicauda* (Baird and Girard), was once a common member of the freshwater fish fauna of California. Attaining a total length somewhat greater than one foot, it inhabited lowland streams, overflow ponds, marshes, and lakes of the Central Valley in the Sacramento-San Joaquin drainage basin. The species also occurred in Clear Lake, 1,325 feet in elevation, in Lake County, and was present in Coyote Creek, a southern tributary of San Francisco Bay. In periods of heavy runoff, as in 1862, it probably inhabited surface waters of this bay (Ayres, 1862; Snyder, 1905). During the latter part of the 19th century, this chub was of sufficient abundance to appear in the San Francisco market; and midden material from an Indian mound indicates it also was used for food by aborigines (Miller, 1961: 382-383).

Drastic change of its habitat by man—through lake drainage, marsh reclamation, dam building, and irrigation practices—is thought to have initiated its decline. Very probably the establishment of exotic species has also contributed to the inevitable extinction of this minnow. Although it may still survive locally, there appears to be no reliable source from which fresh material can now be obtained. The last capture known to me was made in 1950 in the Sacramento River near Rio Vista, Solano County (Miller, 1961). The thicktail chub was included by Shapovalov, Dill, and Cordone (1959) among a list of Californian fishes, "now either extinct or extremely rare." Since *Gila crassicauda* has remained little known and additional material is not likely to be forthcoming, it is my purpose in this paper to diagnose the species, describe its nomenclatural history and variation, and document the occurrence of natural hybridization between it and the hitch, *Lavinia exilicauda* (Baird and Girard).

Gila crassicauda (Baird and Girard)

THICKTAIL CHUB

(Figure 1)

Leuciscus gibbosus Ayres (1854a, May 30). Rejected as a junior primary homonym of *Leuciscus gibbosus* Storer (1845).

Lavinia crassicauda Baird and Girard in Girard (1854, Oct. 20).

Lavinia conformis Baird and Girard in Girard *(op. cit.)*.

Lavinia gibbosa Ayres (1854b, Dec. 18).

Tigoma crassa Girard (1856).

[1] Submitted for publication July 1962.

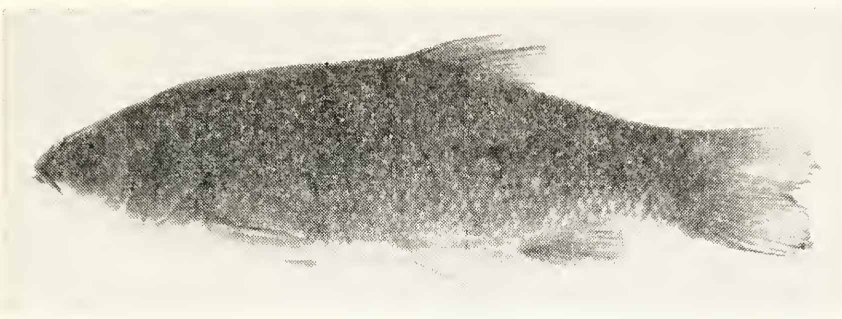

FIGURE 1. Last known specimen of *Gila crassicauda*, CAS 20456, an adult 156 mm in standard length, from the Sacramento River near Rio Vista, August 7, 1950. *Photo by Moulin Studios (San Francisco).*

Although the thicktail chub was first described by Ayres as *Leuciscus gibbosus,* from the San Francisco market, that name cannot be used since it was earlier applied to a minnow from Alabama by Storer. The next available description (Baird and Girard in Girard, 1854: 137) was based on specimens from the San Joaquin River and appeared under the name *Lavinia crassicauda.* In the same publication, these authors again described the species, this time as *Lavinia conformis* from Poso Creek (just north of Bakersfield). A few months later, Ayres (1854b: 20-21) provided an excellent description of the same fish under the name *Lavinia gibbosa,* probably on the basis of a market specimen. Girard subsequently (1856: 207) assigned the name *Tigoma crassa* to the species, based on a specimen from the Sacramento River near Redding. In the same paper, Girard (1856: 208) established the genus *Siboma* for two species, *Lavinia crassicauda* and *Siboma* [= *Gila*] *atraria; S. crassicauda* was listed by error from the Mohave River of southern California. Jordan and Evermann (1896: 231) referred *crassicauda* to the European genus *Leuciscus,* retaining *Siboma* as a subgenus.

Jordan, Evermann and Clark (1930: 120) re-established *Siboma* at the generic level, an action followed by many other authors. Shapovalov (1941: 444) questioned its generic validity, and Miller (1945: 105) again relegated *Siboma* to subgeneric status. Uyeno (1960)[2] has shown it is more logical to regard *Siboma* as a species group only.

In his penetrating study of the fishes of the Central Valley of California, Rutter (1908: 134) recognized the specific identity of *crassa* and *crassicauda* but provisionally maintained *conformis* as a separate species, evidently on the basis of the two specimens he examined (which are here interpreted as hybrids; see below, under hybridization). Although he questioned the validity of this nominal species, the name *conformis* was carried in the literature for nearly 40 years more (Jordan, Evermann and Clark, 1930: 120; Murphy, 1941: 168), despite the statement (Jordan and Evermann, 1896: 231) that it perhaps represents the young of *G. crassicauda.* Subsequent examination of the holotype of *Lavinia conformis* showed it was a large-scaled variant of *L. crassicauda* (Miller, 1945: 105).

[2] Osteology and phylogeny of the American cyprinid fishes allied to the genus *Gila.* Ph.D. thesis, University of Michigan, 1960, 174 pp., 35 pls.

Thus the thicktail chub has been described five times under three generic names and has been referred to five genera. Lack of adequate material, lack of good comparative collections of related species, and insufficient information on the phylogeny of American minnows, all contributed to these misinterpretations.

The following redescription of *Gila crassicauda* is based on data from 101 specimens, which probably represent 98 percent of the existing material in scientific collections.

Diagnosis.—A species of *Gila* characterized by: Caudal peduncle rather short, very deep, and thick (Girard, 1858, pl. 64, fig. 1), whence the specific name. Head short, cone-shaped, the dorsal profile ascending steeply from snout to nape in adults. Scales large and regular, 49 to 60 in the lateral line, bearing apical radii only, and weakly shield-shaped to broadly rounded at the base; predorsal scales 27 to 36, usually 31 or 32. Dorsal and anal fins almost always with 8, and pelvics typically with 9, rays. Gill rakers short and denticulate, numbering 8 to 14, usually 10 to 12. Pharyngeal dental formula, 2,5-4,2 (rarely 2,5-5,2 or 2,4-4,2), the teeth in the major row usually hooked and without grinding surfaces, the pharyngeal arches strong. Origin of dorsal fin over or slightly behind the insertion of the pelvics. Intestine with a single S-shaped loop (Figure 2) that bears a characteristic restriction at the second loop, as illustrated by the Group 2 type of Kafuku (1958: 56). Peritoneum silvery, with sparse to numerous, small to large, brown punctulations. Dermosphenotic enlarged, its width about two and one-half to three times its length, occupying somewhat more than half of the lateral temporal fossa (Figure 3).

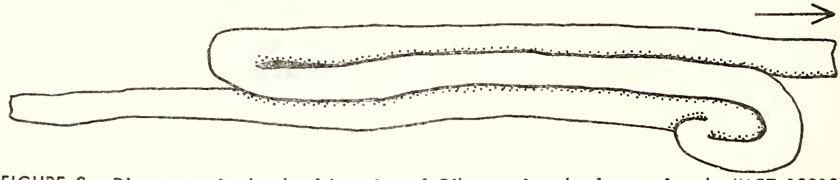

FIGURE 2. Diagrammatic sketch of intestine of *Gila crassicauda*, from a female (MCZ 18918) 213 mm s.l. Arrow indicates anterior end of body.

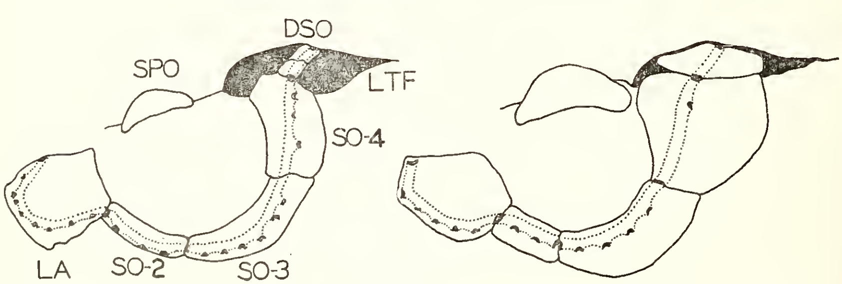

FIGURE 3. Outline of the orbital region to illustrate the bones of the suborbital series in *Gila atraria* (left) and *Gila crassicauda* (right). DSO, dermosphenotic; LA, lachrymal; LTF, lateral temporal fossa; SO, suborbital; and SPO, supraorbital. Drawing of *G. atraria* taken from Uyeno, 1960 (see footnote 2); that of *G. crassicauda* based on UMMZ 87277, a specimen 210 mm s.l.

Variation. The number of fin rays varies as follows: Dorsal, 8 (90), 9 (4), ave. 8.04; anal, 7 (2), 8 (86), 9 (6), ave. 8.04; pectorals (both fins), 16 (6), 17 (55), 18 (85), 19 (38), 20 (3), ave. 17.88; pelvics (both fins), 8 (7), 9 (154), 10 (27), ave. 9.11, with only 9 specimens having 10 rays in each fin and only 2 with 8 rays in each fin. Caudal rays almost invariably 19 (3 of 57 specimens have 18), as typical of American cyprinids. Scales in the lateral line, 49 (1), 50 (3), 51 (7), 52 (7), 53 (16), 54 (4), 55 (13), 56 (8), 57 (9), 58 (3), 59 (5), 60 (2), ave. 54.47. Body-circumference scales—above lateral line, 21-24 (21.92), below lateral line, 20-24 (22.49), total count, 44 (3), 45 (15), 46 (4), 47 (8), 48 (13), 49 (2), ave. 46.42. Scales around caudal peduncle—above lateral line, 10-13 (11.80), below lateral line, 11-13 (11.35), total count, 23 (4), 24 (13), 25 (12), 26 (11), 27 (6), 28 (1), ave. 25.11. Scales, dorsal to lateral line, 9 (11), 10 (32), 11 (11), ave. 10.00; anal to lateral line, 7 (9), 8 (32), 9 (11), 10 (1), ave. 8.07; pelvic to lateral line, 6 (9), 7 (39), 8 (2), ave. 6.86. Predorsal scales, 27 (2), 28 (2), 29 (3), 30 (7), 31 (14), 32 (12), 33 (5), 34 (4), 35 (2), ave. 31.29. Gill rakers (both sides counted in some), 8 (1), 9 (5), 10 (30), 11 (53), 12 (34), 13 (14), 14 (3), ave. 11.20. Vertebrae (including hypural complex and 4 in Weberian apparatus), 41 (20), 42 (25), 43 (4), ave. 41.67. Number of pharyngeal teeth (32 specimens): 2,5-4,2 (27), 2,5-5,2 (3), 2,4-4,2 (2).

The life colors of *Gila crassicauda* have been recorded by several workers (Ayres, 1854b; Girard, 1854, 1856; and Rutter, 1908). The back varies from greenish-brown through bluish and purplish-brown to purplish-black; the sides are lighter, with a yellowish ground color.

TABLE 1

Measurements of *Gila crassicauda*

The proportions are expressed as thousandths of the standard length. Specimens 1-3 = SU 23895; 4 = SU 37361; 5, 7 = UMMZ 86884; 6, 8 = SU 21031; and 9 = SU 29510

Measurement	1	2	3	4	5	6	7	8	9
Standard length (mm)	202	151	142	121	105	102	98	85	49
Dorsal origin to snout tip	590	565	558	547	564	549	571	566	591
Dorsal origin to occiput	400	391	373	364	372	367	391	372	381
Pelvic insertion to snout tip	570	566	558	547	572	531	555	541	583
Body, greatest depth	301	283	290	284	285	295	306	291	—
Head, length	254	257	264	277	277	263	280	270	314
Depth	187	184	195	195	202	191	198	189	217
Width	152	151	154	149	152	154	158	152	—
Caudal peduncle, length	180	185	185	183	185	176	182	192	170
Least depth	139	141	144	136	139	157	135	135	137
Snout, length	77	82	81	79	80	78	85	75	93
Eye, length	41	45	47	—	53	52	52	57	69
Interorbital, least bony width	113	101	104	101	105	100	108	99	112
Upper jaw, length	76	73	77	72	77	74	81	76	91
Mandible, length	91	91	88	92	99	88	104	92	108
Dorsal fin, depressed length	228	230	228	235	231	246	244	236	236
Dorsal fin base	131	132	132	147	131	139	144	134	134
Anal fin, depressed length	188	197	196	198	196	219	198	200	189
Anal fine base	109	109	109	126	127	124	116	109	117
Pectoral fin, length	166	171	166	175	176	195	191	191	168
Pelvic fin, length	172	171	169	168	160	185	168	165	151

The venter is unicolor, usually described as silvery but also recorded as dull yellowish. The opercular bones are tinged with purple and, in males, the body is clouded all over with numerous, small melanophores appearing as puncticulations, that are especially prominent during the spawning season (Ayres). The young have a black spot at the base of the caudal fin.

