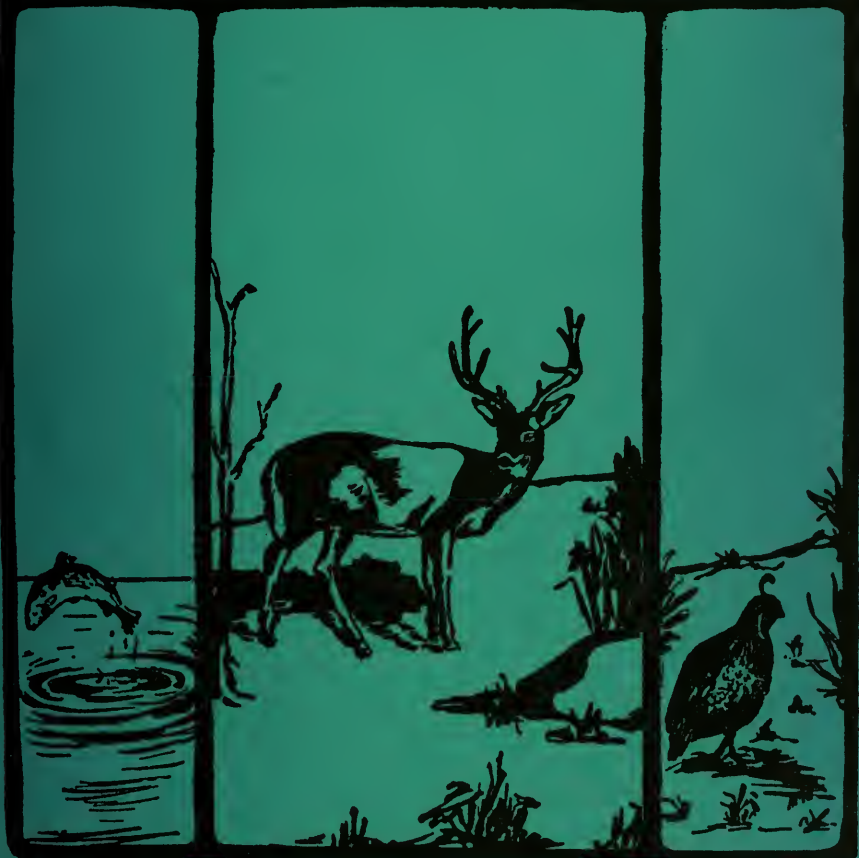
CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 45 JANUARY, 1959 NUMBER 1



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CALIFORNIA FISH AND GAME

VOLUME 45 JANUARY, 1959 NUMBER 1

Published Quarterly by the

CALIFORNIA DEPARTMENT OF FISH AND GAME

SACRAMENTO

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

GOODWIN J. KNIGHT
Governor

FISH AND GAME COMMISSION

SETH GORDON
Director of Fish and Game

CALIFORNIA FISH AND GAME

Editorial Staff

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STATUS OF THE ANIMAL FOOD FISHERY IN NORTHERN CALIFORNIA, 1956 AND 1957[1]

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INTRODUCTION

Since its inception in October of 1952, the utilization of fresh fish for animal food has become "big business" in Northern California. Three processing plants, located at Fields Landing, Fort Bragg, and Oakland, California, are currently utilizing the bulk of the trawl-caught whole fish sold for making animal foods. In 1953, the first full year of operation, about 528,000 pounds of whole fish were processed. Production increased to 3,475,000 pounds in 1956 but dropped to 2,980,000 pounds in 1957 (Table 1). In addition, these plants processed 7,845,000 pounds of fish frames and viscera during 1956 and 8,505,000 pounds in 1957 (Table 1). Figures on the pounds of frames and viscera (fish scraps) used as animal food, were furnished through the courtesy of the industry. Section 8011 of the California Fish and Game Code requires that a receipt indicating the pounds and species of fish landed be made for each delivery of fish. Fish frames and viscera, the waste products from the fish reported on the original landing receipts, need not be reported again unless utilized by a reduction process. This prevents duplication of landing figures.

[1] Submitted for publication August, 1958.

TABLE 1

Pounds of Whole Fish and Fish Frames Used for Animal Foods in Northern California

Month	Whole Fish		Fish Frames	
	1956	1957	1956	1957
January	58,266	163,029	175,845	302,250
February	135,188	150,556	394,845	427,200
March	88,210	206,623	361,505	602,800
April	155,209	131,648	549,280	437,380
May	289,657	382,513	646,961	536,150
June	361,080	420,537	625,425	1,130,230
July	350,754	239,415	834,585	961,920
August	523,607	485,071	1,040,160	1,229,800
September	490,014	331,201	910,135	1,069,295
October	379,844	262,320	831,100	710,880
November	375,849	58,853	954,146	579,970
December	267,315	147,800	521,500	517,480
Totals	3,471,993	2,979,566	7,845,487	8,505,355

On ocean fishing grounds where several species of fish are mixed, the modern otter trawl is remarkably nonselective as to what it can catch. At present, the current seafood markets are highly selective as to the species they will purchase or use. Consequently, the fisherman is confronted with the problem of disposing of his unmarketable fish. In the past, this unsalable portion of the catch has been disposed of at sea; in many instances this practice still prevails. Recently, however, the use of unmarketable species has created a new industry in practically every area where otter trawling is practiced. Unsalable species, referred to herein as "trash" fish, are sometimes used as fresh-frozen or processed food for domestically reared fur-bearers and pets, or are reduced into meal (Edwards & Lux, 1958, and Sayles, 1951). Trawl-caught whole fish are not reduced into meal at the present time in California.[2]

METHOD OF OPERATION

The Fields Landing and Fort Bragg plants grind and freeze both whole fish and fish frames for ultimate use by the fur industry, while the Oakland plant employs a canning process and produces pet food from these raw materials. The animal food plants depend on waste

[2] Since the preparation of this paper a plant designed to reduce fish scraps and trash fish to a liquid concentrate has been established at Eureka, California.

FIGURE 1. Unloading trash fish from otter trawl vessel. Note the mixed species and presence of ice on the fish. *Photograph by W. A. Dahlstrom, May, 1958.*

material from local fish processing plants as a primary source of raw material. The supply of such material (fish frames and viscera) is of a more dependable nature than is the supply of whole fish. Whole fish are handled, processed, and stored separately from the fillet plant by-products.

Practically all fishes are usable with the notable exception of sharks and rays. The plants require that all fish be in a fresh condition when received. The necessitates icing at sea (just as market fish are iced) if fishing trips exceed more than one day in duration (Figure 1). At present, four northern California otter-trawl vessels deliver all of the trash fish they are able to catch. Two of these vessels make daily deliveries while the other two make extended trips and ice their entire catch including trash fish. Approximately 10 additional boats bring in the trash fish that does not need to be iced. This consists of fish caught only during the last day of an extended fishing trip. No fishermen are fishing solely for the animal food markets, but use this industry to supplement their income from market fish.

The most economical processing of trash fish depends on large quantities and rapid handling. The fish are unloaded, weighed, and dumped into an elevator which transports them to a washer. A second elevator

FIGURE 2. Method of filling boxes prior to freezing. Large grinder and storage hopper is in right background, pump and timing apparatus shown in right foreground. *Photograph by E. A. Best, August, 1956.*

moves the fish from the washer to a large food grinder. When ground, the whole fish or fish frames drop into a hopper which serves as a reservoir to feed a specially designed pump. A mechanical timer automatically stops the pump when a predetermined weight, usually 50 pounds, of ground fish has been pumped into a waxed box (Figure 2). The ground fish is then frozen for storage.

SAMPLING METHOD

With the rapid development of a fishery of this magnitude, many questions arose concerning the ultimate effect, if any, on market species. With this in mind a shoreside sampling program was instituted in April, 1956. This program was designed to obtain information on size and species composition of the animal food fishery that could be used to supplement data previously compiled by sampling at sea (Gates, 1955).

Manpower limitations confined the sampling activities of this program to the ports of Fields Landing and Fort Bragg. Sampling at Fort Bragg, however, was insufficient to permit a species breakdown and the data have not been included in this report. The same varieties were observed in the samples collected at Fort Bragg as at Fields Landing and it is doubtful if the composition of the landings would vary greatly. General fishing conditions and species landed for the fresh fish markets are similar for both ports.

Samples of the landings were collected as frequently as fishing conditions and the work load permitted. During the summer months, landings were generally available for sampling every week. Winter storms often held the fleet in port for periods of two or three weeks at a time, reducing the sampling activities to a minimum. Individual loads from which these samples were taken ranged in weight from 80 pounds to over 20,000 pounds. The samples amounted to 0.3 and 0.4 percent of the total weight of trash fish landed at Fields Landing during 1956 and 1957 respectively. However, these samples were collected over a period of two years and from vessels fishing a relatively restricted area between Cape Mendocino, California, and Cape Blanco, Oregon, and it is felt that they give a satisfactory picture of the species, and their size structure, in the overall landings.

Each sample was sorted and the aggregate weight obtained by species. All fish were measured (total length) to obtain a picture of length composition by species. Common names used in this report follow the terminology established by Phillips (1957) and Roedel (1953).

The availability of the various bottom fish changes throughout the year and market demands alter the fishing habits of the fleet from time to time. Thus it was found expedient to summarize the samples by three-month periods. The total pounds of fish landed for animal food have been multiplied by the appropriate percentage for the major contributing species (as determined from the sampling program) to obtain the number of pounds each contributed to the total catch during each quarter year (Tables 3 through 9). The poundages attributed to the various species for each quarter year were then totaled for the calendar years 1956 and 1957 (Tables 10 and 11 and Figure 3).

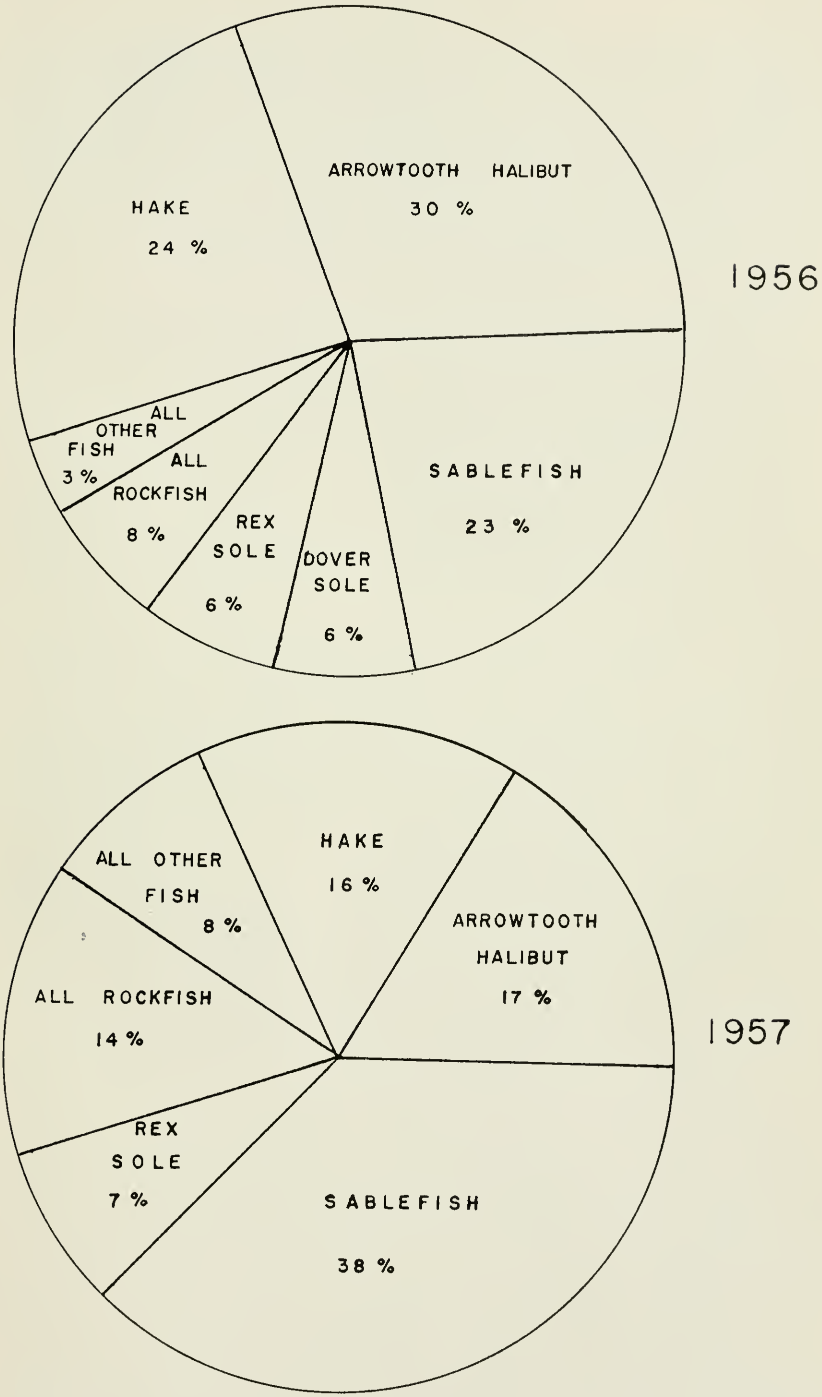

FIGURE 3. Species composition by weight of animal food landings at Fields Landing, California, 1956 and 1957.

PRINCIPAL SPECIES USED

Of the many species in the overall trawl catch, arrowtooth halibut (*Atheresthes stomias*), hake (*Merluccius productus*), and the sablefish (*Anoplopoma fimbria*) accounted for nearly three-fourths by weight of all the fish used for animal food. This figure agrees with the earlier findings of Gates (op. cit.). At present hake have no value on the fresh fish market and arrowtooth halibut are used only in limited amounts when more desirable species are scarce. Thus the animal food industry makes use of fish species that previously were nearly always discarded at sea.

The sampling program showed that in 1956 and 1957 sablefish comprised 23 and 38 percent respectively of the total poundage used for making animal food. These were small fish, averaging 18½ inches in length and less than two pounds in round weight; a size not desired by the fresh fish markets. During 1957, small sablefish were extremely abundant in Northern California, so much so that at times heavy concentrations prompted fishermen to move to other trawling grounds.

Rex sole (*Glyptocephalus zachirus*) accounted for six percent by weight of the animal food landings in 1956 and seven percent in 1957. The markets are able to utilize only a limited amount of rex sole and that used for animal food is either small fish or the excess above market orders.

Dover sole (*Microstomus pacificus*) comprised six percent of the animal food landings by weight in 1956 but dropped to two percent in 1957. These were almost entirely small fish (shorter than 14 inches in total length) and hence unacceptable to the markets. There is no minimum size for bottom fish in the California commercial fishing regulations. However, many markets set a minimum size that is acceptable for their operations. The size range of the dover sole used in the animal food compares with that of the small dover sole observed during routine sampling of market landings.

Other species of sole normally utilized by the fresh fish markets were present in negligible quantities in the fish destined for animal food, making up two and six percent of the landings by weight in 1956 and 1957 respectively. Curlfin turbot (*Pleuronichthys decurrens*) and Pacific sanddab (*Citharichthys sordidus*) provided the bulk of this group. Here again the markets are able to use only limited amounts of these fish. They are taken chiefly during the January-March quarter when inclement weather forces the boat to work in shallower water and closer to port.

The total contribution of all rockfish increased from 8 percent by weight in 1956 to 14 percent in 1957. Increased market demand in Northern California during 1957 caused an upsurge in the amount of fishing effort expended upon these fish and larger catches of unmarketable rockfish species resulted. Only rarely do marketable species of rockfish appear in the animal food landings. Five kinds (shortspine channel rockfish *Sebastolobus alascanus*, stripetail rockfish *Sebastodes saxicola*, dark-blotched rockfish *S. crameri*, splitnose rockfish *S. diploproa*, and greenstriped rockfish *S. elongatus*) accounted for about 85 percent by weight of the total rockfish utilized. Of these, only the dark-blotched and splitnose rockfishes are used by the fresh fish markets and then only to a limited extent.

TABLE 2

Fishes Observed in Animal Food Landings, Field Landing, California, 1956 and 1957

	FAMILY CLUPEIDAE—Herrings
Pacific herring	*Clupea pallasi* Valenciennes
American shad	*Alosa sapidissima* (Wilson)
	FAMILY OSMERIDAE—Smelts
Eulachon	*Thaleichthys pacificus* (Richardson)
	FAMILY MERLUCCIIDAE—Hakes
Pacific hake	*Merluccius productus* (Ayres)
	FAMILY GADIDAE—Cods
Pacific tomcod	*Microgadus proximus* (Girard)
	FAMILY BOTHIDAE—Lefteyed flounders
Pacific sanddab	*Citharichthys sordidus* (Girard)
	FAMILY PLEURONECTIDAE—Righteyed flounders
Arrowtooth halibut	*Atheresthes stomias* (Jordan & Gilbert)
Slender sole	*Lyopsetta exilis* (Jordan & Gilbert)
Petrale sole	*Eopsetta jordani* (Lockington)
Curlfin turbot	*Pleuronichthys decurrens* Jordan & Gilbert
Sealyfin sole	*Isopsetta isolepis* (Lockington)
English sole	*Parophyrys vetulus* Girard
Rock sole	*Lepidopsetta bilineata* (Ayres)
Dover sole	*Microstomus pacificus* (Lockington)
Deepsea sole	*Embassichythys bathybius* (Gilbert)
Rex sole	*Glyptocephalus zachirus* Lockington
Starry flounder	*Platichthys stellatus* (Pallas)
	FAMILY CARANGIDAE—Jacks
Jack mackerel	*Trachurus symetricus* (Ayres)
	FAMILY SCORPAENIDAE—Rockfishes
Shortspine channel rockfish	*Sebastolobus alascanus* Bean
Bocaccio	*Sebastodes paucispinis* (Ayres)
Chilipepper	*Sebastodes goodei* Eigenmann & Eigenmann
Yellowtail rockfish	*Sebastodes flavidus* Ayres
Dark-blotched rockfish	*Sebastodes crameri* Jordan
Pacific ocean perch	*Sebastodes alutus* (Gilbert)
Stripetail rockfish	*Sebastodes saxicola* (Gilbert)
Rougheye rockfish	*Sebastodes aleutianus* Jordan & Evermann
Splitnose rockfish	*Sebastodes diploproa* (Gilbert)
Flag rockfish	*Sebastodes rubrivinctus* (Jordan & Gilbert)
Greenstriped rockfish	*Sebastodes elongatus* (Ayres)
Greenspotted rockfish	*Sebastodes chlorosticutus* (Jordan & Gilbert)
	FAMILY ANOPLOPOMATIDAE—Sablefishes
Sablefish	*Anoplopoma fimbria* (Pallas)
	FAMILY OPHIODONTIDAE—Lingcods
Lingcod	*Ophiodon elongatus* Girard
	FAMILY COTTIDAE—Sculpins
Cottids	not identified to species
	FAMILY ZOARCIDAE—Eelpouts
Eelpouts	not identified to species
	FAMILY LOLIGINIDAE—Squid
Squid	*Loligo opalescens* Berry

