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WATERFOWL HARVEST AT TULE LAKE NATIONAL WILDLIFE REFUGE, 1936–41 [1]

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Waterfowl harvest at Tule Lake National Wildlife Refuge (NWR) for the 6-yr period 1936–41 is described and compared with a recent (1978–83) period. During the early period, 46,987 geese and 76,143 ducks were bagged during 48,610 hunter-visits. Hunting seasons were 30 to 60 d in length. Greater White-fronted Geese, *Anser albifrons*, followed by Northern Pintails, *Anas acuta,* and Cackling Canada Geese, *Branta canadensis minima*, were the most important birds in the harvest. Average harvest was 1.0 goose and 1.6 ducks per hunter-visit. A short (30-d) and late hunting season drastically curtailed harvest in 1937. Reduced hunting activity in 1941 was attributed to military mobilization. During the 1978–83 period, 34,416 geese and 63,458 ducks were bagged during 69,170 hunter-visits. Hunting seasons during this period were mostly 93 d in length. The most important bird in the harvest was the Mallard, *A. platyrhynchos*, followed by White-fronted Goose and Northern Pintail. Average harvest was 0.5 goose and 0.9 duck per hunter-visit. In general, dabbling ducks increased in overall importance while diving ducks decreased between the two periods. Harvest decreased 20.5% while hunter-visits increased 42.3%.

INTRODUCTION

During fall and spring migrations a major portion of Pacific Flyway ducks and geese pass through the Klamath Basin in northeastern California and south-central Oregon. Tule Lake National Wildlife Refuge (NWR), located within the Klamath Basin, is a traditional stopover point and the site of concentrations that often exceed 5 million waterfowl (O'Neill 1979). It is considered the most important single waterfowl refuge in the nation (Laycock 1965) and is known for its outstanding duck and goose hunting. Established in 1928, it became part of the Klamath Basin refuge system which also contains the Lower Klamath NWR, designated in 1908 as the nation's first waterfowl refuge.

Tule Lake NWR had its beginning during a critical period for North American waterfowl. A major drought in the prairie pothole region from 1929 until about 1938 severely depleted continental duck populations (Day 1949). The drought-

[1] Accepted for publication February 1986.

stricken prairie region normally would have produced many of the ducks migrating through the Klamath Basin (Kozlik 1975). At the peak of the drought, waterfowl hunting regulations became very restrictive, but as prairie habitat conditions improved and duck populations increased the regulations were relaxed (Bellrose 1944).

Detailed accounts of waterfowl hunting during the 1930's and 1940's are few; only Illinois (Bellrose 1944), Utah (Van Den Akker and Wilson 1951, Nelson 1959), and Wisconsin (Bartonek, Hickey, and Keith 1964; Jahn and Hunt 1964) have good records. Our purpose is to describe waterfowl harvests in California at Tule Lake NWR from 1936 to 1941 and to compare them with more recent (1978–83) harvests.

In 1936, Tule Lake NWR comprised approximately 11,000 acres of water and marsh and another 23,000 acres of grain fields open to public hunting (unpub. refuge reports). Hunter check stations were established on access roads into the refuge to survey waterfowl hunting. Two check stations were operated in 1936 and three stations from 1937 to 1941. Each station was operated by a refuge employee and two enrollees of the Civilian Conservation Corps (CCC), a federal program that provided employment to young men on conservation projects throughout the nation (Dearborn 1936). All station attendants were trained to identify waterfowl. All refuge hunters were accounted for in a checking system based on that used at the Bear River Migratory Bird Refuge, Utah (unpub. refuge reports, Van Den Akker and Wilson 1951). At check-in time, the name, residence, and hunting license number of each hunter were recorded, his shotgun was inspected for compliance with the three-shell law (enacted in 1935), and a 1-d permit issued. Species and quantity of all waterfowl bagged by each hunter were recorded by check station attendants after the hunt was completed. Check station record-keeping was discontinued after 1941 with elimination of the CCC program and staff reduction due to national defense mobilization for World War II (unpub. refuge reports).

REGULATIONS

Season length in the Pacific Flyway was sharply reduced from 107 d in 1930 to 30 d during 1934–37 as a result of declining waterfowl populations. Seasons were lengthened to 45 d during 1938–39 and to 60 d during 1940–41 (Table 1). Since 1937, seasons have never been less than 40 d except for a 35-d season in 1947 (Bartonek 1981).

The starting dates for hunting seasons varied from 15 October 1938 to 27 November 1937 (Table 1). The late season in 1937 created considerable discontent among Tule Lake hunters because the seasonal cold weather forced many waterfowl from the area before hunting began. It also prompted the opening date in 1938 to be 1.5 months earlier (unpub. refuge reports).

Daily bag limits for ducks remained 10 through the 6-yr period; daily limits on geese varied from 3 to 5. Possession limits were usually double the daily limits. Shooting hours were from 0700 to 1600 h during 1936–39 and from sunrise to 1600 h during 1940–41.

A closed season on Canvasbacks, *Aythya valisineria*; Redheads, *A. americana;* Buffleheads, *Bucephala albeola*; and Ruddy Ducks, *Oxyura jamaicensis*, was in effect in 1936 and 1937. After 1937, several of these species were permitted in the hunter's bag. Ross' Geese, *Chen rossii*, and Wood Ducks, *Aix sponsa*, were protected during the 6-yr period, except one Wood Duck was allowed in 1941.

TABLE 1. Waterfowl Hunting Regulations at Tule Lake NWR for the Period 1936–41.

	Season			*Bag/possession limits*		
Year	*Length* [1]	*Opening day*	*Dates*	*Ducks*	*Geese*	*Special restrictions*
1936	30	Sun	11/1–11/30	10/10	4/4	[2]
1937	30	Sat	11/27–12/26	10/10	5/5	[2]
1938	45	Sat	10/15–11/28	10/20	5/10	[3]
1939	45	Sun	10/22–12/5	10/20	4/8	[3]
1940	60	Wed	10/16–12/14	10/20	3/6	[3]
1941	60	Thu	10/16–12/14	10/20	3/6	[4]

[1] Shooting hours 0700 to 1600 h (1936–39), sunrise 1600 h (1940–41).
[2] Closed season: Ruddy Duck, Bufflehead, Canvasback, Redhead, Wood Duck, Ross' Goose, and swans.
[3] Limits of three singly or in the aggregate of diving duck species listed above; closed season on Ross' Goose, Wood Duck, and swans.
[4] Limits of three singly or in the aggregate: Bufflehead, Redhead, one Wood Duck allowed in 1941, closed season on Ross' Goose and swans.

WATERFOWL HARVEST

During 1936–41, 76,143 ducks and 46,987 geese were bagged by hunters on Tule Lake NWR (Table 2). An additional 172 waterfowl were recorded at check stations but were not identified to species. Check station field records did not identify goldeneyes, *Bucephala* spp., or scaup, *Aythya* spp., to species. Geese identified on check station records as Hutchins' Geese, *Branta canadensis hutchinsii?* were included in the Canada Goose, *Branta canadensis* spp., catagory (Kortright 1942, American Ornithologists' Union 1983).

Greater White-fronted Geese, *Anser albifrons*, (49.0%) and Cackling Canada Geese, *B. c. minima*, (36.0%) were the two most important geese in the goose harvest. Cackling Canada Geese winter exclusively in California.

Northern Pintail, *Anas acuta*, was the most important dabbler in the duck bag (24.4%). This species is strongly associated with the Pacific Flyway (Low 1949) and traditionally has been the most important waterfowl in the California harvest (e.g., Kozlik 1955; Carney, Sorensen, and Martin 1983). Northern Shoveler, *A. clypeata*, (17.0%) and the Mallard, *A. platyrhynchos*, (14.1%) were also important. Shoveler abundance in some years (unpub. refuge reports), coupled with its vulnerability (Bellrose 1944, Van Den Akker and Wilson 1951), resulted in exceptionally high harvests in 1937 and 1940. It was much less important in other years. Waterfowl population surveys show the shoveler was the most abundant duck on the Tule Lake refuge during the 1940 hunting season (unpub. refuge reports). The Mallard was consistently important in the bag each year. Canvasbacks and Redheads were completely protected in 1936 and 1937; together they composed nearly 17.3% of the average duck harvest during 1936–41. The Canvasback was the second most important duck in the harvest in 1939 and 1940 when it was only partially protected.

From 1936 to 1941, hunting activity at Tule Lake totalled 48,610 hunter-visits with peak hunting activity occurring in 1939. A hunter-visit occurred each time a hunter was registered at a refuge check station. Despite longer season lengths in 1940 and 1941 (60 vs. 30–45 d), hunting activity declined probably because fuel and ammunition were being restricted as the nation entered a wartime economy (unpub. refuge reports).

TABLE 2. Species Composition of Ducks and Geese Harvested at Tule Lake NWR During Hunting Seasons 1936–41.

Geese			Ducks					
Species	*Number*	*%*	*Dabblers*	*Number*	*%*	*Divers*	*Number*	*%*
White-front	23,003	49.0	N. Pintail	18,590	24.4	Canvasback	8,309	10.9
Cackling	16,923	36.0	N. Shoveler	12,977	17.0	Redhead	4,899	6.4
Snow	5,953	12.7	Mallard	10,770	14.1	Ruddy Duck	2,587	3.4
Canada	1,089	0.9	Am. Wigeon	6,391	8.4	Scaups	2,469	3.2
Ross'	14	tr	Gadwall [1]	3,341	4.4	Bufflehead	1,215	1.6
Brant [1]	3	tr	G-W Teal [1]	2,429	3.2	Ring-necked Duck	951	1.2
Emperor [1]	2	tr	Cinn. Teal [1]	497	0.7	Goldeneyes	689	0.9
			B-W Teal [1]	12	tr	Scoters [1]	10	tr
			Wood Duck	7	tr			
Subtotals				55,014	72.2		21,129	27.6
TOTALS [2]	46,987	100.0			76,143	99.8		

[1] Emperor Goose (*Chen canagica*), Brant (*Branta* spp.), Gadwall (*Anas strepera*), Green-winged Teal (*A. crecca*), Cinnamon Teal (*A. cyanoptera*), Blue-winged Teal (*A. discors*), and Scoter (*Melanitta* spp.).

[2] Does not include one Tundra Swan shot in 1936 or unidentified waterfowl.

Average harvest per hunter-visit was 1.6 ducks and 1.0 goose for the six hunting seasons (Table 3). The ratio of geese to ducks in the harvest (1:1.6) was high by today's standards and reflected the importance of Tule Lake NWR as a stopover for geese migrating to wintering areas in the Central Valley of California. Hunting restrictions apparently curtailed the kill on divers in 1936 and 1937. Generally, season length and opening dates did not consistently influence either duck or goose kill except in 1937 when the kill per hunter-visit was lowest (0.8 duck and 0.6 goose) due to a short, late season.

TABLE 3. Average Waterfowl Harvested per Hunter-visit During Hunting Seasons 1936–41.

	Total		*Average harvest*			
Year	*harvest*	*Hunter-visits*	*Geese*	*Dabblers*	*Divers*	*Total*
1936	20,189	6,884	1.4	1.4	0.1	2.9
1937	5,563	3,970	0.6	0.8	<0.1	1.4
1938	24,532	8,464	1.4	1.1	0.4	2.9
1939	24,845	11,062	0.9	0.8	0.5	2.2
1940	25,905	9,796	0.7	1.2	0.8	2.6
1941	22,268	8,434	0.7	1.4	0.5	2.6
Averages	20,550	8,102	1.0	1.1	0.5	2.6

We evaluated the distribution of the kill among 9,796 hunter-visits during the 1940 season (Table 4). About 71% of the hunter-visits accounted for 25.7% of the total bag. The most successful 10% of the hunter-visits accounted for 38% of the combined duck and goose bag and their average bag size was 9.8.

TABLE 4. Distribution of Combined Duck and Goose Harvest Among Hunters, 1940.

Number of waterfowl in hunter's bag	*% of hunter-visits*	*% of total harvest shot by hunters*
0	39.8	0.0
1	8.9	3.4
2	8.8	6.7
3	13.8	15.6
4	6.0	9.0
5	5.2	9.8
6	4.3	9.8
7	3.1	8.1
8	2.3	6.8
9	2.2	7.5
10	3.3	12.3
11	0.9	3.9
12	0.6	2.9
13	0.9	4.2
14	<0.1	0.1
15	<0.1	0.1

SEASONAL DISTRIBUTION OF HARVEST

The seasonal distribution of hunting kill was plotted for the nine most common species in the bag at the Tule Lake NWR (Figure 1). To eliminate bias resulting from changes in season lengths and numbers of hunter-visits within any weekly interval, the average daily kill per week was expressed as a percentage of the average kill for all seasons. The kill distribution was due to waterfowl abundance and vulnerability, as well as hunting pressure and weather.

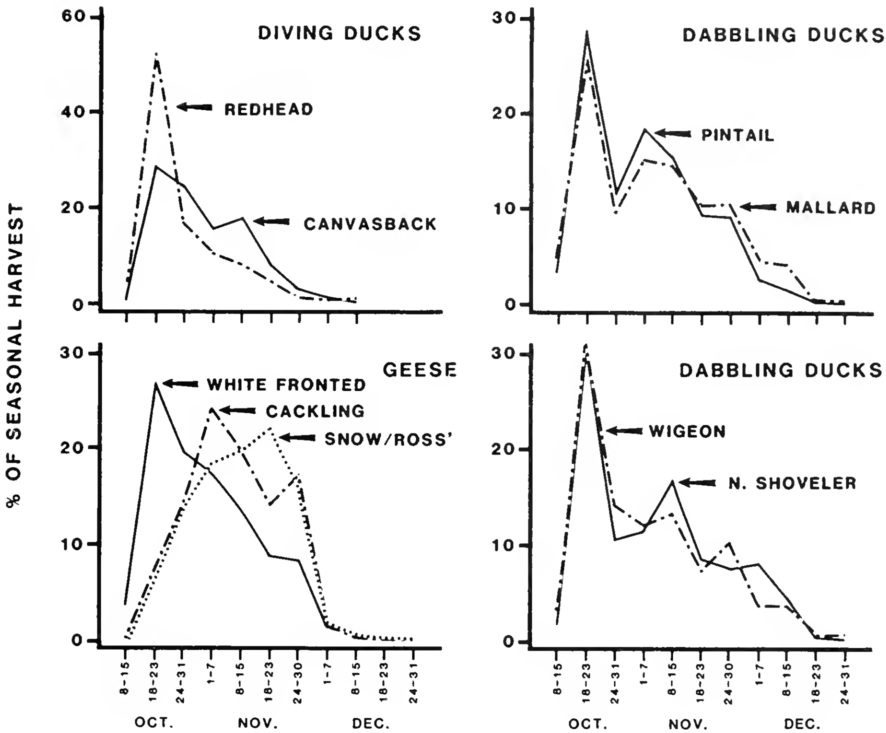

FIGURE 1. Seasonal distribution of nine species of waterfowl bagged at Tule Lake NWR, 1936–41.

Northern Pintails, Mallards, American Wigeons, *A. americana*, Northern Shovelers, and, to a lesser degree, Canvasbacks followed similar harvest patterns. They were most frequently shot during the period 16 to 23 October, with a lesser peak occurring in early or mid-November when the final contingent of northern migrants arrived. Most Redhead harvest also occurred in mid-October, declining thereafter as birds left the area.

Most White-fronted Geese were harvested in mid-October when maximum populations were present in the Klamath Basin. Peak harvests of Cackling Canada Geese and Snow Geese, *C. caerulescens,* were later in the season with a more gradual buildup and decline in the harvest. This pattern reflected numbers of these geese present in the area.

Distribution of the percentage of total waterfowl killed each 7-d period was plotted for each year (Figure 2). The 1937 hunting season was unique. It began very late (27 November) and over 76% of the harvest and 72% of the hunter-visits occurred during the first 7 d of the 30-d season. Harvest and hunter activity dropped off abruptly in subsequent weeks. Intense activity at the beginning of the season was to be expected as hunters tried to take advantage of optimum waterfowl populations before birds moved southward as a result of heavy storms (unpub. refuge reports; Bartonek, Regenthal, and Chattin 1980). This pattern was not as evident in the 30-d season in 1936, perhaps because of an earlier opening date. It was likely that the delayed season in 1937 contributed to the overall reduced harvest and low hunter participation that year.

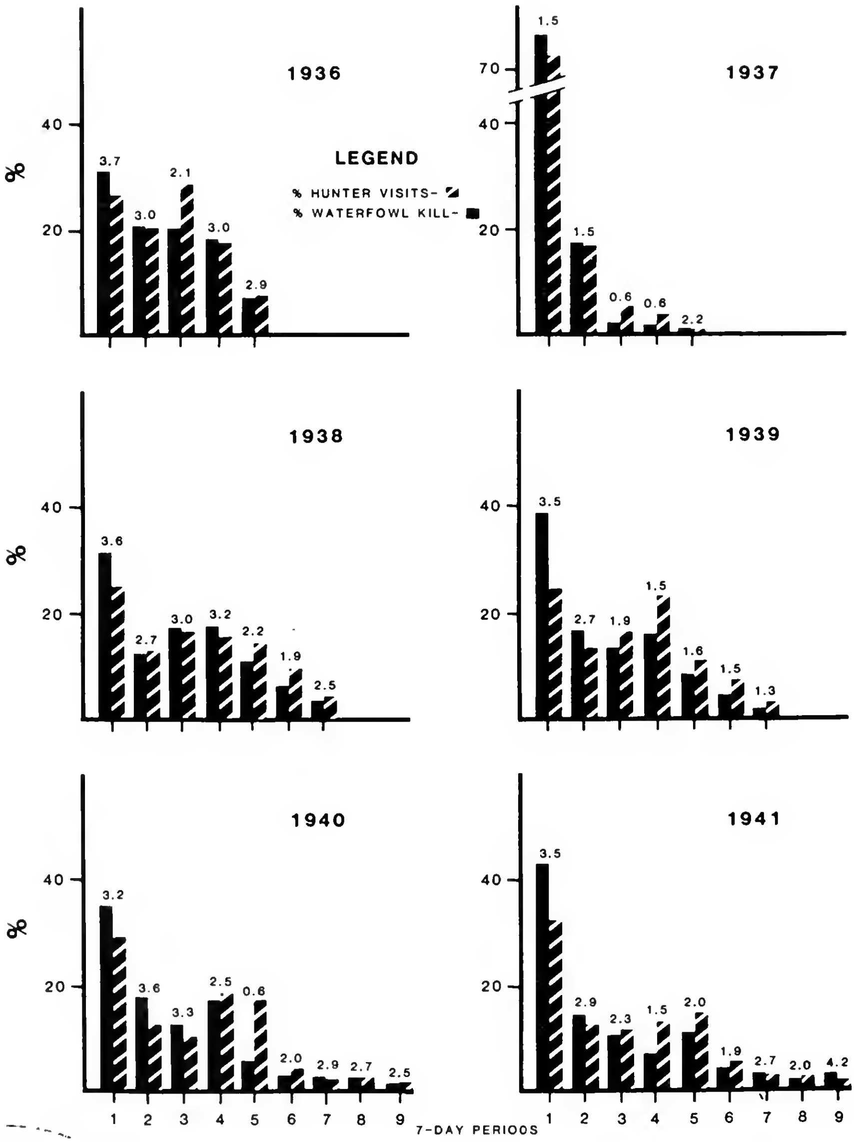

FIGURE 2. Distribution of waterfowl kill and hunter-visits during six hunting seasons at Tule Lake NWR, 1936–41. Average hunter bag for each 7-d period is shown above columns.