Body measurements, in thousandths of the standard length, are given in Table 1. The following ratios were derived by stepping off, with a pair of precision dividers under appropriate magnification, the measurements indicated: Least depth of caudal peduncle into head length, 1.5 to 2.05 (ave. 1.9), and into standard length, 6.2 to 7.5 (ave. 6.9), in 36 specimens varying from 77 to 268 mm in standard length. Distance between caudal base and dorsal origin into predorsal length, 1.05 to 1.4 (ave. 1.2) in 25 specimens 77 to 268 mm long.

Aside from differences in maximum size (females larger), in coloration during the breeding season, and possibly in the development of nuptial tubercles, the only difference noted between the sexes is in the relative position of the dorsal fin. As generally true of American cyprinids, this fin is slightly more anterior in males than in females (see predorsal measurements for specimens 4 and 6, Table 1, which are males). The distance between the caudal base and the origin of the dorsal fin when projected forward usually falls in advance of the orbit in males and over or behind that structure in females.

The species was probably chiefly carnivorous as indicated by the shape of the pharyngeal teeth, the silvery peritoneum, the short intestine, and the moderate number of gill rakers.

HYBRIDIZATION

Perfectly good sympatric species may occasionally hybridize in nature when the barriers to cross-mating break down for one reason or another. Only rarely, however, is there evidence that the hybrids so produced survive beyond the F_1 generation.

The hybrid described below has been collected on only three occasions over a wide time interval (1872-1926) and is not likely to recur since one of the parental species is virtually extinct. Although Hubbs (1955: Fig. 3) showed graphically that *Gila* and *Lavinia* hybridize, he did not designate the species involved. Later I listed the combination (Miller, 1961: 383), but until now the evidence for hybridization between *Gila crassicauda* and *Lavinia exilicauda* has not been presented.

Gila crassicauda × *Lavinia exilicauda*

Leuciscus conformis (*non* Baird and Girard). Rutter, 1908: 134-135 (provisional identification of 2 specimens only, from Sacramento R. and Kaweah R.).

Siboma conformis (*non* Baird and Girard). Evermann and Clark, 1931: 54 (Rutter's material only, referred to above). Murphy, 1941: 168 (based on Rutter's account).

Only five specimens are available for study: MCZ 35692, 1 adult, 115 mm s.l. (sex not determinable), collected by Steindachner in October, 1872, in the Sacramento River at Sacramento (the specimen on which Hubbs based his record of intergeneric hybridization). SU 37856, 1 adult, 130 mm s.l., collected by Rutter and Scofield on May 28, 1898, from the Sacramento River, 20 miles below Grimes, Colusa County (Rutter, 1908: 134-135); in gross aspect the gonad appears abnormal. UMMZ 94166, 3 juveniles, 50, 52, and 66 mm long (all immature), seined by Carl L. Hubbs and Leonard P. Schultz on July 29, 1926, from Putah Creek, tributary to Sacramento River, 4 miles west of Davis, Yolo County. These 3 localities are within a 10-mile radius of each other.

Presumably the specimen described by Rutter (1908: 134-135) from St. John Channel on the Kaweah River is also a hybrid, and it is so treated in Table 2. The Sacramento River and Kaweah River specimens were regarded as the same taxon by Rutter. A thorough search for the Sacramento River specimen failed to disclose it. The dental formula of 1,5-5,1 is particularly suggestive, and the fin-ray and scale counts also agree well with the numbers in the five known hybrids. Rutter collected both parental species with the single hybrid in Kaweah River (Rutter, 1908: 127, 134).

The specimens interpreted as hybrids are compared below (and in Table 2) with the presumed parental species in respect to several characters that readily distinguish *Gila crassicauda* and *Lavinia exilicauda.*

Gill Rakers. The total number of rakers in the outer row of the first gill arch provides very good support for the contention that the specimens in question represent hybrids between *Gila* and *Lavinia* (Table 2). The average number for the hybrids is almost precisely intermediate between that of *G. crassicauda* and those of populations of *L. exilicauda* from the Sacramento-San Joaquin drainages. Material from the Pajaro-Salinas basin was not used since introgression of genes from *Hesperoleucus symmetricus* into *Lavinia exilicauda* may be involved there (Miller, 1946; Hubbs, 1961: 11-12).

Fin Rays. As indicated in Table 2, the numbers of dorsal, anal, pectoral and pelvic fin rays lie between those of *Gila* and *Lavinia.* The average values for the hybrids sometimes approach those of one parent much more closely than those of the other (as in the pectoral-ray count), but in general the figures are as close to precise intermediacy as one might anticipate from such a small sample.

Pharyngeal Teeth. The dental formula of *Gila crassicauda* is typically 2,5-4,2 and that of *Lavinia exilicauda* is almost always 5-5. The hybrids, as expected, have 4 or 5 teeth in the main row and 1 or 2 in the lesser row (Table 2); this number is not only intermediate between those of the parental species but is an unexpected pattern since western minnows normally have either 0 or 2 teeth in the lesser row and preponderantly 5-4, 4-4, or 5-5 in the main row. When the total teeth on both arches are added, the average value for the hybrids lies almost exactly intermediate between that of the assumed parents (Table 2).

Scale Number. The counts for lateral-line scales (Table 2) also indicate the hybrids are intermediate between *G. crassicauda* and *L.*

exilicauda, the average value for this count being slightly closer to that of the *Gila.* In number of predorsal scales, the hybrids show almost exact intermediacy in their average value, with an expected slight overlap on the extreme counts of the two parental forms (Table 2).

Proportional Measurements. The two parental species differ markedly in respect to the relative depth of the caudal peduncle and the length of the anal fin. Using dividers under appropriate magnification

TABLE 2

Comparison of *Gila crassicauda, Lavinia exilicauda,* and the Hybrids Between These Species

For *Gila* and *Lavinia* are given the range, number of specimens (in parentheses), and average values for each item. Specimens 1-3 = UMMZ 94166; 4 = MCZ 35692; and 5-6 = SU 37856 [1]

Item	*Gila*	Hybrids							*Lavinia*
		1	2	3	4	5	6	Ave.	
Gill rakers	8-14(140),11.20	16-17	17-18	17-16	17-17	17-18	-----	17.0	20-27(40),23.53
Dorsal rays	8-9(94),8.04	9	9	9	9	9	10	9.17	10-13(316),10.87
Anal rays	7-9(94),8.04	10	10	9	10	10	10	9.83	10-15(316),12.32
Pectoral rays	16-20(94),17.88	18-18	18-17	17-17	18-18	18-18	-----	17.70	14-18(40),16.35
Pelvic rays	8-10(94),9.11	10-9	9-9	10-10	10-9	10-10	-----	9.60	9-11(40),9.93
Dental formula	2,5-4,2(27)[2]	1,5-4,1	1,5-4,1	2,5-	2,5-5,1	2,5-	1,5-5,1	-----	5-5(26)[3]
Total teeth	12-14(32),13.0	11	11	-----	13	-----	12	11.7	9-11(30),9.9
Lateral-line scales	49-60(78),54.47	61-59	52-53	54-53	59-60	56-55	60	56.55	57-67(40),60.25
Predorsal scales	27-35(51),31.29	36	36	33	35?	33	-----	34.60	34-43(36),38.05
Stepped measurements:									
Head length / C. ped. depth	1.65-2.05(33),1.96	2.3	2.4	2.4	2.3	2.2	-----	2.2	2.5-3.1(34),2.82
S. L. / C. ped. depth	6.5-7.5(32),6.96	8.4	8.5	8.7	8.6	8.3	-----	8.5	10.3-12.2(34),11.26
Anal base / C. ped. depth	0.75-0.95(20),0.83	1.1	1.2	1.15	1.2	1.26	-----	1.2	1.65-2.1(35),1.89

[1] The data for No. 6 are from Rutter (1908: 134) since this specimen is lost; to bring Rutter's dorsal and anal ray counts in line with mine, 1 was subtracted from each of his counts.
[2] 2,5-5,2 in 3; 2,4-4,2 in 2.
[3] 5-4 in 3; 6-5 in 1.

and stepping the least depth of the peduncle into the head length, the standard length, and the basal length of the anal fin, yield ratios that indicate an intermediate position for the hybrids (Table 2).

Other Characters. The margins of the dorsal and anal fins are weakly to strongly falcate in *Lavinia,* rounded in *Gila,* and straight-edged in the hybrids. The caudal fin is notably longer and more deeply cleft in *Lavinia* than it is in *Gila* and again the hybrid appears to have a caudal fin of intermediate length and forking. Unfortunately this fin is broken in most of the specimens; however, Rutter (1908: 135) described the caudal fin of his two specimens as longer than the head and with the upper lobe longer than the lower—features by which these fish differ from *Gila crassicauda* (and approach *Lavinia exilicauda).*

Rutter also pointed out for his specimens that the caudal peduncle is less deep, the dorsal and anal fins longer and the scales smaller than in the thicktail chub; this is also shown by my data (Table 2). The intestine of *G. crassicauda* has only a single S-loop (Fig. 2) and that of *L. exilicauda* is much convoluted, with at least 4 S-loops. Although the scarcity and condition of the 5 hybrids do not permit a careful study, 3 of them seem to have 2 or 3 S-loops—again indicating intermediacy, though with perhaps a closer approach to the intestinal coiling of *Lavinia*.

The dermosphenotic bone was examined in one hybrid (SU 37856) and compared with the development of this structure in the presumed parental species. In *Lavinia crassicauda* the dermosphenotic is usually divided into two parts by a suture (as in *Gila atraria;* see Figure 3), and the lower segment is generally broader than the upper one; the bone (as examined in 7 skeletons) is quite irregular in shape and development (even on the two sides of the same specimen), but it usually occupies from about one-fourth to one-third of the lateral temporal fossa (but nearly one-half in one individual). The bone is much enlarged in *G. crassicauda,* as indicated above in the diagnosis of the species. The dermosphenotic of the hybrid more closely resembles that of *G. crassicauda* in its shape and single structure; it probably occupies about one-half of the lateral temporal fossa. The nature of the dermosphenotic in the genus *Gila* (quite uniformly small and divided except in *G. crassicauda)* and its variability in *Lavinia* cast some doubt upon placing reliance on this structure for delimiting major evolutionary lines in the Cyprinidae, as was done by Tretiakov (1946).

Since so little is known of the life history of *Gila crassicauda* we can only surmise how it and *Lavinia exilicauda* managed to interbreed. The latter species is abundant in sluggish streams and sloughs, places that were the preferred habitat of the thicktail chub. The two species were able to occupy similar ecological niches presumably in large part because of marked differences in their feeding habits. *L. exilicauda* is known to rely largely, if not exclusively (as adults), on plankton, whereas *G. crassicauda* was probably chiefly carnivorous (for reasons suggested above). Although Murphy (1948) demonstrated that the hitch "apparently requires gravel-bottomed streams for successful spawning," Kimsey (1960) showed that this species is not an obligatory stream spawner and will reproduce successfully in lakes, whether over gravel or mud bottom. Data secured by R. G. Miller and W. I. Follett in October 1941, in San Juan Creek, San Luis Obispo County (in the Salinas River basin), further suggest that *Lavinia* may spawn successfully in the absence of gravel. Individuals of *Hesperoleucus symmetricus* and *Lavinia exilicauda* and large numbers of their hybrids (Hubbs, 1961: 11-12) were taken at three stations on San Juan Creek over a bottom that varied from sand to deep mud. Evidently, then, the thicktail chub and the hitch could have spawned in the same areas and, by chance, their sex products could have become mixed. Perhaps the tendency to interbreed received additional impetus from the increasing scarcity of *Gila crassicauda,* for rarity of one species and abundance of a similar relative often sets the stage for hybridization.