TABLE 3

Species Composition of Seven Samples of Trawl Caught Fish Landed April to June, 1956, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Arrowtooth halibut	232	250–720	486	514	2.2	39.37
Sablefish	245	270–730	413	387	1.5	29.64
Rex sole	239	250–420	318	111	0.5	8.50
Dover sole	104	280–500	353	84	0.8	6.43
Stripetail rockfish	62	190–360	304	52	0.8	3.98
Hake	25	430–650	509	49	2.0	3.75
Shortspine channel rockfish	24	170–530	357	31	1.3	2.37
Dark-blotched rockfish	23	220–440	321	31	1.4	2.37
Splitnose rockfish	12	210–330	286	10	0.8	0.77
English sole	10	270–360	314	8	0.8	0.61
Pacific ocean perch	6	310–440	361	8	1.3	0.61
Pacific sanddab	18	210–330	275	7	0.4	0.54
Bocaccio	2	380–490	435	4	2.0	0.32
Greenstriped rockfish	2	330–370	350	3	1.5	0.23
Yellowtail rockfish	1	540	540	3	3.0	0.23
Petrale sole	2	350	350	2	1.0	0.16
Lingcod	1	450	450	1	1.0	0.08
Curlfin turbot	1	250	250	0.5	0.5	0.04
Totals	1,009			1,305.5		100.00

TABLE 4

Species Composition of Nine Samples of Trawl Caught Fish Landed July to September, 1956, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Arrowtooth halibut	309	230–800	457	689	2.2	42.96
Hake	199	430–710	537	423	2.1	26.37
Sablefish	126	370–640	472	244	1.9	15.21
Rex sole	205	230–410	309	86	0.4	5.36
Dover sole	71	280–400	329	50	0.7	3.12
Stripetail rockfish	39	210–340	277	32	0.8	2.00
Shortspine channel rockfish	19	240–350	280	20	1.0	1.21
Pacific sanddab	40	270–340	294	16	0.4	1.00
Greenstriped rockfish	12	290–390	336	16	1.2	1.00
Splitnose rockfish	8	270–360	320	9	1.1	0.56
Petrale sole	6	290–360	313	5	0.8	0.31
Lingcod	1	550	550	5	5.0	0.31
English sole	4	300–330	317	3	0.7	0.19
Dark-blotched rockfish	3	270–350	311	3	1.0	0.19
Rougheye rockfish	1	370	370	2	2.0	0.12
Flag rockfish	1	320	320	1	1.0	0.06
Totals	1,044			1,604		100.00

TABLE 5

Species Composition of Ten Samples of Trawl Caught Fish Landed October to December, 1956, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Hake	258	420–770	528	566	2.2	35.40
Sablefish	252	280–680	454	430	1.7	26.89
Arrowtooth halibut	102	290–680	430	176	1.7	11.01
Dover sole	210	250–460	324	162	0.7	10.13
Rex sole	253	210–370	300	99	0.4	6.19
Greenstriped rockfish	36	260–390	336	45	1.2	2.81
Stripetail rockfish	41	190–410	292	32	0.8	2.00
Shortspine channel rockfish	20	220–520	330	26	1.3	1.63
Dark-blotched rockfish	11	230–420	321	14	1.3	0.88
Pacific sanddab	24	210–320	286	13	0.5	0.81
English sole	17	270–370	304	10	0.6	0.63
Splitnose rockfish	10	200–360	269	8	0.8	0.50
Bocaccio	4	410–460	435	8	2.0	0.50
Slender sole	13	220–300	257	3	0.2	0.19
Pacific ocean perch	2	280–340	310	2	1.0	0.13
Petrale sole	2	290	290	1	0.5	0.06
Curlfin turbot	2	250–270	260	1	0.5	0.06
Chilipepper	1	370	370	1	1.0	0.06
Flag rockfish	1	340	340	1	1.0	0.06
Greenspotted rockfish	1	280	280	1	1.0	0.06
Totals	1,260			1,599		100.00

TABLE 6

Species Composition of Six Samples of Trawl Caught Fish Landed January to March, 1957, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Sablefish	184	300–750	453	326	1.8	33.00
Curlfin turbot	175	190–330	265	122	0.7	12.35
Arrowtooth halibut	60	230–630	444	108	1.8	10.93
Shortspine channel rockfish	56	290–650	402	105	1.9	10.63
Rex sole	212	200–380	299	90	0.4	9.11
English sole	136	250–350	288	59	0.4	5.97
Stripetail rockfish	72	220–350	300	58	0.8	5.87
Pacific Sanddab	122	180–320	285	46	0.4	4.66
Dark-blotched rockfish	25	210–390	266	36	1.2	3.64
Splitnose rockfish	13	210–370	340	16	1.2	1.62
Dover sole	9	280–430	329	7	0.8	0.71
Greenstriped rockfish	3	300–380	342	4	1.3	0.40
Pacific shad	1	500	500	3	3.0	0.30
Slender sole	14	200–300	244	3	0.2	0.30
Lingcod	1	380	380	1	1.0	0.10
Petrale sole	1	290	290	1	1.0	0.10
Deepsea sole	1	416	416	1	1.0	0.10
Flag rockfish	1	350	350	1	1.0	0.10
Bocaccio	1	260	260	1	1.0	0.10
Rock sole	2	230–330	280	--	--	--
Pacific herring	2	150	150	--	--	--
Pacific tomcod	4	210–250	235			-
Totals	1,095			988		99.99

TABLE 7

Species Composition of Ten Samples of Trawl Caught Fish Landed April to June, 1957, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Sablefish	377	300-790	484	759	2.0	40.72
Arrowtooth halibut	253	270-810	464	413	1.6	22.16
Splitnose rockfish	164	190-370	306	163	1.0	8.74
Rex sole	339	230-390	332	154	0.5	8.26
Hake	76	430-730	547	144.5	1.9	7.75
Shortspine channel rockfish	27	240-550	373	44	1.6	2.36
Dover sole	60	290-390	329	42	0.7	2.25
Pacific ocean perch	25	350-440	399	42	1.7	2.25
Dark-blotched rockfish	23	210-420	346	37	1.6	1.98
Stripetail rockfish	45	200-340	282	35	0.8	1.88
Greenstriped rockfish	11	280-400	334	14	1.3	0.75
Slender sole	16	210-270	237	4	0.2	0.21
Flag rockfish	4	240-350	290	3	0.7	0.16
Chilipepper	1	450	450	3	3.0	0.16
English sole	4	300-330	315	2	0.5	0.11
Bocaccio	1	420	420	2	2.0	0.11
Petrale	1	320	320	0.5	0.5	0.03
Eel pout	3	400-460	420	2	0.6	0.11
Totals	1,430			1,864.0		99.99

TABLE 8

Species Composition of Twenty Samples of Trawl Caught Fish Landed July to September, 1957, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Sablefish	616	270-710	484	1,236	2.0	36.85
Hake	431	410-830	573	1,097	2.6	32.71
Arrowtooth halibut	248	230-810	488	611	2.5	18.22
Rex sole	358	220-410	304	140	0.4	4.17
Shortspine channel rockfish	70	280-670	382	114	1.6	3.40
Dover sole	94	220-420	329	65	0.7	1.94
Greenstriped rockfish	18	300-380	352	21	1.2	0.63
Pacific sanddab	50	180-310	253	18	0.4	0.54
Splitnose rockfish	15	240-370	309	14	0.9	0.42
Stripetail rockfish	18	180-340	274	11	0.6	0.33
Dark-blotched rockfish	13	180-330	265	8	0.6	0.23
Pacific shad	3	450-600	503	8	2.7	0.23
Slender sole	16	200-300	241	4	0.3	0.12
Lingcod	2	450-470	460	2	1.0	0.06
Flag rockfish	2	300-340	320	1.5	0.8	0.04
Petrale sole	2	320-340	330	1	0.5	0.03
Curlfin turbot	2	250-310	280	1	0.5	0.03
Chilipepper	1	400	400	1	1.0	0.03
English sole	1	350	350	0.5	0.5	0.02
Totals	1,960			3,354.0		100.00

TABLE 9

Species Composition of Three Samples of Trawl Caught Fish Landed October to December, 1957, at Fields Landing, California, for Use in Production of Animal Food

Species	No. of fish	Size range in mm. (total length)	Average length mm.	Total weight pounds	Average weight pounds	Percent of total weight
Sablefish	41	410–690	576	150	3.7	41.44
Hake	19	500–710	574	53	2.8	14.64
Shortspine channel rockfish	18	310–650	429	45	2.5	12.43
Rex Sole	100	200–360	300	41	0.4	11.33
Scalyfin sole	34	270–400	328	30	0.9	8.29
Arrowtooth halibut	12	350–610	421	19	1.6	5.25
Pacific sanddab	33	190–320	251	12	0.3	3.31
English sole	17	220–310	268	6	0.3	1.66
Dover sole	5	260–330	302	3	0.6	0.83
Splitnose rockfish	2	260–320	290	2	1.0	0.55
Slender sole	2	280	280	0.5	0.3	0.14
Curlfin turbot	1	250	250	0.5	0.5	0.14
Pacific tomcod	1	210	210	--	--	--
Squid	1	--	--	--	--	--
Totals	286			362.0		100.01

REPORTING THE CATCH

Landing records of the catch have been inaccurate in the weight reported for individual species. The practice has been to record the total weight of trash fish landed and then arbitrarily assign the weight to one or two species, rather than to physically separate out and weigh each species for reporting on fish receipts. It was found that the estimated weights were usually entered as arrowtooth halibut and hake, and any market species present were minimized, if reported at all. Sablefish, a major contributor to the landings, have been rarely reported on the fish receipts. The fish receipts indicated 0.67 percent and 0.33 percent of the total poundage as sablefish for the years 1956 and 1957 respectively. The sampling program showed the actual use of sablefish to be much higher, 23 percent in 1956 and 38 percent in 1957 (Tables 10 and 11). On occasion, especially during the winter months when they are scarce on the Northern California trawling grounds, large poundages of hake have been reported when no hake were present in the delivery.

These fish receipts and the errors they contain become incorporated into reports on total landings by species. The total poundage landed is correct, but some species are credited with increased landings while others are reduced by a similar amount.

With this system of reporting the landings it is exceedingly difficult to separate out fish destined for animal food and that which is to be used for human consumption. The reported price per pound is the only criterion that can be used to determine the ultimate destination. The market fish are somewhat higher priced than the fish used by the animal food industry.

TABLE 10

Summary of Trawl Caught Fish Landed at Fields Landing, California, for Use in Production of Animal Food During 1956

Poundages Derived From Fish Receipts and Sampling Data

Species	From Sampling					From Fish Receipts	
	April-June	July-September	October-December	1956 totals	Percent of yearly total	Pounds	Percent
Arrowtooth halibut	136,829	248,693	61,786	447,308	30.07	655,342	44.05
Hake	13,033	152,654	198,659	364,346	24.49	634,628	42.66
Sablefish	103,013	88,050	150,902	341,965	22.99	9,958	0.67
Dover sole	22,347	18,061	56,848	97,256	6.54	34,074	2.29
Rex sole	29,541	31,029	34,737	95,307	6.41	870	0.06
Stripetail rockfish	13,832	11,578	11,224	36,634	2.46		
Shortspine channel rockfish	8,237	7,179	9,147	24,563	1.65	5,315	0.36
Greenstriped rockfish	799	5,789	15,769	22,357	1.50		
Dark-blotched rockfish	8,237	1,100	4,938	14,275	0.96		
Pacific sanddab	1,877	5,789	4,546	12,212	0.82		
Splitnose rockfish	2,676	3,242	2,806	8,724	0.59	147,436	9.91
English sole	2,120	1,100	3,535	6,755	0.46		
Bocaccio	1,112	--	2,806	3,918	0.26		
Pacific ocean perch	2,120	--	730	2,850	0.19		
Petrale sole	556	1,794	337	2,687	0.18		
Lingcod	278	1,794	--	2,072	0.14		
Slender sole	--	--	1,066	1,066	0.07		
Yellowtail rockfish	799	--	--	799	0.05		
Rougheye rockfish	--	695	--	695	0.05		
Flag rockfish		347	337	684	0.05		
Curlfin turbot	139	--	337	476	0.03		
Chilipepper	--	--	337	337	0.02		
Greenspotted rockfish	--	--	337	337	0.02		
Totals	317,545	578,894	561,184	1,487,623	100.00	1,487,623	100.00

A definite category should be established to report the pounds of fish utilized by the animal food industry or any other industrial use of trawl-caught fish that may develop in the future. This would correct the error that now exists in the record system and give an accurate figure to assess the magnitude of this growing industry.

CONCLUSIONS

At the present time the animal food fishery is doing no harm to the established fisheries. The fish that are the raw material for this industry are those which were formerly discarded at sea. No fishery has developed solely for the purpose of supplying this industry. The existing fleet of market fishermen is using the animal food industry as a means of supplementing income by utilizing a resource that formerly was discarded as a waste product of the fishing operations.

TABLE 11

Summary of Trawl Caught Fish Landed at Fields Landing, California, for Use in Production of Animal Food During 1957

Poundages Derived From Fish Receipts and Sampling Data

Species	From Sampling						From Fish Receipts	
	January-March	April-June	July-September	October-December	1957 totals	Percent of yearly total	Pounds	Percent
Sablefish	99,460	212,912	193,336	77,274	582,982	37.97	5,000	0.33
Arrowtooth halibut	32,942	115,868	95,593	9,790	254,193	16.56	636,478	41.45
Hake	--	40,522	171,615	27,300	239,437	15.59	797,009	51.91
Rex sole	27,457	43,189	21,878	21,127	113,651	7.40	--	--
Shortspine channel rockfish	32,038	12,340	17,838	23,179	85,395	5.56	15,538	1.01
Splitnose rockfish	4,883	45,699	2,204	1,026	53,812	3.50	76,527	4.98
Curlfin turbot	37,222		157	261	37,640	2.45		
Stripetail rockfish	17,693	9,830	1,731		29,254	1.91	--	--
Dover sole	2,140	11,765	10,178	1,548	25,631	1.67	3,339	0.22
Pacific sanddab	14,045	--	2,833	6,172	23,050	1.50	--	--
Dark-blotched rockfish	10,971	10,353	1,207	--	22,531	1.47	--	--
English sole	17,993	575	105	3,095	21,768	1.42		
Scalyfin sole	--	--	--	15,459	15,459	1.01	1,500	0.10
Pacific ocean perch	--	11,765	--	--	11,765	0.77	--	--
Greenstriped rockfish	1,206	3,922	3,305	--	8,433	0.55		
Slender sole	904	1,098	630	261	2,893	0.19		--
American shad	904	--	1,207	--	2,111	0.14		
Flag rockfish	301	837	210		1,348	0.09	--	--
Chilipepper		837	157		994	0.06		
Bocaccio	301	575		--	876	0.06	--	--
Lingcod	301		315		616	0.04		
Petrale sole	301	157	157		615	0.04		
Eel pout		575	--		575	0.04		--
Deepsea sole	301	--	--	--	301	0.02		--
Totals	301,363	522,819	524,656	186,492	1,535,330	100.01	1,535,391	100.00

SUMMARY

1. The annual utilization of trash fish for animal food in Northern California has increased sixfold since this industry began in 1952, and is now using in excess of three million pounds of whole fish each year. It also utilizes an additional eight million pounds of fish carcasses annually.

2. Arrowtooth halibut, hake, and sablefish made up three-quarters of the total poundage of whole fish landed for animal food during 1956 and 1957.

3. Rex sole and Dover sole were utilized in limited amounts. Other marketable species of sole were utilized in negligible amounts.

4. Rockfish species, generally not acceptable by the fresh fish trade, were used in varying amounts. Market orders for fresh fish influenced the amount of rockfish landed as animal food.

5. The species composition was essentially the same as determined by Gates (1955) in his sampling at sea during 1953 and 1954.

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6. A better method of reporting animal food landings is required to eliminate the current practice of reporting practically all landings as hake or arrowtooth halibut.

7. The current animal food fishery is not believed to be harming the bottom fish resources of California.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of fellow workers Messrs. Walter Dahlstrom, John Day, and Brad van Scriver who carried out much of the actual sampling. A special note of thanks is due to the Vita Sea Corporation, Fields Landing, California, for providing adequate space for sampling the landings. Considerable editorial assistance and recommendations were received from Messrs. Joseph Kutkuhn, John Fitch and Edward Greenhood of the California Department of Fish and Game.

REFERENCES

Edwards, Robert L., and Fred E. Lux
1958. New England's industrial fishery. Comm. Fish. Rev., vol. 20, no. 5, pp. 1-6.

Gates, Doyle E.
1955. Preliminary report on the status of trawling for animal food in Northern California. Calif. Dept. Fish and Game, Marine Fisheries Branch, mimeo., 7 pp.

Gunter, Gordon
1956. Should shrimp and game fishes become more or less abundant as pressure increases in the trash fish fishery of the Gulf of Mexico? Louisiana Conservationist, Jan., pp. 11, 14-15, 19.

Phillips, Julius B.
1957. A review of the rockfishes of California. Calif. Dept. Fish and Game, Fish Bull. 104, 158 pp.

Roedel, Phil M.
1953. Official common names of certain marine fishes of California. Calif. Fish and Game, vol. 39, no. 2, pp. 251-262.

Sanford, F. Bruce
1958. Utilization of fish waste in Northern Oregon for mink feed. Comm. Fish. Rev., vol. 19, no. 12, pp. 40-46.

Sayles, Richard E.
1951. The trash fishery of Southern New England in 1950. Comm. Fish. Rev., vol. 13, no. 7, pp. 1-4.

Snow, George F.
1950. Development of trash fishery at New Bedford, Massachusetts. Comm. Fish. Rev., vol. 12, no. 7, pp. 8-10.

A REVIEW OF THE LINGCOD, *OPHIODON ELONGATUS*[1]

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INTRODUCTION

The lingcod is prized as a food and sport fish. Locally in various places there is developing a feeling that possibly conservation measures for the regulation of the fishery may be needed. In order to assess the current facts at hand it was deemed appropriate to set down what is known of the life history of the species together with data on the status of the fishery.

Lingcod range from northern Baja, California to northwest Alaska. They are moderately abundant in California ocean waters. The area of greatest abundance lies north of California, however.

The lingcod is in a family by itself, the Ophiodontidae. It is closely related to the rockfishes (Scorpaenidae), Sculpins (Cottidae), sablefish (Anoplopomatidae), and a few other fish families collectively grouped in the order Scleroparei, or mail-cheeked fishes.

FIGURE 1. Lingcod, 21 inches in total length. *Photo by J. B. Phillips.*

Some early British settlers in the Pacific Northwest observed a resemblance between this fish and the European ling (*Molva*), but indicated a difference by adding the word "cod," thus evolving lingcod.

They vary considerably in color from nearly black or brown to green, with darker mottling and spotting on back and sides. The upper sides and back are often spotted with orange or yellow.

Many names have been attached to the lingcod, including: cultus cod, Pacific cultus, green cod, blue cod, white cod, ling, greenling codfish, leopard cod, buffalo cod, and bocalao.

[1] Submitted for publication September, 1958.

CATCH

Commercial

The annual commercial lingcod catch in California has varied between 400,000 and 2,000,000 pounds since 1916, with the average just under one million. In 1957, landings of one and one-half million pounds marked the sixth highest catch in the 42-year period for which records are available (Table 1).