Seasons of 45 and 60 d were similar with the highest percentage of harvest and hunter-visits occurring during the first 7 d. Another slight increase in the harvest occurred near Thanksgiving Day, presumably because of the holiday.

Relative importance of species in the bag varied considerably among seasons. For instance, in 1937 the Northern Shoveler was the most heavily harvested species and composed 35.2% of the total duck bag, whereas the Northern Pintail was much less important (16.4%) than in most years. A large proportion of the Northern Pintail population may have passed through the Klamath Basin before the 1937 hunting season opened at Tule Lake NWR. In 1940, the Northern Shoveler was again the most important duck in the harvest (28.5%), displacing the Northern Pintail which accounted for only 10.7% of the total duck bag. The longer season (60 d) appeared to increase shoveler harvest in 1940 and, to a lesser extent, in 1941.

At Tule Lake NWR, opening day of hunting season consistently accounted for the highest percentage of birds killed; however, the proportion was not consistently higher on weekend than on weekday openings. For instance, when opening day was on a weekend the proportion of all waterfowl killed was 17.8% in 1936, 31.6% in 1937, 12.6% in 1938, and 16.7% in 1939. On weekday openings the percentage of the season's total kill was 12.5% in 1940 and 15.6% in 1941. In Utah, the average percentage of the kill was 17.9% when opening day was on a weekend and 13.6% when it was on a weekday (Van Den Akker and Wilson 1951).

PROTECTION OF CERTAIN SPECIES

Complete protection was given to Ross' Geese during 1936–41. Few Ross' Geese were reported shot, but it was likely that some were not recorded because of their similarity to Snow Geese. A complete closure existed on Wood Ducks for all years except 1941. However, because this species was seldom seen at Tule Lake (unpub. refuge reports), regulations may have exerted minor influence in limiting the total harvest to seven ducks during the 6-yr period.

According to check station personnel (unpub. refuge reports), very few hunters at Tule Lake NWR could identify ducks in the hand and still fewer could identify them in flight. During 1936 and 1937 when closures existed on most diving ducks, 203 hunters, apparently unknowingly, declared illegal duck species at check stations. Illegal killing of ducks, geese, and swans (one Tundra Swan, *Cygnus columbianus,* shot in 1936) declined from 246 in 1936 to 70 in 1937. This decline followed the trend in total harvest which dropped from over 20,000 ducks and geese in 1936 to about 5,500 in 1937. In 1940, Canvasbacks, Redheads, Ruddy Ducks, and Buffleheads composed 33.8% of the total duck harvest, although they were limited to only three per day either singly or in the aggregate in the hunter's bag (unpub. refuge reports).

Of the 123,302 waterfowl killed at Tule Lake NWR during 1936–41, 166 (0.1%) were in excess of bag limits and 607 (0.5%) were protected. Thus, apparently 773 (0.6%) of the birds killed were in violation of regulations. Although there was evidence of bag violations, records indicate that only 20 citations were issued. In 1936, 169 hunters killed protected species, but no citations were issued because officials believed the shooting was done in ignorance and was unintentional (unpub. refuge reports). Some personnel believed the presence of the check stations reduced regulation violations (unpub. refuge reports).

CHARACTERISTICS OF HUNTERS

Sportsmen travel great distances to participate in waterfowl hunting at Tule Lake NWR. It was apparent that even in 1936–41 hunters were highly dependent on automobiles and were very mobile. Reduced hunting activity in 1941 was attributed to fewer hunters in the field caused by military moblization (unpub. refuge reports).

To identify the major sources of hunters at Tule Lake, we used the 1940 season as an example. That year 40.5% of the total 9,767 hunters travelled from cities and towns within a 100-km radius of the refuge. Other major sources included the San Francisco Bay Area, 12.7%; Los Angeles, 11.9%; and Sacramento/Stockton areas, 6.9%. Other areas in California and out-of-state locations contributed 28.0% of the hunters. The most distant states represented were New York and Florida.

COMPARISONS TO 1978–83 HUNTING SEASONS

To evaluate changes in harvest and hunting regulations that occurred since the 1936–41 period, we selected a recent 6-yr span of hunting seasons (1978–83) for comparison. From 1936–41, waterfowl hunters made 48,610 visits to Tule Lake, bagging 123,302 ducks and geese for an average of 2.6 (1.6 ducks and 1.0 goose) birds per hunter-visit. During 1978–83, 69,170 visits were made by waterfowl hunters. Total waterfowl killed was 97,874 for an average bag of 1.4 birds (0.9 duck and 0.5 goose) per hunter-visit.

Geese in general have changed little in imp rtance in the total average bag between the two periods (38.2 vs. 35.2%) (Table 5). Total goose harvest declined 26.7%. Although the White-fronted Goose is no longer the most important species in the total waterfowl harvest, it actually composed a larger portion (61.7%) of the goose harvest during the 1978–83 period than previously (49.0%). The importance of the Cackling Canada Goose in the harvest has declined considerably (36.0 vs. 11.6%) and can be attributed to both restrictive regulations and reduced populations (Raveling 1984).

Overall percentage of dabblers in the duck harvest has increased from about 72% in 1936–41 to about 96% in the recent period (Table 5). Total dabbler harvest increased 10.5%. The largest change was in the Mallard which increased from an average of 14.1 to 50.9%. In contrast, the Northern Shoveler declined from 17.0 to 4.4%. Poor breeding habitat since 1980 in southern Alberta has curtailed Northern Pintail populations migrating to California, whereas local Mallard production has been generally above average in recent years (unpub. Fish and Wildlife Service reports).

The importance of diving ducks in the harvest declined from 27.6% of the total duck harvest to only 4.2% (Table 5). Total diver harvest declined 87.5%. All diving duck species declined to some degree, but the changes have been greatest in Redhead, followed closely by Ring-necked Duck, *Aythya collaris*, Canvasback, Ruddy Duck, and Scaup, and least for the Goldeneyes and Bufflehead. Reduced populations due to breeding habitat losses are the most likely cause of the lower diver harvest during the recent period. However, habitat conditions less conducive to diving duck harvest may also explain some of this decline. For instance, in 1936–41, 67% of the public hunting area was open water, generally preferred by Canvasbacks and other divers. Today, it is about 50% marsh and 50% uplands (unpub. refuge reports). Changes in migration patterns may have also contributed to the observed changes.

The most noticeable difference in regulations between the two periods was the length of seasons. Relatively short seasons of 30, 45, and 60 d were in effect during the 1936–41 period. In contrast, the 1978–83 duck and goose seasons were 93 d long except in 1979 when the goose season was reduced to 79 d by delaying the opening day 2 wk. The limits for ducks in the more recent period were 7 birds daily with 14 in possession as compared to 10 daily and 20 in possession during most of the 1936–41 period. In 1978–83, no more than two Canvasbacks or two Redheads or one of each could be taken daily. In recent years, the hunting seasons at Tule Lake NWR have opened on the Saturday closest to 1 October, while they were much more sporadic in the early period. Currently, hunting is allowed on the refuge ½ h before sunrise to 1300 h. Goose seasons are currently more complex because of efforts to selectively protect or harvest certain species. More consistent duck regulations in recent years come from the desire to detect relationships between harvests and population changes without the confounding effects caused by variable regulations.

TABLE 5. Species Composition of Geese and Ducks Harvested at Tule Lake NWR During Hunting Seasons 1978–83 and Changes in Species Composition from Hunting Seasons 1936–41.

Species	*Number*	*%*	*% change[1] from 1936–41*
Geese			
White-front	21,233	61.7	+25.9
Cackling	4,009	11.6	−67.8
Snow	6,574	19.1	+50.4
Ross'	891	2.6	+8,630.7
Canada	1,709	5.0	+117.4
TOTAL GEESE	34,416	100.0	
Dabbling Ducks			
N. Pintail	14,142	22.3	−8.6
N. Shoveler	2,820	4.4	−74.1
Mallard	32,315	50.9	+261.0
American Wigeon	5,820	9.2	+9.5
Gadwall	2,594	4.1	−6.8
Green-winged Teal	2,804	4.4	+37.5
Cinnamon Teal/ Blue-winged Teal combined	319	0.5	−28.6
Subtotal—Dabblers	60,814	95.8	+32.5
Diving Ducks			
Canvasback	579	0.9	−91.7
Redhead	292	0.5	−92.2
Ruddy Duck	174	0.3	−91.2
Scaups	403	0.6	−81.3
Bufflehead	737	1.2	−25.0
Ring-necked Duck	93	0.1	−91.7
Goldeneyes	366	0.6	−33.3
Subtotal—Divers	2,644	4.2	−84.8
TOTAL DUCKS	63,458	100.0	

[1] Percentage change calculated using (%1978–83) — (%1936–41) / (%1936–41)

CONCLUSIONS

Historical waterfowl records provide perspective for assessing the current status of waterfowl populations and hunting. Several conclusions are apparent when conditions at Tule Lake NWR in 1936–41 are compared to the present. Species composition in the hunter's bag has changed. A notable increase in the importance of the Mallard and declines in the Cackling Canada Goose, Northern Shoveler, and all diving ducks have occurred. Even though hunting pressure has increased, success and total harvest have declined due to reduced populations, more restrictive bag limits, or both. The significance of these changes is difficult to assess, however, without evaluating long-term trends on a more regional basis.

The period 1936–41 was significant because of its very short seasons. Today's seasons are longer, but overall bag and possession limits are generally more restrictive. Hunting regulations have fluctuated considerably over the last 50 yr, becoming more stabilized for ducks only since 1975. Consistent regulations coupled with innovative efforts to gather harvest and recruitment data will help managers to accurately monitor the influence of hunting on waterfowl populations.

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THE FEEDING BEHAVIOR OF THE JUVENILE DUNGENESS CRAB, *CANCER MAGISTER* DANA, ON THE BIVALVE, *TRANSENNELLA TANTILLA* (GOULD), AND A DETERMINATION OF ITS DAILY CONSUMPTION RATE [1]

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Juvenile Dungeness crabs, *Cancer magister* Dana, 10-30 mm in carapace width, forage for and feed on the small, estuarine bivalve, *Transennella tantilla* (Gould). The crab uses its chelipeds and legs to sift the sediment in a circular motion toward the mouthparts. When a clam is detected, it is quickly and adeptly brought up to the mandibles, where the chelipeds, in unison with the mouthparts, rotate the clam forward about its short axis (clam width). After several rotations, one cheliped maintains the clam's position in the mandibles, while the other probes downward at the valve edges. The "clam-spinning", "dactyl-probing" movements are alternated until the valves are successfully separated. The time spent opening a clam varies from 15 seconds to several minutes. The shells are fastidiously cleaned, but not consumed. The estimated amount of clam tissue eaten per crab during an 82 h laboratory feeding experiment was 162–682 mg (crab carapace widths, 15–24 mm). There was a good correlation between the initial size of the crab and the total tissue consumed. The potential impact of juvenile *C. magister* on the densities of estuarine bivalves is discussed.

INTRODUCTION

Despite the importance of the Dungeness crab fishery, little is known about the foraging behavior, daily consumption rate, population dynamics or community impact of juvenile *Cancer magister* Dana. The primary focus of published studies to date has been the determination of growth rate (Mackay and Weymouth 1935, Cleaver 1949, Poole 1967, Waldron 1958, Butler 1961, Collier 1983) and diet (via gut content analyses) (Gotshall 1977; Feder and Paul 1980; Stevens, Armstrong, and Cusimano 1982) of first year crabs. The importance of estuaries as nursery habitat for first year crabs has also attracted attention (Wickham, Schleser, and Schuur 1976; Stevens 1982; Tasto 1983), but these studies have been aimed at comparing the relative densities and growth rates of juvenile crab populations offshore and in embayments, and at an assessment of the environmental impact of dredging operations on crab settlement in estuaries. Descriptions of the feeding behavior of *C. magister* and field studies on the predatory behavior and impact of *C. magister* on prey populations are few in number and involve only adult animals (Mayer 1973; Pearson, Sugarman, and Woodruff 1979; Boulding and Hay 1984) or animals for which size is not reported (Mackay 1943, Boulding 1984).

This study was designed to document the foraging and feeding behavior of juvenile *C. magister*, 10–30 mm in carapace width (CW), on the small (< 5.0 mm in shell length, SL) venerid bivalve, *Transennella tantilla* (Gould) and to

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determine the daily consumption rate of young crabs. The results suggest that predation by juvenile crabs could lead to substantial reductions in the population densities of small estuarine bivalves, particularly during peak years of crab settlement.

MATERIALS AND METHODS

Preliminary Feeding Trials

T. tantilla and juvenile *C. magister* were hand-collected from the South Slough of Coos Bay, Oregon in July 1981. One-hundred-fifty *T. tantilla* (SL, 1–5 mm) were added to each of two glass aquaria, 61 × 31.5 × 42 cm. The tank bottoms were covered with 10 cm sand. Five *C. magister,* 21, 22, 23, 31 and 34 mm in CW (distance including the tips of the tenth anterolateral spines), were added to one tank; the other tank served as a control. The tanks were dismantled 26 days later. The surviving clams and shell fragments were collected and counted.

Foraging Behavior Observations

T. tantilla were allowed to settle in sand in a glass aquarium. Then, starved *C. magister* (CW, 10–30 mm) were added to the tank and observed searching for, dislodging, and eating clams.

Laboratory Feeding Experiments

Forty-one *Clinocardium nuttalli* (SL, 6.2–58.6 mm) were collected from South Slough in June, 1984. The tissue was removed, blotted, and weighed to the nearest 0.1 mg (SL < 20 mm) or to the nearest 1.0 mg (SL > 20 mm). The wet tissue weight (WTW, mg) was related to shell length (SL, mm) by the regression, $Lg_{10}^{WTW} = 3.08\ Lg_{10}^{SL} - 1.38$ ($r^2 = 0.99$). The regression equation was used to estimate the amount of tissue consumed by juvenile crabs in the feeding experiments.

Two hundred juvenile *C. magister* were hand-collected from South Slough in May 1984 for use in the individual and group feeding experiments. The crabs were retained for 3 weeks in a large, outdoor fiberglass tank (crab density = 1/100 cm^2) until the experiments began. The tank bottom was covered with sand. Unfiltered seawater was supplied to the tank continuously. Living bivalves (adult mussels and bay clams) were opened and fed to the crabs daily. The crabs continued to grow, and there was no evidence of cannibalism (195 crabs were alive after the 3 wk period).

Seventeen molded white plastic aquaria, 17 × 12.5 × 7.5 cm (Freezette Stackable Food Containers), were used to retain crabs for the individual feeding experiments. The base of each aquarium was covered with 3 cm sand. Unfiltered seawater was continuously supplied through perforated Tygon plastic tubing. The aquaria were covered with Nitex (Eastside Net Shop, Bothell, Washington) netting to prevent crab escape.

One juvenile crab was measured and added to each aquarium and given 40 hours to acclimate. Seven (41%) of the crabs (CW, 15–18 mm) were instar IV (Butler 1961) and 10 (59%) were instar V (CW, 19–24 mm). Sixteen hours before the feeding trials began, the crabs were fed clam meat until they were satiated. Food remains were removed. During the experiment, the crabs were fed freshly-collected juvenile *C. nuttalli* (SL, 5–13.5 mm) twice daily. Since the crabs were incapable of efficiently opening the *C. nuttalli* that were offered, the clams were measured, cracked, and fed (in the shell) to each crab one at a time. If the first clam was eaten, a second was offered. Feeding was continued until each crab had been offered one more clam than it would eat. The extra clam was generally eaten before the next feeding trial began. Shells were picked clean, but not consumed. The experiment was carried on for 82 hours and terminated after the last feeding trial. At that time, if necessary, a visual estimate was made of the percent of a whole clam left uneaten. The total tissue consumed per crab was determined by substituting the SL of fed clams into the regression equation of *C. nuttalli* weight vs. length, summing the values, and subtracting the estimated amount of uneaten tissue.

In a separate experiment, 100 juvenile *C. magister* were retained in a large fiberglass tank (160 cm in diameter, 61 cm deep on the outside edges). The tank bottom, which sloped downward from the outer edge to a drain hole in the center, was covered with a layer of sand 1–3 cm deep. A plastic drain pipe was inserted in the drain hole and fitted with a stainless steel mesh sleeve to retain the water level at a constant depth of 16.5 cm in the center decreasing to a depth of 1.3 cm on the tank perimeter. Unfiltered seawater flowed continuously into the tank and was exchanged through the pipe. The mesh sleeve prevented loss of food particles or crabs. After an acclimation period of 18 hours, the feeding study was initiated and continued for 96 hours. Forty-eight percent of the crabs used in the study were instar IV (CW, 13–18 mm), 52% were instar V (CW, 19–24 mm).