Material Examined.—One hundred and one specimens in 19 separate collections, all from California, have been studied as follows: USNM 231, holotype of *Lavinia* *conformis*, ca. 81 mm s.l., "Pose or O-co-ya" Creek, Tulare Valley, A. L. Heermann, 1853 (Girard, 1858: 289); USNM 216 holotype of *Tigoma crassa* (now virtually a skin, the head nearly severed, but scales well preserved), ca. 156 mm, "Sacramento River near Fort Reading," J. S. Newberry, 1855 (Girard, 1858); USNM 235 (recat. 6729), syntypes (2) of *Lavinia crassicauda*, ca. 175 and 192 mm, San Joaquin River, Heermann, 1853 (smaller specimen figured by Girard, 1858: pl. 64, fig. 1); ANSP 4197, syntype of *Lavinia crassicauda*, 108 mm, same data as preceding[3]; ANSP 14733, the type (?) of *Leuciscus gibbosus*, 254 mm, San Francisco (market)[4]; USNM 107752 (4), 94-122 mm, from Fresno, G. Eisen; USNM 30226, 206 mm, Fresno, Eisen, received Sept. 12, 1881; USNM 15407, 155 mm, Cold Creek Lake, L. Stone, March 8, 1873; USNM 19550, 152 mm, Clear Lake, Stone, Feb. 10, 1873; USNM 19565-66 (2), 262 and 258 mm, no locality, Stone, catalogued May 14, 1874; USNM 20905, 221 mm, no data; USNM 27141, 256 mm, Sacramento River, D. S. Jordan; MCZ 18743-46 (32), 76-210 mm, Sacramento River [Sacramento], Hassler Exp., F. Steindachner, Oct., 1872; MCZ 18372 and 25512 (4), 201-261 mm, same data as preceding; MCZ 18918 (2), 193 and 208 mm, San Francisco, Cory, 1862; SU 21031 (2), Coyote Creek, Santa Clara Co., 85 and 102 mm, Snyder (1905: 332); SU 23895 (3), 142-202 mm, Soap Lake, San Benito Co., I. L. Coppell, Dec. 27, 1916; SU 29510 (3), 46-48 mm, Putah Cr.; SU 37361, 121 mm, Clear Lake, M. A. Kayser, May 18, 1938; SU 38966 (22), overflow pond near Wood's Brook, Sacramento R., Nidever and N. B. Scofield, June 21, 1911; Sacramento State Coll. Mus. Nat. Hist. No. 112 (3), 49-55 mm, Putah Cr. near Davis, Yolo Co., H. O. Jenkins, June 26, 1936; UMMZ 86884 (4) and UMMZ 87221 (4), 98-215 mm, same data as MCZ 18743; UMMZ 87276-77 (2), 222 and 267 mm, San Francisco, Cory and L. Agassiz, 1854 and 1857; CAS 11060, 101 mm, "Salinas R.," Martin and Clark, Oct. 17, 1923 (loc. probably wrong, see Hubbs, 1947); CAS 20456, 156 mm, west side of Sacramento R. about 2 mi. N. of Rio Vista, Earle Mitchell, Aug. 7, 1950.

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MISSION BAY
A REVIEW OF PREVIOUS STUDIES AND THE STATUS OF THE SPORTFISHERY [1]

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INTRODUCTION

For many years Mission Bay, San Diego County, California, has been a popular sportfishing area. Because of concern among local interests over a decline in fishing success, the Department of Fish and Game initiated a survey of Mission Bay in 1961 to determine, insofar as possible, any recent changes in the fish fauna. This report gives the results of this survey and, in addition, presents a review of previous investigations, a brief history of the physical development, a description of the fishing facilities available to fishermen, and a limited survey of the invertebrates of Mission Bay.

The 1961 survey began in January and terminated in June, and consisted of six interview periods: one each in January, February, April and June, and two in March. Most interview periods lasted two days (Saturday and Sunday); the one in June lasted three (Friday, Saturday and Sunday). Each followed the previous one by three to four weeks.

Fishermen were questioned as to the type of bait they were using and the length of time they had been fishing, and each fish they had caught was identified, measured and weighed. Only shore fishermen were interviewed, although some data on the catches of boat fishermen were obtained.

HISTORY OF PHYSICAL DEVELOPMENT

In 1929, the California Legislature declared the tidelands and waters of Mission Bay a state park. At that time, a considerable amount of other property was added to the park. Along the northeast corner 65 acres were purchased, some of which have been used for Pacific Coast Highway (U.S. 101). Along the Mission Beach (western) side, a strip of land 1.5 miles long was given to the State by the Spreckles Company.

In April 1945, the State granted the tidelands and submerged lands of Mission Bay to the City of San Diego.

Mission Bay Prior to 1946

Before appreciable dredging and other human "improvements," the entire bay was comparatively shallow with very few areas deeper than 10 feet. There were a number of small low islands in the western portion, some exposed only at low tide, and many large areas of eelgrass, *Zostera* sp. The surrounding area was primarily marshland and mudflats (Figure 1).

[1] Submitted for publication June 1962.

The southern marsh was about two miles long and in most places from 0.5 to 1.0 miles wide, gradually changing from a typical salt marsh to a dry sandy wasteland into which many sloughs and strips of marsh extended. The moist area was a paradise for shore birds and waterfowl and the sloughs provided good fishing.

The San Diego River flowed through the southern marsh and entered the bay at about the middle of the southern shore.

The northern marsh was much smaller than the southern and far inferior as a retreat for birds or as a fishing area.

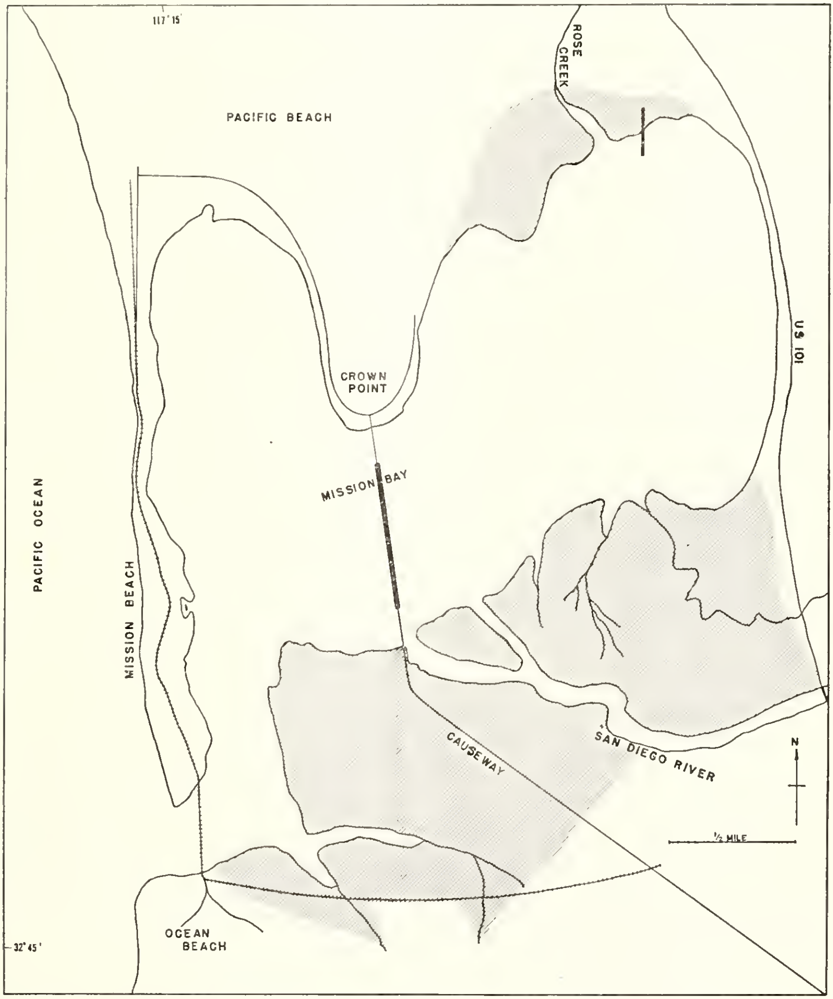

FIGURE 1. Mission Bay as it appeared prior to 1946. Many mudflats and sloughs are not shown. Shaded areas denote marshland.

Crown Point, a mesa projecting about three-quarters of a mile from the northern shore, was connected to the southern marsh by a mile of highway passing over a bridge (North Causeway Bridge), a fill (now

Tierra Del Fuego), then a second bridge (South Causeway Bridge). The highway then passed over the southern marsh on a causeway and joined the Ocean Beach-San Diego Road. The north shore, west of Crown Point, was of sandy clay, low and barren.

Mission Beach, along the western shore of the bay, was on a sand spit $2\frac{1}{4}$ miles long and at no point over one-quarter mile wide. A combination streetcar and automobile bridge (old Ventura Bridge) connected the southern end of the spit with Ocean Beach. This bridge was removed about February 1951. The spit was, and still is, built up fairly solidly with resort-type houses.

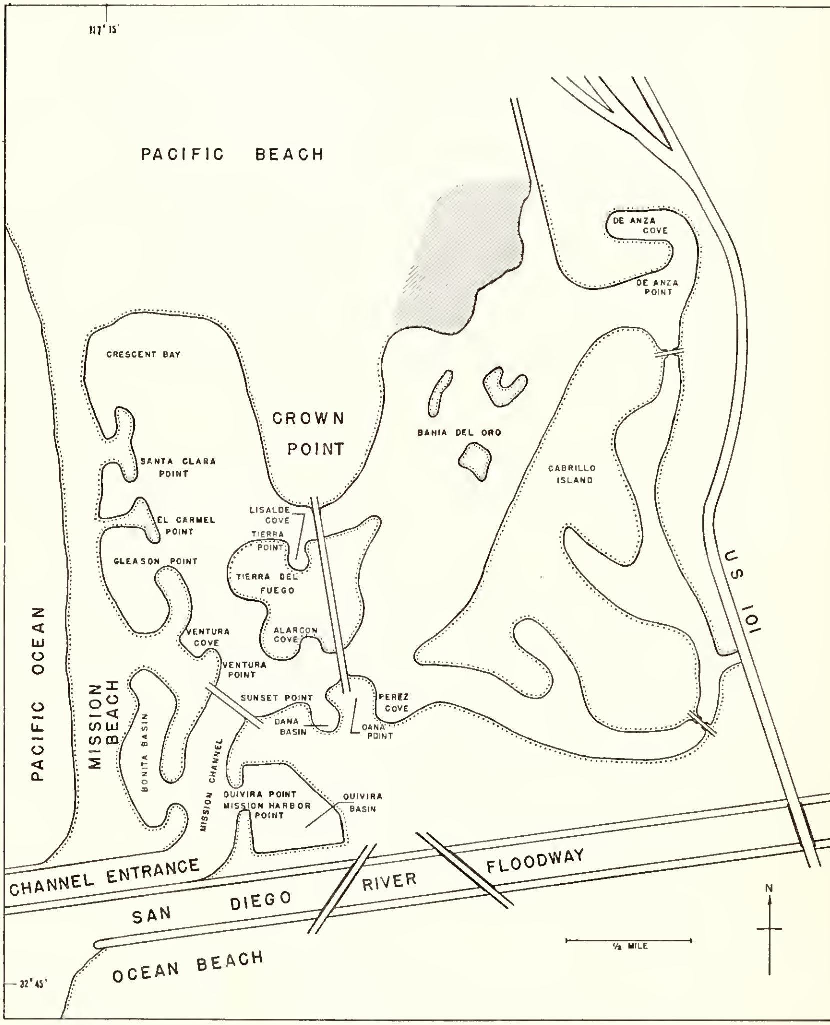

FIGURE 2. Mission Bay as it appeared in 1961. Shaded area denotes marshland.

Prior to 1946, dredging was confined to a narrow channel following the western shore of the bay and a second channel which paralleled the mudflats south of Crown Point. The latter channel was dredged to obtain fill material for constructing the roadway from Crown Point to the Ocean Beach-San Diego Road.

Development of Mission Bay

In 1930, 1935, 1939, 1944, 1956 and 1958 plans for developing Mission Bay as a recreation center were made by the City of San Diego Planning Department. The first elaborate plan, that of February 5, 1945, proposed separate entrance and flood control channels because the San Diego River tended to silt up the marshes and fill in the bay. Fry and Croker (1934) reported hearing of the same proposal. Large lagoons, peninsulas for youth activities, a wildlife area and a park and recreation area south of the proposed floodway and west of the Mission Bay Causeway also were planned.

When the 1945 plan was approved, a program of major dredging was begun, and the Gleason Point area was created. In 1948-49, the south and middle jetties were constructed by the U.S. Army Corps of Engineers and in 1949-50 the north jetty was constructed. By 1952, the San Diego River Floodway was completed; it was partially financed with federal funds.

PHYSICAL CHARACTERISTICS IN 1961

Development of Mission Bay as a recreation area, curtailed by the Korean War, received impetus in 1956 with federal funds appropriated for further dredging. Although early development plans were primarily concerned with the western half of the bay, the 1956 plan (never fully adopted) and the 1958 Master Plan (presently being followed) have been concerned with developing the entire bay (Figure 2).

With the completion of Cabrillo Island in May 1961, dredging came to a temporary halt. However, some areas such as DeAnza Cove, the area around the present wildlife refuge and the eastern portion of the floodway will need dredging about every three years due to wind-wave erosion and silt fill.

The only remaining marsh area in the bay, the wildlife refuge east of Crown Point, is owned by the University of California. Proposals to dredge and "improve" this area have been resisted since Mission Bay is an important feeding and resting ground for migrant ducks and geese, especially black brant, *Branta nigricans*. Because of this, the whole bay was declared a bird refuge about 30 years ago and all hunting prohibited.