TABLE 1

Number of Pounds of Lingcod Landed Annually Along the Pacific Coast of North America

Year	California	Washington and Oregon	British Columbia and Alaska	Pacific Coast Total
1916	617,236	--	--	
1927	930,519		--	
1918	915,368		--	--
1919	1,063,136	--	--	--
1920	687,954	--	--	--
1921	425,543	--	--	--
1922	568,481	--	--	--
1923	467,347	--	--	--
1924	400,432	--		--
1925	683,130	--	--	
1926	649,902	--		--
1927	556,308	--	--	--
1928	853,537	--	--	--
1929	1,167,120	--	--	--
1930	1,288,172			
1931	1,229,088	--		
1932	899,912	--	--	--
1933	1,088,955	--	--	--
1934	857,600	--	--	--
1935	1,017,503			
1936	758,547	1,270,376	6,894,621	8,923,544
1937	968,258	1,598,700	4,288,807	6,855,765
1938	646,004	1,992,476	4,652,982	7,291,462
1939	576,972	1,680,418	4,750,790	7,008,180
1940	692,243	2,358,917	4,768,827	7,819,987
1941	529,772	3,967,719	4,252,728	8,750,219
1942	314,334	6,534,566	4,254,457	11,103,357
1943	719,318	7,591,621	5,901,002	14,211,941
1944	746,039	9,451,754	8,601,235	18,799,028
1945	758,704	8,146,400	8,163,313	17,068,417
1946	1,156,398	6,612,084	7,699,314	15,467,796
1947	1,940,747	4,025,308	3,914,956	9,881,011
1948	2,055,519	6,573,644	6,651,837	15,281,000
1949	1,655,961	5,115,028	7,393,800	14,164,789
1950	1,914,725	3,927,391	4,652,706	10,494,822
1951	1,672,114	3,658,000	4,759,000	10,089,114
1952	1,366,074	3,207,000	4,248,000	8,821,074
1953	952,103	2,018,000	2,945,000	5,945,103
1954	947,383	2,776,000	3,939,000	7,662,383
1955	961,926	4,317,000	3,635,000	8,916,926
1956	931,311	3,739,000	4,776,000	9,446,311
1957	1,601,502	3,815,000	4,765,000	10,181,502

In keeping with a northward abundance of lingcod, the greatest annual landings are made in the northern part of the State. Catches are progressively less important at the more southerly ports. South of Pt. Conception, in the Los Angeles and San Diego regions, commercial landings of lingcod are unimportant.

The total annual catch for Oregon, Washington, British Columbia, and Alaska has varied since 1935 between 6 and 18 million pounds, with the average at about nine million.

Sport

Although lingcod are not as important in the California marine sportcatch as are a number of other fishes, they are a favorite species of many anglers. By numbers, they made up nearly one percent of the California party-boat catch from 1947 to 1957. During this period, the party-boat catch decreased from about 26,000 in 1949 to 13,000 in 1953, but then increased to an all-time high of 38,000 in 1957 (Table 2).

The highest sportcatch of lingcod occurs in the Monterey-Santa Cruz region. The adjacent regions, San Francisco-Halfmoon Bay to the north and San Simeon-Avila to the south, are next in importance. During the past 10 years, 60 percent of the lingcod caught from party-boats were taken out of these northern ports.

TABLE 2

Number of Lingcod Caught by Party-boat Anglers in California During the Years 1947-1957 Compared to Total Number of Fish of All Species Caught

Year	Number of lingcod	Total number all fish
1947	22,011	2,070,432
1948	24,406	2,110,019
1949	26,131	2,339,794
1950	23,868	2,190,413
1951	24,052	2,350,644
1952	17,389	2,305,875
1953	13,011	2,280,158
1954	22,940	3,274,537
1955	29,113	3,113,883
1956	37,649	3,262,995
1957	38,012	3,499,585

The next port of importance is San Diego, at the southern end of the State where about 15 percent of the party-boat catch of lingcod is made. Although they are abundant in northern California waters, as indicated by the commercial catch, the sportcatch is not great in these waters because fishing emphasis is on salmon. About two-thirds of the fish caught from northern California party-boats are salmon.

GEAR

Lingcod are caught mainly with handlines, trolling lines, and otter trawls or drag nets. Live bait on a handline is more effective than dead bait, but dead bait is often accepted when it is jigged up and down just above the bottom. Although they forage around at times, lingcod spend considerable time resting on the bottom, watching the surrounding environment for prey.

Fishing is usually best off rocky areas and shallow-water trolling with bait is usually the most effective system. They may also be taken with trolled salmon spoons, or on nickle-plated lures that are jigged up and down.

Commercial handliners, fishing deeper waters, often use a 2- to 3-foot light metal bar as a ''spreader'' between large hooks attached to short lines at either end of the bar. The mainline is secured to the middle of the bar, with a weight hanging below. This arrangement is sometimes referred to as a ''jig'' because, when baited, it is jigged up

FIGURE 2. A catch of lingcod from 200 feet of water off Trinidad Head. *Photo by J. B. Phillips.*

and down to attract the attention of lingcod that may be lurking in the vicinity.

PRODUCTS

Lingcod are highly esteemed as fresh fish and the bulk of the commercial catch is marketed in this form. A small portion of the catch is frozen. As is the case with cabezon, the flesh may have a greenish color. The green coloring is not harmful and all traces of it disappear upon cooking.

This fish has been found to be one of the richest sources of insulin among the fishes of the world. However, a more dependable supply can be obtained from other sources, so insulin has not been exploited as a commercial by-product of lingcod. Also, the liver oil is extremely rich in vitamins A and D. During the period 1943-1946, lingcod livers brought fishermen $2 a pound, but in 1947, the market for fish livers deteriorated because of the mounting production of synthetic vitamin A.

LIFE HISTORY

In the Pacific Northwest, where lingcod are found in greatest abundance, considerable life history work has been conducted. Preliminary comparisons of spawning season, fecundity, weight-lengths, and size at maturity indicate a close correspondence between the stocks in California and those to the northward.

Habitat

Lingcod live near the bottom, generally in and around rocky areas, around reefs, and in kelp beds, especially where there is a strong tidal movement. Although they are most abundant at depths of 60 fathoms or less, they occasionally are caught in 100 fathoms of water off California, and have been reported to occur as deep as 200 fathoms off the Queen Charlotte Islands, British Columbia (Wilby, 1937).

Migrations

During the years 1939-1954 the Canadian government tagged and liberated 3,145 lingcod on banks in the Strait of Georgia and off the west coast of Vancouver Island, British Columbia. The subsequent recovery of 419 of these tagged fish indicated that only about 9 percent had moved more than five miles from the areas of release. In one case, a movement of 80 miles was noted; however, the few significant movements were random in nature. The movements of immature fish, less than 22 inches in total length, were somewhat more widespread. In a number of cases, they were recovered as far as 25 miles from the areas of release. After maturity was reached a "niche" apparently was found in the environment because the movements of the large, mature fish were more restricted (Hart, 1943b, Chatwin, 1956b).

A tagged male lingcod was recovered after being at libery for 12 years and 2 months in approximately the same locality as that where tagging took place. This recovery was in conformity with the general conclusion, reached after many tagging experiments, that lingcod lead a rather sedentary existence (Fish. Res. Bd. Canada, 1954).

When marking of this species was initiated in Canada, two types of tags were tried. One was a monel-metal or aluminum strap tag that was clinched on the operculum or cheek bone. The other was made by coiling a flat strip of red celluloid upon which a number had been stamped. This latter tag was applied by working it through a slit in the membrane of the upper jaw bone and allowing it to snap into position. Most of the tagging was done with this celluloid tag after it had proved its effectiveness. The lingcod that was recovered after 12 years and 2 months at liberty had been tagged with this latter type.

Food

Wilby (1937) noted that in British Columbia waters very young lingcod fed upon crustaceans such as shrimp until they were large enough to feed on small fishes, such as small herring. Adult lingcod apparently will feed on anything alive including sand lances, herring, young lingcod, dogfish shark, gray cod, pollack, rockfish, crabs, shrimp and squid. A 54-pound lingcod, caught off Monterey, California, on January 27, 1938, had in its stomach a 12-inch starry rockfish that weighed one and one-quarter pounds, and an 18½-inch canary rockfish that weighed three pounds. Occasionally, eelgrass has been found rolled up in the stomach along with hydroids and even gravel. No doubt, this material was ingested along with prey seized at the bottom.

In British Columbia waters, Chatwin (1956b) noted that some banks or reefs always seemed to be inhabited entirely by large fish. The fact that lingcod are given to cannibalism led him to suggest that large fish may suppress recruitment of young fish to certain reefs.

Maturity

During October and November, 1957, at Fort Bragg, California, 119 lingcod (64 males and 55 females) ranging in total length from 17½ inches to 41 inches, were examined for maturity. Because of the nearness of spawning at this time of the year, the gonads of mature fish are well along in development, and differentiation between adult and immature fish is simplified. It was found that male and female fish start to mature when they are approximately 23 inches in total length. Practically all specimens were mature at a length of about 25½ inches.

Female lingcod are about three years old at a length of 23 inches, and four years old at a length of about 25½ inches (Chatwin, 1956a). In British Columbia, the minimum commercial size limit on lingcod is three pounds, dressed, head off, which is equivalent to a total length measurement of about 23 inches (Chatwin, 1954). The 23-inch size is near the break between immature and mature fish.

Spawning

In Pacific Northwest waters, spawning takes place between mid-December and mid-March (Wilby, 1937). In general, this coincides with the spawning season as noted for lingcod in California waters. In certain areas there appears to be a shifting of spawning fish, from deeper offshore waters to inshore subtidal reefs.

The eggs, which are fertilized externally, are adhesive and stick in large masses to rocky crevasses. The male guards the eggs after fertilization, repelling intruders until hatching takes place.

Developing Eggs and Larvae

The eggs when first laid are 2.8 millimeters (⅛ inch) in diameter, and pinkish colored. Upon contact with water, the outer coat swells and the eggs measure 3.5 millimeters in diameter. In a few days they become white, gradually changing to a dull yellow or greenish brown, because of the accumulation of diatoms. About six weeks are required for hatching to take place (Wilby, 1937).

At hatching the one-half-inch long larvae have a yolk sac that disappears on about the tenth day. The larva is elongate, with large blue eyes, large mouth, bright green gall bladder, and a large, yellow oil globule in the region of the liver.

Little is known of the postlarval stages but young fingerlings, from three to five inches in length, are taken occasionally by seining in eelgrass areas during the summer.

Fecundity

The largest females apparently lay at least one-half million eggs in a season. Lingcod eggs are relatively large as are the ripening ovaries. A specimen caught off British Columbia measured 41 inches in total length and weighed 32 pounds. The eggs in the paired ovaries of this fish weighed 10 pounds 14 ounces, which was about one-third the weight of the fish. The total number of eggs was calculated as 518,000 (Table 3). Another specimen, caught off Monterey, California, measured 45 inches in total length and weighed 41½ pounds. The 436,000 eggs in the ovaries of this fish weighed 8.3 pounds, or 20 percent of the total fish weight.

TABLE 3

Calculated Numbers of Eggs in the Paired Gonads of Female Lingcod

Total length of fish in inches	Number of eggs	Authority	Locality
30½	60,000	Wilby, 1937	British Columbia
34	170,000	Clemens & Wilby, 1946	British Columbia
36¾	263,000	Wilby, 1937	British Columbia
38¾	280,000	Phillips (Unpub.)	California
41	518,000	Wilby, 1937	British Columbia
44	436,000	Phillips (Unpub.)	California
46½	176,000	Clemens & Wilby, 1946	British Columbia

Age (Growth)

In the lingcod the usual methods of age determination, such as the counting of the concentric rings on scales or on earstones (otoliths) have been tried without success. Other bony parts of the body were also examined for growth marks but only the vertebrae showed any promise. Vertebrae were cleaned by boiling in water and were then set aside to dry. Dark growth marks, believed to be annual checks, were discernible when the dry vertebrae were examined under a bright light (Chatwin, 1954, 1956a).

As a means of checking the reliability of the readings from vertebrae, comparisons were made with frequency polygons derived from monthly samples of young fish. The young lingcod were obtained in shallow water with beach seines, dip nets (at night), and small-mesh trawls. The agreement between vertebral interpretation and the growth depicted by the O-ring and I-ring fish sampled in shallow water was good. It was found that a group of closely arranged rings in the central region of each vertebra were false checks. On larger fish, vertebral age determinations were checked for reliability by comparing them to the increases in lengths shown by 234 tagged lingcod that were recovered over a period of several years.

A growth curve for males up to 14 years and for females up to 16 years of age was derived by Chatwin (1954 and 1956a) from an analysis of vertebral rings or annuli. Differences in the growth rates of the two sexes were first noted at about age three. These differences were more marked among older fish: the males having a slower growth rate and a shorter life span than females.

TABLE 4

Average Lengths Attained at Different Ages for Male and Female Lingcod in British Columbia Waters *

Age in years	Total length in inches	
	Male	Female
1	10½	10½
2	18½	18½
3	22	23
4	24	25½
5	26	28
6		
7		
8		
9		
10	33½	36
11		
12	35	39
13		
14	36	41½
15		
16		43½

* From Chatwin (1954 and 1956a).

It would appear that a total length of 36¼ inches and a weight of 22 pounds is the maximum attained by male lingcod. The maximum length and weight attained by female lingcod appears to be five feet and 70 pounds, as cited by Wilby (1937) who also encountered a specimen that measured 52 inches in total length and weighed 54 pounds.

REGULATIONS

There are no commercial regulations specifically applied to lingcod in California, Oregon, Washington, or Alaska. British Columbia has a minimum weight limit of three pounds for fish that are cleaned and have their heads off. This corresponds to a 3.6-year-old fish having a total length of approximately 23 inches. In recent years a winter closure of three months (during the spawning season) also has been in effect in British Columbia waters.

Both of these regulations emanated as recommendations from the fishing industry and were not a result of biological necessity. At the present rate of fishing, the minimum size limit seems to be rather appropriately situated in respect to maximum yield. The effect of the spawning season closure has not been measured because there does not appear to be any reliable way to do so.

Sport fishermen in California currently are limited to a bag of 10 lingcod of any size per day.

REFERENCES

Chatwin, B. M.

1954. Growth of young lingcod. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 99, pp. 14-17.

1956a. Age and growth of lingcod *(Ophiodon elongatus)*. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 105, pp. 22-26.

1956b. Further results from tagging experiments on lingcod. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 107, pp. 19-21.

Clemens, W. A., and G. V. Wilby

1946. Fishes of the Pacific Coast of Canada. Fish. Res. Bd. Canada, Bull. 68, 368 pp.

Fisheries Research Board of Canada

1954. A record tagged lingcod. Prog. Rept. Pacific Coast Sta., no. 100, p. 19.

Hart, John Lawson

1943a. Rate of growth in lingcod. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 56, pp. 10-11.

1943b. Migration of lingcod. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 57, pp. 3-7.

Ketchen, K. S.

1950. A study of the winter trawl fisheries at Cape Lazo and Nanoose Bay in the Strait of Georgia with special reference to the capture of lingcod. Fish. Res. Bd. Canada, Prog. Rept. Pacific Coast Sta., no. 84, pp. 64-67.

Schultz, Leonard P.

1938. Treasures of the Pacific. Nat. Geog. Mag., vol. 74, no. 4, pp. 463-498.

Wendler, Henry O.

1953. Length-weight relationships of the lingcod. Wash. Dept. Fish., Fish. Res. Papers, vol. 1, no. 1, pp. 25-32.

Wilby, G. V.

1937. The lingcod, *Ophiodon elongatus* Girard. Biol. Bd. Canada, Bull. no. 54, 24 pp.

THE SYSTEMATICS AND DISTRIBUTION OF CRAYFISHES IN CALIFORNIA[1]

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INTRODUCTION

Crayfishes are interesting and important members of California's freshwater fauna. They are an excellent food, have value as game fish forage, and are used by fishermen as bait for game fish. On the negative side, the burrowing habits of some species at times make them a menace to irrigation structures in agricultural areas.

Because no comprehensive account has heretofore been published on the crayfishes in California, with the exception of a popular report by Bonnot (1930), it is believed this paper will be of value to both the scientist and layman.

Brief descriptions of species of California crayfishes occur in early expedition reports, and a few are mentioned in monographs on various crustacean groups, primarily the cambarines (Hagen, 1871; and Faxon, 1889, 1895, 1898, and 1914), and the marine decapods (Holmes, 1900). About the middle of the 19th century, crayfishes were collected and described by naturalists accompanying the Pacific explorations of the Boundary Commission and the U. S. Exploring Expeditions. In 1852, Charles Girard described *Pacifastacus gambeli*. In the same year, James Dana established *P. leniusculus*. In 1859, William Stimpson described *P. trowbridgi*, *P. nigrescens*, and *P. klamathensis*.

At the time of these early explorations, only two species were found in California, *Pacifastacus nigrescens* and *P. klamathensis*. However, Faxon (1885) referred to a specimen of *P. gambeli* in the Museum of Comparative Zoology, Harvard, which was included with a group of specimens from Santa Barbara, California; but as no other specimen of that species had been found in California, he doubted the validity of the record.

Orconectes virilis (Hagen) and *Procambarus clarki* (Girard) of the subfamily Cambarinae, native to North America east of the Continental Divide, have since been introduced into the State and are thriving. *Pacifastacus leniusculus* has been introduced into California from Oregon and with *Procambarus clarki* is now widely distributed throughout the central part of the State. *Procambarus clarki* is the only crayfish known to inhabit the waters south of the Tehachapi Mountains.

In 1950, Bott revised the genus *Astacus* and proposed the generic name *Pacifastacus* for the astacines native to North America west of

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the Continental Divide. His proposal is accepted in this paper. A further revision of *Pacifastacus* is herein presented, in which *Pacifastacus trowbridgi* is shown to be synonymous with *P. leniusculus*. Descriptions and figures of all species of crayfishes known or reported from California are included.

Materials and distribution records upon which this paper is based were obtained by collections throughout California, by circularizing appropriate institutions in the State, and from the available literature.

SYSTEMATICS

Five species of crayfishes representing two subfamilies and three genera are now known to occur in California. These are *Pacifastacus leniusculus* (Dana), *Pacifastacus klamathensis* (Stimpson), and *Pacifastacus nigrescens* (Stimpson) of the subfamily Astacinae; *Procambarus clarki* (Girard) and *Orconectes virilis* (Hagen) of the subfamily Cambarinae. *Pacifastacus trowbridgi*, though generally assumed to be a distinct species, is here considered to be only a variation of *P. leniusculus*. Of the above-named species, only *P. klamathensis* and *P. nigrescens* may be considered as native to California; the others were presumably introduced.

Bott (1950) proposed the generic name *Pacifastacus* for the Astacinae of western North America. This proposal seems valid considering certain morphological differences between the European and North American species. In discussing the new name, he remarked that *Pacifastacus* is confined to the coastal region of North America between the Pacific Ocean and the Rocky Mountains. Similar characteristics in the gonopods of the male and other morphological characteristics indicate a direct relationship of *Pacifastacus* with Bott's two European genera, *Astacus* and *Austropotamobius*.

Hobbs (1941), in a generic revision of the subfamily Cambarinae, split *Cambarus* into five genera and added a new monotypic genus to make six, namely, *Cambarus*, *Cambarellus*, *Procambarus*, *Orconectes*, *Troglocambarus* (the new monotypic genus), and *Paracambarus*. Of these, only *Procambarus* and *Orconectes* are represented in California.