During the group feeding study, freshly-collected, adult *C. nuttalli* were fed to the crabs, as needed, to maintain a food supply that was in excess of the amount consumed. Clams were cracked in a pan and the tissue was removed and minced. Shells, tissue, and juices were distributed around the tank. Molts were recorded and removed as they were found. At the termination of the experiment, the crabs were removed, measured, and counted. The sand was sieved through a 500 μm mesh screen and the remaining clam tissue was removed and weighed. Crabs cleaned adherent tissue from shell remains, eliminating the need to correct for uneaten tissue from this source. The amount of tissue consumed was determined by totaling the estimated WTW of fed clams (using the weight vs. length equation above) and subtracting the amount recovered from the sediment.

The small aquaria and the large fiberglass tank used in the feeding experiments were housed in an outdoor covered shelter that allowed natural light to penetrate through overhead fiberglass windows. The shelter was exposed to open air.

The sand used in all experiments was collected from the supratidal zone of South Slough. It was sieved through a one mm mesh screen and washed with seawater before it was added to the tanks.

The seawater temperature and salinity in the tanks was measured regularly. It reflected that of the bay throughout the study period (T = 11–15°C; salinity = 30–31 $^{0}/_{00}$.

RESULTS

Preliminary Feeding Trials

Results from the preliminary feeding experiment demonstrated that juvenile *C. magister* can prey on *T. tantilla* (Table 1). The shell remains indicated that clams that died from crab predation could be identified by the presence of half-shells and shell fragments. The half-shells were either broken just below the umbo or included the hinge region and a piece of the complementary half-shell. The shells of clams that died in the control tank were intact and articulated.

TABLE 1. One hundred fifty *T. tantilla* were allowed to settle in 10 cm sand in each of two glass aquaria. Five juvenile *C. magister* were added to one tank; the other tank served as a control. The tanks were dismantled 26 days later and the surviving clams and shell remains were categorized and counted.

Number of C. magister	*Number of living T. tantilla*	*Number of Articulated shells*	*Number of Half-Shells*
5	0	1	103
0	118	29	2

Foraging Behavior

During non-feeding periods, juvenile *C. magister* sat quietly, partially or completely buried in the sand. Foraging was initiated when the crab rose from its resting position with its chelipeds extended forward and above the surface of the sand. The crab searched for prey as it moved from one side of the aquarium to the other, using its chelipeds to sift the sediment in a circular motion that was directed toward the mouthparts. During the search, the crab stopped occasionally and reoriented its antennules. When a clam was encountered, it was grasped between the dactylus and the propodus and quickly and adeptly brought up to the mandibles. The chelipeds, in coordination with the maxillipeds and the maxillae, positioned the clam upright against the mandibles with one valve in contact with each cheliped. The chelipeds, in unison with the mouthparts, turned the clam forward around its short axis (clam width). After several rotations of the clam, one cheliped maintained the clam's position in the mandibles, and the dactylus of the other probed downward at the valve edges. The crab alternated "clam-spinning" with "dactyl-probing". At times, the direction of the spin was reversed. These activities were continued until the crab successfully penetrated the valves. When the valves were separated, the chelipeds closed on either valve and pried the shells apart. In the process, one valve was broken in several pieces, generally close to the umbo, and the other half-shell was left intact. The time spent opening a clam varied from 15 seconds to several minutes.

The crab used it chelipeds to remove the tissue from the half-shell and shell pieces. The dactyls were used like cocktail forks to scoop out clam meat and direct it to the maxillipeds and mandibles. The shells were also directed into the mouthparts where they were fastidiously cleaned and subsequently ejected onto the substrate. The shells were never ingested.

Individual Feeding Experiment

The total number of clams consumed by each crab during the 82 h period was summarized (Table 2). The eight instar IV crabs ate an average of 2.0 ($\pm$ 0.6) clams•crab^{-1}•day^{-1}; the nine instar V crabs ate an average of 4.0 ($\pm$ 0.7) clams•crab^{-1}•day^{-1}. The mean shell length of clams fed to each size-class of crabs was the same: 9.1 ($\pm$ 1.6 mm).

TABLE 2. Total number of *C. nuttalli* and total amount of tissue consumed by juvenile *C. magister* during an 82 h feeding experiment. One crab was present in each aquarium. The crabs were fed *C. nuttalli*, twice daily. At each feeding trial, the clams were offered one at a time, until each crab had been offered one more clam than it would eat.

Inital CW (mm) [a]	*Total Number of clams consumed* [b]	*Total tissue consumed (mg)* [c]
15	3.8	181
15	5.0	162
16	8.1	247
16	5.8	260
16	6.0	205
17	9.9	436
18	8.6	388
19	9.5	397
21	12.0	463
21	10.9	412
22	15.0	528
22	15.4	628
22	15.0	574
22	10.5	418
22	14.2	599
23	14.9	659
24	16.9	682

[a] CW is the carapace width of the crab
[b] Mean (± SD) shell length of clams was 9.1 (± 1.6mm)
[c] The regression equation used to estimate the amount of tissue consumed is $Lg_{10}^{WTW} = 3.08\ Lg_{10}^{SL} - 1.38$, where WTW is wet tissue weight (mg) and SL is shell length (mm).

The estimated amount of tissue eaten per crab during the 82 h period (Table 2) ranged from 162 to 682 mg. There was a good correlation between the initial size of the crab (CW, mm) and the total tissue consumed (WTW, mg), WTW = 51 CW − 565 ($r^2 = 0.86$). The average tissue consumed•crab $^{-1}$•day $^{-1}$ was 124 (± 50) mg. All 17 crabs ate on the firt day; all but one ate on the second and third days; all but two ate during the last 10 h of the feeding trials. Daily tissue consumption varied considerably for each crab, but there were no consistent trends to suggest, for instance, that crabs were hungrier on the first day than on subsequent days, or that culture conditions became more or less favorable with time.

Two crabs molted during the individual feeding experiment; one increased in CW from 15 to 21 mm, the other from 22 to 30 mm. One of these crabs refused to eat and the other ate a negligible amount the day before molting.

Group Feeding Experiment

The total amount of clam tissue consumed in the 96-h period was 72.09 g. The average consumption was 180 mg•crab $^{-1}$•day $^{-1}$. In general, crabs fed at night and were inactive during the day. Twenty-five crabs molted during the experiment. Before the experiment, crab CW were 13–23 mm ($\bar{X} \pm SD = 18 \pm 3$ mm); after the experiment, they were 13-30 mm ($\bar{X} \pm SD = 20 \pm 3$ mm). Agonistic behavior was observed, but there were no incidences of cannibalism. One crab died from unknown causes.

DISCUSSION

Juvenile *C. magister* attempt to open all small bivalves they encounter. They have been observed feeding on juvenile *Macoma* sp., *Prototheca staminea*, *C. nuttalli*, and small *Cryptomya* sp. (personal observation, unpublished). *C. magister* (CW, < 30 mm) open *T. tantilla* and juvenile *Macoma* sp. (SL, 5 mm) within a few minutes. They have difficulty opening strong-shelled species, such as *C. nuttalli* (SL, 5 mm), and do so only after spending a considerable amount of time and effort. The crabs use a variety of techniques to open small bivalves. The "clam-spinning" and "dactyl-probing" technique is used to open oval-shelled species, such as *T. tantilla*, *P. staminea*, and *C. nuttalli*. Oblong, flattened, thin-shelled clams are opened by working the chelipeds about the edges of the valves until the shells gape, and subsequently chipping off portions of the shell. Small crabs feed on clams, such as *Cryptomya* sp., by using one cheliped and several legs to brace the clam, inserting the other cheliped into the naturally-occurring valve-gape, and prising up. The half-shell remains that are left when juvenile *C. magister* feed on *T. tantilla* are not characteristic for other species of bivalves.

In 1984, there was a tremendous crash in the population of *T. tantilla* in South Slough (personal observation, unpublished). The disappearance of the clams coincided with the settlement of juvenile *C. magister*. Before the arrival of *C. magister* megalops, *T. tantilla* could be found in South Slough with a minimum of effort (P. Rudy, Oregon Institute of Marine Biology, Charleston, Oregon, personal comm.), but by June, only 6 living *T. tantilla* were found after hours of searching the mudflat and sieving samples of sediment. At the same time, numerous *T. tantilla* half-shells and shell fragments were observed in areas of the mudflat where *T. tantilla* had commonly been found. Large numbers of juvenile *C. magister* were also observed in South Slough during May and June, 1984 (personal observation, unpublished). A much less severe decline in densities of *T. tantilla* in South Slough had been observed in the spring and summer of 1981 (Asson-Batres 1982). At that time, the decline in numbers also coincided with the settlement of post-larval crabs.

As *T. tantilla* were unavailable, I used the smallest bivalves available (*C. nuttalli*, SL, 5–13.5 mm) in the individual feeding experiments. Although daily tissue consumption was variable, there were no obvious trends in the data. The variation may have occurred because crabs were in different stages of the molting cycle. Repantian crustaceans store food reserves during intermolt-early premolt stages and deplete them during late premolt-postmolt (Schwabe, Scheer, and Scheer 1952; Scheer 1959; Heath and Barnes 1970). This behavior is suggested by the two crabs that stopped eating before they molted. Another source of variation may have been the availability of water-borne prey in the seawater supply. If crabs were feeding on such extraneous matter, it would have led to an underestimate of the daily consumption rate. The linearity of the relationship between total tissue consumed and crab size suggests that potential interference from these sources was averaged out over the 82 h period.

Because the crabs had difficulty (or were incapable of) opening the *C. nuttalli* offered, their feeding was restricted to a schedule in the individual feeding experiment. To check whether the feeding regimen may have had an adverse effect on the feeding rate of crabs, a group feeding experiment was run simultaneously, in which excess clam meat was available all hours of the day. The proportion of instar IV and V crabs was similar in both experiments. The results indicate that, on average, the crabs ate more in the group feeding experiment (180 mg•crab $^{-1}$•day $^{-1}$) than in the individual feeding experiment (124 mg •crab $^{-1}$•day $^{-1}$). The potential for interference from crab-to-crab variation in the molting cycle or from the supply of extraneous food matter in the seawater would have been similar in both experiments. Hence, the difference was due to an effect of the culture conditions, the feeding procedure, or an intraspecific, density-dependent effect on feeding behavior. The results suggest that the consumption rate determined in the individual feeding experiments was conservative.

To provide the determined consumption rate of 124 mg tissue•crab $^{-1}$ •day $^{-1}$, a crab would need to consume 300 clams 2 mm in SL, 20 clams 5 mm in SL, or 2 clams 10 mm in SL per day (using the weight vs. length regression for *C. nuttalli*). Handling efficiency, clam abundance, ease of detection, and accessibility would determine the clam size selected. As shown in this study, *T. tantilla* is handled with great efficiency, particularly in comparison with thick-shelled species such as *C. nuttali*. Although *C. magister* is capable of opening *T. tantilla* 5.0 mm in SL, this size is rare in South Slough; more commonly, the clams are less than 4.0 mm in SL (Asson-Batres 1982). In 1981, densities of 1000–3000 *T. tantilla* /m^2 were common in South Slough (Asson-Batres 1982). At these densities, *T. tantilla* is easily located and consumption rates of 50–100 clams•crab $^{-1}$ •day $^{-1}$ would not be unreasonable, since *C. magister* is capable of dislodging, opening, and eating *T. tantilla* within minutes. *T. tantilla* is patchily distributed on the mudflat (Obrebski 1968), so the capacity for crabs to maintain such a consumption schedule would be dependent on their ability to discover isolated pockets of prey. Juvenile *C. magister* probably use chemoreception to locate prey and may be able to key in on dense assemblages of clams. Such foraging tactics have been described for adult *C. magister* (Pearson, Sugarman, and Woodruff 1979; Boulding and Hay 1984).

The impact of juvenile crab predation on densities of small, estuarine clams is ultimately determined by the yearly abundance of young crabs in the estuary and the preference crabs show for clams in the field. Crab settlement densities in west coast (USA) estuaries show considerable year-to-year variation, but estimated abundances of more than 20 million juvenile crabs in Bodega Bay, California (Poole 1967) and 30 million in Grays Harbor, Washington (Stevens, 1982) have been reported. Stevens, Armstrong, and Cusimano (1982) have found, by analyzing the gut contents of juvenile crabs by the Index of Relative Importance (Pinkas, Oliphant, and Iverson 1971), that clams are a major part of the diet of first year crabs. In fact, they may have underestimated the importance of clams, since the crabs I observed never ingested shells. Given the consumption rate determined in this study and the observation that young crabs show a preference for clams in their diet, juvenile Dungeness crabs could have a significant effect on the densities of small bay clams, particularly during peak years of crab settlement. A similar predator/prey relationship has been reported for juvenile *Carcinus maenas* and juvenile *Cerastoderma edule* in the Danish Wadden Sea (Jensen and Jensen 1985). The authors report that, as observed for

T. tantilla (this study and Asson-Batres 1982), clam densities declined coincidentally with the arrival of juvenile crabs into the estuary. They (Jensen and Jensen 1985) attributed 26.1% of the elimination of cockle spat to predation by the incoming settlement of juvenile crabs.

In summary, this is the first report of the foraging and feeding behavior of juvenile *C. magister* on small, estuarine bivalves, and the first determination of a daily consumption rate for juvenile Dungeness crabs.

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HABITAT SELECTION BY SOUTHERN MULE DEER [1]

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Habitat selection by southern mule deer, *Odocoileus hemionus fuliginatus,* was studied at Cuyamaca Rancho State Park, San Diego County, California from June 1977–January 1979. Direct observations, spotlight transects, and track counts indicated meadows were most preferred by active deer followed by stands of oaks, and pine; deer avoided dense brushfields of chaparral. Deer bedding at midday exhibited a marked preference for the oak plant community. Because meadows were used extensively by feeding deer, this habitat was subdivided into an additional seven vegetative types. Deer preference ratings were highest for the deer grass type, followed by mustard, cheat grass, rose, wild oat, chokecherry, and buckwheat types. No significant variation occurred in the preferences of deer for vegetative types between seasons. Further, few differences occurred among sex and age classes of deer in their preferences for vegetative types; however, newborn fawns made extensive use of deer grass habitat. Deer occurred most often on west-facing slopes, probably because of the palatable foods that occurred on these areas; preferences of deer for different slope exposures did not vary significantly among seasons. Deer occurred most often at distances of 41–50 m from concealment cover. Most deer were found within 1 km of free water during summer. Deer distribution was correlated significantly with the availability of *Sisymbrium altissimum,* a preferred forage.

INTRODUCTION

Southern mule deer, *Odocoileus hemionus fuliginatus,* are thought to occupy primarily chaparral regions of extreme southern California (Cowan 1956, Wallmo 1981). This subspecies, however, possesses a dark, sooty-colored pelage uncharacteristic of most mule deer that occur in chaparral or other arid environments (Bowyer and Bleich 1984*a,* Cowan 1956). Habitat preferences of southern mule deer have not been described fully, and accounts that indicated chaparral habitat was preferred often lacked quantification. Indeed, until recently (Bowyer and Bleich 1980, Bowyer and Bleich 1984*b,* Bowyer 1984) little was known of the ecology of these deer. Further, the southern mule deer is an important game species in southern California (Bowyer 1981), and information concerning habitat selection would be useful in its management.

The purpose of this study was to quantify seasonal changes in habitat preferences of various sex and age classes of southern mule deer. Components of habitat important in the ecology of California deer (Leopold et al 1951, Taber and Dasmann 1958) that were assessed in this research include: i) diel changes in the use of vegetative types; ii) the concealment cover provided by vegetative types and the distances deer occurred from escape cover; iii) seasonal variation in the use of differing slope exposures; iv) the distribution of deer relative to free water during summer; and v) the influence of preferred forage on deer distribution.

STUDY AREA

Location and Climate

Research was conducted at an elevation of 1520 m on 1250 ha of East Mesa, Cuyamaca Rancho State Park, San Diego Co., California (32° 59′ N, 116° 35′ W).

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The Park is located 65 km east of San Diego and 40 km north of Mexico in the Cuyamaca Mountains of California's Peninsular Range.

Annual precipitation averages 88 cm; most precipitation occurs between November and April. Snowfall averages 92 cm per year. December–March is the period of greatest snowfall. Snow does not accumulate but usually melts within several weeks.

The mean annual temperature is 12° C; while summer maxima seldom exceed 38° C and winter minima rarely fall below −10° C. The hottest period is June–September and the coldest December–March. Monthly variation in temperature during the study approximated the 50-year mean.

Prevailing winds are from the southwest, but Santa Ana winds (extremely hot, dry winds originating in the Great Basin) come from the northeast. Santa Ana conditions are most prevalent from September through early December, but may occur in any month.

Flora and Fauna

East Mesa was dominated by upland meadows (619 ha) interspersed with stands of oak (149 ha) or pine (241 ha) and surrounded by old-growth chaparral (241 ha) (Figure 1). Percent cover for species typifying the chaparral community was *Quercus wislizenii* (17.8%), *Cercocarpus betuloides* (17.3%), *Adenstoma fasciculatum* (11.2%), *Ceanothus palmeri* (2.9%), *Eriogonum fasciculatum* (2.9%), *Rhamnus crocea* (1.8%), and *Salvia apiana* (1.7%) (see Methods for sampling details).