Mission Bay Park contains 4,604 acres including both land and water. The 1958 Master Plan was designed to provide 2,065 acres of usable water, i.e., for swimming, boating and fishing, and 2,134 acres of usable land. The floodway has a total area of 405 acres.

The entrance channel between the north and middle jetties has been dredged to minus 20 feet. Mission Channel, the northeastern extension of the entrance channel, is almost 3,500 feet long, 1,000 feet wide and 20 feet deep. All other channels have been dredged to minus eight feet. Riprap lines: the shores of the entrance channel; Mission Channel along the north side to and including Ventura Point and along the south side to and including Sunset Point; the shorelines from Dana Basin around to Perez Cove; the southern half of Tierra Del Fuego; and all of Quivira Basin. Some portions of Cabrillo Island and Bonita Basin may need riprap in the future to prevent erosion. The remaining shorelines are sandy beach or boat launching areas.

Recreational Facilities

A motorboat racecourse was planned in the Bahia del Oro region, however, the floodway has since been designated as the Marine Stadium and the former reserved for water-ski enthusiasts.

There are numerous small motorboat and sailboat moorings along the western shore around Santa Clara Point, El Carmel Point and Santa Barbara Cove. Private concerns have provided slip space for larger boats in Quivira Basin.

The Crescent Bay area will be a sailboat area and Portola Lagoon, upon completion, will be for small nonpower boats.

Tierra Del Fuego, the central island of the bay, is also a center of much activity. There is a model-boat basin, a model-airplane flying area, picnicking facilities, water-ski launching ramps, and beach and rocky-shore fishing.

Cabrillo Island will offer Boy Scout and Girl Scout campgrounds as well as picnic and play areas for the general public.

The basic concept behind all planning has been to develop an area providing the greatest use for the greatest number of people. Mission Bay is probably the only recreation area of its type in the United States, if not the world.

MISSION BAY FISHERY

Previous Surveys

There have been three previous surveys of the Mission Bay fishery and one compilation of the animals occurring there. The first, a survey by Fry and Croker in 1933, was made shortly after the bay was declared a State Park. The second, a three-day study in 1949 by John E. Fitch, California Department of Fish and Game, was a simple check on the sport and bait species found within the bay. The third, was made by Merrel Taylor, San Diego State College, between March 1950 and April 1951. The results of the last two surveys were published by Marine Advisers (1957).

The checklist of Mission Bay animals was prepared by Rohlf and Keller (1958). This list is a mimeographed compilation of all the organisms they saw plus those for which they found verified reports. It gives common and scientific names but does not indicate abundance.

Scripps Institution of Oceanography has records of fishes taken in beach-seining operations between 1944 and 1958. Almost all collections were made in the immediate vicinity of either Crown Point or Ventura Bridge.

A total of 78 fish species has been reported from Mission Bay (Table 1). Most of these were caught during Scripps' beach-seining operations.

TABLE 1

Fishes Reported From Mission Bay, California

(Compiled from several sources)

Common name	*Scientific name*
Anchovy, deepbody	*Anchoa compressa* (Girard)
Anchovy, northern *	*Engraulis mordax* Girard
Anchovy, slough	*Anchoa delicatissima* (Girard)
Barracuda, California * †	*Sphyraena argentea* (Girard)
Bass, kelp * †	*Paralabrax clathratus* (Girard)
Bass, sand * †	*Paralabrax nebulifer* (Girard)
Bass, spotted sand * †	*Paralabrax maculatofasciatus* (Steindachner)
Bass, striped †	*Roccus saxatilis* (Walbaum)
Blacksmith †	*Chromis punctipinnis* (Cooper)
Blenny, bay *	*Hypsoblennius gentilis* (Girard)
Blenny, mussel *	*Hypsoblennius* sp.
Blenny, rockpool	*Hypsoblennius gilberti* (Jordan)
Bonito, Pacific * †	*Sarda chiliensis* (Cuvier)
Cabezon †	*Scorpaenichthys marmoratus* (Ayres)
Corbina, California †	*Menticirrhus undulatus* (Girard)
Croaker, black †	*Cheilotrema saturnum* (Girard)
Croaker, spotfin * †	*Roncador stearnsi* (Steindachner)
Croaker, white †	*Genyonemus lineatus* (Ayres)
Croaker, yellowfin * †	*Umbrina roncador* Jordan and Gilbert
Finspot, Mission Bay *	*Paraclinus* sp.
Fringehead, sarcastic	*Neoclinus blanchardi* Girard
Garibaldi ‡	*Hypsypops rubicunda* (Girard)
Goby, arrow *	*Clevelandia ios* (Jordan and Gilbert)
Goby, cheekspot *	*Ilypnus gilberti* (Eigenmann and Eigenmann)
Goby, shadow	*Quietula ycauda* (Jenkins and Evermann)
Greenling, painted	*Oxylebius pictus* Gill
Guitarfish, shovelnose †	*Rhinobatos productus* (Ayres)
Halfbeak, California *	*Hyporhamphus rosae* (Jordan and Gilbert)
Halibut, California * †	*Paralichthys californicus* (Ayres)
Jacksmelt * †	*Atherinopsis californiensis* (Girard)
Kelpfish, giant *	*Heterostichus rostratus* Girard
Kelpfish, spotted *	*Gibbonsia elegans* (Cooper)
Kelpfish, striped	*Gibbonsia metzi* Hubbs
Killifish, California *	*Fundulus parvipinnis* Girard
Mackerel, jack †	*Trachurus symmetricus* (Ayres)
Mackerel, Pacific * †	*Pneumatophorus diego* (Ayres)
Midshipman, specklefin *	*Porichthys myriaster* Hubbs and Schultz
Mudsucker, longjaw *	*Gillichythys mirabilis* Cooper
Mullet, striped	*Mugil cephalus* Linnaeus
Needlefish, California * †	*Strongylura exilis* (Girard)
Opaleye * †	*Girella nigricans* (Ayres)
Perch, black * †	*Embiotoca jacksoni* Agassiz
Perch, dwarf *	*Micrometrus minimus* (Gibbons)
Perch, kelp *	*Brachyistius frenatus* Gill
Perch, pile * †	*Rhacochilus vacca* (Girard)
Perch, shiner * †	*Cymatogaster aggregata* Gibbons
Pipefish, bay *	*Syngnathus griseolineatus* Ayres
Pipefish, barred *	*Syngnathus auliscus* (Swain)
Pipefish, kelp *	*Syngnathus californiensis* Storer
Queenfish †	*Seriphus politus* Ayres

TABLE 1—Continued

Fishes Reported From Mission Bay, California

(Compiled from several sources)

Common name	*Scientific name*
Ray, bat * †	*Myliobatis californicus* Gill
Ray, California butterfly †	*Gymnura marmorata* (Cooper)
Ray, Pacific electric	*Torpedo californica* Ayres
Rockfish, olive †	*Sebastodes serranoides* Eigenmann and Eigenmann
Salema * †	*Xenistius californiensis* (Steindachner)
Sanddab, speckled *	*Citharichthys stigmaeus* Jordan and Gilbert
Sargo * †	*Anisotremus davidsoni* (Steindachner)
Sculpin * †	*Scorpaena guttata* Girard
Sculpin, Pacific staghorn *	*Leptocottus armatus* Girard
Sculpin, wooly	*Clinocottus analis* (Girard)
Sea bass, giant †	*Stereolepis gigas* Ayres
Seabass, white * †	*Cynoscion nobilis* (Ayres)
Seaperch, white †	*Phanerodon furcatus* Girard
Señorita	*Oxyjulis californica* (Günther)
Shark, horn †	*Heterodontus francisci* (Girard)
Shark, leopard * †	*Triakis semifasciata* Girard
Shark, Pacific angel †	*Squatina californica* Ayres
Smoothhound, brown †	*Triakis henlei* (Gill)
Smoothhound, gray * †	*Mystelus californicus* Gill
Sole, English *	*Parophrys vetulus* Girard
Stingray, round * †	*Urolophus halleri* Cooper
Surfperch, walleye †	*Hyperprosopon argenteum* Gibbons
Tonguefish, California *	*Symphurus atricauda* (Jordan and Gilbert)
Topsmelt *	*Atherinops affinis* (Ayres)
Turbot, C-O * †	*Pleuronichthys coenosus* Girard
Turbot, diamond * †	*Hypsopsetta guttulata* (Girard)
Wrasse, rock †	*Halichoeres semicinctus* (Ayres)
Yellowtail, California †	*Seriola dorsalis* (Gill)

* Abundant.
† Considered important as a sport fish (sharks and rays probably are seldom eaten but many anglers specifically seek them).
‡ May not be taken at any time.

The 1961 Survey

Areas Surveyed

Twenty-five separate locations were surveyed in 1961 (Table 2). Most of these coincided with areas given specific names by the 1958 Master Plan. It was necessary to stretch some boundaries and in one case unofficially designate a name for an area.

Yacht Club Point also includes the shore area along Mission Channel to Ventura Bridge.

Mission Harbor Point also includes the shoreline south to the middle jetty.

Quivira Point also includes the shoreline along Mission Channel to the Ventura Bridge.

Sunset Point also includes the shoreline west to the Ventura Bridge.

Dana Point, an unofficial name, is used to describe the area from the northeastern corner of Dana Basin to the South Causeway Bridge.

Lisalde Cove also includes the shoreline from the western tip of the cove to the North Causeway Bridge.

The roadway through Tierra del Fuego divides the island into east and west regions.

Results

During 1961, the 1,024 fishermen interviewed had fished 2,547 hours and caught 397 fish, an average of 0.156 fish per hour (Table 3). Success varied from 0.029 fish per hour in April to 0.522 during March. Some fish were caught at all locations except Perez Cove which was visited only in June.

Approximately 20 were commonly caught species with four contributing 57.68 percent of the total catch (Table 4). These were: spotfin croaker 29.22 percent, spotted sand bass 13.35 percent, California halibut 8.06 percent, and opaleye 7.05 percent. Various surfperches (family Embiotocidae) contributed 8.31 percent.

TABLE 2

Success of Mission Bay Fishermen by Locality During 1961 Survey

Locality	*Number fishermen*	*Number hours fished*	*Number fish caught*	*Percent total catch*	*Catch per hour*
Ventura Cove	7	8.25	9	2.27	1.091
Crown Point Channel (skiffs)	6	21.75	11	2,77	0.506
Quivira Basin	50	106.65	43	10.83	0.403
Bonita Basin	3	7.75	3	0.76	0.387
North Jetty	23	42.50	16	4.03	0.376
Alarcon Cove	19	21.50	7	1.76	0.326
Middle Jetty	58	189.75	61	15.37	0.321
De Anza Cove	77	174.00	47	11.84	0.270
North Causeway Bridge	4	23.25	6	1.51	0.258
Dana Basin	7	8.75	2	0.50	0.229
Mission Harbor Point	49	84.55	18	4.53	0.213
Ventura Bridge (skiffs)	6	48.00	10	2.52	0.208
South Causeway Bridge	1	5.00	1	0.25	0.200
Dana Point	16	10.50	2	0.50	0.190
De Anza Point	5	14.75	2	0.50	0.136
East Side Tierra del Fuego	284	826.80	101	25.44	0.122
Lisalde Cove	38	92.00	10	2.52	0.109
Yacht Club Point	93	164.50	18	4.53	0.109
Point Medanos	31	56.75	4	1.01	0.070
Quivira Point	60	141.75	9	2.27	0.063
Sunset Point	36	75.00	4	1.01	0.053
Ventura Point	16	21.50	1	0.25	0.047
Tierra Point West	80	247.75	8	1.76	0.032
Crown Point (east side)	52	148.75	4	1.01	0.027
Perez Cove	3	5.75	0	0.00	0.00
Totals	1,024	2,547.50	397	100.00	0.156

TABLE 3

Success of Mission Bay Fishermen by Interview Period

Interview period	*Total fishermen*	*Number of hours fishing*	*Number of fish*	*Catch per hour*	*Successful fishermen*	*Percent successful*
January 28-29, 1961	123	211.75	51	0.241	21	17.07
February 11-12, 1961	125	315.90	90	0.285	24	19.20
March 4-5, 1961	40	95.75	50	0.522	19	47.50
March 25-26, 1961	193	454.05	105	0.231	41	21.24
April 29-30, 1961	273	794.00	23	0.029	10	3.66
June 2-4, 1961	270	676.05	78	0.115	32	11.85
Totals	1,024	2,547.50	397	0.156	147	14.36

TABLE 4

Number of Fish by Species Taken by Mission Bay Fishermen During the 1961 Survey

Species	Jan. 28-29	Feb. 11-12	Mar. 4-5	Mar. 25-26	Apr. 29-30	June 2-4	Total	Catch per hour	Percent of catch
Bass, kelp and sand	8	10	0	2	0	1	21	0.008	5.29
Bass, spotted sand	8	21	13	3	7	1	53	0.021	13.35
Bonito, Pacific	1	2	1	0	2	7	13	0.005	3.27
Corbina, California	0	0	0	0	0	11	11	0.004	2.77
Croaker, spotfin	0	5	18	77	5	11	116	0.046	29.22
Croaker, yellowfin	0	0	0	4	1	6	11	0.004	2.77
Halibut, California	3	4	7	6	2	10	32	0.013	8.06
Mackerel, Pacific	0	15	0	0	0	0	15	0.006	3.78
Opaleye	7	18	0	2	0	1	28	0.011	7.05
Queenfish	0	0	2	0	0	4	6	0.002	1.51
Sargo	0	3	0	0	0	4	7	0.003	1.76
Seabass, white	4	1	0	0	0	8	13	0.005	3.27
Sharks and rays	1	0	3	0	3	1	8	0.003	2.02
Surfperches	14	7	0	5	0	7	33	0.013	8.31
Turbot, diamond	1	0	3	3	1	0	8	0.003	2.02
All others	4	4	3	3	2	6	22	0.009	5.54
Totals	51	90	50	105	23	78	397	0.156	99.99

Fishing success was relatively equal throughout the bay; however, not all species were caught in all areas. The south shore of the channel between Crown Point and Tierra Del Fuego has a wide sandy beach and occasionally offered good spotfin croaker and California corbina runs. These were interspersed with periods producing poor if not downright terrible fishing. California halibut, sargo and an occasional spotted sand bass or diamond turbot also were caught.