Systematic Revision of *Pacifastacus*

Since species of cambarines are now differentiated chiefly on the morphology of the male first pleopod, and since the sexual apparatus is generally a conservative systematic character, the writer has attempted to distinguish members of *Pacifastacus* on that basis. Comparison of the sexual appendages of the previously determined species shows four of the five original species are valid. These are *Pacifastacus leniusculus*, *P. klamathensis*, *P. gambeli*, and *P. nigrescens* (see remarks after the species description). The fifth, *P. trowbridgi*, is only a variant of *P. leniusculus*, as will be shown. It is difficult, however, to differentiate species of *Pacifastacus* by the sexual appendages alone, as those structures look so nearly alike. Unless an investigator is quite familiar with the peculiarities exhibited in each, there is considerable possibility of error. Further, individuals of the same species, but of different age (size) groups, vary slightly in the conformation of the sexual appendages. No dimorphism can be recognized in the gonopods, as is seen so strikingly in the subfamily Cambarinae.

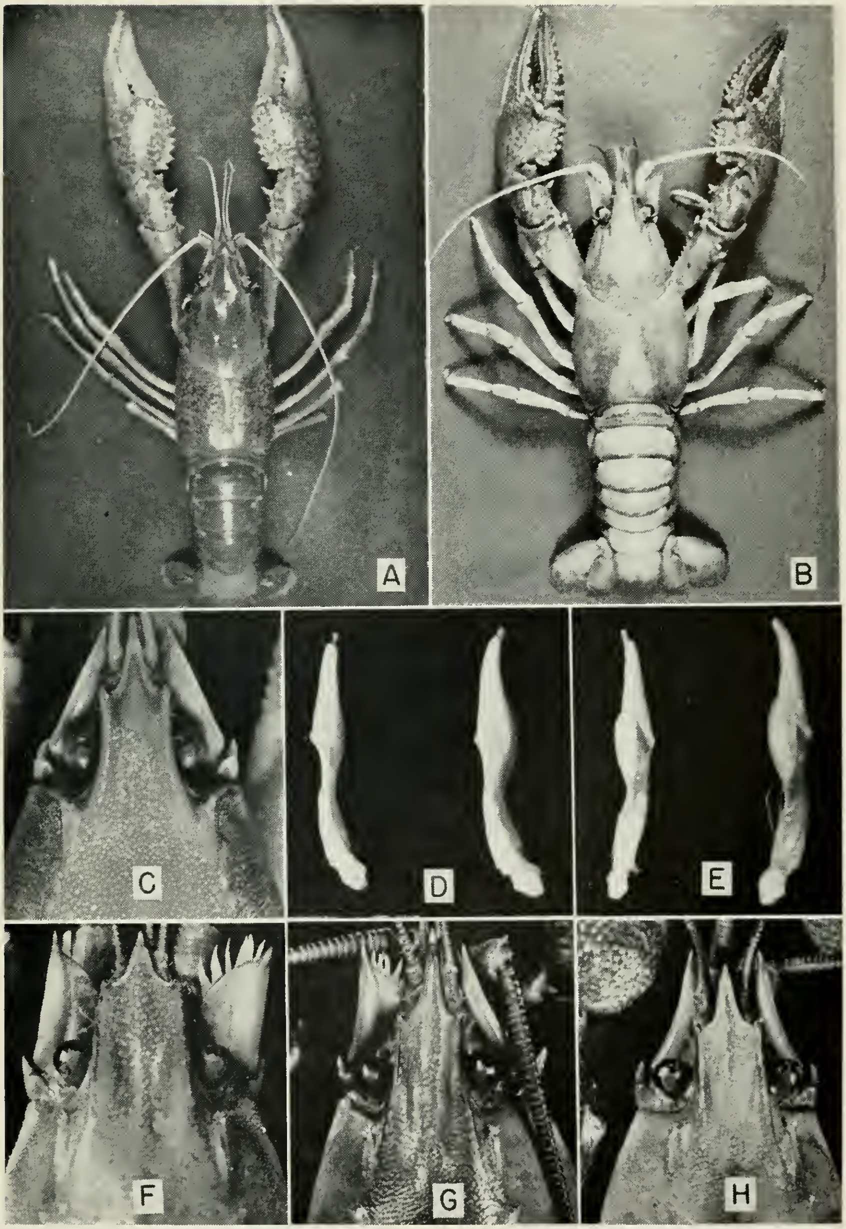

FIGURE 1. A. *Procambarus clarki* (Girard) X ½.
B. *Orconectes virilis* (Hagen) X ½.
C. Rostral area of *Pacifastacus trowbridgi* male cotype X 2.
D. Dorsal view of left gonopod of *Pacifastacus trowbridgi* cotype (left) and *P. leniusculus* (right) X 3.
E. Ventral view of left gonopod of *Pacifastacus trowbridgi* cotype (left) and *P. leniusculus* (right) X 3.
F-H. Illustration of variation in rostral acumen length and posterior postorbital spines in three male *Pacifastacus leniusculus* (from a single collection). *Photographs by George C. Clinton.*

Differences in the sexual appendages of *Pacifastacus leniusculus* and *P. trowbridgi* (Figure 1 D, E) are indistinguishable, indicating the probability that they are not separate species. Comparison of other characters that have been used in differentiating these two species clearly confirms the suspicion that *P. trowbridgi* is but a junior synonym of *P. leniusculus*. *P. leniusculus* has been characterized as having well-developed posterior postorbital spines and an acumen exceeding in length the distance between the lateral spines of the rostrum, while typical *P. trowbridgi* has obsolete posterior postorbital spines and an acumen not exceeding in length the distance between the lateral spines of the rostrum (Figure 1 F-H). In a large series of *P. leniusculus*, posterior postorbital spines vary from the low tubercles characteristic of *P. trowbridgi* (Figure 1 F) to the well-developed spines characteristic of *P. leniusculus* (Figure 1 H). The rostral acumen varies from a relatively short one characteristic of *P. trowbridgi* (Figure 1 F) to a relatively long one characteristic of *P. leniusculus* (Figure 1 H). The apparent lack of correlation between the presence or absence of the posterior postorbital spines and the length of the rostral acumen is illustrated in Figure 1 G. Therefore, "typical" *P. leniusculus* and *P. trowbridgi* merely represent extremes in variation with respect to these two characters; and this, together with the similarity of their sexual appendages, clearly dictates that *P. trowbridgi* be considered a synonym of *P. leniusculus*.

With the elimination of *P. trowbridgi* as a valid species, determination of *Pacifastacus* species can readily be made on a combination of structural characters more distinct than the sexual appendage.

GLOSSARY OF TERMS USED IN CRAYFISH SYSTEMATICS

ANNULUS VENTRALIS: Blind pouch between the bases of the fifth pair of walking legs in female Cambarinae. Used for the storage of sperms until the time of extrusion of the eggs.

BASIS: Second segment of a walking leg.

CARPUS: Fifth segment of a walking leg.

COXA: First or basal segment of a walking leg.

DACTYLUS: Seventh segment of a walking leg.

EPISTOME: Region of the ventral wall of the head just anterior to the mouth.

GONOPOD: First and second abdominal appendages of male crayfishes, which have been modified for sperm transfer.

ISCHIUM: Third segment of a walking leg.

MERUS: Fourth segment of a walking leg.

PEREIOPOD: Appendage (leg) of the thorax.

PLEOPOD: Appendage (leg) of the abdomen.

PLEUROBRANCH: Gills arising from the medial wall of the gill chamber.

PROPOPOD: Sixth segment of a walking leg.

Key to the California Crayfishes

Characters used commonly in crayfish systematics are shown in Figure 2 and defined in the glossary.

1 Last thoracic segment lacking pleurobranch; green gland orifice at or near apex of tubercle; ischium of one or more pairs of thoracic legs of male hooked (subfamily Cambarinae: *Orconectes* or *Procambarus*, genera native to North America east of continental divide) ______ 2

1′ Last thoracic segment bearing a pleurobranch; green gland orifice at or near base of tubercle; none of thoracic legs of male hooked (subfamily Astacinae: *Pacifastacus*, only native genus of western North America) 3

2 Ischium of third and fourth pairs of thoracic legs of male hooked; epistome truncate, carapace markedly tuberculate (Figure 1 A and Figure 4) *Procambarus clarki* (Girard).

2′ Ischium of third pair of thoracic legs of male hooked; epistome truncate with medium low tubercle on anterior border, carapace slightly granulate laterally (Figure 1 B and Figure 5) .... *Orconectes virilis* (Hagen).

3′ Margins of rostrum smooth 4

3 Margins of rostrum denticulate 5

4 Postorbital ridge with or without posterior spine or tubercle; white or blue-green patch across junction of dactylus and propopod of cheliped (Figure 3 A and Figure 6) .... *Pacifastacus leniusculus* (Dana)

4′ Postorbital ridge never with posterior spine or tubercle; no white or blue-green patch as above (Figure 3 B and Figure 7) *Pacifastacus klamathensis* (Stimpson).

5 Chelae with one or two patches of soft setae on outer face (Figure 3 C and Figure 8) .... *Pacifastacus gambeli* (Girard)

5′ Chelae naked on outer face (Figure 3 D and Figure 9) *Pacifastacus nigrescens* (Stimpson).

Genus PROCAMBARUS Ortman

***Procambarus* Ortman, 1905. Carnegie Mus. Ann., vol. 3, no. 3, p. 437.**

"First pleopod of first form male terminating in from two to five distinct parts which may be truncate, platelike, or spiniform. Shoulders present on cephalic surface of distal third. If the pleopod terminates in only two parts this shoulder is always present. Hooks present on the ischiopod of the third or of the third and fourth pereiopods in the male. Third maxillipedes of normal size bearing a row of teeth along the inner margins of the ischiopod." Hobbs, 1942.

Procambarus clarki (Girard)

***Cambarus clarki* Girard, 1852. Acad. Nat. Sci. Phila., Proc., vol. 6, p. 91.**

"*Male form I:* carapace and chelae markedly tuberculate or granulate; hooks on third and fourth legs of male; areola very narrow or obliterated; rostrum edges ridgelike and greatly excavated, sides converging to point of lateral spines; very prominent spine on inner edge and ventral surface of carpus of chelae; double row of tubercles or spines on ventral surface of merus of chelae; first abdominal legs of male truncate with three short recurved teeth" Faxon, 1885. Annulus ventralis of female oval with a sigmoid groove across the center, with two tubercles at the anterior border.

Male form II: differs from male form I in having the three points on the end of the first pleopod less distinct.

Type locality: "Somewhere between San Antonio and El Paso del Norte, Texas" Faxon, (1898).

Localities:[3] Contra Costa County, Diablo Creek one-half mile southwest Concord, Diablo Creek 2½ miles west Cavell; Fresno County, cattail pond 1½ miles southeast Mendota; Imperial County,

[3] Unless otherwise stated, all localities are in California.

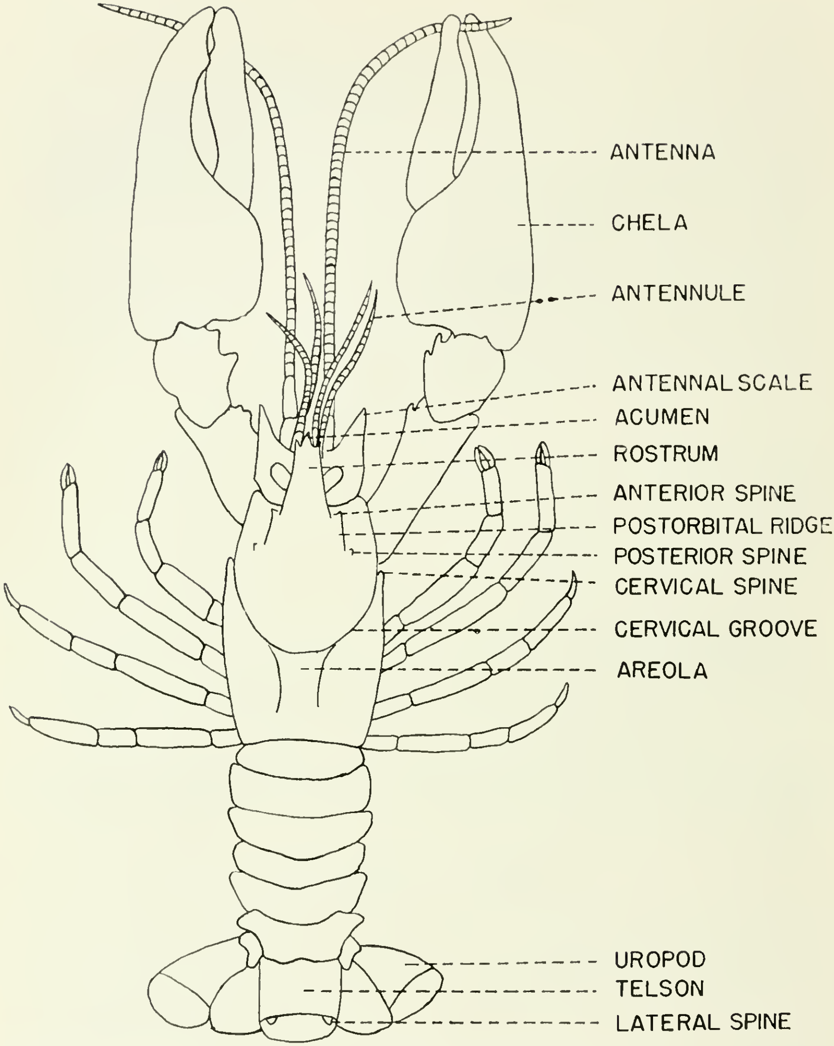

FIGURE 2. Dorsal view of a crayfish with characters labeled that are important systematically.

Colorado River opposite Yuma; Kern County, Bakersfield, irrigation canal 10 miles south Bakersfield; Los Angeles County, Balboa Creek near Venice, Puddingstone Dam five miles west Pomona, Puente Creek near Whittier; Madera County, irrigation ditch near Madera; Mariposa County, Roadside Slough 12 miles south Merced on U. S. Highway 99; Monterey County, Trembladero Slough north of Salinas River mouth; Orange County, Costa Mesa; Riverside County, Arlington Gage Canal; Sacramento County, Dry Creek below Roseville, slough parallel American River three miles northwest Sacramento; San Bernardino County, Lake Arrowhead near Emerald Bay, Santa Ana River near Arlington; San Diego

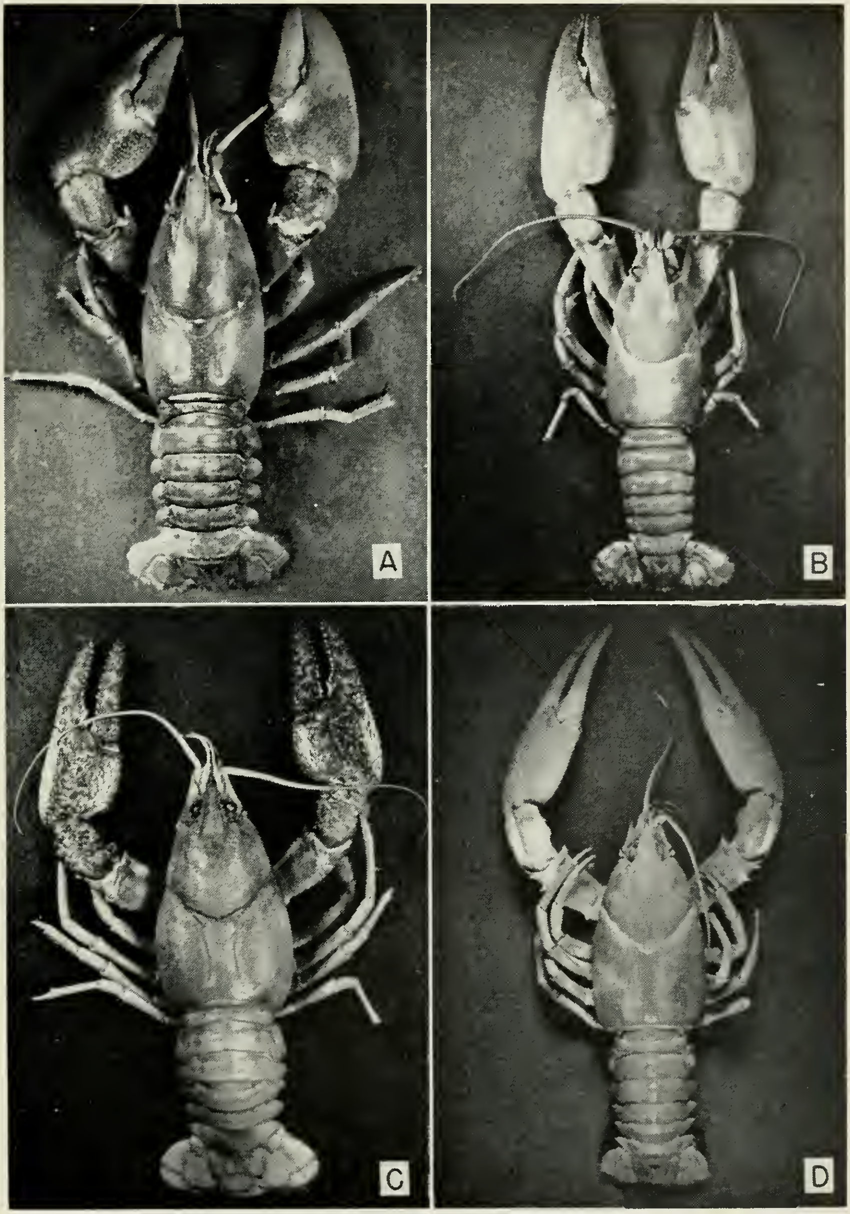

FIGURE 3. A. *Pacifastacus leniusculus* (Dana) X ½.
B. *Pacifastacus klamathensis* (Stimpson) X ½.
C. *Pacifastacus gambeli* (Girard) X ½.
D. *Pacifastacus nigrescens* (Stimpson) X ½.
Photographs by George C. Clinton

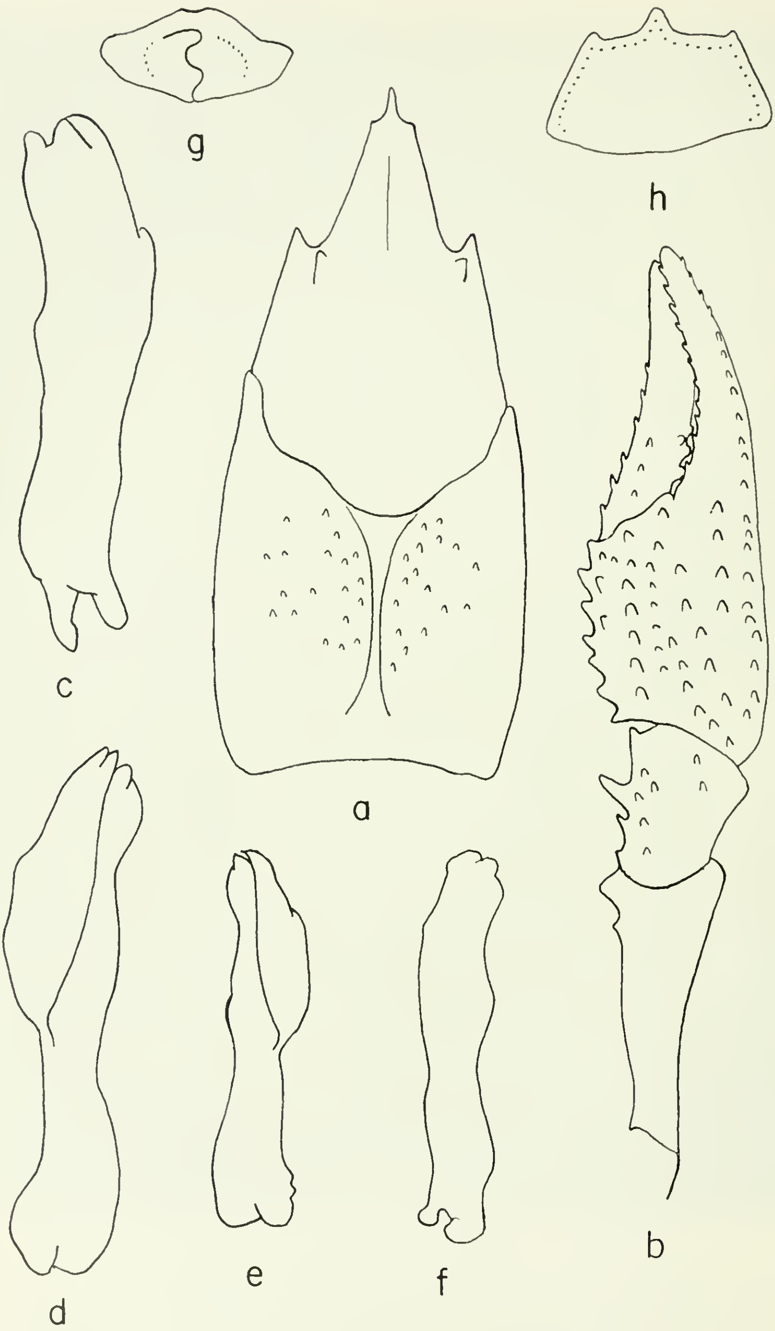

FIGURE 4. *Procambarus clarki* (Girard). a. cephalothorax. b. right chela. c. gonopod of 1st form male, dorsal view. d. gonopod of 1st form male, ventral view. e. gonopod of 2nd form male, ventral view. f. gonopod of 2nd form male, dorsal view. g. annulus ventralis of female. h. anterior process of epistome.