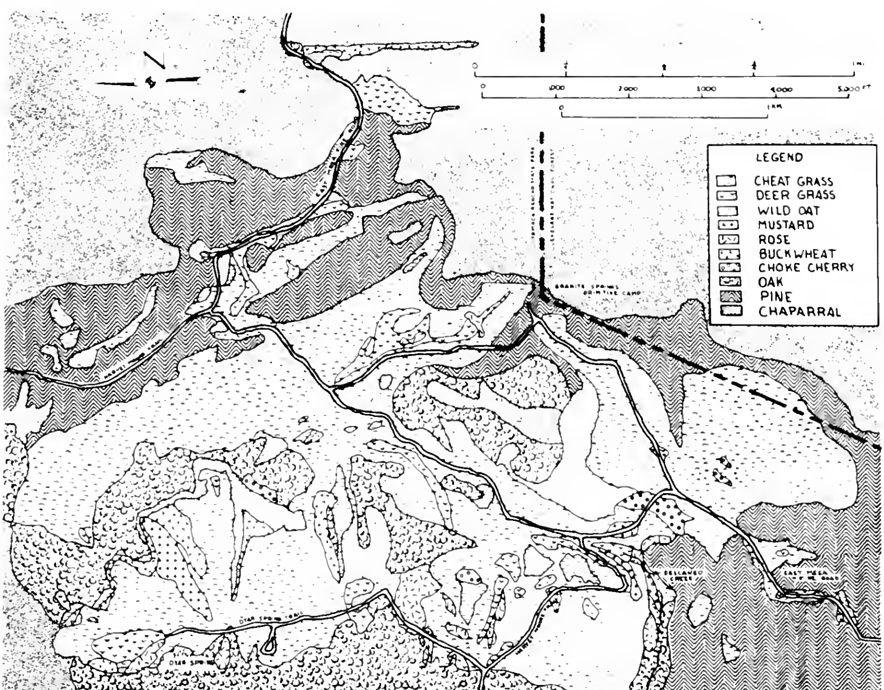

FIGURE 1. Vegetative types of East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

Percent cover for trees of the pine community was: *Pinus jeffreyi* (3.4%), *Quercus kelloggi* (1.9%), *Q. agrifolia* (1.6%), *Pinus ponderosa* (0.1%), and *P. coulteri* (0.1%). The dominant understory shrub was *Arctostaphylos pungens* (0.3%). Other common species in the understory were *Bromus diandrus* (5.9%), *Festuca octoflora* (5.7%), *Bromus tectorum* (3.2%), and *Leptodactylon pungens* (2.4%).

Percent cover of trees in the oak community was *Quercus kelloggi* (4.6%), *Q. agrifolia* (2.8%), and *Q. wislizenii* (0.9%). Common understory shrubs included *Rhus trilobata* (2.5%) and *Rhamnus californica* (0.8%). Understory grasses were predominantly *Bromus diandrus* (18.2%), *B. tectorum* (5.8%) and *B. marginatus* (4.5%).

Feeding deer occurred frequently in meadows, consequently this community was divided into seven vegetative types that formed relatively discrete patches and were distinquished easily in the field. The most common type was cheat grass (509 ha). Percent cover for common species was: *Bromus tectorum* (18.4%), *Festuca octoflora* (10.7%), *Erodium citutarium* (6.7%), *Ambrosia psilostachya* (3.2%), *Bromus diandrus* (3.1%), and *Sisymbrium altissimum* (1.9%).

Percent cover for common species in the wild oat type (37 ha) was: *Avena barbata* (23.7%), *Eriogonum nudum* (6.6%), *E. davidsonii* (2.3%), *Ambrosia psilostachya* (2.1%), *Erodium cicutarium* (1.8%), and *Gutierrezia californica* (1.2%).

Percent cover for species in the deer grass type (36 ha) was: *Carex* sp. (27.8%), *Muhlenbergia ridgens* (22.9%), *Festuca octoflora* (5.6%), *Bromus tectorum* (4.3%), *Eriogonum nudum* (2.5%), and *Juncus xiphoides* (1.4%).

The buckwheat type encompassed 15 ha and percent cover for common species was: *Eriogonum fasciculatum* (29.2%), *Rhus trilobata* (6.7%), *Bromus tectorum* (5.6%), and *Festuca octoflora* (4.4%).

Percent cover for species typical of the rose type (11 ha) was: *Symphoricarpos mollis* (17.7%), *Rosa californica* (12.7%), *Eriogonum nudum* (5.8%), *Bromus tectorum* (5.8%), *Festuca octoflora* (4.9%), and *Prunus virginiana* (1.4%).

The mustard type totaled 7 ha and percent cover for characteristic species was: *Bromus diandrus* (22.1%), *B. tectorum* (13.9%), *Sisymbrium altissimum* (11.8%), and *Erodium cicutarium* (1.6%).

The chokecherry type (5 ha) was dominated by *Prunus virginiana* (25.9%), *Bromus tectorum* (20.8%), and *Ambrosia psilostachya* (1.4%). Plant nomenclature follows to Munz (1974).

An unhunted population of approximately 250 nonmigratory southern mule deer inhabited East Mesa. Predators including coyote, *Canis latrans,* and bobcat, *Lynx rufus,* were common. Further descriptions of the flora and fauna of this area are available elsewhere (Bowyer and Bleich 1980, Bowyer et al 1983, Bowyer and Bleich 1984*b,* Bowyer 1984)

METHODS

Direct Observations

Deer were observed on 268 days from June 1977–January 1979 with the unaided eye, 7 X binoculars or a 20–45 X spotting scope from a vehicle or on foot over distances of 5–800 m. Observations were made primarily during the three to four hours about sunrise and sunset when deer were most active. Some sampling also was conductd at midday to determine the habitat preferences of bedding deer. Observation periods of 24 h were undertaken when weather permitted. Nighttime observations were dependent upon clear, moonlit conditions.

A fixed transect of 8.2 km typically was driven once each morning and evening when roads on East Mesa were passable. The portion of East Mesa sampled first was alternated with each sampling effort from eastern to western areas to help neutralize the influence of time of day on deer activity. A 7.5-km, fixed transect was walked when snow or mud prevented driving on East Mesa.

Data were collected only from groups of deer that were undisturbed by my presence. If any member of a group exhibited alert or alarm postures at my approach, data collection was terminated. Care was taken to assure a complete count and accurate identification of deer in each group. No data were recorded unless I was confident that deer were not hidden by hills, gullies, or vegetation. Extra time was spent with groups in dense habitats to assure all group members were counted. Sampling of habitat use by active deer was determined, in part, by the location of roads on East Mesa. From spring through autumn 625 ha were sampled for deer use, whereas 557 ha were sampled during winter. Overall, meadows composed 88.8% of the area sampled, followed by oak (5.2%), pine (3.4%), and chaparral (2.6%) plant communities. Sampling effort within meadow types was most intense in cheat grass (73.3%), followed by wild oat (5.9%), deer grass (4.7%), buckwheat (2.3%), mustard (1.2%), rose (1.1%), and chokecherry (0.5%).

Sex and age of deer in each group also were recorded. Categories recognized were bucks (adult males older than two years of age), male yearlings, does (adult females older than two years of age), female yearlings, and fawns (deer of either sex less than one year of age). All categories were distinguished easily for most of the year from body size and form or antler development.

Locations of deer were determined using an aerial photograph divided into grids equivalent to 25 m^2. Whenever deer were encountered, data on vegetative type, slope exposure, distance from escape cover (cover sufficient to conceal a standing deer from view), distance from free water (in summer), and activity patterns (standing, feeding, bedding) were collected using scan sampling procedures (Altmann 1974).

Spotlight and Track Counts

Weather permitting, monthly spotlighting transects (Progulske and Duerre 1964, McCullough 1982) were conducted on East Mesa. Transects were arranged so there was no chance of double counting deer, and the area sampled was determined by multiplying the length of the transect in each plant community by the mean distance the spotlight beam penetrated the vegetation. The area sampled for each plant community was: meadow (60.8 ha), oak (14.1 ha), pine (7.3 ha), and chaparral (13.0 ha). A more complete description of this procedure is provided by Bowyer and Bleich (1984*b*).

Track counts were conducted monthly along a 2.5-km section of East Mesa's road system. Fresh tracks were used to assess deer use of vegetative types by noting the number of tracks entering and leaving various plant communities. Meadows composed 61.0% of the area sampled, oak 22.7%, pine 10.6% and chaparral 5.7%.

Vegetation Sampling

A modification (Bowyer and Bleich 1984*b*) of the step-point method (Evans and Love 1957) was used to determine percent cover of plant species. Starting points and direction of travel were selected randomly and samples were stratified by vegetative type and season. Percent cover corresponded with the proportion of times a thin line ($<$ 1 mm) on the toe of a boot struck a plant species. A total of 20,631 step-points were used to describe vegetative types on East Mesa.

Measures of concealment cover were made with a 1.2 m by 1.2 m board divided into 100 squares. Sample points were located with a random numbers table and grid. The board was held perpendicular to the ground and observed from a distance of 15 m from four cardinal directions at each location. If a square on the board was 50% or more covered, it was recorded as concealed; if less than 50% was covered by vegetation, it was not counted. Adequate sample sizes were determined by stabilizing means (Kershaw 1964:29); a total of 1440 samples were collected. Brush fields of chaparral were too thick to enter with a sampling board, thus data were collected on the more open periphery of these stands.

Data Analyses

Most data were analyzed using the MIDAS statistical package at the University of Michigan. The degree of kurtosis, skewness and other assumptions concerning statistical inference were evaluated and the most appropriate test applied. Statistical tests used in these analyses included the *G*-test of independence (Sokal and Rohlf 1969), Kolmogorov-Smirnov test, Mann-Whitney *U*-test, Kruskal-Wallis one-way analysis of variance, Friedman two-way analysis of variance, and Spearman rank correlation (Siegel 1956). Preference ratings were calculated according to Petrides (1975). Although differences in the total number of deer observed occurred between the first and second year of the study, no significant ($P > 0.40$) difference was found in their preferences for vegetative types. Thus, data from both years were pooled.

RESULTS

Selection of Vegetative Types

Differences in diel activities strongly influenced the use of vegetative types by southern mule deer. Deer found bedded at midday preferred stands of oak and pine over open meadows or dense brush fields of chaparral (Table 1). Deer bedded in a significantly ($G = 135.90$, $P < 0.001$, 3 *d.f.*) different pattern than would have been expected from the availability of vegetative types. All undisturbed groups encountered at midday were bedded, but their precipitous flight after detecting my presence prevented any meaningful analyses of group composition or size.

The occurrence of active (standing) mule deer in different vegetative types was assessed by direct observations, spotlight transects and track counts. All three procedures indicated deer occurred most often in meadows, followed by oak, pine, and chaparral communities (Table 2). Preference ratings for vegetative types exhibited a similar pattern; however, track counts rated oaks slightly above meadows, perhaps because this technique included the movements of deer to stands of oak where they typically bedded. Nonetheless, a Friedman two-way analysis of variance showed no significant difference ($X^2_r = 2.62$, $P > 0.20$, 2 *d.f.*) among the techniques used to evaluate preference. Thus, direct observation was as reliable as the other methods for evaluating habitat selection by southern mule deer.

TABLE 1. Selection of Vegetative Types of 110 Groups of Bedded Southern Mule Deer at Midday, East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

Vegetative Type	*N*	*% Groups*	*Preference rating*
Meadow	22	20.0	0.2
Oak	83	75.5	14.5
Pine	5	4.5	1.3
Chaparral	0	0.0	0.0

TABLE 2. Selection of Vegetative Types by Active Southern Mule Deer Observed on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

	Direct Observations (N = 9,260 Deer)		*Spotlight Tranects (N = 369 Deer)*		*Track Counts (N = 522 sets of tracks)*	
Vegetative Types	*%*	*Preference Rating*	*%*	*Preference Rating*	*%*	*Preference Rating*
Meadow	94.8	1.1	85.9	2.0	77.8	1.3
Oak	3.6	0.7	8.9	0.3	16.3	1.4
Pine	1.4	0.4	4.9	0.3	5.6	0.5
Chaparral	0.2	0.1	0.3	<0.1	0.4	0.1

Direct observations indicated the distribution of 9,260 active deer differed significantly ($G = 348.86$, $P < 0.001$, 3 *d.f.*) from expected values based on the availability of vegetative types. A Friedman two-way analysis of variance indicated no significant difference ($X^2_r = 2.77$, $P > 0.50$, 3 *d.f.*) in deer preferences for vegetative types among seasons (Table 3). Meadows generally were most preferred followed by oak, pine, and chaparral; this overall pattern of deer preference was highly significant ($X^2_r = 12.45$, $P < 0.001$, 3 *d.f.*).

Because meadows were highly preferred, and nearly 95% of active deer were observed in this habitat, meadows were subdivided into an additional seven vegetation types (Table 4). As before, the Friedman two-way analysis of variance showed season had little influence ($X^2_r = 2.01$, $P > 0.50$, 3 *d.f.* on the preferences of deer for these meadow types. Over all seasons, deer tended to prefer deer grass most often, followed by mustard, cheat grass, rose, wild oak, chokecherry, and buckwheat types (Table 4); this pattern was significant ($X^2_r = 15.62$, $P < 0.02$, 6 *d.f.*).

No significant ($X^2_r = 1.60$, $P > 0.80$, 4 *d.f.*) difference in preferences among different sex and age classes of deer occurred for meadow, oak, pine, or chaparral vegetative types (Table 5). Likewise, no significant difference was found among the preferences of deer sex and age classes for the seven meadow types ($X^2_r = 3.46$, $P > 0.30$, 4 *d.f.*). During the fawning season in late June through early July, however, neonates exhibited a marked preference for deer grass, oak, and rose vegetative types (Figure 2). Although the sample size was small (N=26), a Kolmogorov-Smirnov test showed that young fawns were distributed in vegetative types in a significantly ($D = 0.46$, $P < 0.01$) different pattern than would have been expected from the availability of those types.

TABLE 3. Seasonal Changes in the Use of Vegetative Types by Active Southern Mule Deer Observed on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

Vegetative Type	Spring (N = 1,831)		Summer (N = 2,234)		Autumn (N = 3,628)		Winter (N = 1,567)	
	%	Preference Rating	%	Preference Rating	%	Preference Rating	%	Preference Rating
Meadow	93.4	1.1	92.6	1.0	96.1	1.1	96.9	1.0
Oak	3.4	0.7	5.5	1.1	3.0	0.6	2.3	0.4
Pine	3.1	0.8	1.5	0.4	0.8	0.2	0.8	<0.1
Chaparral	0.1	<0.1	0.4	0.1	0.1	<0.1	0.0	0.0

TABLE 4. Seasonal Variation in the Use of Seven Meadow Vegetative Types by Active Southern Mule Deer Observed on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

Meadow Types	Spring (N = 1,831)		Summer (N = 2,234)		Autumn (N = 3,628)		Winter (N = 1,567)	
	%	Preference Rating	%	Preference Rating	%	Preference Rating	%	Preference Rating
Cheat Grass	59.3	0.8	61.3	0.9	72.9	1.0	70.4	0.9
Deer Grass	27.0	5.4	18.7	3.7	13.3	2.7	13.4	3.6
Wild Oat	3.1	0.5	4.6	0.8	3.3	0.6	7.9	1.4
Mustard	3.2	2.8	3.3	2.9	5.2	4.6	4.0	3.1
Rose	0.7	0.7	3.2	3.0	1.0	1.0	0.0	0.0
Buckwheat	0.0	0.0	0.0	0.0	0.4	0.2	1.2	0.6
Chokecherry	0.1	0.2	1.5	3.4	0.0	0.0	0.0	0.0

TABLE 5. Selection of Vegetative Types by Different Sex and Age Classes of Southern Mule Deer Observed on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

Vegetative types	Sex and age class									
	Buck (N = 1,388)		Male yearling (N = 553)		Doe (N = 5,937)		Female yearling (N = 246)		Fawn (N = 1,110)	
	%	Preference rating	%	Preference rating	%	Preference rating	%	Preference rating	%	Preference rating
MEADOW	93.5	1.1	88.4	1.0	95.7	1.1	93.5	1.1	95.1	1.1
Cheat Grass	59.7	0.8	68.4	0.9	69.9	0.9	51.0	0.7	68.6	0.9
Deer Grass	22.4	4.8	16.5	3.5	15.8	3.4	41.2	8.8	16.8	3.6
Wild Oak	5.3	0.9	3.6	0.6	3.9	0.7	3.9	0.7	3.6	0.6
Mustard	4.8	4.1	4.5	3.8	4.2	3.6	3.9	3.3	3.5	3.0
Rose	0.4	0.4	1.1	1.0	1.3	1.2	0.0	0.0	2.1	1.9
Buckwheat	0.3	0.1	0.0	0.0	0.4	0.2	0.0	0.0	0.5	0.2
Chokecherry	0.6	1.3	0.5	1.1	0.2	0.4	0.0	0.0	0.0	0.0
OAK	3.9	0.8	8.3	1.6	3.4	0.7	4.9	1.0	4.6	0.9
PINE	2.4	0.7	3.3	1.0	0.8	0.2	1.6	0.5	0.3	0.1
CHAPARRAL	0.2	0.1	0.0	0.0	0.1	<0.1	0.0	0.0	0.0	0.0

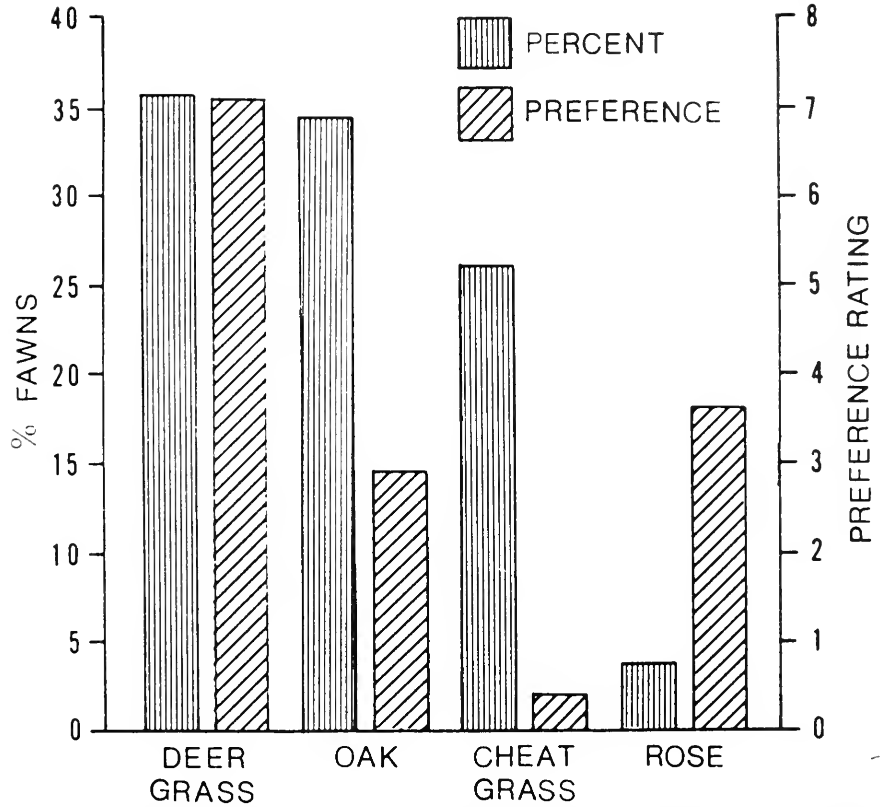

FIGURE 2. Preference and percent occurrence of 26 neonate fawns for vegetative types on East Mesa, Cuyamaca Rancho State Park, San Diego County, California during June through July.

Selection of Slope Aspect

Slope exposures on East Mesa faced predominantly east (20%) and west (31%); most deer occurred on west-facing slopes (Table 6). The occurrence of deer on all slope aspects was significantly different than if deer were distributed randomly over the study area during spring ($G = 298.80$, $P < 0.001$, 8 *d.f.*), summer ($G = 357.88$, $P < 0.0001$, 8 *d.f.*), autumn ($G = 1078.36$, $P < 0.001$, 8 *d.f.*), and winter ($G = 626.48$, $P < 0.001$, 8 *d.f.*). Deer exhibited a clear preference for west facing slopes (Table 6); no significant difference occurred among seasons in the preference of deer for various slope exposures (X^2, = 1.97, $P > 0.50$, 3 *d.f.*).

Concealment Cover

Chaparral provided the greatest concealment cover (100% for all seasons) of any plant community. Southern mule deer, however, consistently avoided the dense brush fields of chaparral that surrounded East Mesa. I often herded groups of deer in front of my vehicle where the road passed through chaparral. Deer typically followed the road to the next meadow or more open stand of oak or pine rather than fleeing into nearby old-growth chaparral. Pine had the next highest value for concealment cover, followed by oak and meadow plant communities (Figure 3).

TABLE 6. Seasonal Variation in Selection of Slope Exposures by Southern Mule Deer Observed on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

	Spring (*N* = *1,831*)		*Summer* (*N* = *2,234*)		*Autumn* (*N* = *3,628*)		*Winter* (*N* = *1,567*)		*Total* (*N* = *9,260*)	
Slope aspect	*%*	*Preference rating*	*%*	*Preference rating*	*%*	*Preference rating*	*%*	*Preference rating*	*%*	*Preference rating*
North	1.8	0.3	5.4	0.8	3.8	0.6	1.2	0.3	3.4	0.6
Northwest	0.5	0.4	3.5	2.5	0.6	0.4	0.7	0.7	1.3	1.0
West	52.0	1.7	54.1	1.8	64.1	2.1	70.8	2.3	60.5	2.0
Southwest	5.7	0.4	7.2	0.5	5.6	0.4	6.2	2.6	6.1	0.4
South	5.8	0.5	7.9	0.7	8.2	0.8	5.2	0.5	7.1	0.7
Southeast	7.9	0.9	2.9	0.3	2.5	0.3	3.5	0.4	3.8	0.4
East	13.4	0.6	13.7	0.7	14.2	0.7	12.5	0.6	13.6	0.7
Northeast	3.2	2.5	2.3	1.8	0.8	0.6	0.0	0.0	1.5	0.2
None	9.9	1.5	3.0	0.4	0.1	<0.1	0.0	0.0	2.7	0.4

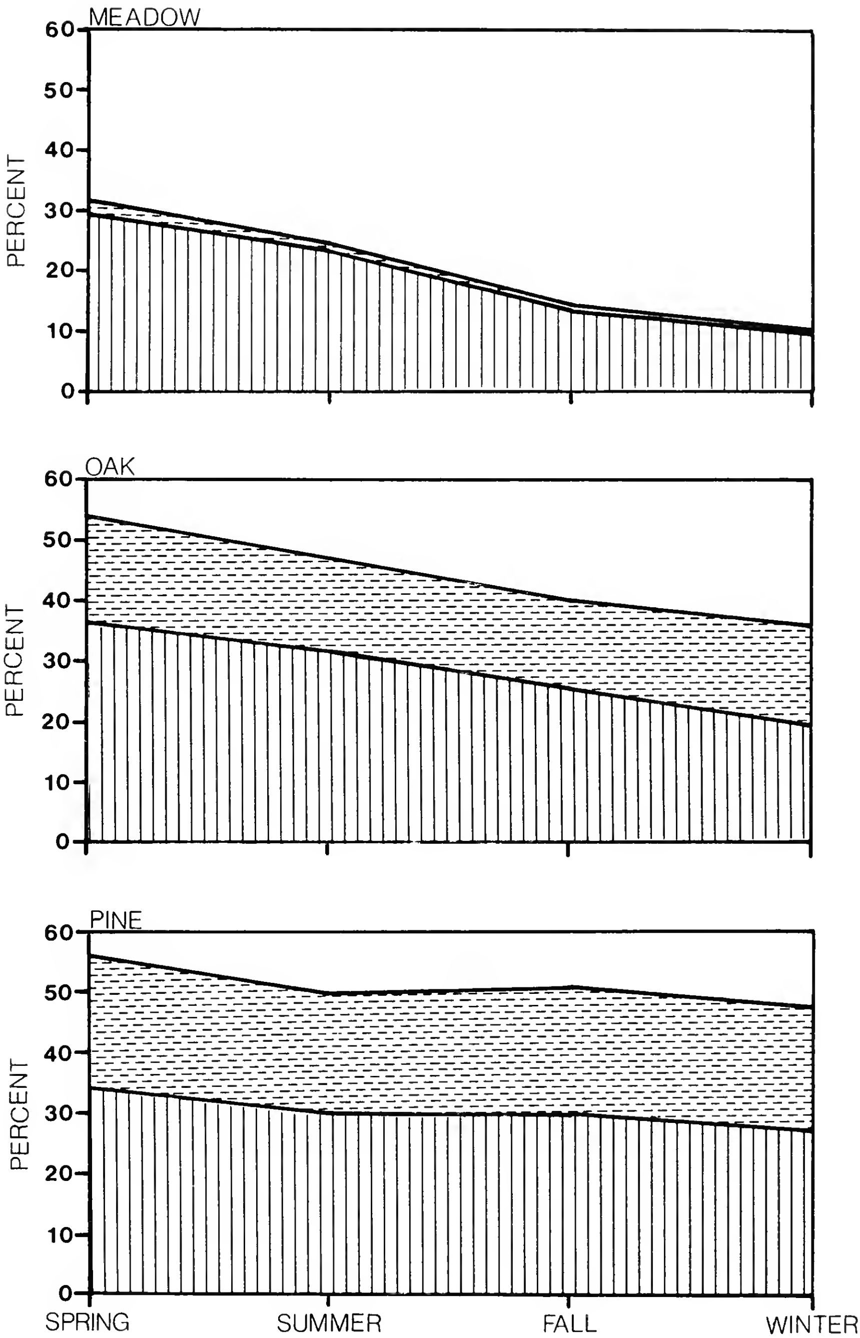

FIGURE 3. Seasonal changes in percent concealment cover of vegetative types at heights of 0–0.61 m (continuous vertical lines) and 0.61–1.22 m (broken horizontal lines) above the ground, East Mesa, Cuyamaca Rancho State Park, San Diego County, California.

Concealment cover for deer declined from spring through winter with this trend being most pronounced in meadows. Concealment cover in the predominant meadow types (Figure 4) exhibited similar seasonal patterns; deer grass furnished the greatest cover, followed by wild oat, and cheat grass types. Additionally, rose declined from 44% cover below and 5% beyond 0.61 m in height during autumn to 30% below and 1% beyond 0.61 m in winter. Buckwheat (41% within and 4% beyond 0.61 m) and chokecherry (48% below and 48% beyond 0.61 m) were sampled only during autumn.

Approximately 30–40% concealment cover at heights below 0.61 m was sufficient to hide a bedded deer; an additional 15–20% cover at heights of 0.61–1.22 m was necessary to obscure a standing deer from view.

The selection of trees or shrubs for escape cover by alarmed deer was determined by recording the plant species into which deer fled and became completely concealed from view. The use of trees and shrubs by 122 deer fleeing from predators, primarily coyote and bobcat, included *Quercus agrifolia* (43.5%), *Q. kelloggii* (12.3%), *Pinus jeffreyi* (12.3%), *Prunus virginana* (7.4%), *Rhamnus californica* (4.9%), *Salix lasiandra* (4.9%), *Sambucus caerulea* (4.9%) and *Cercocarpus betuloides* (2.5%). Alarmed deer made significantly ($G = 13.12$, $P < 0.001$, 1 *d.f.*) greater use of *Q. agrifolia* than would have been predicted by chance. Lateral branches of *Q. agrifolia* extended to ground level except in old trees, and alarmed deer often ran behind or beneath this dense cover. Although deer often concealed themselves by bedding in deer grass, they did not seek shelter in this vegetative type when pursued by predators.

The mean distance that 2,639 groups of active southern mule deer occurred from escape cover was 34.6 m (SD = 28.8 m, range = 0–300 m); 75% of all groups were found within 50 m of cover, but the highest percentage of deer was found 41–50 m from concealment cover (Figure 5). The Kruskal-Wallis one-way analysis of variance showed no significant difference ($H = 6.68$, $P > 0.05$, 3 *d.f.*) in the distances deer occurred from escape cover in spring ($\bar{X} = 33.7$ m, SD = 29.6 m), summer ($\bar{X} = 29.4$ m, SD = 22.0 m), autumn ($\bar{X} = 42.8$ m, SD = 36.3 m), or winter ($\bar{X} = 29.2$ m, SD = 21.9 m).

Because many groups contained more than one sex and age class, lone deer were used to evaluate how far active individuals in each sex and age class would venture from cover. Bucks and male yearlings were found the farthest whereas fawns occurred the closest to concealment cover (Table 7). The Mann-Whitney U – test showed significant ($P < 0.05$) differences in distances from cover for all sex and age class pairings except buck-male yearling, and doe-female yearling. The distance that fawns occurred from cover was small because neonates composed a substantial proportion of observations for lone fawns. Nonetheless, the tendency for fawns to remain closer to cover was evident for groups of two; does with fawns ($\bar{X} = 24.3$ m, SD = 19.8) occurred significantly ($P < 0.05$) nearer cover than does without them ($\bar{X} = 36.0$, SD = 22.7).

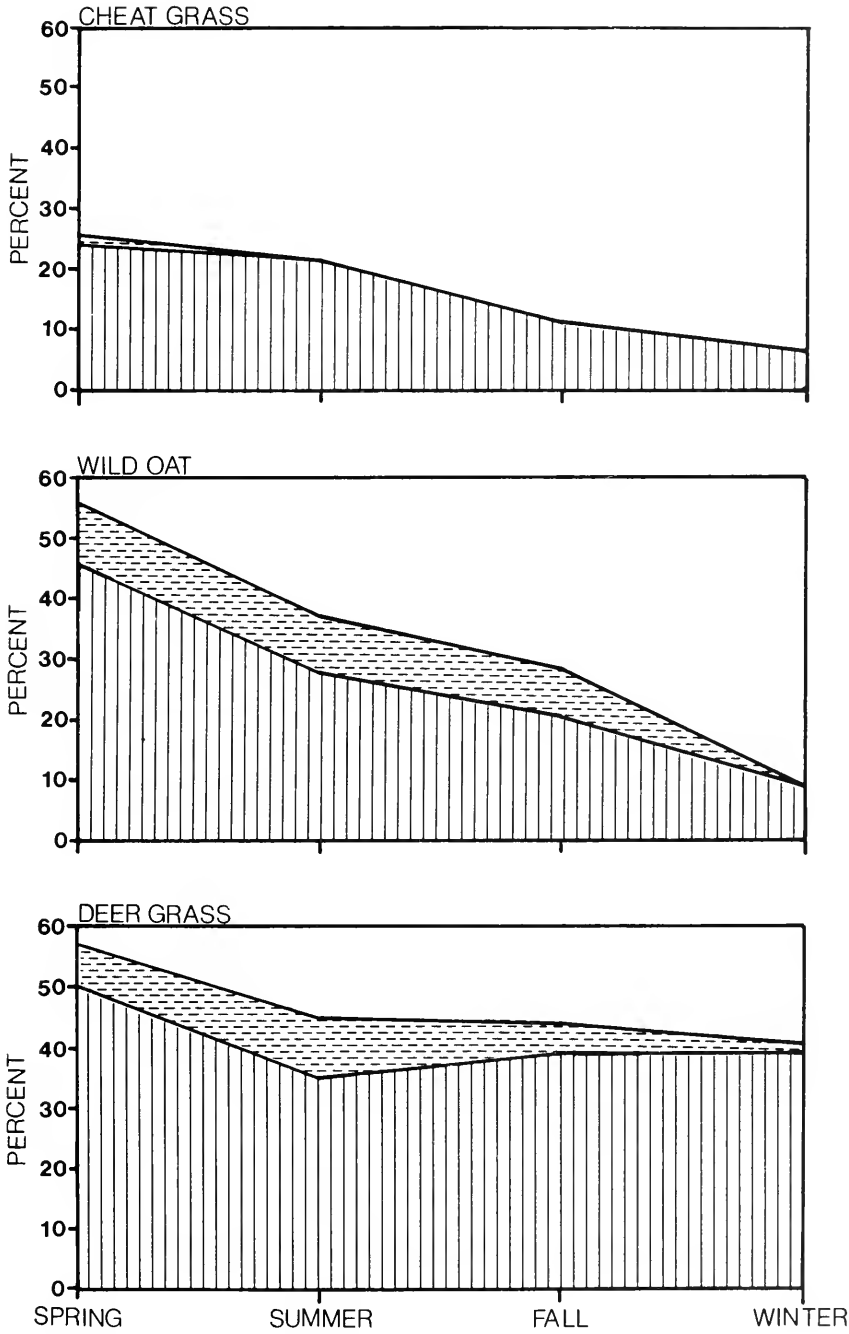

FIGURE 4. Seasonal changes in concealment cover of selected meadow types at heights of 0–0.61 m (continuous vertical lines) and 0.61–1.22 m (broken horizontal lines) above the ground, East Mesa, Cuyamaca Rancho State Park, San Diego County, California.

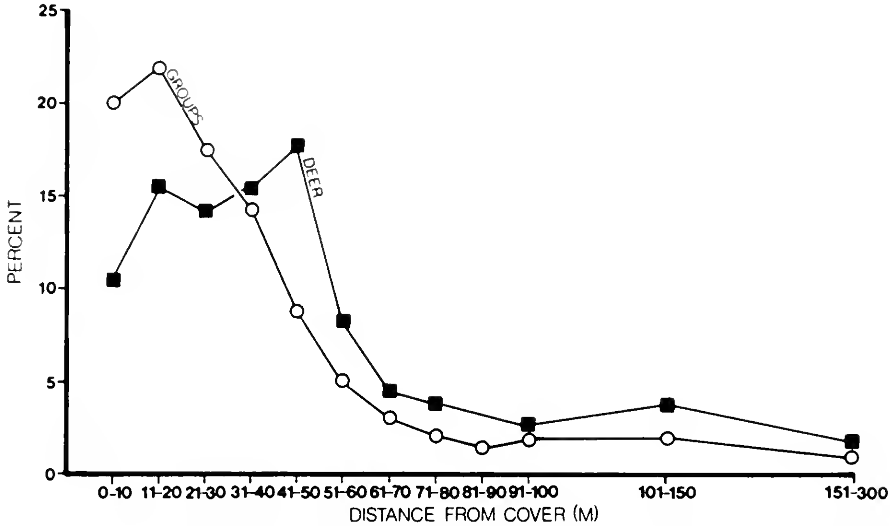

FIGURE 5. Distances 2,639 groups totaling 9,260 individual southern mule deer were observed from escape cover (cover sufficient to conceal a standing deer from view) on East Mesa, Cuyamaca Rancho State Park, San Diego County, California. 1977–1979.

TABLE 7. Sex and Age-class Differences in the Distances Lone Southern Mule Deer Were Observed from Concealment Cover on East Mesa, Cuyamaca Rancho State Park, San Diego County, California, 1977–1979.

	Distance from cover (m)			
Sex and age class	*N*	*$\bar{X}$*	*SD*	*Range*
Bucks	224	29.8	25.8	0–200
Male Yearlings	119	29.8	25.0	1–150
Does	554	25.0	22.7	0–150
Female Yearlings	27	25.1	19.5	1–60
Fawns	13	9.2	7.6	0–25

Free Water

During the wet portion of the year (November–April), water was readily available throughout the study area. Small creeks and seeps occurred even in areas that were exceptionally dry in summer. With the onset of drier, hotter weather in June, however, sources of water became limited and remained so until replenished by autumn rains. Of 3,053 southern mule deer observed during the dry months of June–September, 97% occurred within 1 km of free water. The mean distance deer occurred from free water during this dry period was 380 m (Bowyer 1984). Moreover, bucks occurred furthest from free water, followed by male yearlings, does, female yearlings, and fawns (Bowyer 1984).

Preferred Forage

The distribution of southern mule deer was influenced by the availability of preferred foods. Direct observations of 4,960 feeding deer indicated they ingested vegetation with herbaceous stems (grazing) more often than those with woody stems (browsing); < 5% of all deer were observed browsing throughout the study. The importance of palatable forbs, especially *Sisymbrium altissimum,* in the ecology of southern mule deer has been substantiated previously (Bowyer and Bleich 1980, 1984*b*; Bowyer 1984). The influence of *S. altissimum* on the distribution of deer was demonstrated by significant correlations between deer density and the percent cover of this forb in each of the nine vegetative types on East Mesa, and for the eight meadow systems on East Mesa (Bowyer 1984).

DISCUSSION

Southern mule deer avoided dense stands of chaparral during periods of activity and when bedding at midday even when this vegetation was readily available. Perhaps the thick brush made it difficult for deer to elude predators. Fleeing deer never were observed to seek cover in chaparral, even when this habitat was nearby. The extensive use of oaks by alarmed deer, and the preference of bedding deer for this vegetation suggest it provided both concealment and thermal cover.

Taber and Dasmann (1958) reported that the nutritive value of shrubs in old stands of chaparral was low. Nonetheless, mule deer in northern and central California occurred at low densities even in old-growth chaparral (Taber and Dasmann 1958, Biswell 1961). This is one respect in which southern mule deer differ from other California subspecies; their use of chaparral was sporadic at best. Southern mule deer are primarily a species of meadows, oaks and pines; their morphology, including their dark pelage, is adapted to these habitats.

The most efficacious management for southern mule deer must include meadows. Nearly 95% of all active deer were observed in this vegetative type. Levels of cattle stocked on public lands in San Diego County, however, were sufficiently high to nearly eliminate southern mule deer from preferred meadow habitats outside the Park (Bowyer and Bleich 1984*b*). Moreover, heavy cattle grazing reduced the availability of deer grass (Bowyer and Bleich 1984*b*). Deer grass was used extensively by fawns for concealment cover on East Mesa. Salwasser et al. (1978) suggested that an absence of suitable fawning habitat may have increased the mortality rate of neonates in a herd of California mule deer, *O. h. californicus.*

Taber and Dasmann (1958) suggested that Columbian black-tailed deer, *O. h. columbianus,* made greater use of cooler north-facing slopes in summer and shifted their distribution to warmer southerly exposures in winter. Southern mule deer showed no significant differences in their preferences for various slope exposures among seasons. Mackie (1970) reported similar results for Rocky Mountain mule deer, *O. h. hemionus.* The preference of southern mule deer for west-facing slopes probably related to the availability of preferred forbs on westerly exposures on East Mesa.

Manipulation of chaparral has benefited mule deer in central and northern California (Biswell et al. 1952, Taber 1953, Taber and Dasmann 1958). Fire or the mechanical removal of brush produces successional changes that improve deer forage by increasing its protein content; however, such increases are temporary (Dasmann and Dasmann 1963). Modification of chaparral also may enhance habitat for southern mule deer. Bowyer (1981) reported a marked increase in deer harvested in San Diego County following the Laguna fire in 1970.

Nevertheless, the types of manipulation that will benefit southern mule deer may be more restricted than for other deer that occur at greater densities in chaparral.

The proximity of treated areas to other vegetative types preferred by southern mule deer may be a critical factor in determining the response of deer populations to alterations in old-growth chaparral. Short-lived increases in forage quality in areas with few deer will do little to promote population growth. Thus, to be effective, habitat modifications should adjoin meadow, oak, or pine vegetative types that are not heavily stocked with cattle. Further, oaks, which provided cover for bedded deer, were used to escape pursuing predators, and also provided fawning habitat. Acorns were a highly preferred food of these deer (Bowyer and Bleich 1980). The presence of *Quercus kelloggii* or *Q. agrifolia* on or near manipulated areas would improve these localities for southern mule deer.

The size of the opening produced by manipulating brushlands also may affect its use by southern mule deer. Deer made optimum use of areas 41–50 m from cover; they occurred infrequently at great distances from cover, and vast open areas are of little use to this subspecies.

The availability of free water during summer is a major factor regulating the distribution of southern mule deer. Sexual segregation in southern mule deer begins during the fawning season and then wanes with the approach of rut (Bowyer 1984). Bucks occurred predominantly on dry areas with little water, whereas does and fawns were concentrated on ranges with more succulent vegetation and some free water (Bowyer 1984). Areas farther than 1 km from free water received limited summer use by southern mule deer. Further, areas without sources of summer water typically were devoid of fawns (Bowyer 1984). Thus, habitat manipulations greater than 1 km from free water are unlikely to increase populations of southern mule deer. Clearly, an understanding of relationships among vegetation types, the foods and cover such habitats provide, the proximity of summer water, and how deer distribute themselves with respect to these variables is essential to the sound management of this important game species.

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NOTES

INTRASPECIFIC CLEANING BY JUVENILE SALEMA, *XENESTIUS CALIFORNIENSIS* (PISCES: HAEMULIDAE)

The list of California inshore fishes known to engage in cleaning activity (removal of ectoparasites or other deleterious material from the surface of another fish) has grown considerably and now includes the following: six species of embiotocids (Limbaugh 1955, 1961; Gotshall 1967, Hobson 1971, Bray and Ebeling 1975); three species of labrids (Hobson 1971, 1976; Coyer 1980); three species of kyphosids (Hixon 1979, DeMartini and Coyer 1981); and one pomacentrid (Turner, Ebert and Given 1969). This note reports an addition to this list, the salema, *Xenestius californiensis* (family Haemulidae).

The first observation of cleaning was made during the morning of 19 September 1984 at La Jolla Cove, San Diego County. While free-diving in 4 m of water, I noticed a large shoal (*sensu* Pitcher 1983) of juvenile salema (estimated to range in size from 3 to 6 cm) feeding on plankton in the water column. Following several seconds of observation, I noticed a concentration of 5 to 10 individuals in a head down-tail up position, a position adopted by some fishes while soliciting cleaning (Hobson 1971, Losey 1971). These posing individuals appeared paler than surrounding, non-posing individuals. Approximately 30 s subsequent to this observation I noticed a single, non-posing individual "picking" at the ventral surfaces of some of the posing (client) individuals. This activity lasted for approximately 3 min before both cleaner and clients resumed feeding in the water column. Observations made of some 50 cleaning "bouts" (*sensu* Hobson 1971) on 15 subsequent days, between 19 September and 27 November, revealed the following generalizations: i) Juvenile salema in La Jolla Cove appeared in shoals of from 20 to more than 100 individuals. ii) For a given cleaning bout, the number of posing individuals ranged from one to approximately 20, while the number of active cleaners ranged from one to five. On no occasion was a client observed to receive more than two "nips" from a given cleaner. All inspecting and picking was directed toward the ventral and lateral surfaces of the client. iii) Most interactions appeared to be initiated by clients. It was not uncommon for clients to pose for nearly 2 min in the absence of a detectable cleaner. iv) Cleaners did not appear to exhibit any unique morphological or behavioral features which might afford them easy recognition by clients. v) Physical contact of the client by the cleaner only occurred during the actual nip. While clients generally continued to pose after being cleaned, acceleration by the client away from the cleaner following a nip was not infrequent. vi) Interspecific cleaning by salema was not observed, although on several occasions, señorita, *Oxyjulus californica*, were observed cleaning posing salema. Also, on two occasions, giant kelpfish, *Heterostichus rostratus*, were observed to adopt a posing posture among a group of posing salema. These individuals however, were not observed to receive attention from cleaners.

The occurrence of cleaning activity among juvenile salema is not surprising since juveniles of a wide variety of species are known to clean (Randall 1962, Brockman and Hailman 1976, Coyer 1980, DeMartini and Coyer 1981). Furthermore, although the majority of non-habitual cleaners appear to be primarily substrate pickers (Hobson 1971), cleaning has been reported for other midwater planktivores (Turner et al. 1969, Hobson 1969, McCourt and Thomson 1984). The salema's cleaning behavior does seem unique in one respect. Other cleaners usually direct their activities toward heterospecifics and only occasionally clean intraspecifically (Feder 1966, Hobson 1971, 1976, DeMartini and Coyer 1981, McCourt and Thomson 1984). By contrast, cleaning in salema appears to be directed exclusively toward conspecifics. Although known in freshwater species (Wyman and Ward 1973), exclusive intraspecific cleaning has not, to my knowledge, been reported for a marine species.

I observed juvenile salema throughout the summer and fall of 1984 at two locations in the La Jolla area, and only witnessed cleaning activity during periods of good to exceptional visibility (5–15 m, in La Jolla Cove, 19 September to 27 November; water temperatures ranged from 16 to 22°C). During days of good visibility, I also noticed an unusual amount of cleaning activity involving other species; specifically adult *Oxyjulus californica* and juvenile *Hermosilla azurea, Girella nigricans,* and *Medialuna californiensis* were observed cleaning adult topsmelt, *Atherinops affinis.* While I observed shoals of salema during days of limited visibility, cleaning activity was rarely seen and individuals swam in a tightly packed, highly polarized fashion. I attribute this to an increase in the risk of attack by predators since during periods of low visibility it was quite common to see predators such as yellowtail, *Seriola lalandi,* and kelp bass, *Paralabrax clathratus,* attacking foraging groups of salema. Such activity was not observed when visibility was good. Predation risk may also be an important factor in limiting cleaning to conspecific individuals. Leaving the group to clean heterospecifics may increase the cleaner's exposure to predators, and the cleaning activity itself may both increase the cleaner's conspicuousness and reduce its vigilance.

An obvious question of particular ecological interest that arises from the observations presented above is, are ectoparasites present on clients and are they being removed by cleaners? From a sample of 14 fish, a single parasitic copepod, *Peniculus fissipes,* ca. 0.5 cm long, was found imbedded in the caudal peduncle of a 5 cm (standard length) individual captured while posing. Of the remaining 13 sampled fishes, none showed signs of infestation by ectoparasites; however, only one of these was captured while posing (also, the method of capture, using a small hand-spear, may have resulted in the departure of ectoparasites from the struggling host).

Hobson (1971) reported finding *P. fissipes* on several other fish species in the La Jolla area but did not find it among the gut contents of 27 señorita (the most active cleaner in the area) speared while cleaning. Thus, if *P. fissipes* were sufficiently abundant on salema but not removed by señorita, it might be a readily available food source for other cleaners (e.g. conspecifics). While no ectoparasites were found among the gut contents of the individuals examined by me, no known cleaners were among those sampled.

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NEW RECORDS OF THE RAGGED-TOOTH SHARK, *ODONTASPIS FEROX*, FROM CALIFORNIA WATERS

A female ragged-tooth shark, *Odontaspis ferox*, was caught on 3 February 1985 about one km off Newport Beach, Orange County, California, and is deposited in the Natural History Museum of Los Angeles County (LACM 43762-1). A review of museum records and personal field notes revealed that subsequent to the initial report of *Odontaspis* off California by Daugherty (1964), one specimen had been captured and measured in 1979 and an additional specimen had been photographed, measured, and dissected by one of us (LJVC) in 1968.

Data for the three new records are: 1) LACM 43762-1, 280.0 cm total length (TL), 149 kg, female, California, Orange County, about 1 km off Newport Beach, bottom-set gill net, 22 fm, 3 February 1985; 2) LACM uncataloged, 367.0 cm TL, 323 kg (eviscerated), female, California, about 5 km off Santa Barbara Island, bottom-set gill net, 85–110 fm, 8 February 1979; 3) LJVC-0272, 274.6 cm TL, 159 kg, male, California, San Clemente Island, about 2 km off China Point, gill net, 26 November 1968. Measurements for all specimens are given in Table 1.

The first records of *Odontaspis ferox* from California waters were of an unsexed specimen, "perhaps 10 feet long" caught on 2 November 1962 at "about the middle of the north side of San Clemente Island," and a male, 169.3 cm TL, caught on 10 January 1963 about 3.5–6.5 km off of San Onofre (Daugherty 1964). Several authors (Castro 1983, Compagno 1984, Quero 1984) have noted that male *O. ferox* mature at 275 cm TL and females at 360 cm TL; therefore, the 1979 specimen (female) and the 1968 specimen (male) are presumed to be mature adults. The 1985 specimen (female) is probably immature; there were no pups or mature ova observed in the ovaries.

Castro (1983) noted that the diet of *O. ferox* had not been reported. Subsequently, Compagno (1984) and Quero (1984) stated that *O. ferox* feeds on fishes, squids, and crustaceans. Stomach content analyses for two of the three new records revealed that the 1968 specimen was feeding on fishes (teleosts), the 1979 specimen had eaten rockfish (*Sebastes* spp.) and was observed feeding in the net. It was noted that "pieces of an unidentified ray" fell from the mouth of the 1985 specimen while it was being weighed (R. Shelton, pers. comm.).

Daugherty (1964) commented on the color pattern of *O. ferox,* listed the initial California records as "almost uniform light grey above, and slightly lighter below" and noted that "darkening" of the fins was not noticable in these two specimens. However, her Figure 1 clearly shows the darkened edges of all fins in one specimen. Color notes for the 1968 specimen described the color as "grey brown or olive brown dorsally, ventrally fading to cream" with no distinctive markings or spots. A photograph of the 1968 shark, although quite moribund, revealed dark edges on the second dorsal, anal, and caudal fins. The 1979 specimen was described as "uniform grey to light grey," although correspondence written approximately three weeks after the capture of the specimen indicated that the "specimen was mottled and blotched . . ." (R. J. Lavenberg, pers. comm.). Three days after capture the 1985 specimen was dull grey dorsally, fading to white ventrally, the posterior edges of all fins dark. There was also a noticable, dark spot posterior and slightly dorsal to the angle of the mouth (Figure 1). Although no live color observations were made, it is presumed that the large spot on the 1985 specimen and the color pattern noted for the 1979 specimen correspond to the large, dark marks on the back and sides of *O. ferox* as detailed by numerous authors (Daugherty 1964, Garrick 1974, Compagno 1984, Quero 1984).

Based primarily on differences in color, Garrick (1974) recognized the "uniform grey" *Odontaspis,* including the two California specimens reported by Daugherty (1964), as belonging to *O. herbsti,* a name initially used by Whitley (1950) for the Australian *Odontaspis.* We follow more recent authors (Robins et al. 1980; Castro 1983; Eschmeyer, Herald, and Hammann 1983; Compagno 1984; Quero 1984) and recognize the eastern Pacific ragged-tooth shark as *Odontaspis ferox* (Risso, 1810).

TABLE 1. Measurements for Three California Records of *Odontaspis ferox*. Measurements Taken Point-to-Point to Nearest 0.5mm, also Expressed as Percent of Total Length.

	LACM 43762-1	*%TL*	*LACM UNCAT.*	*%TL*	*LJVC 0272*	
TL	2800		3670		2746	
Snout tip to:						
Outer nostril	171	6.1	204	5.5	± 134	4.9
Eye	209	7.5	265	7.2	211	7.7
Spiracle	366	13.1	451	12.3	362	13.2
Mouth	182	6.5	252	6.9	157	5.7
1st gill	556	19.8	712	19.4	562	20.5
2nd gill	603.5	21.5	754	20.5	–	–
3rd gill	652	23.3	840	22.9	–	–
4th gill	695	24.9	915	24.9	–	–
5th gill	739	26.4	931	25.4	732	26.6
1st dorsal origin	926	33.1	1116	30.4	965	35.1
2nd dorsal origin	1,737	62.0	2,335	63.6	1,803	65.6
Anal fin origin	1,937	69.2	2,545	69.3	2,033	74.0
Upper caudal origin	2,105	75.2	2,938	80.0	2,106	76.6
Vent	1,696	60.6	–	–	1,680	61.1
Distance between 1st and 2nd dorsal fins	464	16.6	721	19.6	486	17.7
Mouth width	168	6.0	269	7.3	± 155	5.6
Mouth length	± 190	6.8	331	9.0	± 150	5.5
Height						
1st gill slit	159	5.7	210	5.7	173	6.3
2nd gill slit	166	5.9	212	5.8	–	–
3rd gill slit	167	6.0	225	6.1	–	–
4th gill slit	162	5.8	215	5.8	–	–
5th gill slit	149	5.3	217	5.9	160	5.8
Orbit length	46.5	1.6	47	1.3	43	1.6
Orbit height	33	1.2	55	1.5	36	1.3
1st dorsal fin						
Overall length	407	14.5	539	14.7	420	15.3
Length of base	320	11.4	429	11.7	335	12.2
Height	207	7.4	302	8.2	195	7.1
2nd dorsal fin						
Overall length	276	9.8	364	9.9	274	10.0
Length of base	207.5	7.4	266	7.2	200	7.3
Height	154	5.5	227	6.2	146	5.3
Anal fin						
Overall length	217	7.7	260	7.1	196	7.1
Length of base	170	6.1	182	4.9	141	5.1
Height	170	6.1	209	5.7	138	5.0
Pectoral fin						
Length of base	178	6.3	232	6.3	172	6.2
Anterior margin	385	13.7	504	13.7	370	13.5
Pelvic fin						
Overall length	326	11.6	402	10.9	345	12.6
Length of base	178	6.3	233	6.3	–	–
Clasper						
Outer margin	–	–	–	–	180	6.5
Inner margin	–	–	–	–	± 250	9.1
Caudal fin						
Length dorsal lobe	721	25.7	761	20.7	666	24.2
Length ventral lobe	296.5	10.6	346	9.4	302	11.0
Tip to notch	127	4.5	84.5	2.3	132	4.8
Depth of notch	86	3.0	137	3.7	77	2.8
Trunk @ pectoral origin						
Width	± 260	9.3	350	9.5	± 270	9.8
Height	± 480	17.1	630	17.1	500	18.2

FIGURE 1. *Odontaspis ferox*, LACM 43762-1, 280.0 cm TL, showing large, dark spot posterior and slightly dorsal to the angle of the mouth. Photo by S. Gipson (LACM).

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FIRST RECORD OF THE SPOTTED SCORPIONFISH, *SCORPAENA PLUMIERI,* FROM CALIFORNIA: THE CURTAIN FALLS ON "A COMEDY OF ERRORS."

In a paper with a title that ended in ". . . a comedy of errors," Carl Hubbs (1945) related several misidentifications of specimens of *Scorpaena* from California. He commented on the previous carelessness of ichthyologists in documenting species of *Scorpaena* from California, and exhaustively compared *S. guttata* Girard, 1854 with *S. mystes* Jordan and Starks, *in* Jordan, 1895, the latter usually regarded as a subspecies of *S. plumieri* (Ginsburg 1953, Eschmeyer 1969). Hubbs confirmed that *S. guttata* was the only species known from California. He surmised that the record of a third species, *Scorpaena histrio* Jenyns, 1842, from San Pedro (Evermann and Latimer 1910) was also based on *S. guttata,* subsequently confirmed by examination of specimens (Teresa Greenfield, pers. comm.). On the morning of 13 December 1984, a specimen of spotted scorpionfish, *Scorpaena plumieri,* was taken at Scattergood Steam Generating Plant, Redondo Beach, Los Angeles County, California, during a routine "heat treatment." The specimen, collected by the author, is deposited in the Natural History Museum of Los Angeles County, LACM 43533-1, measured 230 mm SL, 292 mm TL, and weighed 662 g when fresh. It possesses the distinctive black pigment with white spots in the upper two-thirds of the pectoral axil. Other data (following Eschmeyer 1969) are: Dorsal fin XII, 9; anal fin III, 5; pectoral fin 20,20; lower unbranched pectoral rays 10,10; gill rakers 6 + 8 (including rudiments); scales in lateral series 46 (number of pored scales uncertain). The large, squarish occipital pit is 15.8 mm wide and 15.6 mm long. A well-developed triangular pit anteroventrad to and ca. one-third the size of eye. The head and body dark (bluish in life) with faint mottling of lighter colors. Caudal peduncle distinctly lighter than body or tail. Other details of coloration are described by Hubbs (1945), Ginsburg (1953), and Thompson, Findley and Kerstitch (1979).

Scorpaena plumieri superficially resembles *S. guttata*. Five easily observed characters will separate the two taxa (Table 1). The coloration of the pectoral axil is the easiest and best diagnostic character. Differences in pectoral fin size, apparent when compared specimens of the two species, are not reflected in the measurements of the pectoral fin by Ginsburg (1953) and Eschmeyer (1969), i.e. from the base of the first (uppermost) pectoral ray to the (posterior) apex of the fin margin. However, length measured from the base of the last (lowermost) pectoral ray and the length of the pectoral fin base (straight line distance between the bases of the uppermost and lowermost rays) both demonstrate a clear, non-overlapping difference in pectoral fin proportions (Table 1). Several other subtle character differences are given by Hubbs (1945).

TABLE 1. Characters Differentiating *Scorpaena plumieri* from *S. guttata*.* Measurements in Thousandths of Standard Length Following Eschmeyer (1969), but see text.

Character	*plumieri*	*guttata*
Pectoral axil	half or more dusky or black with small white spots and vermiculations	pale with a few dark spots
Pectoral rays	19–20	17–18
Pectoral size	larger, expansive	smaller, narrow
length of fin	433–485	338–378
length of base	178–188	122–137
Eye	small; 076–087	large; 092–098
End of maxilla	to or behind a vertical through posterior margin of eye	distinctly in front of vertical through posterior margin of eye

* *Scorpaena plumieri*, LACM 43533-1 and 32083-6 (4 specimens, 132–230 mm SL); *Scorpaena guttata*, LACM 35685-19 (8 specimens, 115–215 mm SL).

This record extends the range of the species about 740 km northward along the coast. The previous northern record being the vicinity of Sebastian Viscaino Bay, Baja California del Norte. Greenfield (1973) and Thompson et al. (1979) based this on the unpublished checklist of fishes of the Gulf of California by Boyd Walker and Kenneth Norris. Specimens cannot be located to verify this record. Otherwise, the northernmost records on the outer coast of Baja California are from the vicinity of Punta Abreojos (CAS, SIO, and LACM collections).

Scorpaena plumieri occurs southward to Peru in the eastern Pacific Ocean, and is also widespread in the western Atlantic from the southeastern United States to Brazil (Eschmeyer 1969). Atlantic and Pacific populations are very similar morphologically (Ginsburg 1953, Eschmeyer 1965, 1969) and genetically (Vawter, Rosenblatt, and Gorman 1980). They usually have been called subspecies, reflecting their similarity also noted by earlier workers (Jordan and Evermann 1898, Meek and Hildebrand 1928, Hildebrand 1945). Only Hubbs (1945) and Thompson et al. (1979) have recognized them as species among recent authors.

This record coincides with the end of the El Niño event of 1982–83 (Cane 1983, Barber and Chavez 1983) the effects of which extended into 1984 (McGowan 1984). Many such records of southern taxa in California occur during warming events (Hubbs 1948, Radovich 1961, Lea 1985). In the absence of contrary evidence this occurence is considered to be a natural consequence of this most recent and particularly strong El Niño event.

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BIRTH OF A NORTHERN FUR SEAL ON THE MAINLAND CALIFORNIA COAST

The known breeding rookeries of the northern fur seal, *Callorhinus ursinus,* are the Pribilof Islands of Alaska; the Commander Islands, Robben Island, and the Kurile Islands, U.S.S.R.; San Miguel Island, California; and a recently discovered rookery on Bogoslof Island, Alaska (Loughlin, Miller and Goebel 1983). Incidences of pupping away from known rookeries are unusual. Although Fiscus (1978) reports that a northern fur seal was born on the Washington coast in 1959, the birth recorded herein is the first known for the mainland coast of California.

The mother-pup pair (Figure 1) was first observed by members of the Humboldt Wildlife Care Center at approximately 1500 h on 14 July 1983 at College Cove, Trinidad, California (lat 41° 9′ N). Prior to their arrival, a beachcomber reported having seen a placenta-like membrance attached to the pup, suggesting that the birth occurred at College Cove earlier that morning.

FIGURE 1. Female *Callorhinus ursinus* nursing her newborn pup on College Cove Beach, 14 July 1983. Photograph by Warren J. Houck.

The mother appeared to be weak. She was inactive throughout much of the first day, resting on her abdomen with her flippers tucked underneath in a probable heat conserving posture. The pup appeared to be well-coordinated, and actively moved around the mother, vocalizing and nosing various parts of her body apparently searching for a nipple. The mother was unreceptive to the pup's nursing attempts during most of the first day and occasionally responded with open mouth threats and small bites. Suckling was first observed at approximately 2100 h, and bouts became more frequent on the second day. Suckling was always initiated by the pup.

Representatives from the California Marine Mammal Center transported the pair to their facility at Fort Cronkite on the evening of 15 July. The adult female measured 114 cm standard length (SL) and weighed 27.4 kg, within the range of mean weights for post partum females of her size (North Pacific Fur Seal Commission 1969). The mother's condition deteriorated and she died on 22 July. A gross necropsy showed that the female had a number of nonperforating ulcers with bleeding in the stomach and upper duodenum that probably contributed to her depressed condition, lack of appetite and ultimate death (Marc Webber, California Marine Mammal Center, Fort Cronkite, CA., pers. comm.). The female pup measured 76 cm and weighed 3.1 kg, 1.4 kg below the average for a newborn female. The pup was sustained by a bottle feeding until 25 December 1983 when she died of respiratory arrest attributed to a dosage of valium administered prior to a force feeding attempt (Laurie Gage, Marine World Africa U.S.A., Redwood City, CA., pers. comm.).

Pupping of northern fur seals occurs in June and July. Most Pribilof seals leave the rookery islands during October through December and migrate south. Southern limits of migration are about 32° N on both sides of the Pacific (FAO 1979), with animals most abundant thirty to seventy miles offshore (Orr 1972). It is the young seals of both sexes and the adult females that range farthest. Most San Miguel Island seals are thought to move to waters north of Point Conception (lat 34° 27′ N) after the breeding season (Robert DeLong, National Marine Mammal Laboratory, Seattle, WA., pers. comm.).

During their migratory period fur seals rarely come ashore. Sixty-two live fur seal strandings have been recorded along the Pacific coast from 1973–1983. Nineteen, five, and thirty-eight strandings have been reported on the Washington, Oregon, and California coasts respectively (SEAN Bull. 1976–1982; Tag Gornall, Marine Animal Resource Center, Seattle, WA., pers. comm.; Robin Brown, Oregon State University, Marine Science Center, Newport, OR., pers. comm.; John Scholl, California Department of Fish and Game, Long Beach, CA., pers. comm.; Dana Seagers, NMFS, Terminal Island, CA., pers. comm.). Most of the stranded animals were sick or injured.

One hypothesis is that establishment of new breeding areas occur when females, failing to return to their normal pupping areas for various reasons, give birth at new sites. This new location then becomes the natal site for the pups born there. For this reason, it would have been interesting to see if the pup could have been successfully reared on the birth site. However, a high level of both human and dog disturbance on this beach necessitated removal of the seals. Had they survived until weaning, the pair would have been re-released near the birth site.

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SHELL THICKNESS AND ORGANOCHLORINE PESTICIDES IN OSPREY EGGS FROM EAGLE LAKE, CALIFORNIA

It has been reported that osprey, *Pandion haliaetus,* reproduction has been affected by the DDT family of pesticides (Hickey and Anderson 1968, Anderson and Hickey 1972, Garber 1972, Wiemeyer et al. 1975, Henny et al. 1977, Spitzer et al. 1978, Wiemeyer et al. 1978, Ohlendorf 1981). Breeding populations of osprey at Eagle Lake, California have been studied by researchers at Humboldt State University (HSU) and others for several years. Non-viable eggs were collected incidental to banding and other studies by the HSU workers and the U.S. Forest Service (USFS). Osprey eggs, collected in the years 1973–1979, and again in 1983, and 1984 were submitted to the Pesticide Investigations Unit, Environmental Services Branch, of the California Department of Fish and Game (DFG) and subjected to analyses for chlorinated hydrocarbons and eggshell thickness. The results of this informal monitoring program are reported here to provide some data on pesticide residue levels in this California population of osprey.

MATERIALS AND METHODS

Eggs were collected by HSU faculty and students as part of routine osprey studies at Eagle Lake. Eggs were held frozen at HSU by Dr. J. R. Koplin until they were delivered to the DFG Pesticide Investigations Unit. Eight additional eggs were furnished by the USFS. No viable eggs were sampled.

Collection dates for most eggs furnished by Koplin were lost prior to receipt by the DFG. Egg number four was collected in 1977, eggs 15–17 were collected in 1983, and eggs 18–22 were collected in 1984.

Egg contents were partially thawed, removed, weighed, and refrozen before chemical analysis. Contents were placed in chemically clean glass jars. Additional preparation and chemical analysis was conducted by T. Lew, pesticide chemist for the DFG Fish and Wildlife Water Pollution Control Laboratory. One to five g subsamples of egg contents were ground with anhydrous sodium sulfate and blended with two 150 ml portions of petroleum ether. After vacuum filtration, the volumes were adjusted to 250 ml. A 200 ml aliquot was evaporated to dryness to determine the lipid content. The 50 ml aliquot was passed through a florisil column and eluted with 200 ml petroleum ether, 200 ml 6% ethyl ether in petroleum ether, and 200 ml 15% ethyl ether in petroleum ether. Eluates were concentrated to 10 ml, and analyzed with a Varian model 370 gas chromatograph equipped with Ni^{63}-electron capture detector. A fused silica capillary column 30 m long with an inside diameter of 0.25 mm was used. Flow rate was 27 cm/s of nitrogen. The inside of the column was coated with SE-30. Results were confirmed with a second column coated with SE-54. Residue values from intact eggs were adjusted for moisture loss (Stickel, Wiemeyer, and Blus 1973).

Thicknesses of washed and dried eggshells without membranes were measured by a Model 35 PS Federal bench comparator thickness gauge at the Western Foundation of Vertebrate Zoology at Los Angeles by S. Sumida. Membranes were measured and found to average 0.133 mm. Values were combined to compare against normal thickness. Pre-1947 eggshell data (Anderson and Hickey 1972) are used here as the pre-DDT base thickness.

RESULTS AND DISCUSSION

It should be noted all eggs were non-viable. Thus, the sample is possibly biased towards those eggs with higher pesticide loading. Eggshell thickness and embryo development was noted, and DDE residues were determined in the osprey eggs examined (Table 1). Eggs 5, 7, 8, 9, 11, 12, and 21 were not analyzed because they were either cracked or broken, thereby invalidating residue analyses. However, eggshell thickness and embryo development data have been included in Table 1 as these data may still be used. Despite these deficiencies, the data are valuable as an indication that pesticide contamination and eggshell thinning was still occurring to some extent during the 1973–1984 period. Eggs contained residues of pp'DDE, the chemical causing eggshell thinning in many birds (Cooke 1973, Hickey and Anderson 1968). Sixteen of 22 eggshells were below the 0.50 mm normal level for thickness.

Additional chlorinated hydrocarbons were detected (Table 2). pp'DDD, pp'DDT, pp'DDMU, pp'DDMS, HCB, BHC, trans-nonachlor, cis-chlordane, chlorbenside, heptachlor epoxide, dieldrin, PCB-1260, and oxychlordane were all present at low levels. PP'DDD was found up to 2.9 ppm. All other compounds were found in less than 1 ppm levels. These levels are not considered deleterious.

Additional file data are available from two earlier studies (DFG unpublished laboratory reports, 1971, 1974). In these, whole egg contents were analyzed for pp'DDT and related metabolites and PCB (Table 3). No eggshell thicknesses were determined. Levels of pp'DDE are similar to those found in the period 1973–1985.

TABLE 1. Pesticide Content and Eggshell Thickness of Osprey Eggs from Eagle Lake, California, 1973–1984. A Dash Indicates No Analysis Conducted.

Egg Number	*Eggshell thickness (Normal = .50mm)*	*pp'DDE (ppm wet wt. corrected for moisture loss)*	*pp'DDE (ppm lipid basis)*	*Embryo development*[1]
1	.42	6.1	174	N
2	.42	7.6	153	N
3	.42	4.0	134	¾
4	.48	1.9	66	N
5	.52	–	–	N
6	.53	3.5	86	N
7	.46	–	–	N
8	.46	–	–	N
9	.48	–	–	¾
10	.48	1.7	93	¾
11	.48	–	–	¾
12	.50	–	–	N
13	.47	10	395	¾
14	.48	22	509	N
15	.48	0.82	37	N
16	.46	1.5	35	N
17	.50	2.9	36	N
18	.50	4.23	109	N
19	.55	1.58	50	N
20	.49	5.92	149	N
21	.47	–	–	¾
22	.47	3.77	96	N

[1] No development = N; three-quarters through term = ¾.

TABLE 2. Organochlorine Pesticide and Metabolite Residue Levels in Osprey Eggs, 1973–1984. Values in ppm Wet Weight Corrected for Moisture Loss. A Dash Indicates No Chemical Detected. Eggs 18–22 Were Run Only For DDT-R and PCB.

Residue	*Detection limit*	*Egg Number* 1	2	3	4	6	10	13	14	15	16	17	18	19	20	22
%lipid	–	3.5	5.0	3.2	2.9	4.0	1.8	2.6	4.3	2.2	4.3	8.1	4.3	3.4	6.3	5.3
pp'DDE	0.005	6.1	7.6	4.0	1.9	3.5	1.7	10	22	0.82	1.5	2.9	4.2	1.6	5.9	3.8
pp'DDD	0.010	1.0	0.64	0.37	0.47	0.45	0.37	2.7	2.9	0.047	0.23	0.13	0.46	0.078	0.11	0.57
pp'DDT	0.010	0.12	0.09	0.019	–	–	–	–	0.13	–	–	–	0.022	0.013	–	–
pp'DDMU	0.010	0.022	0.016	0.011	–	0.014	0.017	0.09	0.16	0.014	0.017	0.017	0.01	–	0.048	0.051
pp'DDMS	–	–	–	–	–	–	–	–	–	–	–	–	0.030	–	–	
HCB	0.001	–	–	–	–	0.002	0.001	–	–	–	–	–				
BHC	0.010	–	–	–	0.084	0.025	0.049	0.010	0.22	–	–	–				
Trans-nonachlor	0.003	–	–	–	–	0.004	–	–	0.006	0.0044	–	0.003				
cis-chlordane	0.004	–	–	–	–	–	0.0043	0.004	0.01							
heptachlor epoxide	0.003	–	–	–	–	0.007	–	–	0.004	0.003	–	0.003				
dieldrin	0.005	–	–	–	–	0.07	–	–	0.018	0.0059	–	–				
PCB-1260	0.05	0.38	0.44	0.24	0.55	0.45	0.22	0.36	0.17	0.48	0.29	0.88	0.58	0.40	5.3	0.52
oxychlordane	0.001	–	–	–						0.003	0.0012	0.006				

The osprey population at Eagle Lake appears to be stable at the present time. Reproduction appears to be equal to or slightly greater than mortality (D. Airola, U.S. Forest Service, pers. comm.; Henny *et al.* 1978). The adverse effects of DDE eggshell thinning are not apparently a major mortality factor at this time. Monitoring will continue so that we may determine if DDT and related compounds are no longer a threat to osprey reproduction.

TABLE 3. DDT and Metabolites and PCB Content in Osprey Eggs From Eagle Lake, California, 1971 and 1972. Values in ppm Wet Weight. E.P. No. 840 Corrected For Moisture Loss.

E.P. No.	*pp'DDE*	*pp'DDD*	*pp'DDT*	*op DDT*	*PCB (as 1254)*
720-2	2.18	N.D.[1]	0.38	N.D.	–[2]
720-3	3.59	1.94	0.98	N.D.	–
720-4	1.13	1.40	0.98	N.D.	–
840-1	4.7	0.7	0.07	–	1.8
840-2	9.6	2.8	0.04	–	5.4
840-3	7.8	3.3	0.1	–	5.7

[1] N.D. = Non detected, detection limit 0.01
[2] = No analysis conducted

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JUVENILE BLUE CATFISH IN THE SACRAMENTO-SAN JOAQUIN DELTA OF CALIFORNIA

Juvenile blue catfish, *Ictalurus furcatus* (LeSueur), were collected at the John E. Skinner Delta Fish Protective Facility near Byron, Contra Costa County, California. This facility is located at the head of the California Aqueduct which pumps water from the Sacramento-San Joaquin Delta via Old River.

Three specimens were collected between 24 September and 3 October 1984. A fourth specimen was collected on 19 July 1985. Anal fin ray counts were made for each fish, as well as standard and fork lengths and wet weight (preserved) measurements (Table 1).

TABLE 1. Anal Fin Ray Counts, Standard and Fork Lengths and Wet Weights of Blue Catfish Collected at the Delta Fish Protective Facility at Byron, California.

Date Collected	*Anal ray count*	*Standard length (mm)*	*Fork length (mm)*	*Wet weight (g)*
24 September 1984	31	141	151	37.0
2 October 1984	35	92	98	9.5
3 October 1984	31	78	82	5.8
19 July 1985	32	152	168	51.2

Taylor (1980) reported the first catch of a blue catfish, an adult female in the Sacramento-San Joaquin Delta. However, this is the first recorded occurrence for juvenile blue catfish in public waters of northern California.

Dr. Peter Moyle, University of California, Davis, identified three of the specimens based on anal fin ray counts greater than 30, a straight distal margin of the anal fin, deeply forked tail, and lack of spots on the body. I identified the fourth specimen using characteristics given by Moyle (1976) and Trautman (1957).

The specimens identified by Moyle were deposited with the University of California, Davis, Division of Wildlife and Fisheries Biology (Catalog Number 129-06-02).

Blue catfish are found in rivers, including the main channels of the Mississippi River, from Minnesota and Ohio, southward into Mexico (Pelzman 1971). They were first introduced into California by the Department of Fish and Game in October 1969 at Lake Jennings, San Diego County (Richardson et al. 1970), and since then have been introduced into Lake Mathews, Sutherlund Reservoir, El Capitan Reservoir, San Vincente Reservoir and the Santee Lake chain, San Diego County (Moyle 1976).

As speculated by Taylor (1980), a possible source of blue catfish in the Delta are the more than a dozen registered aquaculturists authorized to rear this species in the area. The relative small size and apparent earlier sighting of the blue catfish at the fish facility, however, suggest that natural reproduction may be occurring in the Delta.

ACKNOWLEDGMENTS

I wish to thank P. B. Moyle for verifying the identification of the specimens.

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—*Paul F. Raquel, Bay-Delta Fishery Project, California Department of Fish and Game, 4001 North Wilson Way, Stockton, CA 95205.* *Accepted for publication January 1986.*

AN ADDITION TO THE KNOWN RANGE OF STEPHENS' KANGAROO RAT, *DIPODOMYS STEPHENSI*, IN SAN DIEGO COUNTY, CALIFORNIA

The Stephens' kangaroo rat, *Dipodomys stephensi,* currently is listed as Threatened by the California Fish and Game Commission and is known only from a limited range in northern San Diego County, western Riverside County, and southwestern San Bernardino County, California (Bleich 1977). Recently, *D. stephensi* was believed to have been taken from Warner Springs (APEC 1981). In 1983, while performing a focused constraint analysis for a proposed solar energy development, we positively confirmed the existence of *D. stephensi* in the same valley. A single specimen identified as *D. stephensi* was located in the Museum of Vertebrate Zoology, University of California, Berkeley; the animal was collected 7 February 1922 at Warner's, San Diego Co., but has been previously unreported in the literature. Studies are underway to assess the impact of solar development on the species. These offer a preliminary evaluation of the distribution within the valley.

The current distribution of *D. stephensi* including that of the present report is known (Figure 1). The unnamed valley in question lies at the southeastern base of the Palomar Mountains (T10S, T11S and R2E, R3E, SBBM) and is comprised of the San Jose del Valle and the Valle de San Jose Mexican land grants. These land grants form the Warner Ranch which is administered by Vista Irrigation District. The occurrence of *D. stephensi* in this valley adds to the known range, the nearest point of which is approximately 42 airline km over chaparral- and forest-covered mountains.

The topography of the valley consists of rolling grassland from the eastern shore of Lake Henshaw to the oak woodland, chaparral, or coastal sage scrub of the foothills around the fringe of the valley (835 to 975 m elevation). The San Luis Rey River, Agua Caliente Creek, and Buena Vista Creek cross the valley, yielding riparian, marsh, and salt grass-rush vegetation associations. The grassland changes composition from predominantly annual species in the southwestern half of the valley, grading into primarily perennial species in the northeastern portion. Dominant annual species consists of wild oat, *Avena fatua;* brome grass, *Bromus* spp.; dove weed, *Eremocarpus setigerus;* filaree, *Erodium* spp.; and vinegar weed, *Trichostema lanceolatum.* Dominant perennial species are triple-awned grass, *Aristida* sp., and dropseed, *Sporobolus airoides.* Most of the grassland is used for cattle grazing, although there are scattered portions in active agriculture, mainly alfalfa and potatoes.

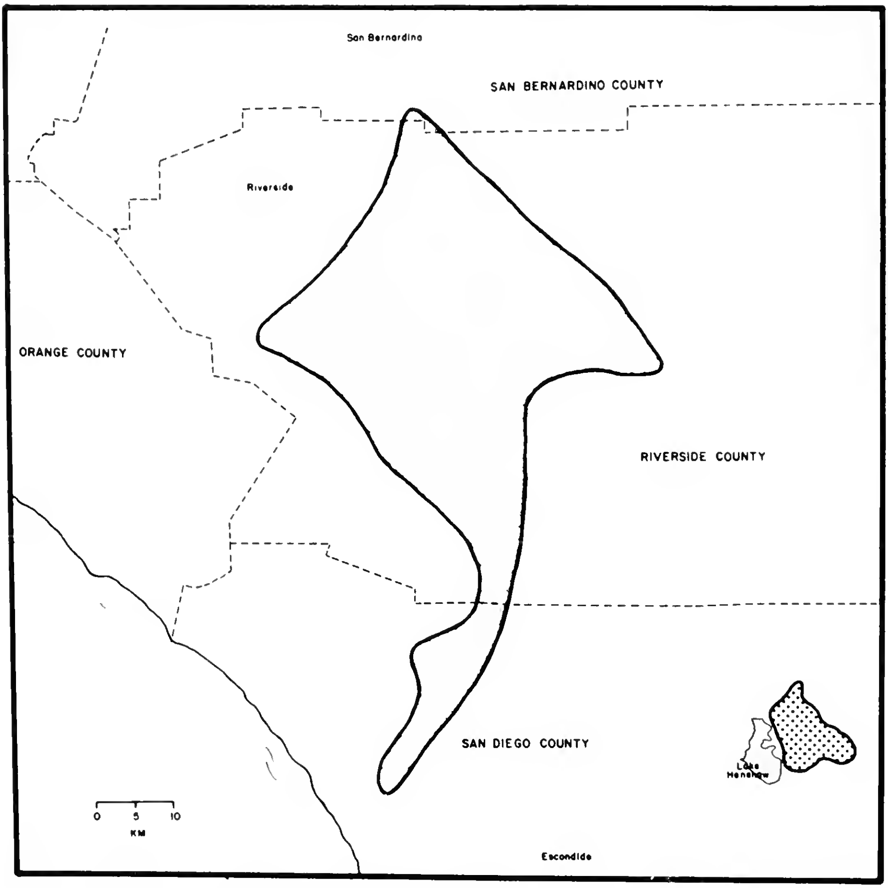

FIGURE 1. The known range of the Stephens' kangaroo rat, *Dipodomys stephensi* (Thomas 1973) shown in crosshatch and the new location shown by stipling.

The Stephens' kangaroo rat is distributed throughout the grassland, but is absent from the drainages, shrublands, and agricultural areas. Relative abundance within the grassland, based upon counts of active burrows, is patchy, ranging from 8/1000 m^2 to 94/1000 m^2. This is not to imply one kangaroo rat per one burrow, but rather is a crude index of potential population size. Studies in progress are attempting to determine the habitat factors which limit the species' abundance and distribution. Preliminary results indicate *D. stephensi* avoids soils high in clay content. Abundance appears to be inversely related to vegetative ground cover and standing litter height, and appears to be greater when there is a greater contribution of *Erodium* and *Eremocarpus* as opposed to annual grasses.

Thomas (1973) presented estimates of the quantity of suitable habitat at 16 locations. Areas ranged from 0.4 to 40.5 ha but only 3 sites exceeded 15 ha. He further reported that only 3 previously known sites were still extant. Extirpation was attributed to urban development with recreation and agriculture as secondary factors. Using information presented by Bleich (1973) we estimate roughly

2000 ha of potential habitat at the Fallbrook Naval Weapons Annex. We examined the main site on the Santa Rosa Plateau reported by Bontrager (1973) and found no remaining kangaroo rat habitat because of recent housing and pasture development. Our location consists of about 5100 ha of suitable habitat known to harbor the species. The Lake Henshaw population of Stephens' kangaroo rat represents a major addition to the known boundaries and abundance of the species.

It is evident that *D. stephensi* is only patchily distributed within the relatively narrow geographic confines in areas where it occurs (Figure 1). Part of this is due to the patchy distribution of suitable habitat and part is due to habitat alteration or destruction. The former possible connections between these disjunct populations are currently occupied with urban and agricultural development. Although new locations may be found, the number of extirpations due to human encroachment speaks eloquently for the need to protect the remaining populations of this species.

ACKNOWLEDGMENTS

We wish to thank J. C. Fisher, Jr. for his botanical expertise and field assistance. P. Dory of Vista Irrigation District kindly granted access to the Warner Ranch properties. J. L. Patton provided the information on the museum specimen. R. Friesen reviewed the manuscript. T. B. O'Farrell prepared the range map. The field effort was supported by LaJet Energy Company. Permission to capture Stephens' kangaroo rats was granted by the California Department of Fish and Game.

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BOOK REVIEWS

The Printer's Catch

An Artist's Guide to Pacific Coast Edible Marine Animals By Christopher M. Dewees. Sea Challengers, Monterey. 128 p. $26.95.

Gyotaku, the Japanese technique of fish rubbing, was utilized at first as a record of an individual catch. This method can yield exquisite detail of a fish that can often be used to identify it to species. It did not take the artistic Japanese long to see the intrinsic beauty of the print, thus a new art form was born. "The Printer's Catch: An Artist's Guide to Pacific Coast Edible Marine Animals" is about gyotaku, but it is also more. The author has presented 63 of his prints, including more than 53 fishes, and 10 invertebrates important along the Pacific Coast. There is information on the life history, the fishery and consumer use of these marine animals. For the readers who have been inspired to make their own prints, there is a description of the techniques and materials needed to assist the reader in producing his or her own prints. The author thoughtfully includes sources for materials used in gyotaku, and a glossary of some of the fishery terms used in the text.

It was difficult for me to pigeon-hole this book, as it attempts to address several purposes, some of which are carried out better than others. The strength of "A Printer's Catch" is the author's prints, many of which are presented in multiple colors. I spent quite a long time examining the plates and was thoroughly amazed at the detail that can be captured in the gyotaku process. I was especially impressed with the prints of the invertebrates, particularly the abalone, the squid and the octopus.

The author states he has ". . . found that people who enjoy fish prints ("gyotaku") want to know more about the fish." It is commendable that the author should want to inform and educate the reader, but the same careful attention he gave to the prints is lacking in the text. Throughout the text there are inaccuracies in the information presented, inconsistencies and incomplete descriptions of fisheries. For instance, in the description of the scallops (which, together with the oysters comes before a heading of Class Bivalvia, the class to which the scallops and oysters belong) the rock scallop is listed as being harvested by ". . . commercial abalone pickers . . .". This scallop is not a commercial species, and commercial abalone fishermen are not permitted to take other species with abalone. In the section on the flatfishes a discussion of right-eyed and left-eyed flatfishes, notes that some individuals of the right-eyed flatfishes may have their eyes on the left side, but does not note that the California halibut is almost equally right- and left-eyed, a point that could cause confusion. In the description of the Family Sciaenidae, drums (usually called croakers on the Pacific Coast), the common name of the white seabass is given in the correct form as well as the incorrect (white sea bass) form.

These are only a few of the errors which appear in the book. There are more than a few typographical errors to be found as well. It is apparent that the editing of this work was quite cursory, and that lack does significant damage to the author's credibility.

My last comment deals with the quality of the printing of the text. It appears as if two different type styles, a regular and a bold, were used randomly in the printing of the text. This book is the worst example of printing I have seen. I often found myself trying to determine why a part was being emphasized with bold type before I realized the problem. Unfortunately, the problem was not just an isolated case, as it appeared in every copy of the book I examined.

The scientific and educational value of this book is limited by the errors in the text and the poor editing. The fish prints should be the only reason for anyone to purchase this work, and at that the $26.95 price is high.—*Peter L. Haaker*

The Ecological Web More on the Distribution and Abundance of Animals

By H. G. Andrewartha and L. C. Birch, University of Chicago Press, 1985. xiv, 506 p. Illustrated, cloth, $35.00.

This book follows by 30 years the authors' earlier classic, "The Distribution and Abundance of Animals." In that book, theory rested largely on empirical studies. However, the authors hope that their new book, with its emphasis on theory, will be accepted as a new contribution to population ecology. The theory presented is amply illuminated by copious empirical studies from the population literature.

The book is divided into three sections. In Part I, the theory of the environment is developed. In their environmental model, mates, predators, resources and malentities comprise "the centrum" of components that acts directly on the organism, whereas components which indirectly affect the organism comprise "the web". For example, in their rabbit population model, rainfall is a web component that affects the centrum resource, food. The authors use envirograms to identify the relationships of environmental components in the centrum and web for each population highlighted in the book.

In my opinion, envirograms could be a useful conceptual tool for conservation biologists to use in defining a problem, developing a hypothesis or describing a population and its environment.

Populations of European rabbit, spruce budworm, African buffalo and Queensland fruitfly are used to illustrate the application of envirograms to the theory of environment. Chapters in this section are devoted to each major component of the centrum; resources, mates, predators and malentities. In particular, the discussion of extrinsic and intrinsic food shortages is of interest to biologists concerned with population and food supply interactions.

In Part 2, "The General Theory of Population Ecology," the concept of population is defined, population measurement techniques briefly discussed, and the concept of multipartite populations or local populations patchily distributed in a heterogeneous environment is described. This multipartite population distribution spreads the risk of extinction. While local populations may go extinct, others survive to disperse and recolonize. Multipartite populations can also spread the risk in evolution by maintaining genetic diversity and adaptiveness.

In Part 3, "Population Ecology As It Is Practiced," the ecologies of European rabbit, black backed magpie and gray teal, all Australian populations, are described in great detail. These life history investigations were based largely on the theory of environment proposed by the authors. They believe that this approach resulted in comprehensive and satisfying understandings of the studied populations. In contrast, the authors, in a very brief section, were critical of fisheries research on oceanic fish populations. In their opinion, oceanic fishery models neglect components of the environment other than the fishery. The authors state, "We know of no single species of fish in the oceans for which information is available to construct an envirogram with any degree of completeness." Unfortunately, the briefness of their discussion perhaps does injustice to work in this area.

Finally, the authors devote 22 pages to describing *Homo sapiens* in terms of their theory of environment and population. There was little that was new here. Humanity now creates most of its own malentities that jeopardize its future survival, e.g., nuclear weaponry, stress, pollution. The human future centers largely on whether these malentities can be controlled and whether resources can be managed so as to avoid either intrinsic or extrinsic shortages of food and water as the population of *Homo sapiens* continues in an outbreak mode.

This is a book which every serious minded ecologist and conservation biologist will want to own and use. The treatment is rigorous and the empirical life history and case history literature drawn from many disciplines in biology is fascinating reading.—*Lee W. Miller*

A Natural History Notebook of North American Animals.

Illustrated by Charles Douglas; National Museum of Natural Sciences, Canada, published and distributed by Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632; 1985; 160 p. $11.95

This beautifully illustrated notebook is one in a series of volumes that the publisher touts as being specifically designed for the amateur naturalist. This volume hits the mark and goes beyond. It contains short, concise descriptions of animals that once lived in North America as well as present day inhabitants. While admittedly brief, these descriptions will effectively whet the appetite of most amateur naturalists to further pursue their avocation. The bibliography or selected reading list will guide these pursuits while avoiding being too technical.

The descriptions of animals of the past include the giant beaver which became extinct about 10,000 years ago. Estimates are that it reached lengths of over 8 feet and weighed up to an incredible 480 pounds, over 10 times the weight of the average present day beaver. Discussions of the massive blue whale on down to the homely star-nosed mole will provide entertaining and informative reading. Over 30 species of the past and 121 present day species are illustrated and described in this work.

This notebook could serve legitimately as something other than a reference for present day amateur naturalists. The simple and interesting nature of the book could also serve as a teaching aid for grade school and high school teachers. This notebook is just the kind of book that many current professional biologists read during their grade school days that helped kindle their desire to pursue their current careers. Potential future professional and amateur naturalists will both benefit from this book. In addition, this notebook may dovetail into a formal teaching program such as California Department of Fish and Game's "Project Wild".—*Frank Wernette*

Fishery Management

By J.L. McHugh; Volume 10, Lecture Notes on Coastal and Estuarine Studies; Springer-Verlog. New York Inc., 1984, 205 p. $15; (paper bound)

The author describes his reasons for publishing another book on fisheries management in the preface. His primary reason is "no adequate broad treatment of the sociopolitical aspects of fishery management has yet appeared". In keeping with that purpose about half of the book is case histories of interstate and international efforts to manage fishery resources, primarily through the regulation of commercial fisheries. The remainder of the book consists of a brief overview of fishery biology in a chapter entitled, "Marine Fishery Research"; case histories of selected fisheries; a "Fishery Oceanography" chapter, which is largely a discussion of biological consequences of environmental variability; and an overview of fishery economics. The author does a good job of presenting an overview of his thoughts on fishery management in the introduction and summary chapters.

I found the primary value of the book to be the overview of interstate and international management programs. These, however included little on the role of marine recreational fishing and only scattered references to the consequences of the management changes resulting from the Fishery Conservation and Management Act of 1976.

The book's value as a reference document is diminished by the fact that sources are often not cited, so one would be forced to consult the list of references at the end of each chapter to document facts. Perhaps of most concern in this regard is the uncertainty it creates as to when the author is summarizing conclusions of other authors and when he is stating his own conclusions. Often the supporting evidence is not cited. Two examples are a rather broad condemnation of hatcheries for sockeye salmon (p 119 3rd paragraph) and praise for spawning channels (p 122, last paragraph).—*Harold K. Chadwick*

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