The southern shores of Tierra Del Fuego are riprap-lined and at times yielded good spotted sand bass fishing and an occasional California halibut. The spotted sand bass caught there were usually small (150 to 260 mm) but gave the fishermen some feeling of success.

De Anza Cove was good for spotfin croakers and California corbina with an occasional California halibut and diamond turbot showing up.

Quivira Basin was fished by many individuals for bonito and mackerel, which were apparently drawn into the basin by the bait receivers kept by partyboat fishing concerns.

The middle and north jetties offered the greatest variety. Opaleye, sargo, California halibut, spotted sand bass, white seabass, kelp bass and sand bass were caught most frequently.

Sharks and rays are caught more frequently and in greater numbers than the data in Table 4 indicate. Many fishermen did not report these and since most were discarded, shark-fishing success could not be measured. Round stingrays and bat rays were seen lying three to six deep on the beaches. The principal sharks caught were gray smoothhounds, brown smoothhounds and leopard sharks. California butterfly rays and shovelnose guitarfish were also caught. Sharks and rays ranged throughout the bay and were a nuisance to fishermen (although they do put up a good fight) and, in the case of stingrays, a menace to bathers.

Skiff fishermen reported catching California halibut, spotfin croakers, yellowfin croakers, white seabass, California corbina, bonito, diamond turbots, barracuda, jacksmelt, spotted sand bass and striped bass.

Comparison With Previous Surveys

A review of previous survey data revealed an obvious consistency throughout the years in the fish species taken in Mission Bay. This stability is significant since it indicates the various changes man has made in the ecology of the bay over a 30-year interval have not permanently upset the fish population. This gives promise that future plans for the bay will not be too disturbing if carried out with proper consideration for the habitat necessary to maintain the fishery.

Fry and Croker (1934) listed as commonly taken species: kelp bass, sand bass, spotfin croakers, diamond turbots and round stingrays. Less frequently taken were yellowfin croakers, California halibut, California corbina and white seabass.

Fitch, in June 1949, found spotfin croakers, yellowfin croakers, diamond turbots, California halibut and round stingrays, the most commonly taken species.

Those most frequently taken in Taylor's 1950-51 survey were spotfin croakers, diamond turbots, kelp bass, sand bass, California halibut and round stingrays. Yellowfin croakers made up 2 percent of the catch and spotted sand bass 3 percent. The combined catch of surfperches was large (41.8 percent) but no single species was outstanding (Table 5). Taylor's survey was based largely on interviews with beach and pier fishermen although he also questioned a few men fishing from boats. During the 14 months, the 2,046 fishermen interviewed reported 5,739 hours fishing with a catch of 1,150 fish. The average catch per hour was 0.200 fish, which is not significantly higher than the 1961 average.

TABLE 5

Number of Fish by Species Taken by Mission Bay Fishermen During the 1950-51 Survey [1]

	Number	*Catch per hour*	*Percent of catch*
Bass, kelp and sand	109	0.019	9.5
Bass, spotted sand	30	0.005	2.6
Corbina, California	3	0.001	0.3
Croaker, spotfin	129	0.022	11.2
Croaker, yellowfin	25	0.004	2.2
Halibut, California	74	0.013	6.4
Seabass, white	4	0.001	0.3
Sharks and rays	60	0.010	5.2
Stingray, round	61	0.011	5.3
Surfperches	481	0.084	41.8
Turbot, diamond	118	0.021	10.2
All others	56	0.010	4.9
Total	1,150	0.200	99.9

[1] Data from Merrel Taylor, San Diego State College.

The 1961 survey showed 0.156 fish per hour, only a slight decrease from the 1950-51 survey. Many factors could have produced this decrease.

Taylor's survey, as did the 1961 survey, indicated that fishing success was about equally distributed throughout the bay. Kelp bass, sand bass, spotfin croakers and yellowfin croakers were taken in the channels. California halibut were more frequent in the deep channels near the entrance. The surfperches were also more abundant near the bay entrance, especially around pilings. Diamond turbots and round stingrays were throughout the bay.

The obvious differences between Taylor's survey and that of 1961 are the decreased numbers of kelp bass and sand bass and the increase in spotted sand bass. Conspicuously new to the bay sportcatch since Taylor's survey were bonito, Pacific mackerel and opaleye.

Evaluation of 1961 Survey

Extensive dredging, creation of new land masses, riprapping of many sand beaches and other physical changes which have been in progress since 1945, and particularly since 1956, have kept Mission Bay in a constant state of turmoil, so far as providing stable fish habitat. These factors most likely are largely responsible for the reported degradation of fishing between 1957 and 1959. Apparently in 1961 bottom conditions were gradually recovering stability, bottom organisms which are the natural food of fishes were regaining footholds, and fishing appeared to be improving. Quite surprising was the fact fishing was as good as the 1961 survey indicated in view of the many changes made in the bay.

Changing the ecology of the bay brought some changes in the fish fauna. Apparently suitable habitat for kelp bass and sand bass has decreased while that suitable to bonito, Pacific mackerel, spotted sand bass and opaleye has increased or been created. When Taylor made his survey, most of the riprap areas were nonexistent. These areas provide very suitable habitat for opaleye and spotted sand bass. The decrease in kelp bass and sand bass also may be due to overfishing or to the 12-inch minimum size limit which went into effect in March 1959. (The same size limit applies to spotted sand bass, however.)

Another factor which may have had an effect on Mission Bay is water temperatures. It may be significant that poorest fishing was reported during the warm-water years 1957 to 1959 discussed by Radovich (1961).

Mission Bay is subjected to heavy fishing pressure. With San Diego's increase in population, despite the potential for an increase in the fish populations, individual fishing success may never return to the level of the "good old days." More fish will probably be caught than ever before but they will be divided among many more anglers.

MISSION BAY FISHING FACILITIES

Mission Bay fishermen are fortunate in having bait and tackle shops, several kinds of bait, and access roads available to them. There are three bait and tackle stores in the immediate vicinity; one is right on the bay and the other two are within one-half mile of it.

Several kinds of bait are used in Mission Bay, principally jackknife clams *(Tagelus californianus)*, blood worms *(Glycera dibranchiata)* shipped in from the Atlantic coast and red ghost shrimp *(Callianassa californiensis)* known to the bay fishermen as crawfish. Live and salted northern anchovies are also available and frequently used. Less commonly used are longjaw mudsuckers, spileworms *(Neanthes* sp.), mussels *(Mytilus* spp.) and squid *(Loligo opalescens)*. Frozen green peas are used for opaleye bait with fair success on the jetties. A few fishermen trap silversides (fish family Atherinidae) for bait. Most of the mudsuckers, jackknife clams, mussels and spileworms are taken in Tijuana Slough south of Imperial Beach in San Diego County, and in San Diego Bay. Fishermen were beginning to dig their own jackknife clams in Mission Bay for bait, after having undergone several years when quantities were limited. Most of them were dug in the De Anza Cove area and along the north shore of Tierra Del Fuego, indicating some bottom organisms were regaining strength of numbers. Mussels were also becoming abundant enough in the bay to be gathered for bait.

Access is likely a large factor in the popularity of Mission Bay. Many individuals fish from their automobiles, while others prefer to walk 50 to 75 yards to their favorite hole. These conditions may change when landscaping is completed, but even then a walk of over 100 yards will not be necessary.

Two partyboat sportfishing concerns in Quivira Basin ran daily trips to the La Jolla and Point Loma kelp beds and Los Coronados Islands.

Rental skiffs and rowboats were available at Dana Basin and Quivira Basin. There are small-boat launching ramps in Dana Basin, De Anza Cove and at Santa Clara Point. The Dana Basin ramp operators reported launching as many as 200 boats on summer weekends.

MISSION BAY INVERTEBRATES

My invertebrate survey in Mission Bay was necessarily limited. Those listed as a result of this survey are species most commonly seen by fishermen. Rohlf and Keller (1958) reported 201 species in Mission Bay, of which 58 percent were mollusks.

Among the more obvious echinoderms in 1961 were spiny sand stars *(Astropecten armatus)*, bat stars *(Patiria miniata)*, pink stars *(Pisaster ochraceus segnis)*, ultraspiny brittle stars *(Ophiothrix spiculata)*, red sea urchins *(Strongylocentrotus franciscanus)*, and purple sea urchins *(S. purpuratus)*. A few holothuroideans (sea cucumbers) were seen but not identified. Many starfish are "caught" by fishermen, much to their surprise and disappointment.

Mollusks, being a source of bait, were a commonly reported group. Cockles (family Cardiidae) especially basket cockles *(Clinocardium nuttalli)* seemed fairly abundant as were bay mussels *(Mytilus edulis)* and sea mussels *(Mytilus californianus)*. Jackknife clams were present in sufficient quantities for fishermen to dig them for bait. Marine slugs (tectibranchs and nudibranchs), principally sea hares *(Aplysia californica)* and sea slugs *(Navanax inermis)*, were also plentiful.

Crabs, to many fishermen, are pests in that they steal bait. Commonly noted were purple shore crabs *(Hemigrapsus nudus)* and lined shore crabs *(Pachygrapsus crassipes)*. Rock crabs *(Cancer antennarius)* were also seen, especially around the north and middle jetties. There was also a small red ghost shrimp population, however, this species, formerly very abundant, was not seen.

The mollusks, shrimps and crabs have been seriously depleted; either they have disappeared from the bay or were dug up by dredging operations. However, their populations seem to be gaining in numbers and barring further setbacks, they may again become a large portion of the biomass.

DISCUSSION

Mission Bay has undergone many physical changes since declared a state park in 1929 and each change has altered the ecology. Four surveys of the fishery have indicated that fishing success and the locations where the various species are caught have remained relatively unaltered. Also the consistency of fish species occurring and caught in the bay has remained quite stable.

Fishing facilities have been improved making it much easier for fishermen to obtain necessary supplies and enjoy their sport.

Although the invertebrates have apparently suffered from man's attempts to improve the bay, in 1961 they were begining to regain their strength and ecological niches.

All things considered, fishing in 1961 was as good as could be expected and barring drastic future changes it should continue to improve as bottom conditions reach stability.

SUMMARY

1. In 1929, the State Legislature declared the tidelands and waters of Mission Bay a state park and in 1945 the State granted the tidelands and submerged lands of Mission Bay to the City of San Diego.

2. Before 1945, the area around Mission Bay was primarily marshland. Major dredging and construction created the Gleason Point area in 1945, the Floodway Channel from 1948 to 1952, and numerous other recreation and fishing areas almost every year since. Mission Bay's development is now directed by the 1958 Master Plan.

3. The Department of Fish and Game's 1961 Mission Bay survey began in January and terminated in June, after six interview periods covering 25 separate bay locations. In all, 1,024 fishermen were interviewed who had fished 2,547 hours and caught 397 fish for an average of 0.156 fish per hour. Approximately 20 were commonly caught species and 4 of these made up 57.68 percent of the catch.

4. Fishing success was relatively equal throughout the bay and compared favorably with success noted during three previous surveys. However, four species noted in 1961 were not reported during previous surveys.

5. Fishing facilities available to bay fishermen have been improved, making fishing much easier and more enjoyable than in the past.

6. Angling appeared to be as good as could be expected in view of the changes made in Mission Bay. Fishing should improve as the various habitats stabilize, barring future drastic changes, of course.