County, Spook Canyon near Escondido, small creek near Carlsbad, San Dieguito River three miles below Lake Hodges, Lake Hodges near U. S. Highway 395 bridge, Doane Lake tributary to San Luis Rey River; San Joaquin County, Mokelumne River near Lodi, irrigation ditch one mile north Stockton; Santa Barbara County, Santa Ynez River at Los Prietos, ditch on Hope Ranch near Santa Barbara; Sonoma County, Russian River at Mirabel Park; Stanislaus County, Tuolumne River three miles above junction with San Joaquin River.

Remarks: Procambarus clarki seems well adapted to its new environment in central and southern California. It prefers sloughs where the water is relatively warm and vegetation plentiful, but it is often found in large streams. It commonly is found in rice fields and irrigation ditches in the Central Valley, where it is regarded as a pest because its burrowing causes considerable damage to those structures. In southern California, where streams commonly run dry during the summer, it is able to survive by burrowing to the water level.

Preliminary observations indicate that in California *Procambarus clarki* breeds in late summer and early fall; the offspring hatch early in the fall. The male *P. clarki* undergoes a moult shortly before the breeding season by which it changes from second to first form, the latter being the sexually mature form. Whether first form males can return again to second form is not known. Second form males predominate in collections made before or after the breeding season. These observations concur with the natural history of *P. clarki* in its native Louisiana (Penn, 1943).

Genus ORCONECTES Cope

Orconectes Cope, 1872. Amer. Nat., vol. 6, p. 419.

"First pleopod of first form male terminating in two distinct parts, both parts ending in straight, gently curved, short, or long spines (occasionally the central projection, 'outer part,' terminates in a blade-like process). Never is a strongly developed shoulder present on the cephalic margin near the tip of the appendage. The central projection is cornious, while the mesial process is usually much softer. In the male, hooks are generally present on the ischiopod of the third and fourth pereiopods. Third maxillipeds of normal size with a row of teeth along the inner margin of the ischiopod." Hobbs, 1942.

Orconectes *virilis* (Hagen)

Cambarus *virilis* Hagen, 1871. Harvard Mus. Comp. Zool. Illus. Cat., no. 3, p. 63.

Male form I: Carapace smooth, granulated on the sides; hooks present on third segment of third pair of thoracic legs of male; areola narrow; double row of prominent tubercles on inner edge of dactylus and propopod of chelae; double row of tubercles on ventral surface of merus of chelae; moderate size spine on inner edge of carpus of chelae; epistome truncate, with a median low tubercle on the anterior border; first abdominal appendages deeply bifid, with two styliform rami, the outermost of which continues to the base of the second pair of thoracic legs; rostrum broad, well excavated, with edges parallel at base and converging only slightly to the lateral teeth; lateral teeth present, but

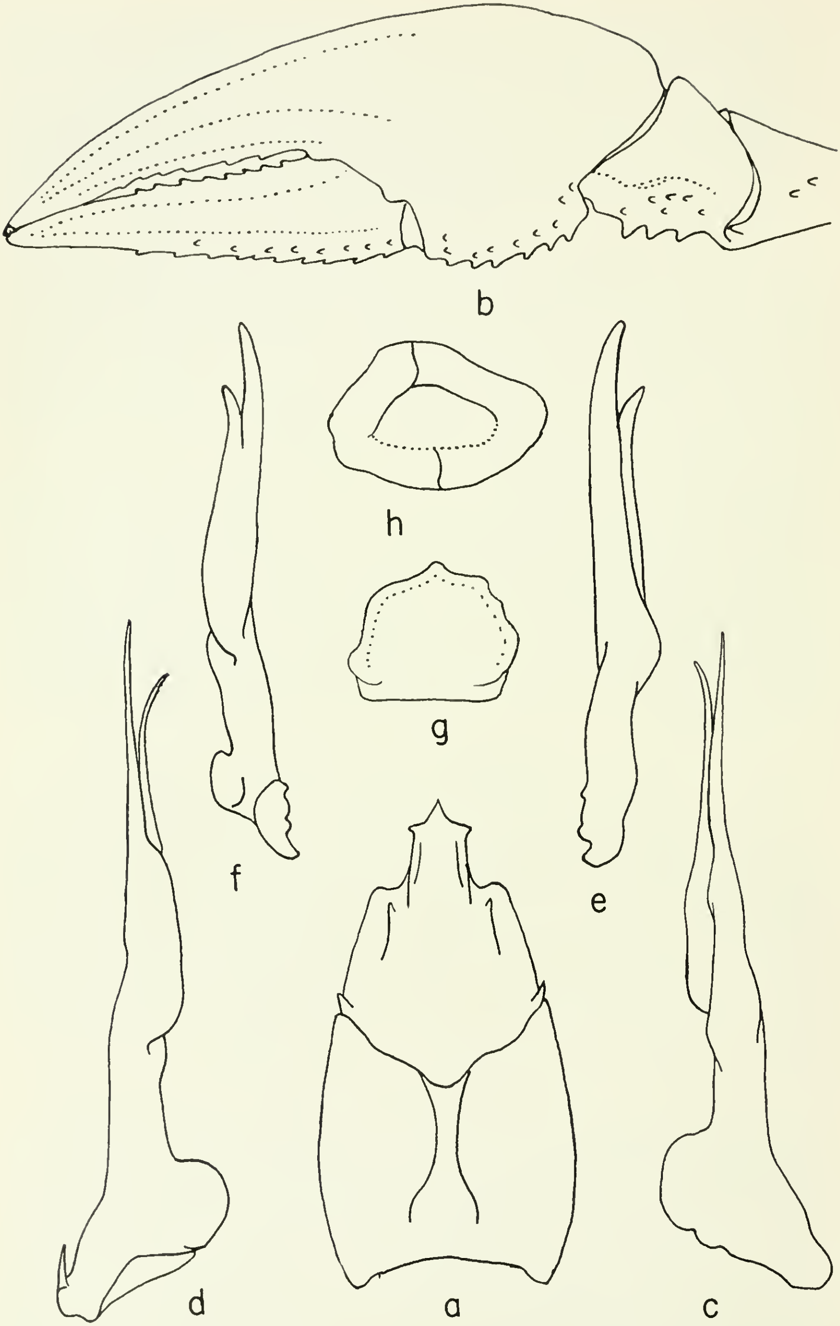

FIGURE 5. *Orconectes virilis* (Hagen). a. cephalothorax. b. chela. c. gonopod of 1st form male, ventral view. d. gonopod of 1st form male, dorsal view. e. gonopod of 2nd form male, ventral view. f. gonopod of 2nd form male, dorsal view. g. anterior process of epistome. h. annulus ventralis of female.

small; acumen of moderate length; postorbital ridge possesses only anterior spine or tubercle. Total body length of adults varies from three to six inches depending on density of population and age. (Modified from Hagen, 1871.)

Male form II: Differs from male form I in possessing narrower, less tuberculated hands; first abdominal appendages terminating in two parts, but not intertwined and not deeply bifid, mesial part thick.

Type locality: Lake Superior.

Localities: Butte County, drainage ditch seven miles southwest Chico, semi-stagnant pool Little Chico Creek in Chico; Colusa County, rice field near Williams; San Joaquin County, Cosumnes River near confluence with Mokelumne River; Yolo County, drainage ditch four miles east Woodland, Putah Creek two miles south Davis, irrigation ditch near causeway six miles northeast Davis.

Remarks: This species was identified by Dr. Horton H. Hobbs, Jr., of the Samuel Miller Biological Laboratories, University of Virginia, Charlottesville. *Orconectes virilis* is highly variable in its native habitat (Indiana, Illinois, and other midwestern states), but little variation can be seen in more than 200 California specimens examined. The habitat is similar in most respects to that of *Procambarus clarki*. It is also a rice field pest. Four specimens of *O. virilis* were dug out of burrows on the bottom of a drained pond near Davis, Yolo County, but whether they had burrowed to escape the dry period, or the burrows were their normal abode could not be ascertained.

Genus PACIFASTACUS Bott

***Pacifastacus* Bott, 1950. Abhandl. Senckenberg. Naturfor. Gesell., vol. 483, p. 24.**

Bott described this genus as follows: *Pacifastacus* is distinguished from *Astacus* and *Austropotamobius* in the following characteristics: Terminal portion of the first gonopods of the male gradually antennuated from the middle becoming suddenly tubular distally. The involution is so tight at the termination that a closed tube results, which appears regularly cut off at the termination; thus no sudden spoon-shaped points can be detected (as in the European genera). Second gonopod of the male with ligamentous exopodite. The cone-shaped involution of the endopodites is nearly one-third the entire length of the endopodite and placed distinctly against the basal portion. The merus of the third maxillipeds is regularly spined on its entire inner margin and possesses an especially large and strong spine at the distal end. In all, eight spines on the inner margin are perceived. Epistome without spines or ridges behind the orifice of the green gland. The genotype is *Pacifastacus klamathensis*.

Pacifastacus leniusculus (Dana)

***Astacus leniusculus* Dana, 1852. Crustacea, part I. U. S. Exploring Expedition, vol. 13, p. 524.**

Dana described this species as follows: "Beak tridentate, teeth acute, middle tooth slender elongate. Carapace smooth punctate, behind beak either side with two spines (the posterior obsolescent in young individuals); postero-dorsal areolet between the longitudinal sutures broad.

Anterior feet compressed, in no part tuberculate or spinous, hand smooth, punctate; carpus but little oblong, inner margin straight, unarmed, except a short spine at apex; arm with anterior margin denticulate, and longer tooth at apex, on outer margin, short distance from apex, unispinous. Following pairs of feet nearly naked. Caudal segment sparingly oblong, sides nearly parallel. Fifth pair of feet bearing small branchiae." Useful characters in addition to those given in the original description are: White or blue-green band across junction of dactylus and propopod of chelae. Length and width of rostrum, length of acumen, and spination of the postorbital ridge variable.

Type locality: Lower Columbia River in Oregon.

Localities: Alameda County, Alameda Creek one mile east Niles; Lake County, Clear Lake Narrows; Marin County, stream below Phoenix Lake Reservoir near San Anselmo, Alpine Dam near San Raphael; Mariposa County, Big Creek at Fish Camp; Mendocino County, Coldwater Creek five miles northeast Ukiah; Merced County, Snelling, Merced River near Irwin; Monterey County, Carmel River two miles east of Pacific Ocean, Little Sur River one mile east of Pacific Ocean; Napa County, Putah Creek four miles north Middletown; Nevada County, Donner Lake; Placer County, Truckee River two miles west Tahoe City; Plumas County, south end Lake Almanor; Sacramento County, Sacramento River between Knight's Landing and Feather River mouth, Pacific Gas and Electric powerhouse canal at Folsom, Sacramento River near M Street bridge, Fremont Weir, Sacramento River northwest Sacramento; San Mateo County, San Gregorio Creek at San Gregorio, Pescadero Creek in San Mateo Memorial Park and at Pescadero; Santa Clara County, Arroyo Hondo near Calaveras Reservoir, Smith Creek at base of Mt. Hamilton; Santa Cruz County, Mill Creek one mile north Wanton, Brookdale Hatchery at Brookdale; Shasta County, Cottonwood Creek at Cottonwood; Siskiyou County, Abram's Lake near Mt. Shasta; Sonoma County, Austin Creek near Cazadero, stream near Duncan's Mill, Russian River at Mirabel Park, East Fork Austin Creek; Yolo County, Cache Slough, Putah Creek 6½ miles west Winters.

Remarks: Pacifastacus leniusculus occupies a fairly wide range of habitats. It may be found in large rivers, swift or sluggish streams, lakes, and occasionally muddy sloughs. On one occasion, it was collected in dilute brackish water. It lives under large rocks and vegetable debris.

From preliminary observations it appears that *Pacifastacus leniusculus* breeds in late fall. The eggs are carried by the female over the winter, and hatch in late spring. It is probable that females "in berry" (carrying eggs) remain secluded in their dens for the winter, as the writer has been unable to collect ovigerous females after the onset of the breeding season. Most females collected in late spring (April or May) bear evidence of having recently discharged the young; *i.e.*, the threads which attach the eggs to the pleopods have not yet been removed by moult.

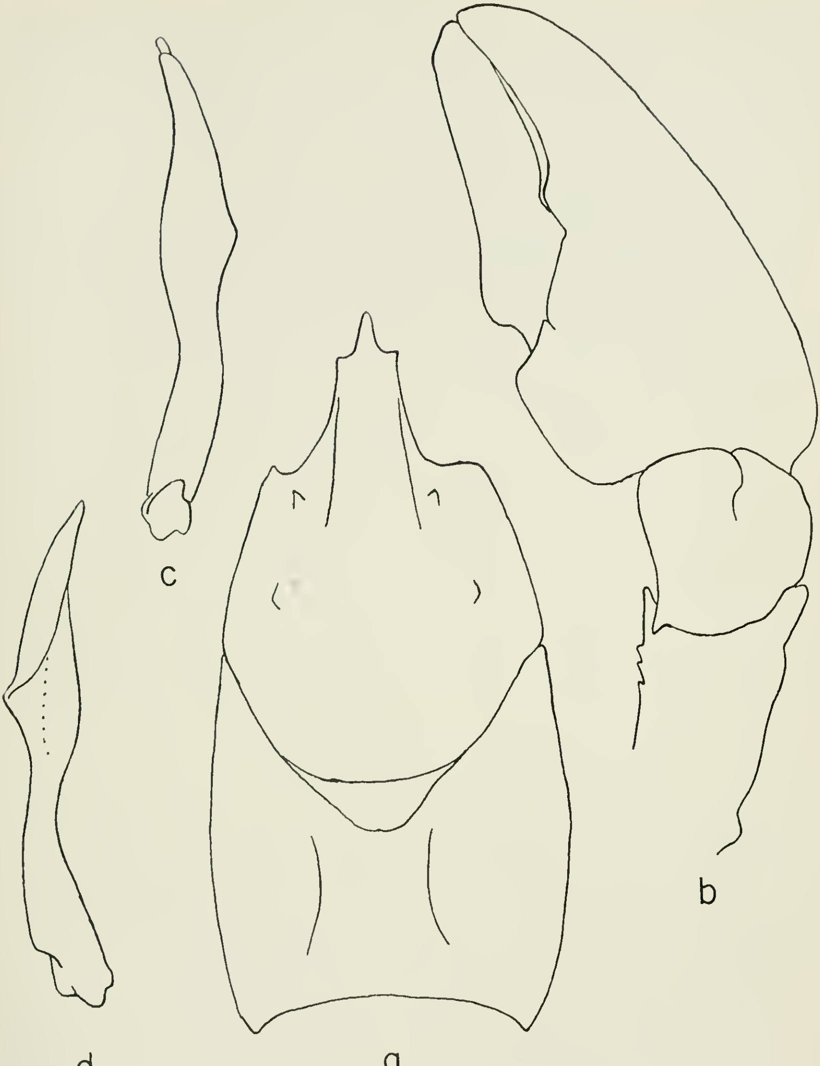

FIGURE 6. *Pacifastacus leniusculus* (Dana). a. cephalothorax. b. chela. c. gonopod of male, dorsal view. d. gonopod of male, ventral view.

Pacifastacus klamathensis (Stimpson)

***Astacus klamathensis* Stimpson, 1859. Boston Soc. Nat. Hist. Proc., vol. 6, p. 87.**

Stimpson described this species as follows: "Thorax smooth above, rather contracted in front. Rostrum subtriangular, but with lateral teeth sufficiently distinct, sides smooth, converging. Posterior pair of thoracic spines obsolete. Hands small, dentation of inferior edge of arm slight. Lateral margins of abdominal segments broadly rounded, scarcely at all angular . . . Color, bright yellowish white; hand tinted bluish. (Possibly this description was made from specimens faded by preservative; the color stated below is the only one known by the writer to be characteristic of true *Pacifastacus klamathensis*.) Length, three inches." Descriptive characters in addition to the original description are: Color, brick-red, total body length rarely exceeding five inches.

Type locality: Klamath Lake, Oregon.

Localities: Colusa County, Bear Creek 18 miles northeast Clear Lake; Del Norte County, Smith River; El Dorado County, Upper Truckee River, Fallen Leaf Lake, Truckee River below Lake Tahoe, Taylor Creek tributary to Lake Tahoe, south shore Lake Ta-

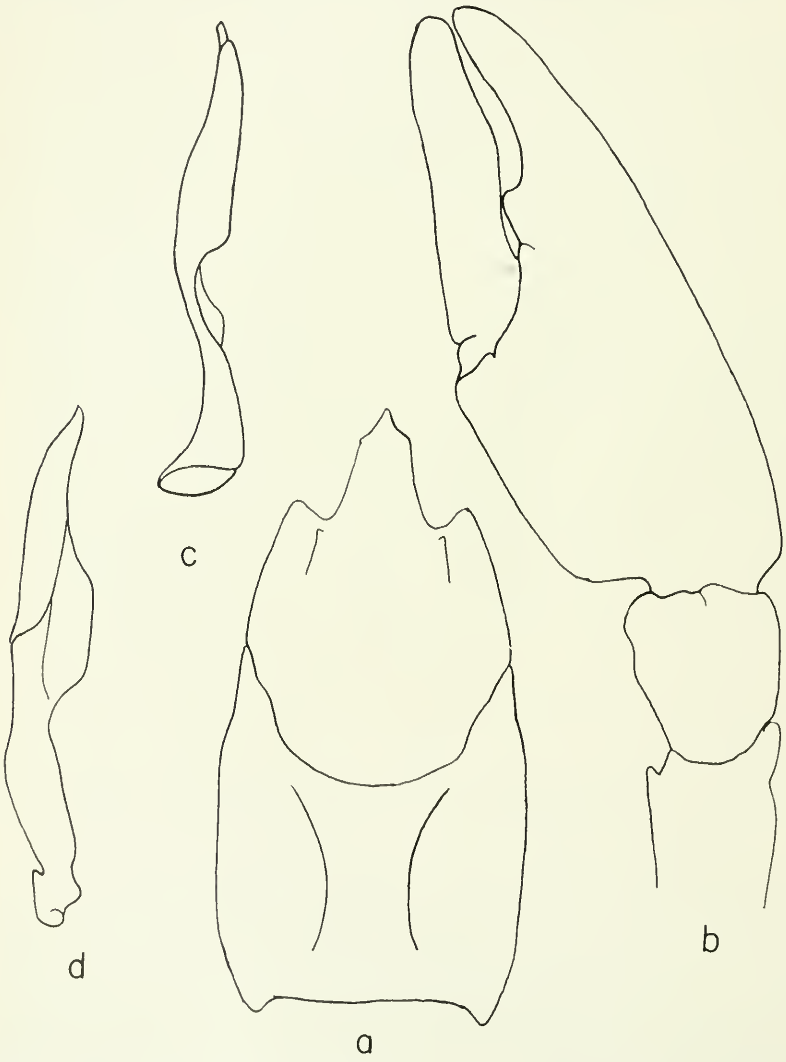

FIGURE 7. *Pacifastacus klamathensis* (Stimpson). a. cephalothorax. b. chela. c. gonopod of male, dorsal view. d. gonopod of male, ventral view.

hoe; Humboldt County, Trinity River at Willow Creek, Trinity River at Hoopa, Briceland; Mendocino County, Garcia River, South Fork Eel River at Devoy Grove; Placer County, Lake Tahoe at Tahoe City; Siskiyou County, Klamath River one mile west Ash Creek, Klamath River at Klamathon Racks near Hornbrook, one mile southwest Mayten, tributary Klamath River five miles east Yreka, Cottonwood Creek near Hornbrook; Trinity County, South Fork Trinity River one mile southwest Salyer, Trinity River at Lewiston, Trinity River at Susy Q Ranch near Salyer, Trinity River near Lewiston, Brown Creek, Big Creek, Tule Creek.

Remarks: Pacifastacus klamathensis occupies the cold, swift-running rivers and streams of northwestern and north-central California, where it lives under large rocks and fallen logs along the bank. Unlike any other species of its genus, it is commonly seen foraging among the rocks of very swift-flowing water.

Specimens of crayfishes taken from Waddell Creek, Santa Cruz County, have been identified by Dr. Waldo L. Schmitt of the U. S. National Museum as *Astacus (=Pacifastacus) klamathensis* (Shapovalov, 1954). The writer has not had the opportunity to examine these crayfish specimens, but based on a knowledge of the characters used by Dr. Schmitt in identifying *P. klamathensis* (letter, Waldo L. Schmitt to Leo Shapovalov, Calif. Dept. of Fish and Game, 19 August 1942), it is doubtful that a correct determination was made. The systematic characters used were the shape of the chelipeds and the areolar width, which are quite variable within all species of *Pacifastacus*.

Pacifastacus gambeli (Girard)

***Cambarus gambeli* Girard, 1852. Acad. Nat. Sci. Phila., Proc., vol. 6, p. 90-91.**

Holmes (1900) describes this species thus: "Carapace obese, punctate; rostrum short, acute, concave above, with the sides denticulated and converging to the tip; a small spine on either side of the base behind which there may be a trace of a second pair; dorsal area over twice as long as the width across the middle; chelae large; merus much compressed, the lower margins spinulose; a spine on the upper side near the distal end; carpus devoid of spines, the upper edge with a longitudinal median depression; hands large, broad, scabrous, the upper surface of the palm thickly pilose on either side of the middle; lower side of palm inflated."

Type locality: "California" (Girard, 1852). Girard made no mention of where in California the type specimen was collected, and *Pacifastacus gambeli* has not been found in this State since. (See introduction.)

Remarks: Faxon (1914) separated both *Pacifastacus gambeli* and *P. nigrescens* into subspecies, the new ones being *P. gambeli connectens* and *P. nigrescens fortis*. The characters on which the subspecies were based are the length, spination, and width of the rostrum, spination of the postorbital ridge, and length and width of the claws. The writer has not seen sufficient numbers of either species to ascertain the validity of the aforementioned subspecies, but observations of large numbers of *P. klamathensis* and *P. leniusculus* show that those characters exhibit

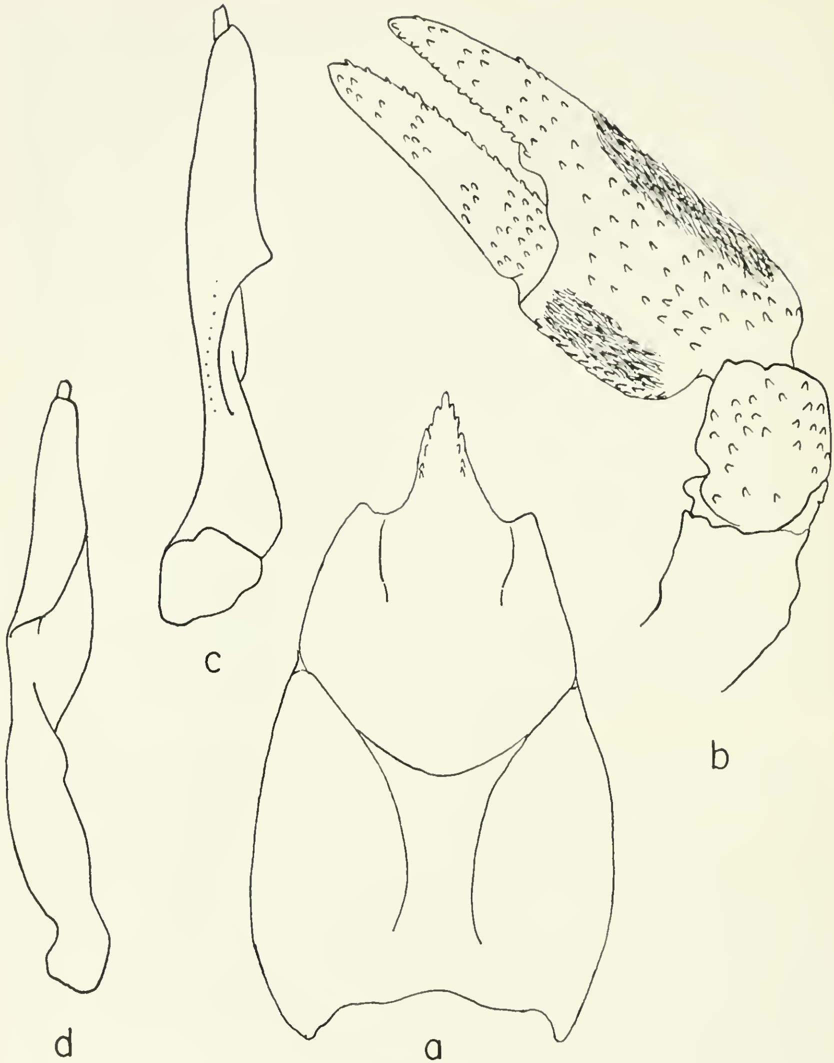

FIGURE 8. *Pacifastacus gambeli* (Girard). a. cephalothorax. b. chela. c. ganopod of male, dorsal view. d. ganapad af male, ventral view.

considerable variation. Therefore, it is unlikely that those characters in *P. gambeli* and *P. nigrescens* are static enough to justify the retention of Faxon's subspecies. (See remarks after description of *P. nigrescens.*)

Pacifastacus nigrescens (Stimpson)

***Astacus nigrescens* Stimpson, 1859. Boston Soc. Nat. Hist. Proc., vol. 6, p. 87.**

Stimpson described this species as follows: "Margins of the rostrum nearly parallel, denticulated with five or six small sharp spines on either side; the two anterior thoracic spines rather long. Dorsal area between the branchial regions as wide as in *A. gambelii*, from which this species differs in its smaller and more slender hands, which are also without pubescence. The lateral angles of the abdominal segments are sharp, and caudal segment has two slender spines on each side. Color, blackish. Length, three inches."

Type locality: Vicinity of San Francisco.

Localities: Localities marked with an asterisk are taken from Faxon (1914). Shasta County, one-half mile northwest of Cassel, Fall River,* Fall City Mills,* Hat Creek at Cassel.*

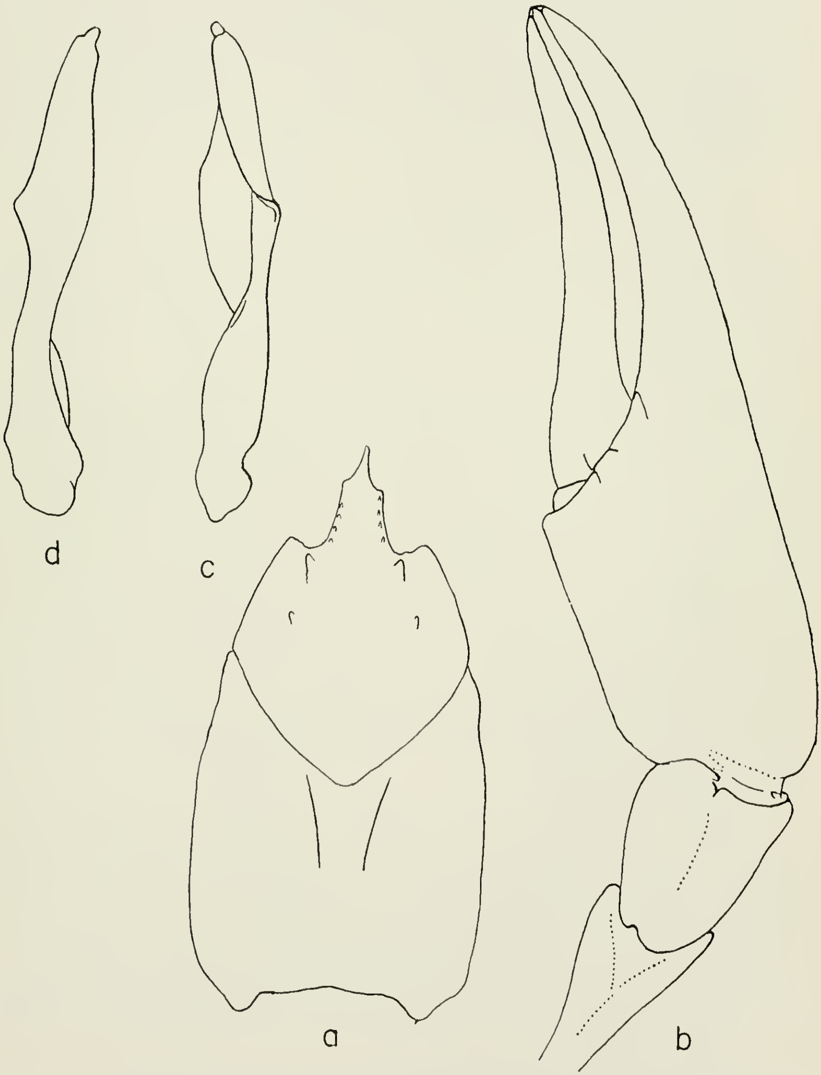

FIGURE 9. *Pacifastacus nigrescens* (Stimpson). a. cephalothorax. b. chela. c. gonopod of male, ventral view. d. gonopod of male, dorsal view.

Remarks: Pacifastacus nigrescens once inhabited the creeks in the vicinity of San Francisco (Faxon, 1885, 1889, 1898, 1914; Hagen, 1871; Holmes, 1900; Stimpson, 1859), but the writer's extensive collections in that area have netted only *P. leniusculus*, a transplanted species. It is entirely possible that in those creeks where *P. leniusculus* is found, this transplanted species has eliminated *P. nigrescens*. In two collecting trips to the Burney-Fall River Mills area of Shasta County, the writer failed to find any specimens of *P. nigrescens*, but some of the residents there stated that they had caught crayfish recently or had found young ones in the stomachs of trout.

Much similarity exists in the conformation of the gonopods of *Pacifastacus nigrescens* and *P. gambeli* (see Figures 8 and 9). Only two male specimens of the former and four male specimens of the latter species have been examined. Until a large series of both species can be examined, the writer can only express the suspicion that these two forms have not separated beyond the subspecies level. (See also remarks under *P. gambeli*.)

DISTRIBUTIONAL NOTES

The localities where crayfishes have not been reported in the State are as follows: Coastal area from the Big Sur River, Monterey County, to Santa Barbara County; and in the streams draining the eastern slope of the Sierra Nevada from southern Mono County to northern San Bernardino County.

The mode of introduction into California of members of Cambarinae, a subfamily native to North America east of the continental divide, has long been a subject of speculation. An attempt was made by Dr. Tracy I. Storer, of Davis, to trace the means by which these alien crayfishes entered the State. Only one reference could be found, which related to an importation of *Procambarus clarki* in 1932 by a frog farmer in Lakeside, San Diego County, for the purpose of providing food for frogs (letter, 6 February 1932, W. W. Harriman to T. I. Storer, Dept. of Zoology files). Mr. Harriman stated, however, that *P. clarki* had already been found in the State in small quantities prior to that time. Mr. J. Bruce Kimsey, of the California Department of Fish and Game, states that *Orconectes virilis* was first introduced into California waters at Chico, Butte County, when live crayfish of that species were being kept in ponds in the vicinity of Chico State College, where they were used as laboratory specimens. This introduction probably occurred between 1939 and 1941.

In 1912, crayfishes of the species *Pacifastacus leniusculus* were shipped in large batches to the Brookdale Hatchery of the California Fish and Game Commission in Santa Cruz County, California. These specimens were obtained from the Columbia River and were used to determine their depredatory effects upon young trout. Later, many were released into the San Lorenzo River near Santa Cruz, and about 200 were shipped to Nevada County, California, and released in a private pond on the Shebley Ranch between Colfax and Grass Valley. They were thriving 18 years later (letter, 23 September 1930, W. H. Shebley to T. I. Storer, Dept. of Zoology files).

In 1916, crayfishes were shipped to Lake Tahoe, El Dorado County, California, from the Klamath River and were thriving in the lake

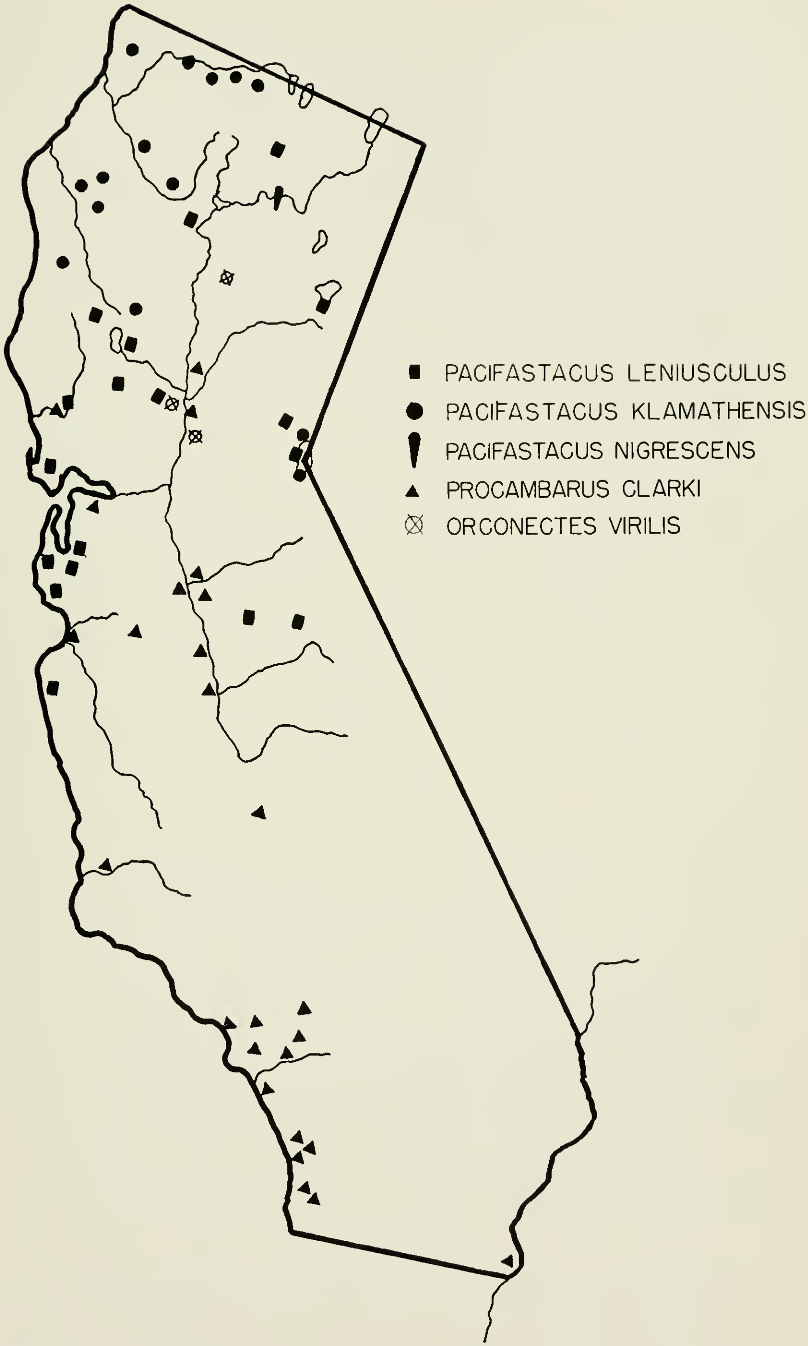

FIGURE 10. Map showing the distribution of California crayfishes. Each symbol represents the general area in which at least one collection was made.

proper and in the tributary streams 16 years later (letter, 23 January 1932, James Moffett to T. I. Storer, Dept. of Zoology files). Presumably the species was *Pacifastacus klamathensis*, as that form has been collected in Lake Tahoe and is the sole known inhabitant of the Klamath River.

From conversations with inhabitants of various parts of the State and from letters, the writer concludes that the present wide distribution of at least three species, *Pacifastacus leniusculus*, *Procambarus clarki*, and *Orconectes virilis*, is due to extensive transplantations, generally either for food or fishing purposes. According to some of the older zoologists at Stanford University, there were no native crayfishes south of the Klamath River, with the possible exception of the Eel River system, at the time of the early (ca. 1900) Stanford University fish-collecting trips (letter, Leo Shapovalov, Calif. Dept. of Fish and Game, to Waldo L. Schmitt, U. S. National Museum, 28 July 1942). As further evidence, several of the reservoir lakes in the Los Angeles area had to be closed to fishing to prevent introduction of crayfishes.

The distribution of species as given in this paper is generalized, being made on the basis of limited collections throughout the State. In a state the size of California (158,693 square miles), a study which would sharply delineate the distributional boundaries of each species would require a much longer period of more extensive collections than has been attempted in the present work. The discussion of importations and transplantations indicates that the status of several species is not constant, and continued transplantations as well as new importations of alien species could change the present situation in a relatively short period of time.

A distribution map is given for the California crayfishes in Figure 10.

SUMMARY

The systematics and distribution of California crayfishes are herein revised and brought up to date.

A systematic revision of the genus *Pacifastacus* Bott shows that *Pacifastacus trowbridgi* (Stimpson) is synonomous with *Pacifastacus leniusculus* (Dana), lying within the range of morphological variation of the latter species.