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VARIANT HEMOGLOBIN AND ELECTROPHORETIC WHOLE BLOOD STUDIES IN TWO TUNAS AND THREE OTHER FISH SPECIES[1]

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INTRODUCTION

In recent years, fisheries biologists have turned increasing attention to serology as a tool for identifying genetically distinct or separate, noninterbreeding populations of a number of important species. The problem among the various tunas is particularly significant and is receiving considerable emphasis in several laboratories. The California Department of Fish and Game in its studies of bluefin tuna (*Thunnus thynnus*) and albacore (*T. alalunga*) is experimenting with hitherto untried serological approaches in a pilot study using readily available fishes, regardless of species, as well as tunas.

Variant or rare types of hemoglobin, having a genetic basis, may well be used as indicators of a fish population's genetic structure. The first variant hemoglobin was identified by Pauling *et al.* (1949) when they studied by electrophoresis the red cells of normal people and those sick with a disease called sickle cell anemia. They found that the hemoglobins had different charges and thus revealed an abnormal variant (sickle cell type) of hemoglobin for the first time. Ingram (1958) credits various researches, particularly those of J. V. Neel (University of Michigan), with having proved that the abnormal hemoglobin was hereditary and traceable to a single mutant gene. Allison (1956) states that the sickle cell gene is prevalent among 9 percent of the population in the United States and among 40 percent of some African Negroes.

Numerous hemoglobin varieties rarer than the sickle cell type have since been identified, shown to be the products of mutant genes, and found to exist in certain frequencies in different populations of people. The present list of hemoglobin types for man includes: A (normal adult), D, E, F, G, H, I, J, K, M, and S (sickle cell). All have minor differences in molecular structure which cause differences in net charge. When electrophoresed, they may be identified by differential mobilities and curves. Because reduced sickle cell hemoglobin grossly distorts the erythrocytes into a sickle or holly shape, its presence also can be determined by mixing some blood with a reducing agent (e.g. sodium bisulfite) and looking for distortation of the red cells (Miller, 1960).

[1] Submitted for publication July 1962.

Since the initial demonstration of abnormal hemoglobin by Pauling *et al.* (1949), electrophoretic studies have been conducted on species other than man. Multiple hemoglobins have been reported in various mammals, birds, amphibians, reptiles, and fishes. According to Hashimoto and Matsuura (1959), the report of Pedersen (1933) seems to contain the earliest reference to electrophoretical heterogeneity of hemoglobin in fish; he worked with the oyster toadfish *(Opsanus tau)*. More recently, Hashimoto and Matsuura (1959) noted two components in carp *(Cyprinus carpio)* and chum salmon *(Oncorhynchus keta)*, and three components in yellowtail *(Seriola quinqueradiata)* and rainbow trout *(Salmo gairdneri)*. Buhler and Shanks (1959) found two components in the sockeye salmon *(Oncorhynchus nerka)*, silver salmon *(O. kisutch)*, chinook salmon *(O. tshawytscha)*, American shad *(Alosa sapidissima)*, and largemouth black bass *(Micropterus salmoides)*; and three components in rainbow trout and brook trout *(Salvelinus fontinalis)*. Patterson (n.d.), working with three copper rockfish *(Sebastodes caurinus)*, four blue rockfish *(S. mystinus)*, and three yellowtail rockfish *(S. flavidus)*, demonstrated distinctive electrophoretic patterns for each species. He also demonstrated different electrophoretic mobilities of the hemoglobin from single specimens of lingcod *(Ophiodon elongatus)*, canary rockfish *(Sebastodes pinniger)*, vermilion rockfish *(S. miniatus)*, gopher rockfish *(S. carnatus)*, flag rockfish *(S. rubrivinctus)*, greenspotted rockfish *(S. chlorostictus)*, and kelp bass *(Paralabrax clathratus)*.

There is also a relationship between serum proteins and genotype, but it has not been investigated as thoroughly as in the case of hemoglobin. Starr and Fosberg (1957) electrophoresed the serum proteins of four shark species and demonstrated similar patterns among individuals of the same species, significant variation between individuals of different genera, and lesser variation between different species of the same genera. Gunter, Sulya, and Box (1961) studied by electrophoresis the serum proteins of 26 species of elasmobranch and teleost fishes, and concluded that closely related forms could be distinguished by the presence or absence of plasma proteins, with some exceptions. No major intraspecific pattern differences were reported in either paper.

My study was carried out to determine if variant hemoglobins and electrophoretic whole blood patterns existed among tunas and three other Pacific fishes by observing for sickling of red blood cells when a reducing agent was added and by electrophoresing whole blood; and to evaluate these methods for identifying separate, noninterbreeding populations within the same species.

MATERIALS AND METHODS

In my work I used northern anchovies *(Engraulis mordax)*, kelp bass, spotted bass *(Paralabrax maculatofasciatus)*, rubberlip perch *(Rhacochilus toxotes)*, albacore and bluefin tuna.

Sickle cell studies were made by mixing blood collected from live fish with a few crystals of sodium citrate and an equal volume of commercially available (Medical Chemical Corporation) 2 percent sodium bisulfite solution, allowing the mixture to stand for several hours and then removing one drop to a slide to observe for sickling under a microscope. A control slide (without the sodium bisulfite) for each sickle cell preparation also was examined after standing for several hours.

Blood to be studied by electrophoresis was collected from the severed peduncles of live kelp bass and from the pericardial cavities of dead, thawing albacore and bluefin tuna. The blood was collected in commercially available Vacutainer tubes (catalog no. 3204 Q) containing 7 mg of EDTA (disodium ethylenediaminetetraacetate dihydrate). The tubes were filled approximately halfway with blood and stored at 5° to 6° C. until ready for electrophoresis.

Electrophoresis of whole blood was carried out as described by Spinco, Division of Beckman Instruments (1961) except for preparation of the blood-containing capilliary tubes. Microhematocrit capilliary tubes were half-filled with blood from the Vacutainer tubes and half with distilled water, then sealed at one end with clay and centrifuged for 15 minutes. After centrifugation, the portion of the capillary tube containing the packed cellular debris was broken off and discarded, and the adjacent end with the most concentrated lysate was applied to the electrophoresis paper strip by means of the Spinco sample applicator. The separation was carried out in a Spinco Model R Electrophoresis System, in Spinco B-1 buffer. Five hundred volts were used per cell and allowed to flow for four hours.

At the completion of separation, the paper strips were dried in an oven at 120° to 130° C., and then stained by immersing in methanol (6 minutes), in bromphenol blue dye (30 minutes), and in three consecutive rinses of 5 percent glacial acetic acid (6 minutes each). The strips were then dried in an oven at 120° to 130° C., and placed for 15 minutes in an atmosphere of ammonium hydroxide vapor.

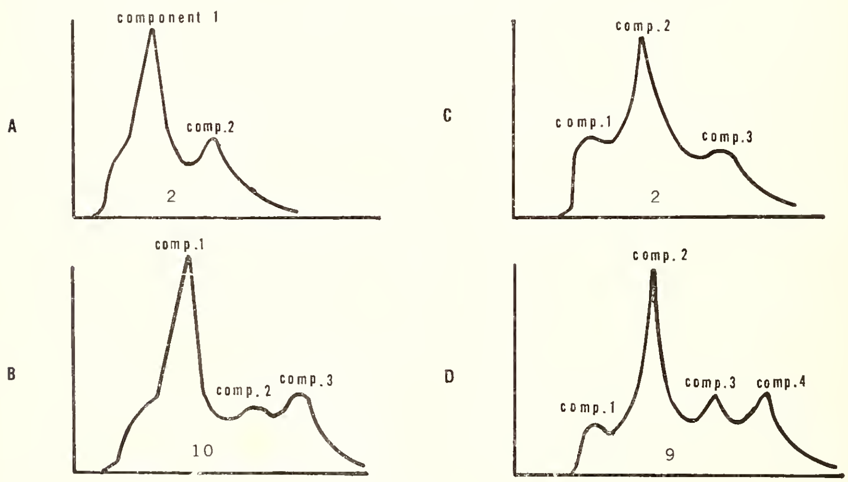

FIGURE 1. Four generalized patterns of 23 kelp bass whole blood samples on electrophoresis. The number within each curve designates the number of fish showing that curve.

EXPERIMENTAL RESULTS AND DISCUSSION

No sickling of red cells from 100 anchovies, and single specimens of rubberlip perch and spotted bass was observed when the reducing agent was added. Apparently the sickle cell variant of normal hemoglobin

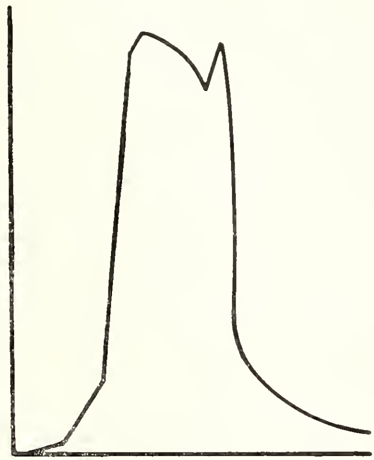

FIGURE 2. The generalized pattern of eight albacore whole blood samples on electrophoresis.

was not present in the fish sampled or the method of demonstrating a variant hemoglobin in man may not be applicable to identifying variant hemoglobins in fish; however, more fish should be tested as the method is so very simple.

Electrophoresis of kelp bass whole blood revealed no differences in net electrical charge, and therefore no differential mobilities among

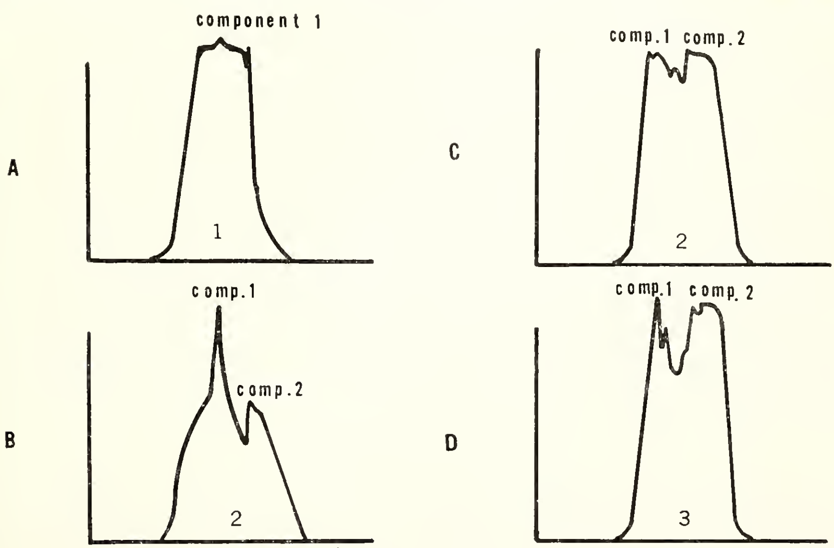

FIGURE 3. Four generalized patterns of eight bluefin tuna whole blood samples on electrophoresis. The number within each curve designates the number of fish showing that curve.

the 23 individuals. However, the components and patterns could be grouped to form four kinds of curves (Figure 1). This may reflect four genetic types of individuals among the kelp bass tested.

Electrophoresis of albacore whole blood demonstrated only one general curve in the eight individuals tested (Figure 2). However, some possible differences in mobility were noted, but the fuzziness of the margins of the migrated protein made it impossible to measure the distances of migration satisfactorily. Testing additional individuals may yet reveal other types of curves.

Electrophoresis of the whole blood from eight bluefin tuna revealed a situation similar to that noted for albacore: There were fuzzy migrated protein margins so it was not possible to measure satisfactorily protein mobilities. However, the electrophoretic curves demonstrated patterns which could be grouped into four kinds of curves (Figure 3). Curves C and D appear somewhat similar; therefore, at least three and possibly four electrophoretic patterns were demonstrated. This may reflect the presence of three or four genetic types of individuals within the species.

Demonstrating substantial differences in the whole blood among individuals within a species (by electrophoresis) may offer a practical method of identifying separate, noninterbreeding fish populations: differential frequencies of any clearly rare electrophoretic pattern may distinguish them. The method appears immediately applicable to kelp bass and bluefin tuna population studies because clear whole blood electrophoretic pattern variations were noted for these species. The method does not appear immediately applicable to albacore population studies because it did not demonstrate more than one type of whole blood electrophoretic pattern, although other kinds may be discovered when more individuals are studied.

SUMMARY

Red cells from 100 northern anchovies and single specimens of rubberlip perch and spotted bass were tested for sickling by adding a reducing agent (sodium bisulfite); none was observed.

Twenty-three kelp bass demonstrated, on electrophoresis, the presence of at least four different kinds of whole blood patterns.

Eight albacore demonstrated, on electrophoresis, one kind of whole blood pattern as reflected by curves that were enough alike so they could be grouped into one general curve representing the species.

Eight bluefin tuna demonstrated, on electrophoresis, four general types of whole blood curves, but two were somewhat similar.

Kelp bass whole blood proteins did not show differential mobilities among individuals. In albacore and bluefin tuna, differential mobilities could not be determined definitely due to the fuzziness of the migrated protein margins.

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A NEW NORTHERN RECORD OF THE SMOOTH STARGAZER[1]

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On August 8, 1960, a smooth stargazer, *Kathetostoma averruncus* Jordan and Bollman, was trawled off Piedras Blancas, San Luis Obispo County in 600 feet of water, 200 miles north of the species' previous recorded range. Since 1959, when the first California specimen (Figure 1) was trawled in Santa Monica Bay (Radovich, 1961), an additional 11 have been taken (Table 1). Quite possibly, oceanic currents carried them north from Baja California waters as pelagic young and their continued development was facilitated by the warm-water conditions prevailing off California from 1957 through 1959. Otolith age determinations by John E. Fitch (pers. comm.) show that none was old enough to have arrived before 1957.

FIGURE 1. Smooth stargazer, *Kathetostoma averruncus* Jordan and Bollman. *Photograph by Jack W. Schott.*

Six specimens were females but the sexes of the rest could not be determined. The stomachs of six contained partially digested fish. The Piedras Blancas stargazer contained a lingcod, *Ophiodon elongatus,* 120 mm total length; one trawled off Rincon Point contained a shortspine combfish *Zaniolepis frenata,* and a partially digested northern anchovy, *Engraulis mordax* (Outdoor California, 1961); and another from off Rincon Point contained a partially digested flatfish, family Bothidae.

We encountered difficulty determining whether the California stargazers were *K. averruncus* (type locality: Panama) or *K. ornatus* Wade (type locality: near San Benito Islands, Baja California). On the basis of geographical distribution, it would seem logical to identify those collected to the north as *K. ornatus.* However, since stargazers have

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pelagic young, distribution alone cannot be used as a criterion for identification. We compared the California fish with descriptions of *K. averruncus* (Jordan and Bollman, 1889; Garman, 1899) and *K. ornatus* (Wade, 1946) and although meristic counts in the early descriptions were of some value, the measurements were too general to be useful. Therefore, we compared ours with nine *K. averruncus* from near the type locality, Panama. All counts and measurements follow Hubbs and Lagler (1958) and Berry and Anderson (1961). The California fish

TABLE 1

Collection Data for 11 Smooth Stargazers Taken in California Since 1959

Date	Locality	Depth (feet)	Sex	Standard length (mm)	Collector
15 May 1960	5-7 mi. north of and parallel to Santa Cruz Id.	720-1080	Not determined	169.5	Unknown
24 June 1960	5 mi. off Ballona Ck., Santa Monica Bay	300	Not determined	159.5	John Baxter
8 Aug. 1960	Off Piedras Blancas	600	♀ Mature	193.5	Neil Burton
13 Dec. 1960	Off Ventura	Unknown	♀ Immature	133.6	Vic Castagnola
12 Jan. 1961	5¾ mi. west of Hyperion, Santa Monica Bay	222-312	Not determined	143.9	Gordon Chapman
13 Apr. 1961	Off Rincon Point, Santa Barbara	294	♀ Mature	195.5	Harry Barrington
12 May 1961	Off Rincon Point, Santa Barbara	300	Not determined	156.0	Floyd Watson
9 Nov. 1961	6¼ mi. west of Hyperion, Santa Monica Bay	306-324	♀ Mature	208.5	William Donnelly
22 Mar. 1962	Inside of Santa Cruz Id.	750	♀ Immature	186.0	Harry Barrington
22 Mar. 1962	Inside of Santa Cruz Id.	750	♀ Mature	190.5	Harry Barrington
Unknown	Probably off Santa Barbara	Unknown	Not determined	133.9	Unknown

TABLE 2

Comparison of Selected Characters of *Kathetostoma averruncus* and *K. ornatus*

	California specimens (11)	Panama specimens* (9)	Redescription of *K. averruncus* (Garman, 1899)	Description of *K. ornatus* (Wade, 1946)
Size range (s. l., in mm)	133.6-208.5	61.0-75.6		72.0-90.5
Counts (number of fish in parentheses)				
Dorsal rays	13(1), 14(1), 15(5), 16(3), 18(1)	14(7), 15(2)	14-15 (rarely 13)	15(1), 16(1)
Anal rays	13(3), 14(6), 15(2)	13(6), 14(2)	13-14	13(1), 14(1)
Pectoral rays	18(2), 19(2), 20(2), 21(4), 22(1)	18(1), 19(3), 20(4), 21(1)	19	20(1), 21(1)
Measurements (mean values in parentheses)				
In head:				
Orbit	4.71-5.88 (5.27)	4.13-4.57 (4.39)		5.0-5.1 (5.05)
Interorbital	3.11-3.63 (3.36)	3.35-3.67 (3.51)		3.65-3.90 (3.78)
Snout	4.35-5.10 (4.70)	4.35-5.18 (4.81)		5.83-6.02 (5.93)
In interorbital:				
Premaxillary groove width	1.65-2.36 (1.99)	1.61-2.36 (1.82)		1.73 (Holotype only)

* University of California, Los Angeles Collection, W53-311, taken between Islas Perlas and Islas Otoque, Panama (lat. 8° 32′ 10″ N., long. 79° 21′ 11″ W.) at 210 feet. 19 Mar 1953. W. Baldwin, collector.

agreed quite closely with the smaller Panama individuals except for the orbit-into-head proportion which could be due to allometric growth. Both lots could be separated from the *K. ornatus* description by minor differences in snout length and interorbital distance (Table 2). A re-examination of *K. ornatus* may show it is a synonym of *K. averruncus.*

All specimens in Table 1 are or will be deposited at the University of California, Los Angeles, except for the two lots dated May 15, 1960, and "unknown" which are housed at the University of California, Santa Barbara. We wish to thank the personnel of these two institutions for their co-operation and acknowledge the helpful advice and criticisms of John Baxter, John Fitch, and Leo Pinkas of the California State Fisheries Laboratory.

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NOTES

THE FIRST CALIFORNIA RECORD OF SIERRA, *SCOMBEROMORUS SIERRA* JORDAN AND STARKS

A 4-pound, 5-ounce mature female sierra, 594 mm fork length, was caught July 10, 1962, from a party boat at the kelp bed off La Jolla. This is the first valid sierra record from California waters (Figure 1).

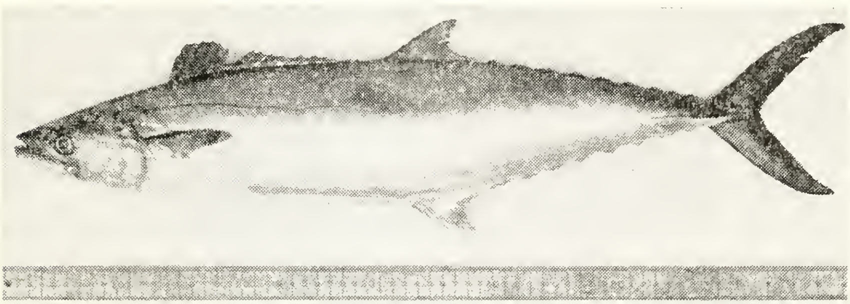

FIGURE 1. Sierra (*Scomberomorus sierra*) caught off La Jolla July 10, 1962. *Photograph by James Rupert, Scripps Institution of Oceanography.*

Sierra have been recorded at one time or another from northern Peru (Hildebrand, 1946, as *S. maculatus*) and the Galapagos Islands (Snodgrass and Heller, 1905) north through the Gulf of California and into southern California (Daugherty, 1946; Fitch, 1949). However, all previous California records refer to the superficially similar Monterey spanish mackerel, *S. concolor* (Lockington) (Fitch and Flechsig, 1949; J. E. Fitch, personal communication). Roedel (1962) wrote that sierra have not been recorded from the State, and we were unable to find California specimens of sierra in the collections of Scripps Institution of Oceanography, University of California at Los Angeles, Allan Hancock Foundation, Stanford University, California Academy of Sciences, or U.S. National Museum.

The previous northernmost published record that definitely refers to sierra is that of Fitch (1950) who reported them abundant along the coast of Baja California and Mexico. We examined a sierra from Bahía Magdalena (Scripps Institution of Oceanography number 60-235-43A) and Eckles (1949) described two juveniles (probably sierra) from Bahía Ballenas.

Sierra differ from Monterey spanish mackerel primarily in having fewer gill rakers on the first arch (4 on the upper limb, 10 to 12 on the lower) and several rows of moderate-sized orange-yellow spots on their sides (see color plate 39, Walford, 1937). Monterey spanish mackerel have more gill rakers (5 to 9 + 15 to 20) and few, if any, orange-yellow spots.

We compared our specimen (SIO 62-338) with sierra and Monterey spanish mackerel in the Scripps collection and with the type of *S. sierra* (Stanford University 1720) and found it typical in all respects with sierra described by Jordan and Starks in Jordan (1895) and by Hildebrand (1946). Counts are: gill rakers 4+11=15, first dorsal spines 17, second dorsal rays 16, dorsal free finlets 9, anal rays 17, anal free finlets 7. Color notes, taken while the fish was still fresh, were: body silver-blue above to silver below; 5 to 6 rows of golden-yellow spots on the sides of the body, all smaller than the pupil of the eye; tail dusky; first dorsal fin yellow, tinged with dusky on the leading edge, black distally, white proximally; second dorsal fin silvery.

Besides being an interesting addition to California's fish fauna and a northward range extension, this represents another typical Panamic species which has gone beyond the tropical zone between Cabo San Lucas and Bahía Magdalena, Baja California (Hubbs, 1960). Radovich (1961) was able to correlate northern captures of typically southern species during 1957-1959 with unusually high water temperatures. Records at the Scripps Institution of Oceanography show that the temperature of local waters has been below the long-term (35-year) average in the period August 1961-August 1962. It is possible the specimen taken in July 1962 had been resident in California waters since the 1959 warm period. We believe, however, it is a recent migrant.

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THE SCHOOLING BEHAVIOR OF PACIFIC YELLOWFIN AND SKIPJACK TUNA HELD IN A BAIT WELL

During May and June 1962, the Inter-American Tropical Tuna Commission chartered the tuna clipper *South Seas* to study certain aspects of yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) physiology and to conduct other research off Baja California. Groups of 15 to 30 pole-and-line-caught tunas were kept alive in a bait well aboard the vessel for up to 12 hours, affording us an opportunity to observe their behavior. The bait well was approxicately 2.6 meters wide by 4.0 meters long (port to starboard) by 1.6 meters deep, and held about 17,000 liters of sea water, which was exchanged at the rate of 2,100 liters per minute. Temperatures during the experiments ranged from 20° to 23° C.

When yellowfin were placed in the wells they immediately adapted themselves to their new environment and assumed a "leisurely," circular swimming pattern around the bottom; almost all swam in the same direction. When only skipjack were placed in the wells their movements were relatively faster than yellowfin. Tester (1952) noted these same behavior differences for yellowfin and skipjack held in captivity in the Hawaiian Islands area. In our experiments, skipjack did not form as uniform nor as compact a group as yellowfin. Skipjack, when alone, also appeared constantly "excited" and "nervous." They moved much more erratically than yellowfin held alone; a few skipjack were always swimming independently in various directions rather than with the group.

On several occasions when yellowfin and skipjack were together, yellowfin assumed their customary "leisurely" and uniform swimming rate while skipjack, under these circumstances, seemed to adapt to yellowfin behavior. Their movements were less erratic, and their speed apparently was adjusted to that of yellowfin. Skipjack predominated in the upper layer of what seemed a two-layer system. This pronounced change in skipjack behavior was evident whenever the two species were held together. Yuen (1962) observed a similar layering effect with skipjack and yellowfin off Roca Partida, Revillagigedo Islands.

The apparent slowing effect yellowfin have on skipjack in captivity may also occur in nature. This suggests the need to investigate the possibility that skipjack are more vulnerable to purse-seine gear when schooled with yellowfin.

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—*James Joseph and Izadore Barrett, Inter-American Tropical Tuna Commission, Scripps Institution of Oceanography, La Jolla, California, July 1962.*

BOOK REVIEWS

Common Seashore Life of the Pacific Northwest

By Lynwood Smith; Naturegraph Company, Healdsburg, California, 1962; 11 color pictures plus 85 text drawings, $1.75 (paperbound).

Students of marine life and seashore visitors alike will find this booklet of interest. Although he covers a vast area, Northern California to southern Alaska, Mr. Smith has limited his discussions to just over 100 of what he considers are the more common, conspicuous representatives of this area.

The complex interrelationship of seashore inhabitants is treated in broad terminology, with additional material on the subject in the suggested reference section.

The line drawings are adequate; but, additional color plates would have enhanced the volume.

Sections dealing with where to find various animals, their needs for survival, special animals in special places, and what to do with the animals after you collect them, are well handled for a general text.

By suggestion and example, lay readers are encouraged to become more observant and knowledgeable beachgoers. The section on beach conservation stresses an important phase of seashore observing.

Despite some minor mistakes, this small booklet should be a welcome addition to the libraries of persons interested in seashore life. The material is covered in a manner calculated to increase interest, leading to a study of more detailed texts.—*Charles H. Turner, California Department of Fish and Game.*

Fisheries Hydrography

By Ilmo Hela and Taivo Laevastu; Fishing News (Books) Ltd., London, England, 1962; 137 pp., 69 figs., £2 15 0.

Fisheries hydrography is defined, in part, by the authors as the "study and application of oceanography, maritime meterology and aquatic ecology to those practical problems in fisheries which are related to the productivity of the oceans or to the resources. . . ." Using a minimum of scientific terms, they have summarized and reported a large number of field and laboratory experiments on:

1. Influence of the environmental factors on fish behavior
2. Application of hydrography in fisheries
3. Maritime meteorology in the service of fisheries
4. Coastal fisheries in respect to weather and hydrography.

However, the practical fisherman will find frequent use for the section entitled "Explanation of Terms."

Although the equipment for catching fish has been greatly improved, the actual catching of fish has remained a true hunting-type occupation. During this same time technical advancements have been made in oceanographic techniques and many extensive oceanic surveys have been made. However, relatively little effort has been spent on oceanographic research leading to direct increases in yield per fishing unit. Some nations, principally Japan and Russia, have taken steps in this direction by sending research vessels and oceanographers with their high-seas fishing fleets. This book suggests synoptic oceanographic survey and improved weather forecasts as tools better to predict availability and abundance of fishery resources.

This is a stimulating approach to a new era of co-operation within the marine sciences. Anyone reading this text is bound to get some new ideas about the environment and fish.—*E. A. Best, California Department of Fish and Game.*

Growth and Regulation of Animal Populations

By Lawrence B. Slobodkin; Holt, Rinehart and Winston, Inc., New York, 1961; viii+184 pp., illus., $5.

In the author's own words, "The point of this book is to indicate briefly the present state of theory relating to the number and kinds of animals and plants that are found in nature." In developing this thesis, he briefly discusses such integrated concepts as communities, populations, niches, survival and growth curves, predator-prey interactions, and cycles.

The presentation is brief, generally clear, and well-seasoned with thought-provoking analogies. The book is too short to be considered comprehensive in this important field of ecology, but it certainly presents a select and informative choice of materials.

The book is highly recommended to fisheries and game biologists alike, as it offers a sophisticated introduction to pertinent and basic concepts of population ecology.—*John R. Calaprice, California Department of Fish and Game.*

Handbook of North American Birds. Vol. 1 Loons Through Flamingos

By Ralph S. Palmer; Yale University Press, New Haven, Conn., 1962; 567 pp., illustrated with color plates, range maps and numerous other figures; $15.

This beautifully done volume is the first of a series sponsored by the American Ornithologists' Union and published by Yale University Press. It treats some 81 species of water birds from the common loon through the greater flamingo, generally following the systematic order of classification used in the fifth edition of the American Ornithologists' Union Checklist of North American Birds and covering the same geographical area with exception of Baja California.

The 17-page introduction deals with general remarks, higher taxonomic categories, species treatment, definitions of terms, a fine color chart to illustrate color references throughout the text, examples of linear measurements, bird topography and egg profiles as well as some remarks and explanations pertaining to the various sectional headings for each species. Also included is a "new" method of describing molts and plumage cycles.

Each species is treated quite thoroughly for the most part in nontechnical language and includes the latest up-to-date information on description, plumage stages, color phases, weights, measurements, field identification, voice, habitat, distribution and migration, reproduction, food, etc. In addition to the foregoing "standard" information, some sections, completely new to this type of work, are presented also. These include banding data and returns, survival, and many fine, detailed distribution maps. The material in this book is generally well presented, especially in view of the fact that in most instances the descriptions of several contributing authors are utilized for a given species. I observed no misspelled words, typographical errors or factual errors as such. Several departures from vernacular and Latin names, as used in the 1957 A.O.U. checklist, were noted and there is a pronounced tendency toward lumping in the latter chapters even though several of the species involved are generally considered valid in their own right. There is a very ample reference section as well as a complete list of contributing authors.

The several color plates by Peterson and Mengel are beautifully done—though somewhat out of context.

I do not hesitate to recommend the first volume of the *Handbook of North American Birds* to anyone interested in ornithology. There is little doubt this volume and those to follow will quickly take their places alongside such classical presentations in this field as those of Bent and Ridgway.—*William D. Hawes, California Department of Fish and Game.*

Practical Freshwater Fishing

By Francis E. Sell; The Ronald Press Company, New York, 1960; 198 pages and 27 photographs, $5.50.

In this age of mass recreation pressures there is a great need for a change in the philosophy of the participants. The appetites of the unskilled are insatiable.

No single book can adequately cover the subject of freshwater fishing, but a good book can add to an angler's skills, and perhaps change his ethics too! This is one of those good books. Although the title is broad, it deals largely with trout and fly fishing. Only one of the chapters discusses spinning.

Considerable emphasis is placed on studying insects and the need to match them with artificial flies.

There is a chapter on "reading" trout water. You have only to watch a beginner a few minutes to agree that this is an important subject. The author handles it well.

Several chapters are devoted to subjects apart from actual fishing techniques and equipment. Both "Birds along a trout stream," and "The wild fishers" point out enjoyable features of the stream communities. Many people today seem too intent on their primary recreational pursuit to enjoy the other values of nature.

One of the best chapters is on taking a boy fishing. It should bring some parents up short.

There are a number of excellent photos but the several plates of artificial flies without color or material description are largely wasted—*James D. Stokes, California Department of Fish and Game.*

The Giant Snakes

By Clifford H. Pope; Alfred A. Knopf, New York, 1961; xvii + 290 + vi pp., 24 black and white photographs, $6.95.

Written by a well-known herpetologist who has authored several semipopular books, this work also is interesting reading for the layman and informative for the scientist. It was inspired by his experience in keeping Sylvia, an Indian python, as a pet from the time she was a little over 3 feet long and perhaps 6 months old, until she reached an age of 6 years, a length of almost 11 feet, and a weight of 34 pounds. Chicago must be more tolerant than many communities, as Sylvia survived extensive publicity in local newspapers and in Life magazine, as well as a facetious answer to a newspaper photographer who inquired timidly how dangerous she might be: "Well, the last man she got around we managed to get free in about an hour." At the age of six, Sylvia, who had never been known to bite anyone, was loaned indefinitely to a nature lecturer, and at last report was still flourishing.

The author discusses the six largest snakes which are all members of the family Boidae. One, the boa constrictor (which is also its scientific name), may reach a maximum of about 18-19 feet; the others, the Indian, amethystine, African rock, and reticulated pythons, and the anaconda, range from 20 to 33 feet, or possibly a little more, the last three all reaching over 30 feet. The author points out that while the king cobra reaches a little over 18 feet, it is a much more slender snake and is therefore not included. The next largest snakes reach only 12 feet.

The text of the book applies to some extent to snakes in general, but with special emphasis on the giant ones. It covers such things as their strength and powers of constriction; their feeding; their rate of growth and longevity; their reproduction, their enemies; and their danger to man. Other interesting sections deal with fear of giant snakes; worship of snakes; popular beliefs about them; and man's use of them for leather, food, exhibition purposes, etc. Particularly amusing are the advice to missionaries as to how to confront a python and the bits about strip-tease dancers and their snakes.

There are several pages on the geographic ranges and habitats of the six giant snakes; however the book suffers from the lack of distribution maps. These would have been satisfactory on a worldwide basis and possibly giving also a breakdown into tropical forest, desert, etc., regions. In addition, I would have liked to have seen a map of tropical America giving the names and ranges of the various subspecies of *Boa constrictor* (imperfectly though these may be known at the present time); however, the author expressly stated this was not the concern of the book.

A chapter on the various parasites and diseases of giant snakes and others assembles a good deal of interesting information. Unfortunately—though the author later in the book devotes several pages to keeping snakes as pets—the chapter on ailments does not give any information about their treatment, even about such a simple thing as the recently discovered use of silica gel for treating mites. Perhaps the whole subject of the care of reptiles (and amphibians) as pets, with ideas about the most desirable species (plus discussion of less desirable ones), housing, feeding, treatment of ailments, sources of specimens, and so on, could well be made the subject of an entire volume. The highly enthusiastic amateur keepers of such animals, as well as the professional or semiprofessional ones, should welcome such a book.—*Anita E. Daugherty, California Department of Fish and Game.*

The Wonderful World of Nature

By F. A. Roedelberger (English text by Mary Phillips) ; the Viking Press, Inc., New York, 1962; 214 pp., 24 color plates, numerous black and white photos, $7.50.

This is one of the most fascinating books I have had the pleasure to read. It is an English version based on the Swiss original bilingual edition; thus, most of the pictured plants and animals are European.

The works of 60 nature photographers are represented by 24 color plates and almost 300 black and white photographs of superb quality. Most of the photographs are accompanied by brief, well-written descriptions of the chief natural history facets of the organism pictured. Almost every illustrated subject is identified to genus and species, a valuable aid to both the serious biologist and the amateur naturalist. The subject matter leans heaviest upon birds—almost one-third of the photographs deal with their natural history. The book is well indexed to both the common and scientific names of the plants and animals pictured and is remarkably free of typographical errors.

I would wholeheartedly recommend this volume to anyone who has an interest in "The Wonderful World of Nature."—*Michael L. Johnson, California Department of Fish and Game.*

Whose Woods These Are: The Story of the National Forests

By Michael Frome; Doubleday and Co., Inc., New York, 1962; 360 pp., illustrated with black and white text figures and 12 color plates; $5.95.

The unusual title of this well-written and interesting book is from a poem "Stopping by the Woods on a Snowy Evening," by Robert Frost. As might be gathered from the poetic title, this is not a technical book on the national forests, nor on the economics of timber management, but one written to give the uninformed or those who have an aesthetic interest in the forests, a view of their grandeur and their history.

The book is divided into two parts. The first and shortest is a brief and fairly complete early history of our land and the indiscriminate destruction and waste of our natural resources. The author then brings you to the end of the 19th century and the gradual awareness of a few persons with foresight who realize that something will have to be done to conserve our forest lands for the future. Theodore Roosevelt was the power in government who enacted legislation to hold back crooked politicians and merciless land grabbers. Before this the laws allowed land monopolizing by a few and complete destruction of timber and other resources. Roosevelt's ally and technical advisor was Gifford Pinchot, one of the famous early foresters, and it was from the leadership of these two men that the United States Forest Service got its start and now has under its protection nearly 180 million acres of forests, mountains, and plains.

The second portion of the book, about three-fourths of the contents, contains the author's descriptions of the various national forests within the United States, and some of the persons who were, and are, connected to them in some way. He covers the country from the Green Mountains of New England to the swamps and piney woods of Florida, and from the deserts of Southern California to the mountains of Alaska, many times bringing out the philosophies of naturalists such as Muir and Thoreau.

The book is different from the usual text-type pertaining to our forests and dealing only with facts and figures. It is well written and shows an appreciation that more people should have of our heritage.—*Hugh L. Thomas, California Department of Fish and Game.*

Why Fish Bite and Why They Don't

By James Westman; Prentice-Hall, Inc., New York, 1961; 211 pp., 39 black and white illustrations, $3.95.

As a general rule about 10 percent of the anglers in most fisheries take approximately 90 percent of the catch. Dr. Westman's book embodies the thought processes and working philosophy of this group of piscatologists.

To me a better title would have been *What Makes a Successful Angler.* Although some biology and limnology, important to the angler, are included, these fields are only lightly discussed.

Novice anglers attempt to purchase an ability to catch fish, as seen by the numerous lures manufactured to hook fishermen rather than fish. The finest equipment does not insure success. Even a technique is sterile without the knowledge to guide it. This is why the author emphasizes the mental aspects of the art and science of fishing. He points out that the most valuable piece of equipment an angler has is "his head."

A quotation highlights these general considerations.

> "The practice of medicine—whether veterinary or human—is often described as an art based upon a science. The same definition applies to angling, except that in angling the art is emphasized almost to the exclusion of the science. This is why famed anglers are apt to be specialists for one or two species of fish, and often in limited situations. By devoting their efforts and study to such specialties, they obtain the necessary knowledge upon which to base their skill presentations. And let us be quick to acknowledge that these specialists can become very, very good. Our hat is off to them."

A major portion of the book is devoted to fresh-water angling. Basic information is provided as to limnological conditions: What to observe, and things to be considered in obtaining a good catch. Although Dr. Westman reviews briefly some of the information on fish psychology and behavior, this section is not a compendium, by any stretch of the imagination, on what is known about fish behavior. He discusses briefly the effects of color, sound, etc., but emphasizes the importance of correctly presenting the lure. Additional emphasis is placed upon experimentation.

The book should be of great value to any angler wishing to develop a philosophical approach to the piscatorial art. It does not provide a specific guide to catching fish; it provides the angler with a frame of reference for improving his thinking approach to the art. In this, it is extremely valuable.—*Robert L. Butler, California Department of Fish and Game.*

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