Two species of the subfamily Cambarinae, *Orconectes virilis* (Hagen) and *Procambarus clarki* (Girard), and one representative of the subfamily Astacinae, *Pacifastacus leniusculus*, have been introduced into the State and are thriving.

A distribution map and distribution records are given for all species, showing that *Procambarus clarki* and *Pacifastacus leniusculus* are widely distributed in central California, while *Procambarus clarki* is the only species to be found south of the Tehachapi Mountains. *Orconectes virilis* has a limited, but widening distribution in the Central Valley from Butte County in the north to San Joaquin County in the south. *Pacifastacus klamathensis* is confined to the waters of northwestern California and to the area around Lake Tahoe, into which it has been introduced. *Pacifastacus nigrescens* appears to have been eliminated from its former range in the San Francisco Bay area and now probably survives only in the upper reaches of the Pit River in northeastern California.

Keys and descriptions of all crayfish species known or reported from California are given with some general comments on ecology and natural history.

ACKNOWLEDGMENTS

Grateful acknowledgment is given to Dr. Milton A. Miller for his guidance and helpful criticism during the period of this study; to Dr. Tracy I. Storer for his graciousness in allowing the writer free use of his files and for financial assistance, without which a great part of the collecting work of the study could not have been accomplished; to Dr. R. M. Bohart for critical review of the manuscript; to Mr. George Clinton for valuable aid in photography; and to Dr. Horton H. Hobbs, Jr., for his helpful information and advice and identification of *Orconectes virilis.* Sincere thanks for aid in obtaining specimens go to Mr. Lloyd Tevis, Jr., Dr. E. W. Jameson, Jr., and Mr. Neal Phillips of the University of California at Davis, Dr. A. E. Culbertson of Fresno State College, Dr. Donald Wootton of the University of California, Santa Barbara College, Dr. A. L. Allen of Orange Coast College, Mr. Robert Glaser of Sacramento Junior College, Dr. Ralph I. Smith of the University of California at Berkeley, Dr. G. S. Myers of Stanford University, Dr. Verna R. Johnston of Stockton College, personnel of the Inland Fisheries Branch of the California Department of Fish and Game, and finally, special thanks to Dr. Eugene N. Kozloff of Lewis and Clark College, Portland, Oregon.

REFERENCES

Bonnot, Paul
1930. Crayfish. Calif. Fish and Game, vol. 16, no. 3, pp. 212-216.

Bott, R.
1950. Die Flusskrebse Europas. Abhandl. Senckenberg, Naturfor. Gesll., vol. 483, pp. 1-36.

Dana, James
1852. No title. Crustacea, part I. U. S. Exploring Expedition, vol. 13, p. 524. [Original description of *Pacifastacus leniusculus.*]

Faxon, Walter
1885. A revision of the Astacidae: part 1 the genera *Cambarus* and *Astacus*. Harvard Mus. Comp. Zool., Mem., vol. 10, no. 4, pp. 1-186.
1889. Notes on North American crayfishes—family Astacidae. U. S. Nat. Mus., Proc., vol. 12, pp. 619-634.
1898. Observations on the Astacidae in the United States National Museum and the Museum of Comparative Zoology, with descriptions of new species. U. S. Nat. Mus., Proc., vol. 20, pp. 643-694.
1914. Notes on crayfishes in the United States National Museum and the Museum of Comparative Zoology with descriptions of new species and subspecies. Harvard Mus. Comp. Zool., Mem., vol. 40, no. 8, pp. 352-427.

Girard, Charles
1852. A revision of the North American Astaci, with observations on their habits and geographical distribution. Acad. Nat. Sci. Phila., Proc., vol. 6, pp. 87-91.

Hagen, H.
1871. A monograph of the North American Astacidae. Harvard Mus. Comp. Zool., Illus. Cat., no. 3 (or Harvard Mus. Comp. Zool., vol. 2, no. 1).

Hobbs, Horton H., Jr.
1942. A generic revision of the crayfishes of the subfamily Cambarinae (Decapoda, Astacidae) with the description of a new genus and species. Amer. Midl. Nat., vol. 28, no. 2, pp. 334-357.

Holmes, Samuel J.
1900. Synopsis of the California stalk-eyed Crustacea. Cal'f. Acad. Sci., Occas. Pap., vol. 7, pp. 163-167.

Penn, G. H.
1943. A study of the life history of the Louisiana red-crawfish, *Cambarus clarkii*, Girard. Ecology, vol. 24, no. 1, pp. 1-18.

Pennak, R.
1953. Freshwater invertebrates of the United States. Ronald Press Co., New York, pp. 447-469.

Shapovalov, Leo, and Alan C. Taft
1954. The life histories of the steelhead rainbow trout *(Salmo gairdneri gairdneri)* and silver salmon *(Oncorhynchus kisutch)* with special reference to Waddell Creek, California, and recommendations regarding their management. Calif. Dept. Fish and Game, Fish Bull. 98, p. 261.

Stimpson, William
1859. No title. Boston Soc. Nat. Hist. Proc., vol. 6, p. 87. [Original descriptions of *Pacifastacus nigrescens*, *P. trowbridgi*, and *P. klamathensis*.]

AN INTERSPECIES CHAIN IN A FOWL CHOLERA EPIZOOTIC[1]

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Game Management Branch
California Department of Fish and Game

INTRODUCTION

During the course of an investigation of fowl cholera, it was noted that an unusual disease chain of hosts were involved. The situation became more interesting due to the complicating factors of another disease and heavy losses in the same hosts as the result of a poison campaign. This paper is a report of the observations made during the period of the epizootic; the incidental bacteriological and serological data obtained at the time; and of the natural susceptibility of the weasel, *Mustela* sp.; the meadow mouse, *Microtus montanus;* and the short-eared owl, *Asio flammeus.*

THE 1958 EPIZOOTIC

Fowl cholera in California waterfowl has been recognized in epizootic proportions almost every winter since 1944 (Rosen and Bischoff, 1949, 1950). The principle host species involved with each annual appearance of the disease rarely has varied. In the most severe outbreak recorded, 1948-49, the coot, *Fulica americana* suffered the highest mortality. As in most such epizootics, the coot was the first bird affected as well as the principle host, although large numbers of ducks, geese, gulls, and shorebirds succumbed. By contrast, the outbreak of pasteurellosis among waterfowl in February, 1955, seemed to be concentrated on whistling swans, *Olor columbianus.* Four hundred and six carcasses were counted in the Sacramento River Delta. The 1958 epizootic began with the usual pattern of dead coots, but it later developed a decidedly different characteristic.

The first appearance of fowl cholera was noticed in January in Yolo County (Figure 1). Wind action had lined the low dikes of the ponds with dead ducks, geese, and gulls. The dead coots were isolated from the other dead waterfowl in a field approximately one mile distant. Shortly thereafter, a report was received that fowl cholera had appeared at the Grizzly Island State Waterfowl Management Area in Solano County.

[1] Submitted for publication October, 1958. This study is a contribution of Federal Aid in Wildlife Restoration Project California, W-52-R "Wildlife Investigations Laboratory."

[2] The authors wish to acknowledge appreciation to Mr. Thomas Horn and personnel of the U. S. Fish and Wildlife Service at Tule Lake National Wildlife Refuge for their invaluable assistance.

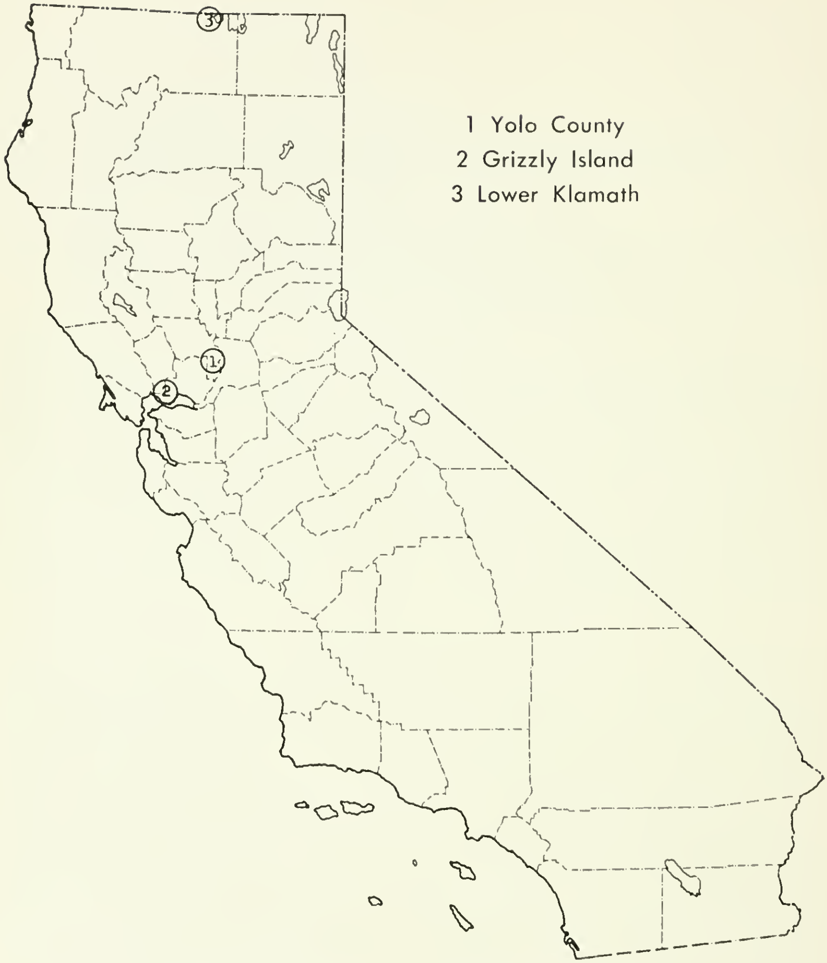

FIGURE 1. Locations of the 1958 fowl cholera epizootic.

The first birds affected at Grizzly Island were coots. Some significance may be attached to the fact that the disease started in exactly the same location on the island, and on the same date, January 29, as it had in the previous year. Within one week, the disease had spread to the ducks and 1,000 of them perished. As suddenly as fowl cholera had appeared at Grizzly Island, it disappeared.

A series of storms with heavy rainfall and high winds began in the first week of February and continued through most of the month. Flood conditions prevailed, and waterfowl were no longer evident in any significant numbers on the aforementioned areas. No evidence of fowl cholera was found at either place. However, it suddenly was present far to the north at the Oregon border.

United States Fish and Wildlife personnel of the Lower Klamath National Wildlife Refuge noticed dead birds on February 10th. Thirteen days elapsed since fowl cholera had begun at Grizzly Island, and five days since the first heavy storm had served to disperse the birds. Lower Klamath Refuge is 275 air-line miles from Grizzly Island. Several waterfowl areas lie in the intervening country, but no fowl cholera or sudden influx of waterfowl was reported. During a severe spontaneous outbreak in poultry an exceedingly high percentage of the birds became carriers (Pritchett et al., 1930a, 1930b). Considering all these facts, the conclusion could be made that sick birds, or carrier birds had flown directly from Grizzly Island to the National Refuge on the Oregon border.

The virulence of the disease was the same on the lower Klamath in that there was the explosive outbreak with large numbers of dead waterfowl and no sick birds evident during February. In March, sick birds were seen, and as the month progressed more sick ducks were observed in proportion to the number of carcasses found.

Personnel of the National Wildlife Refuge collected all carcasses and kept an inventory of the numbers of each species involved. There were a total of 1,266 ducks of which 80 percent were widgeon, *Mareca americana;* and a miscellaneous assortment of species that included 23 snow geese, *Chen hyperborea*, 13 coots, 18 gulls, 27 pheasants, *Phasianus colchicus*, 44 short-eared owls, and five marsh hawks, *Circus cyaneus hudsonius*.

During April nine ducks were picked up, and approximately 100 gulls were collected and the carcasses destroyed. This constituted the termination of the 1958 fowl cholera epizootic.

INCIDENTAL SEROLOGY AND BACTERIOLOGY

An irruption of meadow mice and white-footed mice, *Peromyscus* sp. in the Klamath Basin of Oregon and California was close to its peak at the time of the fowl cholera epizootic. Personnel of various governmental agencies were concerned and carried on independent investigations. Representatives of the Rocky Mountain Laboratory and San Francisco Communicable Disease Center Field Station of the United States Public Health Service determined that the mice were harboring tularemia.

The standard procedure of the Public Health Service for the determination of tularemia in rodents is essentially the Ascoli Thermoprecipitin test as published by Larson (1951). In his publication he states that he used three strains of *P. multocida (septica)*, but neglected to mention the species from which they originated. Considering this fact, and despite his obtaining negative reactions with those three strains, it was thought that the possibility existed of a serological cross reaction in blood taken from mice that had died of the fowl cholera organism.

The authors tested dead meadow mice in the Lower Klamath Refuge and found they had succumbed to hemorrhagic septicemia caused by *P. multocida*. These mice were tested by Larson's method as modified by the Public Health Service using anti-tularemia serum prepared and donated by the San Francisco Field Station. All tests were negative indicating that mice dying of *P. multocida* infection of waterfowl origin would not give a false positive reaction for *Pasteurella tularensis*.

For the purposes of studying the disease processes in the birds and mammals concerned, the following technique was adopted. A presumptive diagnosis of fowl cholera was made by microscopic examination of a blood smear that had been stained appropriately with either Wright's stain or Giemsa's stain, and the observation of the typical bacteremia. Confirmation was essential at several points during the epizootic, particularly when each new host species became involved. The confirmation was obtained by the isolation of the organism on blood agar and reproduction of the disease in white mice.

Cultures made from weasel spleen demonstrated the typical dew-drop type colonies. The culture exhibited a high degree of fluorescence, which is one indication of high virulence in this isolate of *Pasteurella multocida* (Carter, 1952). The fluorescence was most noticeable when the culture tubes were held at a certain angle under fluorescent lights.

THE TRANSMISSION CHAIN OF SPECIES

In the beginning of this epizootic the coot was the primary host, both at the first occurrence in Yolo County and at Grizzly Island. Then the disease spread to ducks, primarily widgeon. Such transmission could be accomplished by droplet infection. The next host to be affected was either mice or gulls. Both species could become infected through the ingestion of diseased duck carcass material or by one eating the other. Tularemia has been transmitted among desert rodents by the ingestion of infective flesh, and this is considered important in the propagation of a tularemia epizootic. (Vest and Marchette, 1958). It is probable that the mice incurred infection ingesting birds. When the mice became involved in the epizootiology it was fairly certain that their predators would also become involved. Autopsy of dead owls disclosed the remnants of mice in the stomach and severe bacterial invasion of the blood stream. Marsh hawks formed another link in the chain.

As the Fish and Wildlife personnel continued to remove all of the carcasses, the opportunity for gulls to contact the disease through ingestion of dead birds was reduced to a negligible point. Nevertheless, more and more gulls were succumbing to the disease as the total mortality curve dropped to lower levels. Post mortem examination of 15 gulls demonstrated the presence of mice in the stomach of each bird.

A dead weasel was found on the bank of one of the waterfowl ponds. Autopsy of the weasel disclosed a mouse in its stomach. As mentioned previously a pure culture of *P. multocida* was isolated from the spleen of this animal. This is believed to be the first record of pasteurellosis caused by this species of bacterium in a weasel, although there are reports of hemorrhagic septicemia in mink caused by *P. multocida* (Lewis, 1929; Linsert, 1940).

The epizootic waned as the mice became scarce in the area. Finally microtus and peromyscus were practically nonexistent on the Lower Klamath as the epizootic ended.

CONCLUSIONS AND SUMMARY

The epizootic of fowl cholera in 1958 presented some aspects of the disease that had not been encountered previously. As it started, the familiar pattern of previous outbreaks was evident, but the first deviation occurred through the advent of violent weather. The delta of the

Sacramento River once again was the point of origin, but no gradual spread throughout the delta and Sacramento Valley occurred; rather, it jumped across intervening distance to the Lower Klamath Refuge on the Oregon border. Thomas Horn, manager of the Tule Lake-Lower Klamath Wildlife Refuges at the time, sent inquiries on fowl cholera to state and federal waterfowl areas north of the Klamath Basin. There was no observation of waterfowl losses due to fowl cholera north of the California-Oregon border.

The typical explosive kind of epizootic was seen at Lower Klamath, however, it deviated from the normal in that it was prolonged by four to six weeks through the inclusion of rodents and raptors in the interspecies transmission chain. It may be assumed that either the resistance of the waterfowl increased or the virulence of the organism decreased as less ducks succumbed during the terminal stages of the outbreak. The former conclusion would seem to be more justified inasmuch as the epizootic swept through the mice and the predators of the microtus.

Obviously, the predators were not responsible for the disappearance of the mice on Lower Klamath. As mentioned previously, a poison campaign was being conducted on adjacent farmlands against the mice, and it was not too successful. It is believed that *P. multocida* infection was responsible for greatly diminishing the numbers of mice on Lower Klamath. The possibility does exist that this organism could be used successfully as a biological control on mouse irruptions of this type. However, it could only be justified where it would not have the possibility of transfer to beneficial species either directly or indirectly, e.g., from mouse through raptor or gull to waterfowl.

The simultaneous occurrence of *P. multocida* and *P. tularensis* in the Klamath Basin presented an opportunity to determine whether there was a cross reaction in the serological test for tularemia. Microtus found to be naturally infected with *P. multocida* did not yield a positive serologic reaction for tularemia.

An excessively high population of mice at a time when an epizootic of fowl cholera appeared brought about the introduction of new or unusual host species for this disease. They included the weasel, meadow mouse, short-eared owl, and marsh hawk. As far as the writers have been able to determine this is the first record of this disease in the weasel.

LITERATURE CITED

Carter, G. R.
1952. Some comments on pasteurellosis. Canadian Jour. Comp. Med. and Vet. Sci. vol. 16, no. 3, pp. 150-152.

Larson, C. L.
1951. Studies on thermostable antigens extracted from *Bacterium tularense* and from tissues of animals dead of tularemia. Jour. Immunol. vol. 66, pp. 249-259.

Lewis, H.
1929. Hemorrhagic septicemia in a mink. Jour. Amer. Vet. Med. Asoc. vol. 75, pp. 771-773.

Linsert, H.
1940. Pasteurellose beim nerz. Dtsch. tierarztl. Wschr. vol. 48, pp. 433-435.

Pritchett, I. W., F. R. Beaudette and T. P. Hughes
1930a. Epidemiology of fowl cholera. IV. Field observations of the "spontaneous" disease. Jour. Exper. Med. vol. 51, pp. 249-258.
1930b. Epidemiology of fowl cholera. V. Further field observations of the "spontaneous" disease. Jour. Exper. Med. vol. 51, pp. 259-274.

Rosen, M. N. and A. I. Bischoff
1949. The 1948-49 outbreak of fowl cholera in birds in the San Francisco Bay area and surrounding counties. Calif. Fish and Game, vol. 35, no. 3, pp. 185-192.
1950. The epidemiology of fowl cholera as it occurs in the wild. Trans. 15th N. Amer. Wildlife Conf. vol. 15, pp. 147-154.

Vest, E. D., and N. J. Marchette
1958. Transmission of *Pasteurella tularensis* among desert rodents through infective carcasses. Sci. vol. 128, no. 3320, pp., 363-364.

NOTES

INTERPRETING CHEMICAL ANALYSES OF BROWSE

Wildlife workers, particularly in deer management, frequently use published chemical analyses of plants as an index to the quality of the diet of the animal in question.

Researchers are becoming more aware of the nature and chemical composition of deer food and tend to judge a range accordingly. Protein in particular has received most of the attention. We have obtained some preliminary results in our nutritional studies which are far from complete and which may have simple explanations not immediately available to us. These results indicate however, that we may be seriously underestimating the true nature and quality of the diet of deer.

It was found, for example, that the rumen contents of nine deer collected in Lake County in October contained an average of 17.6 percent crude protein (oven dry basis). The vegetation in the same area was sampled in a manner assuming the deer were taking the terminal two or three inches of newest growth. These samples then were analyzed for their protein content. The theoretical protein content of the rumen was calculated by multiplying the proportion of each plant in the rumen by its protein content, totalling the figures thus obtained and dividing by 100. This value was 6.9 percent protein.

These observations were repeated on 14 deer collected on the Doyle winter range. The protein contents of these rumens averaged 17.2 percent for January, and 15.1 percent for February. The theoretical protein contents of the rumens based on vegetation sampled at that time, and corrected for the proportion of its occurrence in each rumen were respectively 7.1 and 6.1 percent.

In an effort to determine what relation the protein content of experimental deer rumens bore to the protein content of the feed the deer ate, three deer were placed on standard pellets of alfalfa meal for a week. These deer when sacrificed had rumen contents analyzing 21 percent, 16.2 percent, and 14.7 percent protein. The alfalfa meal pellets analyzed 15.7 percent protein. There is relatively little increase in rumen protein over the alfalfa fed.

The implications are: (1) the deer either select vegetation which is approximately two to three times higher in protein than is generally supposed; or, (2) the protein content of the rumen is enhanced to a very high degree by some factors not now apparent. The alfalfa pellet experiments indicate that the first is more likely.

Wildlife workers should interpret chemical analyses of plant foods with caution, since preliminary evidence seems to indicate that deer are capable of selecting a plant material of a higher protein content than generally supposed.

Further research is needed in order to explain observed differences between values obtained in analyzing rumen contents and range forage samples. *Harold Bissell, Game Management Branch, Laboratory, California Department of Fish and Game, October, 1958.*

A 15-FOOT MANEATER FROM SAN MIGUEL ISLAND, CALIFORNIA

The maneater or great white shark, (*Carcharodon carcharias*), is taken occasionally in California waters. Most of those caught are young specimens, five to seven feet in length. On the night of March 18, 1958, about one-half mile from shore in Tyler Bight, near the western tip of San Miguel Island, California, a 15-foot maneater became entangled in a light 100-foot nylon net. The net consisted of two 50-foot sections having 1¼-inch and ¾-inch stretch mesh, respectively. The shark was attracted by a California sea lion carcass hanging from the stern of the pelagic sealing research vessel *Trinity* as she lay at anchor in 40 feet of water. The net had been set at the surface in an effort to catch small pelagic fishes for use in identifying fish found in the stomachs of seals. One end of the net was attached to the stern of the vessel by ¾-inch line. The shark became entangled at 11.30 p.m. The surface water temperature several hours earlier was 14 degrees C.

FIGURE 1. A female maneater caught near San Miguel Island, California, on the night of March 18, 1958. The presence, nearby, of a large concentration of California sea lions may have attracted the shark to this area. *Photograph by Karl W. Kenyon.*

Upon discovering the great size of the shark, it was allowed to exhaust itself during the remainder of the night while lying on the bottom wrapped in the net. At daybreak, it was hauled to the surface, but the ship's winch and lifting gear lacked sufficient strength to hoist it aboard. Therefore, it was cut into three pieces, hoisted aboard, measured, further dismembered, and weighed on a 150 kg. capacity spring scale. The shark, a female, weighed just over 3,000 pounds (Table 1).

The reproductive tract contained no young. J. R. George was responsible for netting the shark while W. J. Barmore, Jr., T. C. Juelson and S. G. Wright, Jr. assisted in weighing and measuring the specimen. Sample teeth from this specimen were given to Dr. Arthur D. Welander of the University of Washington, Seattle, Washington.—*Karl W. Kenyon, U. S. Fish and Wildlife Service, Seattle, Washington, September, 1958.*

TABLE 1

Weight and Measurements of 15-foot Maneater Captured March 18, 1958, at San Miguel Island, California

Total weight	1,375 kg. (3,031 pounds)[1]
Total length	461 cm. (15.1 feet)[2]
Girth (at first gill slit)	295 cm.
Pectoral fin[3], length	96.5 cm.
Pectoral fin, height	85.5 cm.
First dorsal fin, length	65.0 cm.
First dorsal fin, height	51.0 cm.
Second dorsal fin, length	14.5 cm.
Anal fin, length	14.0 cm.
Upper lobe, caudal fin, length	98.0 cm.
Lower lobe, caudal fin, length	74.0 cm.
Caudal fin (tip to tip)	124.5 cm.
One of largest teeth[4], greatest height	5.5 cm.
One of largest teeth, greatest width	4.31 cm.

[1] The liver, stomach contents, and considerable body fluids were lost overboard and could not be weighed. For these parts, an estimate of 136 kg. is included in the total weight.
[2] Tip of snout to tail notch.
[3] Fin measurements are given as: length = Insertion to tip along leading edge; height = vertical distance, base to tip. (Pelvic fin not measured.)
[4] From the upper jaw, anterior.

IN MEMORIAM

NORMAN B. SCOFIELD

N. B. Scofield, who for 42 years was head of the department's marine fisheries program, passed away on November 27, 1958, in Palo Alto at the age of 89. He had been in retirement from state service since 1939.

Mr. Scofield received his academic training in zoology at Stanford University and was a member of that university's first graduating class in 1895.

Through his foresight and effort, the present Marine Resources program was established. He also founded the California State Fisheries Laboratory at Terminal Island where the early research on ocean fish was started.

His accomplishments were many and varied. He pioneered salmon research in California at the turn of the century. Especially noteworthy was his leadership in setting up a catch statistics system for the state's fisheries, upon which the conservation program is based and on which similar systems throughout the world have been modeled.

Mr. Scofield served on numerous national and international advisory groups and traveled widely in conducting his research and administrative work.

He is survived by his widow and three sons to whom the department extends its sincere sympathy.—*Richard S. Croker, Chief, Marine Fisheries Branch, California Department of Fish and Game.*

REVIEWS

The Presentation of Technical Information

By Reginald O. Kapp; The Macmillan Company, New York, 1948, reprinted 1957; xii + 147 pp. $1.95.

Thistle (1958), Popularizing Science, Science, vol. 127, no. 3304, pp. 951-955, has explained the presence of four barriers in transferring an understanding of science from the scientist to the layman. These barriers of informational transfer are: (1) the barriers of language and sophistication; (2) the barriers of security; (3) the barriers of printability, and (4) barriers inside the audience.

There is very little that the scientist can do to overcome barriers (2) and (3). He may attempt to overcome the fourth barrier, but generally this requires patience and more time than the scientist can devote to the problem. He is obligated to do all that he can to overcome the barrier of the language and sophistication of his discipline if he is to transmit his information.

Writing is as important to the technician as is the understanding and use of the tools and methodology of his work. Unfortunately, the scientist frequently refuses to accept the responsibility of good writing.

Kapp's book will meet the need of the technical writer who wishes to convey his ideas to others. This is not a book of syntax and grammar. It is assumed that the scientist can write a complete sentence. It is a book on what is required of good technical writing and what makes poor technical writing, however, correct the syntax and grammar may be.

Differences between "functional" and "imaginative" literature are examined. It is emphasized that the technical writer know his writing as functional, not imaginative. Functional English is the style of writing the language of logic. It appeals to the intellect; it conveys new information. The words used in this language have narrow specific meaning—they are not imaginative.

Imaginative literature on the other hand appeals to the imagination or emotions. It recalls the familiar. It employs imagery, metaphor, and symbolism. The writer makes use of understatement, play on words, and startling juxtaposition. He creates a mood.

Kapp points out that imaginative writing in functional English may be done; however, it must be done with care. He gives some instruction as to how it can be used.

A major portion of the book is devoted to application of what is known of the learning processes. To transfer new information one must know something of these processes: associating, understanding and memorizing.

Learning cannot be achieved if the pace is too rapid. Kapp shows the importance of pace by comparing the pace of a well-told joke with the pace of a well-written technical paper. Provision of good transition from point to point is required of written material. The reader must be guided smoothly through a discussion without any mental discomfort on his part. The telegraphic technical paper is not condoned.

An adequate portion of the book is devoted to a discussion of "terms of reference," orientation often assumed, ignored, or violated by the technical writer.

The use of qualification is one of the most difficult problems of technical writing. A short but very well-written chapter on the subject includes sections entitled: "Qualification and statement should be clearly separated," and "Means of avoiding qualification."

So often the technical writer must supply examples in support of a generalization. A discussion of the characteristics of examples is given in three points: (1) it should be a true example; (2) it should be as free as possible from complication or extraneous associations; and (3) it should be thoroughly familiar to the person addressed.

The metaphor used so freely in imaginative writing can be used with functional English. Kapp devotes considerable space to the care in selection and the dangers of misusing metaphor.

A chapter on circumlocutions is excellent. Sharp criticisms are made of the jargon: "in the case of, from the point of view of, in regard to, with reference to, etc." Dodging the search for correct nouns, correct prepositions, and dodging the task of recasting a sentence maintains and deepens the rut of poor writing.

A section of the book is devoted to "on meaning what you say." Use of "the careless statement," "overstatement," and "wishful statement" is all too common. Daily conversation is filled with these three faults. The use and acceptance of these in general conversation makes it more difficult to avoid them in writing. Kapp gives ample examples for the reader.

This book should be of great value to the neophyte of technical writing. The veteran of technical writing will find sharp criticism of some of his cherished expressions and other habits of writing. This book should provide an excellent reference for the editor of technical papers.

The technical writer would search a long time to spend more effectively $1.95. The book is in itself a tribute to lucid and convincing writing. Frequent study of its contents should assist any writer of technical information. It should be within reach for continuous application.—*Robert L. Butler, California Department of Fish and Game.*

On the Dynamics of Exploited Fish Populations

By R. J. H. Beverton and S. J. Holt; Her Majesty's Stationery Office, London, 1957; 533 pp., illus. $22.68. Available in the United States from the British Information Services, 45 Rockefeller Plaza, New York 20, N. Y.

Beverton and Holt have made a very important contribution to fishery science with the publication of this book. The approach is directed at the North Sea demersal fisheries but is relevant to other fisheries as well as to populations of animals other than fishes.

Using mathematical models, the authors have theorized on the dynamics of fish populations with special emphasis given to the yields obtainable under conditions of exploitation. Like most other studies in population ecology, the theoretical development is based upon deterministic models rather than probability models.

The book is in four parts. The first two parts are devoted to the theoretical development of four basic population parameters: recruitment, growth, natural mortality and fishery mortality. Models are first developed which assume independence among the parameters and then the models are refined to include certain interactions between parameters. The interactions considered include the density dependence of growth, the density dependence of natural mortality, and the dependence of recruitment on spawning stock size. Part III considers methods of estimating the parameters—a prerequisite to fitting the models to actual populations. The subjects discussed include the estimation of mortality rates from tag recovery and age composition data, the use of commercial effort statistics in estimating fishing mortality, and the effects of spatial variation in the population and in fishing effort on mortality rate estimates. In Part IV the models are applied to data relating to plaice and haddock with some consideration of other North Sea demersal species. Here the effects of regulation, as predicted by theory, are considered and a discussion of the objectives of regulation is given. This discussion covers economic as well as biological factors. The book contains a useful and fairly comprehensive bibliography.

The derivations of theorems and equations are quite detailed with very few steps being omitted. This may seem cumbersome to mathematicians but should be appreciated by biologists. A knowledge of elementary calculus is sufficient to follow most of the mathematical development and only an acquaintanceship with algebra is required to use the derived formulas. However, it is obviously dangerous to apply such formulas in "cookbook" fashion because the theory may well require modification for particular fisheries.

Undoubtedly there will be differences of opinion among fisheries workers over some of the authors' concepts, but this is to be expected in a work of such scope especially considering the paucity of data bearing on many of the fields encompassed.

This is not a book for the layman because even many professional workers will find it rough going, but certainly all fisheries biologists interested in population dynamics will want to read it. Students of other branches of population ecology will also find it a useful reference. Administrators and others who are involved in the making or recommending of fishery regulations should be interested in Section 19: Principles and Methods of Fishery Regulation. This section, which discusses different methods of regulation and their effects, is written clearly and is well illustrated.

The authors deserve commendation for their efforts in producing this work.—*Norman Abramson, California Department of Fish and Game.*

Insects and Mites of Western North America

By E. O. Essig; The Macmillan Company, New York, 1958; xiii + 1,058 pp., illus., $18.

This book is a revision of the classic 1926 edition of "Insects of Western North America." As stated in the forepage of both editions this is a manual and textbook for students in colleges and universities and a handbook for county, state, and federal entomologists and agriculturalists as well as for foresters, farmers, gardeners, travellers, and students of nature.

The early edition of "Essig" has been a valuable reference source in identifying insect material found in the course of doing food habits studies, especially of game birds, and has been useful in the wildlife field. I purposely undertook to read the entire text from cover to cover and the result has been a full realization of what a fine contribution of insect knowledge is this book. The task undertaken by Essig to put under one cover a satisfactory working classification of the insect phylum together with an informative and technical discussion of the insects was no easy chore. The value of this book is enhanced by the systematic organization of the chapters. Each insect order is given a chapter and the reader is introduced to the order by a general description with a list of references pertinent to that order. This is followed by a key to the suborders and families and then a discussion of the more important members of that order. The excellent illustrations and life history accounts and the control measures for the injurious insects gives to the non-technical person an easily read source of information whereas the keys and lists of references allows the technical readers further pursuit into the systematics.

The major revisions of the new edition principally involve recent changes in nomenclature and the advances made in insect control with the newly developed insecticides. This latter information is of concern not only to the entomologist, but to the layman as well.

The cost of this book, $18, is not an outlandish price to pay. To anyone who may be involved with insects either professionally or nonprofessionally, this book is an invaluable asset and should not be overlooked.—*Howard Leach, California Department of Fish and Game.*

Eels, A Biological Study

By Leon Bertin; Cleaver-Hume Press Ltd., London, 1956; vi + 192 pp., 55 figs., and 8 plates. 25 s.

Beginning with the writings of Aristotle, drawing heavily on the many papers of Johannes Schmidt, and finally including some of the more recent studies on the European eel, Professor Bertin has brought together a concise summary of the existing knowledge of the European eel. When conflicting ideas on a subject exist he explains both views and then states his preference and why he chose it. He also mentions some of the questions about eels that remain to be solved.

Each chapter is confined to a different phase of the life history of the eel: history, characteristics and variations, growth, adult migration, migration of the Leptocephalus, etc. Each chapter has a separate bibliography. The concluding chapter of the book is on the other catadromous eels of the world.

The reproductions of the drawings often leave much to be desired and a few minor typographical errors have crept in. With these minor detractions the book is a comprehensive compilation of a multitude of facts and fancy that have been accumulating for more than two thousand years. This edition has been translated and brought up to date from the second edition of *Les Anguilles.*—*E. A. Best, California Department of Fish and Game.*

Experiences With Living Things

By Mathew F. Vessell and Arnold G. Applegarth; Fearon Publishers, San Francisco, Calif., 1957; 195 pp., illus., $3.50.

This publication, whose secondary title is "A Guide to Understanding the Common Western Plants and Animals," is a paperback syllabus developed at San Jose College. Its single stated purpose is that of providing a guide for the training of teachers and youth group leaders in the interpretation of everyday natural history.

Although the specific area of application is central California, it is recommended for general usage throughout the State. Illustrations consisting of simple line drawings are scattered throughout the text.

The guide is divided into three parts. Part I deals with field trips as the basic core of any dynamic natural science course. It is here that interests are kindled and raw materials collected for further classroom study. Field trips cover areas readily available to most western teachers and range from a trip to a vacant lot. the farm and zoo, to streams, mountain areas and the seacoast. The common forms of plants and animals observed in each area are briefly described in relation to their environment. Part II suggests activities related to materials which students have seen or brought back from field trips for further study. Part III consists of a series of keys to the common plants and animals of California. Keys are designed for use by students and are simple but adequate. Additional references are listed for those who desire to pursue the subject further.

All in all, this is the best guide for aiding teachers or laymen in the interpretation of local natural history that has come to the reviewer's attention to date. For its successful employment, a limited background in natural science will suffice.—*Willis A. Evans, California Department of Fish and Game.*

Listening Point

By Sigurd F. Olson; Alfred A. Knopf, New York, 1958; 243 pp., illus. by Frances Lee Jaques. $4.50.

This is Sigurd Olson's second book of essays interpreting his wilderness experiences. The first "The Singing Wilderness" was reviewed here in October 1956 issue.

Mr. Olson developed his fine wilderness sensitivities through a lifetime of guiding and traveling through the canoe country of the Quetico-Superior region. He has directed his abilities toward the preservation of natural areas.

The 28 essays in this book center around Mr. Olson's personal "listening point," a glaciated spit of rock on the shore of a lake near his home in Ely, Minnesota. Though close to urban development, the local has made it possible for the author to reidentify himself with the more remote wilds that he finds so satisfying.

The inspired and perceptive thoughts on the ecology of the pileated woodpecker, the spawning of the eelpout, the effect of successive glacial periods upon the land and the esthetics of shaping a paddle show the author to be a sensitive interpreter of natural phenomena and their personal appeal. His immense satisfaction in wilderness experience carries through to the reader.

This book will offer an experience in reading and rereading to anyone who has ever enjoyed an outing.—*Fred L. Jones, California Department of Fish and Game.*

Wildlife of the Intermountain West

By Vinson Brown, Charles Yocum and Aldene Starbuck; vol. 4 of the American Wildlife Region Series, Naturegraph Company, San Martin, Calif., 1958; 144 pp., illus. paper, $2.50 (also available in cloth).

A single convenient reference that encompasses all of the common wildlife in a particular region has long been sought. This series of books endeavors to put such a reference in the hands of the field student.

This book is the fourth of a series on wildlife regions of America. The authors have encompassed two wildlife regions: the Palouse region of eastern Washington, northeastern Oregon, west central Idaho and south central British Columbia, and the Great Basin plateau region between the Rocky Mountains and the Sierra Nevada.

Included are short descriptions and illustrations of common plants and wildlife habitats, mammals, birds, reptiles and amphibians found in the two regions.

For the amateur naturalist it may be difficult to understand the habitat relationship references in the manner presented.

The illustrations for plants, reptiles and amphibians are excellent, however, the illustrations of mammals and birds lack a professional quality and accuracy that detract from the book.

The wildlife student will find this single reference useful in identifying the common wildlife in the regions covered.—*Trevenen A. Wright, California Department of Fish and Game.*

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printed in CALIFORNIA STATE PRINTING OFFICE

86272 11-58 5,200

STATE OF CALIFORNIA
FISH AND GAME COMMISSION

Notice is hereby given, in accordance with Section 206 of the Fish and Game Code, that the Fish and Game Commission shall meet on February 27, 1959, in the State Employment Building, 722 Capitol Avenue, Sacramento, California, to hear and consider any objections to its determinations or proposed regulations in relation to fish, amphibia, and reptiles, for the 1959 Angling Season, such determinations resulting from hearing held on January 2, 1959.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission

Notice is hereby given that the Fish and Game Commission shall meet on April 3, 1959, in the State Building, First and Broadway, Los Angeles, California, to receive recommendations from its own officers and employees, from the department and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof, in accordance with Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission