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IDENTIFICATION OF SAN JOAQUIN KIT FOX (*VULPES MACROTIS MUTICA*) TRACKS ON ALUMINUM TRACKING PLATES

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We prepared a guide for identifying San Joaquin kit fox tracks from sooted aluminum track plates and differentiating them from those of red fox, gray fox, and domestic house cat. Tracks were collected, measured, and compared from aluminum track station studies conducted throughout California. Tracks left on a hard aluminum surface are smaller and easier to identify because they are more detailed than those left in softer media such as snow, sand, mud, or soft dirt. Standard field guides present only dimensions of tracks found in these natural media and are inadequate for accurate identification, particularly when differences in size and shape of closely-related species are small. A new method of preparing aluminum track stations for collecting tracks, using carpenter's chalk, is also presented.

INTRODUCTION

Hard-surfaced track stations sooted with a kerosene flame were first used to investigate the activity patterns and home ranges of small mammal populations (Mayer 1957, Justice 1961). Barrett (1983) modified this technique using aluminum tracking plates to investigate the distribution of larger mammals. Tracks left on a hard surface are smaller and more detailed than those left in softer media, such as snow, sand, mud, or soft dirt. Standard field guides (e.g., Murie 1954) present only dimensions of tracks found in these natural media and are inadequate for accurate identification, particularly when differences in size and shape of closely-related species are small.

The San Joaquin kit fox (*Vulpes macrotis mutica*), a species state-listed as threatened and federally-listed as endangered, inhabits the Central Valley of California and is the subject of much investigation because of conflict between development and preservation of kit fox habitat. Sooted aluminum track plates are used frequently to document kit fox presence because they give more detail than soft tracking media and enable tracks to be lifted off the plate and preserved using transparent tape.

Even with aluminum track plates, however, differentiating kit foxes from other small carnivores can be difficult. Tracks of three other species encountered in the Central Valley of California can be confused with those of the San Joaquin kit fox. These species are the introduced red fox (*Vulpes vulpes*), the gray fox (*Urocyon cinereoargenteus*), and the domestic house cat. The habitats occupied by these four species overlap considerably.

This paper was prepared to provide a means of distinguishing these tracks. Our approach focused more on form, appearance, and other characteristics of typical tracks than on actual measurements because measurements overlap among these species. Although most of these characteristics generally are true, they are not absolute; therefore, an accurate identification is based more reliably on a combination of characteristics. On the following pages, we have described species-specific characteristics which, if they are clearly imprinted on the tracking medium, can be used to differentiate tracks. We then discuss problems and potential sources of confusion. Finally, we have presented a simple schematic to help identify a good, clear track quickly.

We refer the reader to a paper by Taylor and Raphael (1988) on tracks of medium- and large-sized mammals identified from sooted aluminum track stations in the Pacific Northwest. Of tracks most likely to be confused with kit fox, only the gray fox was included in their paper. Characteristics of the tracks of several other species found within the kit fox's range were presented, including American badger (*Taxidea taxus*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), and ground squirrels and other small mammals.

METHODS

Between 1988 and 1991, we collected animal tracks during studies conducted throughout California. We used the most widely-accepted method: aluminum track plates (914 mm x 914 mm x .08 mm) coated with soot from a kerosene flame. Plates were baited with cat food and commercial scent lures were placed on nearby fence posts as an additional attractant. Tracks were lifted from the track plates with wide strips of transparent adhesive tape, which were then placed on white paper. We did not differentiate tracks of the front feet from tracks of the hind feet because intraspecific differences in the size and shape of front and hind feet are small and we did not feel the reader would benefit from these distinctions. Moreover, our stations often did not show both front and hind tracks, so these distinctions were rarely beneficial for identifying species.

We measured the width and length of each track and computed the mean and standard deviation of the measurement for each species (Fig. 1). We then created composite illustrations showing typical diagnostic characteristics and included these along with actual examples of tracks lifted from aluminum track plates (Figs. 2-5).

There are some new methods for collecting animal tracks, one of which we are publishing here for the first time. This method was developed by Dr. Gary Fellers, a research biologist at Point Reyes National Seashore, and employs carpenter's chalk instead of soot as the tracking medium. We began experimenting with this technique in 1992. We applied chalk to track plates in a thin, even layer using isopropyl alcohol as a dispersant, sprayed through a small garden-type mist sprayer. The chalk was mixed with alcohol in a ratio of two parts chalk to three parts alcohol. We found that tracks obtained from this medium were almost as detailed as those from soot. Carpenter's chalk was much easier to apply and remove, could be reapplied easily in

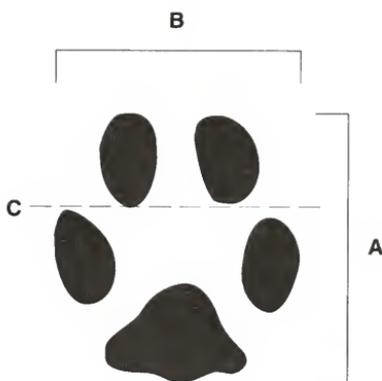


Figure 1. Standard measurement taken on all distinct tracks included:

- A** Length (longest vertical distance from edge of foremost toe to back edge of palm pad);
- B** Width (horizontal distance measuring widest spread of toes);
- C** Straight line drawn between anterior and posterior toe pads.

the field, and did not present a fire hazard. Unlike soot, chalk was easily removed from plates with a dry cloth and did not require regular scrubbing with toxic aluminum jelly; water was sufficient to keep plates clean. We rinsed the sprayer thoroughly each day because the nozzle clogged readily. Other tracking media used in the past, such as ink (Lord et al. 1970) and liquid talc (Brown 1969), proved more difficult to remove than soot.

Another new technique for acquiring tracks has recently been published by Golightly and Fowler (1991). An animal enters a "cubby" box (3 ft long x 1 ft square) and walks on an aluminum plate coated with tracking medium (either soot or chalk) and a piece of contact paper placed sticky side up. The animal picks up tracking medium on its feet at the front of the box and leaves its tracks on the contact paper as it continues into the box toward the bait. This technique produces a detailed "positive" of the track on the contact paper, whereas the track plates produce a "negative" that, typically, is less detailed. Kit fox tracks look quite different on contact paper, however, than they do on track plates. This paper does not address these differences and our discussion here should not be used to try to identify kit fox tracks from contact paper prints.

RESULTS AND DISCUSSION

In general, physical differences in size, shape, and characteristics of each animal's foot were apparent in the tracks we examined. There were, however, some points of confusion, including size-range overlap. These are discussed below.

The tracks of the San Joaquin kit fox usually were smaller than those of the other

San Joaquin kit fox



2a



2b



2c

Gray fox



3a



3b



3c

Figure 2a. Composite illustration showing typical characteristics of San Joaquin kit fox tracks.

2b, 2c. Field examples (actual size).

Figure 3a. Composite illustration showing typical characteristics of gray fox tracks.

3b, 3c. Field examples (actual size).

Red fox



Figure 4a. Composite illustration showing typical characteristics of red fox tracks.

4b, 4c. Field examples (actual size).

Domestic cat

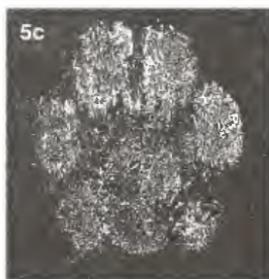


Figure 5a. Composite illustration showing typical characteristics of domestic cat tracks.

5b, 5c. Field examples (actual size).

three fox species. We measured tracks ($n = 21$) ranging from 28 to 34 mm ($\bar{x} = 31$, $SD = 1.45$) in length and 22 to 31 mm ($\bar{x} = 26$, $SD = 2.37$) in width. Kit foxes have well-furred feet which gave the track, especially the palm pad, a fuzzy, indistinct appearance (Fig. 2). The front of the palm pad usually extended to or beyond the back of the posterior toe pads, and the front of the posterior toe pads often extended beyond the back of the anterior toe pads. Most of the time, a straight line drawn between the anterior and posterior toe pads passed through both sets of pads (Fig. 1). Toe pads were somewhat elongated with a pointed tip. The palm pad was triangular to round and was usually slightly larger than an individual toe pad.

Kit fox tracks were more compact than either red or gray fox tracks. We refer to the relative front-to-back spread of anterior toe pads, posterior toe pads, and palm pads as *vertical compression*. As species size increased, vertical compression decreased. Among these three fox species, the most vertical compression occurred in kit foxes; the most spread occurred in red foxes.

Gray fox tracks were larger than those of kit foxes, but there was some size overlap. We measured tracks ($n = 30$) ranging from 33 to 43 mm ($\bar{x} = 37.9$, $SD = 2.56$) in length and 28 to 38 mm ($\bar{x} = 32.7$, $SD = 2.61$) in width. One of the most useful diagnostic features of the gray fox track was the lobed posterior border of the palm pad; unfortunately, this was not always visible (see Problems and Sources of Confusion, below). Gray fox tracks showed less vertical compression than kit fox tracks; the front of the palm pad rarely extended beyond the back of the posterior toe pads, and the front of the posterior toe pads rarely extended beyond the back of the anterior toe pads (Fig. 3). Most of the time, a straight line drawn between anterior and posterior toe pads did not pass through any of the pads (Fig. 1). Gray fox toe pads were more rounded than those of kit or red foxes and, because their feet are not heavily furred, their tracks were more distinct. The palm pad was about twice the size of an individual toe pad, i.e., roughly two toe pads would fit into the palm pad.

Red fox tracks were the largest of the three fox species. We measured tracks ($n = 18$) ranging in size from 40 to 56 mm ($\bar{x} = 47.4$, $SD = 5.8$) in length and 33 to 47 mm ($\bar{x} = 39.4$, $SD = 4.2$) in width. The most revealing diagnostic feature of red fox tracks was a ridge across the palm pad (Fig. 4). Red fox tracks showed the least vertical compression of the four species. The front of the palm pad rarely reached the back of the posterior toe pads, and the front of the posterior toe pads was usually well below the back of the anterior toe pads. The imprint of the toe pads was highly variable. Because the red fox foot is well furred, there was frequently only a small toe pad imprint. Regardless of its size, however, the toe pad imprint was smaller relative to the rest of the track than in either gray or kit fox tracks. Toes appeared more splayed and toe pads more pointed than those of the gray fox. Because of the variability in toe pad size, one to three toe pads, usually two, would fit into the palm pad.

In general, the three foxes can be differentiated from domestic cats by examining the shape of the track and the relative palm pad size. Canid feet are typically slightly compressed laterally giving their tracks an oval shape, whereas cat tracks are more round. Felid palm pads are usually much larger relative to each toe pad than are canid palm pads. Almost three toe pads would fit into the palm pad of a domestic cat, but

usually only one or two would fit into the palm pad of a fox.

Domestic house cat tracks were similar in size to those of kit foxes, but the tracks we measured were highly variable. Measured tracks ($n = 24$) ranged from 24 to 32 mm ($\bar{x} = 28.9$, $SD = 2.06$) in length and 22 to 34 mm ($\bar{x} = 28.6$, $SD = 3.19$) in width (Fig. 5). Domestic cat palm pads had three lobes on the posterior border and either one or two lobes on the anterior. The foot is not well furred so the lobes of the palm pad were usually distinct, as were the toe pads. Vertical compression of toe and palm pads was highest in this species. The anterior portion of the palm pad often extended to a point halfway through the posterior toe pads, and the posterior toe pads often extended almost halfway through the anterior toe pads. Usually, toe pads were slightly oval or round.

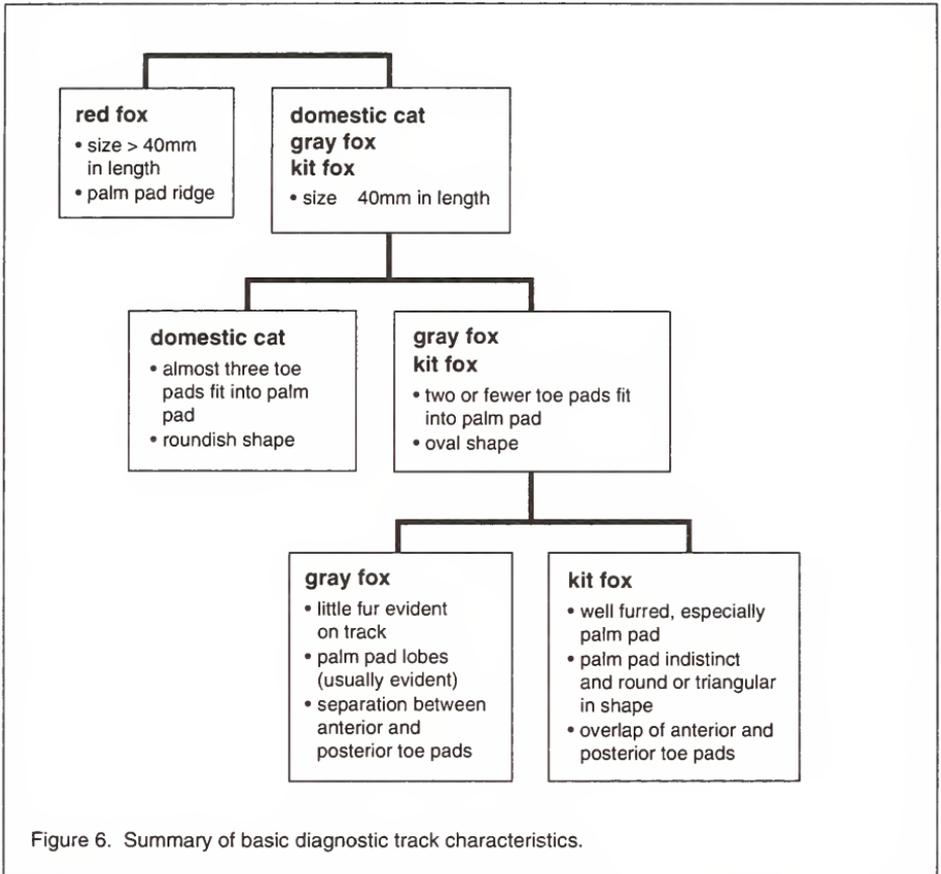
Problems and Sources of Confusion

As many canids may be hesitant when stepping onto aluminum plates, the prints may be indistinct or blurred. A print from an animal that stepped lightly onto the plate and then backed away will probably be difficult to identify. Kit foxes vary greatly in their response to track plates. Some individuals are wary while others have no hesitation, leaving multiple tracks on plates. Cats appear to have no hesitation about the plate, usually placing their full weight on the medium and creating clear, distinct prints.

Size-range overlap among tracks of different species could cause confusion. Although kit fox tracks would seldom be mistaken for red fox tracks, they could be confused with those of a gray fox, particularly a young one. Shape could also cause confusion because some kit and gray fox tracks appear quite round, obscuring the difference between fox and domestic cat tracks. Other key characteristics, such as the degree of vertical compression and palm pad shape and size, are useful for resolving confusion in these instances.

Although the palm pad ridge is the most revealing diagnostic characteristic of a red fox track, it may not always be definitive. If a red fox track is indistinct and the entire palm pad is not clearly impressed in the medium, the ridge can appear to be the posterior border of a gray fox palm pad (Fig. 4c). Conversely, the clump of fur behind the palm pad of a gray fox (Fig. 3b) and a kit fox (Fig. 2c) track can appear to be a ridge on a palm pad, but kit fox tracks are not likely to be confused with those of the red fox because of size differences. Careful examination of the track should clarify whether there actually is a ridge or merely a space between the palm pad and the fur. Identification can be clarified further by assessing size differences, the amount of vertical compression, relative palm pad size, and palm pad lobing.

Differences between gray and kit fox tracks can be subtle. The prints are similar in size and shape and, frequently, the entire palm pad of the gray fox is not clearly impressed in the tracking medium. Sometimes, the outer lobes on the palm pad of a gray fox are indistinct. In such a case, the general outline of the posterior border of the gray fox palm pad is slightly concave, compared to the more convex posterior border of a kit fox palm pad. On occasion, the impression of the outer lobes of the gray



fox palm pad is entirely absent and all that is visible is the central lobe, making the posterior border look convex like that of a kit fox (Fig. 3c). When palm pad shape fails to distinguish a track, the relative palm pad size, vertical compression characteristics, and shape of the toes can be used as indicators. Also, unlike other canids, the hind foot of the kit fox is usually the same length or longer than the front foot.

Figure 6 is a simple schematic summarizing the basic diagnostic characteristics of the four species discussed in this paper. This schematic will be most useful for identifying clear, distinct tracks of adult animals.

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SEASONAL OCCURRENCE OF LEATHERBACK SEA TURTLES (*DERMOCHELYS CORIACEA*) IN THE MONTEREY BAY REGION, WITH NOTES ON OTHER SEA TURTLES, 1986-1991

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Sightings of leatherback sea turtles ($n = 96$) within 50 km of Monterey Bay, California were collected primarily from recreational boat skippers using the area from 1986 to 1991. The greatest number of sightings were recorded in August ($n = 47$), corresponding to the highest monthly mean sea surface temperature (SST) for the study period. Leatherback sea turtles enter Monterey Bay when SST warm to 15-16°C, probably to eat seasonally abundant scyphomedusae. Coastal areas of central California that have high scyphomedusae abundance may attract leatherback sea turtles. Eleven leatherback sea turtles (1961-1991) and five other sea turtles (green and olive ridley, 1982-1991) are known to have stranded in Monterey Bay.

INTRODUCTION

Leatherback sea turtles (*Dermochelys coriacea*) have the most extensive geographic range of all reptiles. They have been reported from 60°N to 42°S latitude in the Pacific Ocean (Stinson 1984) and in all major oceans (Groombridge 1982).

Unlike other sea turtles, leatherback sea turtles can tolerate extreme temperature variations. They routinely migrate into warm waters to lay their eggs on tropical beaches, yet they can also swim vigorously in waters of 0°C (Goff and Lien 1988). In one study, leatherback sea turtles maintained core temperatures 15°C above ambient water temperature of 5°C (Frair et al. 1972). Cylindrical body form, large body mass (for thermal inertia), thick layer of epidermal fat, counter current heat exchangers in the flippers, relatively low freezing point for lipids, dark body color, and potentially heat generating adipose tissue enable the species to maintain elevated body temperatures (Mrosovsky and Pritchard 1971, Frair et al. 1972, Greer et al. 1973, Neill and Stevens

1974, Goff and Stenson 1988, Davenport et al. 1990).

Leatherback sea turtles nest between 30°N and 20°S latitudes. The two major Pacific Ocean nesting colonies are in Melanesia, on the northern coast of New Guinea (Bhaskar 1985); and on the southwestern coast of Mexico, in the states of Michoacan, Guerrero, and Oaxaca. The Mexican colonies constitute the largest known aggregation of nesting leatherback sea turtles in the world, with an estimated 30,000 females nesting each year from November to January (Pritchard 1982). Occasional leatherback sea turtle nests are reported from Baja California, Mexico (e.g., Fritts et al. 1982).

The distribution at sea of leatherback sea turtles after nesting is largely unknown. Pritchard (1982) suggested they disperse over the eastern Pacific Ocean in search of scyphomedusae prey. This may account for sightings in the central Pacific (Balazs 1982), along the west coast of South America (Green and Ortiz-Crespo 1982, Frazier and Brito Montero 1990), and off North America (Myers 1933, Eisenberg and Frazier 1983, Smith and Houck 1984, Stinson 1984).

Ven Denburgh (1922) was the first to describe a leatherback sea turtle off the California coast, and from Monterey Bay (Ven Denburgh 1924). Carr (1952) recorded the collection of a leatherback sea turtle near San Diego in 1907, and Myers (1933) reported two specimens collected near San Francisco in 1929. A leatherback sea turtle washed up on Pebble Beach, Del Norte County, California, and there were numerous undocumented sightings along the California and Oregon coasts in 1984 (Smith and Houck 1984). Stinson (1984) reported 300 observations of leatherback sea turtles along the west coast of North America from 1900 to 1983, concluding that the leatherback sea turtle was the most common sea turtle north of Mexico.

The leatherback sea turtle is listed as an Endangered species throughout its entire range under the U.S. Endangered Species Act of 1973, as amended (35 FR 8495, 2 June 1970). Factors that may influence movements of leatherback sea turtles along the west coast of North America are unknown but should be examined for effective conservation and management efforts. Our objective was to compile observations of leatherback sea turtles within 50 km of Monterey Bay from 1986 to 1991, and to determine if sightings were correlated with sea surface temperature.

METHODS

Sightings of leatherback sea turtles within 50 km of Monterey Bay were collected by interview of recreational party boat skippers (Young 1969) using the area from 1986 to 1991. From March to December of every year, observational effort was equal. During the months of January and February there was a decrease in effort of approximately 10% annually. Means and standard deviations of annual sea surface temperature (SST) for this area (1919-1983) are from Stinson (1984), and were considered normal monthly temperatures. Monthly analysis of leatherback sea turtle observations relative to SST in Monterey Bay follows Stinson (1984). Each month of the study period was identified as "warm" if one standard deviation above the normal mean, or "cool" if one standard deviation below. Each leatherback sea turtle sighting was identified as having occurred during a month and a year characterized by

“normal,” “warm,” or “cool” oceanic conditions.

If normally distributed, 68% of the monthly periods will on average have SST within one standard deviation of the mean. Therefore, if SST were not affecting leatherback sea turtle movements, we would expect 68% of turtle sightings during periods of “normal” SST, 16% during relatively warm SST and 16% during periods of cool temperature. A Chi-square test for goodness-of-fit was used to determine if the frequency of leatherback sea turtles sighted during each monthly category differed from that statistically expected if leatherback sea turtle occurrence within Monterey Bay were not related to SST. To meet the assumptions of the technique, monthly SST

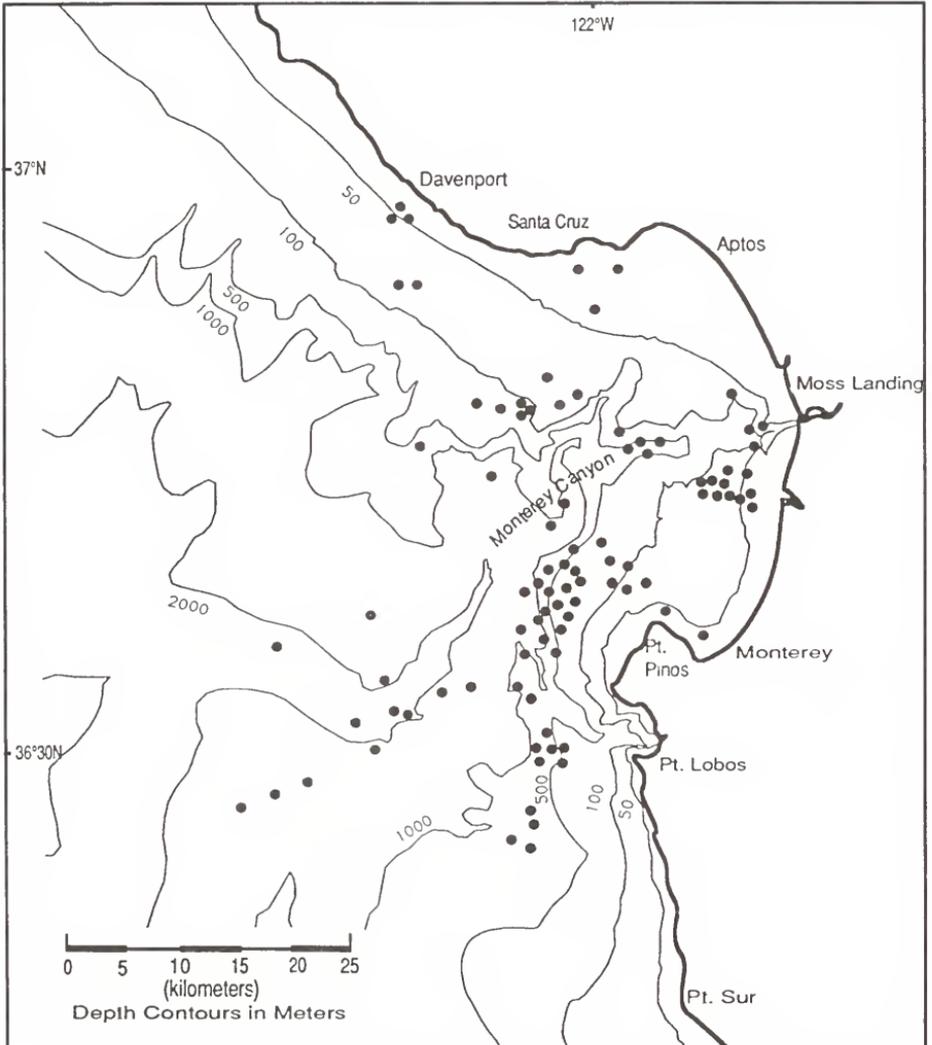


Figure 1. Monterey Bay, California. Dots indicate locations of leatherback sea turtle sightings (1986-1991).

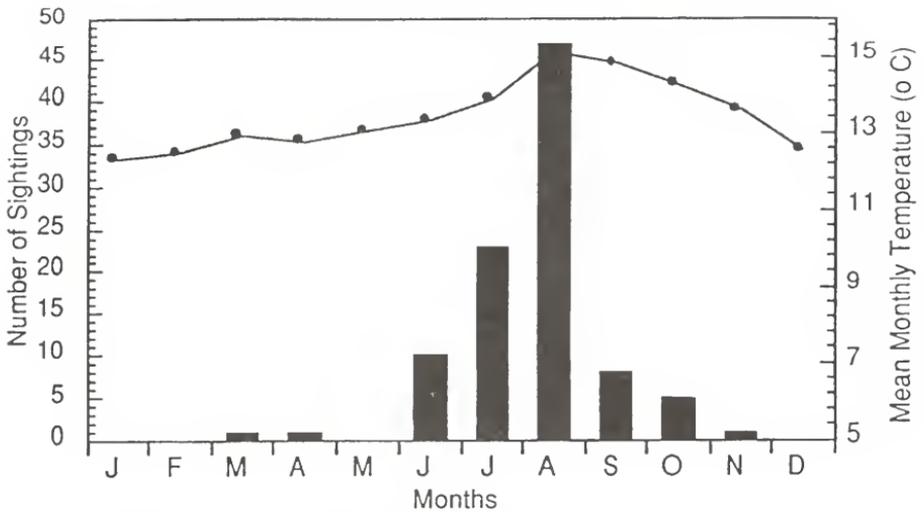


Figure 2. Number of cumulative sightings (bars) for each month of the study period (1986-1991) compared to mean monthly temperatures (line), Monterey Bay, California.

were tested for normality using a Kolmogorov-Smirnov test (Zar 1984).

We assumed all leatherback sea turtle sightings were independent of one another. No two sightings from a single day were used unless sightings were at least 5 km apart or were made by the skipper of the same boat moving along an unchanged heading. Leatherback sea turtle stranding data (1961-1991) and observations of other sea turtles species (green: *Chelonia mydas*; olive ridley: *Lepidochelys olivacea*; 1982-1991) were also compiled for the Monterey Bay area.

RESULTS

Ninety-six observations of leatherback sea turtles were recorded during 1986 to 1991 (Figure 1). The greatest number of sightings occurred in August ($n = 47$), corresponding to the highest mean monthly SST for the study period (Figure 2). There were significantly greater numbers of leatherback sea turtle sightings during months of warm SST than during months of normal or cool SST ($\chi^2 = 120.5$, $P < 0.05$). SST during August 1987, 1988, and 1990 were higher than normal, and these months accounted for 41% of sightings during the study period.

Twelve leatherback sea turtles (Table 1) and five other sea turtles (Table 2) have been reported stranded in Monterey Bay.

DISCUSSION

Stinson (1984) found that observations of leatherback sea turtles correspond with the movement of the 16°C isotherm along the west coast of North America. This isotherm remains offshore during much of the year, but during early spring and summer the coast of California is inundated by warmer offshore waters and the 16°C

isotherm is found close to shore where most leatherback sea turtles are sighted. These waters meet the coast south of San Diego and move north reaching central California during July and August (Roden 1961). As these waters move northward, leatherback sea turtles are observed progressively further north and most often in areas where the 16°C isotherm is encountered (Stinson 1984). Our results and analysis indicate that

Table 1. Listing of leatherback sea turtle strandings in the Monterey Bay, California area (1961-1991).

Date	Location	Comments/Condition/Source
12 Aug. 61	Monterey Bay	Male (229 cm length)/unknown/Pacific Grove Museum of Nat. Hist., Pacific Grove.
2 Sept. 73	City of Monterey	Taken to landfill (weight=420 kg)/decomposed/ Monterey Peninsula Herald.
26 Nov. 76	Monterey Bay	Skeleton in Calif. Academy of Sci. Cast on display/ unknown/Santa Cruz City Museum, Santa Cruz.
11 Nov. 85	Grimes Pt. Beach, Big Sur	Left on beach/unknown/R.J. Jameson (United States Fish and Wildlife Service, USFWS).
23 Aug. 89	Moss Landing Beach	One skull collected by Moss Landing Marine Laboratories
31 Aug. 89	Moss Landing	(MLML)/two decomposed individuals/E.S. Baldrige and J.T. Harvey (MLML).
27 Aug. 89	Whaler's Cove, Pt. Lobos State Res.	Decomposed/J.K. Loomis, Pt. Lobos State Reserve.
20 Nov. 89	Moss Landing Beach	Decomposed/E.S. Baldrige (MLML).
7 Nov. 90	Carmel Bay, Carmel	Male (262 cm length, 374 kg)/found dead outside Stillwater Cove, Pebble Beach. Autopsy found a plastic bag in the lower intestine (25 cm)/A. Baldrige, J.T. Harvey, T. Kieckhefer (MLML, skeleton retained).
31 Aug. 91	Sand City near Fort Ord boundary	Skull collected for the MLML Museum (178 cm carapace length)/ decomposed/ A. Baldrige, L. Osnes, T. Kieckhefer (MLML).
27 Sept. 91	Lover's Pt., Pacific Grove	Skull collected by USFWS/J. Ames (Dept. of Fish and Game)/decomposed male found floating in kelp (228 cm length)/B. Hadfield (USFWS).

Table 2. Listing of other sea turtle species observed near Monterey Bay, between 1982 and 1991.

Date	Species	Comments/Condition/Source
15 Nov. 82	unknown	Observed swimming in shallow water in Monterey Harbor/ lethargic; possibly cold shocked/R.N. Lea (Dept. of Fish and Game) and B. McCurdy.
6 Sept. 84	Pacific ridley	Found on beach and taken to Monterey Bay Aquarium and subsequently released near San Diego/unknown/R. Huettmann and R.N. Lea (Dept. of Fish and Game).
25 July 88	Pacific ridley	Adult female (over-the-curve carapace length was 82 cm)/ dead on Marina State Beach, Monterey Co./A. Baldrige and D. George.
23 May 89	unknown	Observed in kelp near Otter Pt, Pacific Grove /lethargic; possibly cold shocked/A. Baldrige and B. Gulart.
12 Feb. 89	green	Found in kelp near Partington Cove, Big Sur. Taken to Monterey Bay Aquarium and subsequently released near San Diego. Over-the-curve carapace length was approximately 121 cm and weight was 220 kg /lethargic; possibly cold shocked/ A. Baldrige, D. Breese (Long Marine Laboratory, Univ. of CA at Santa Cruz), B. Tershey (Moss Landing Marine Laboratories).

Postscript: A second green sea turtle was found dead at Point Joe, Pebble Beach, Monterey Co. on 10 November 1992 (over-the-curve carapace length was 75 cm, A. Baldrige).

SST influenced the number of leatherback sea turtles sighted. Monterey Bay is dominated by upwelling and associated cool water during much of the year, but during August and September, warmer water can enter the bay directly from the west as winds favoring upwelling begin to relax (Breaker and Broenkow 1989). At these times, SST increases to 15-16°C and leatherback sea turtles are observed most frequently in Monterey Bay.

We suspect that leatherback sea turtles feed on concentrations of scyphomedusae while in Monterey Bay. Six species of large scyphomedusae (*Aurelia aurita*, *Polyorchis montereyensis*, *Cyanea capillata*, *Chrysaora melanaster*, *Pelagia colorata*, *Phacellophora camtschatica*) have been recorded in Monterey Bay, and occur during periods of warm water intrusion (F. Sommer, Monterey Bay Aquarium, pers. comm.). Aggregations of *Aurelia aurita* have been observed in Tomales, Bodega, and Monterey bays (F. Sommer, pers. comm.) and large concentrations of *Chrysaora melanaster* often occur in summer and fall. Leatherback sea turtles have been observed feeding on *Aurelia* spp. off the coast of Washington (Eisenberg and Frazier 1983). Shenker (1984) found that *Chrysaora fuscescans* reached densities of 1,800

liters of medusae per 10^5m^3 during August in surface waters off Oregon. In Monterey Bay, leatherback sea turtles have been photographed feeding on *Pelagia colorata* (F. Harmon, Monterey Bay Fishing Fleet, pers. comm.) and video-taped eating large scyphomedusae similar to *Phacellophora camtschatica* (D. Shearwater, Shearwater Journeys, per. comm; Larsen 1990).

Coastal areas of central California that have high scyphomedusae abundance may attract leatherback sea turtles. Lazell (1980) has suggested that densities of *Cyanea capillata* have an important influence on the distribution of leatherback sea turtles in the western Atlantic Ocean, and that siphomedusae reach greatest densities in calm embayments. We have shown that Monterey Bay, with its high seasonal abundance of scyphomedusae, appears to be of importance to leatherback sea turtles as a feeding area.

OTHER SEA TURTLE SPECIES RECORDED

From 1982 to 1991, there was one confirmed sighting and capture of an adult green turtle, two sightings of adult olive ridley turtles, and two sightings of an unknown hard-shelled turtle species near Monterey Bay (Table 2). The green turtle and one of the olive ridley turtles were taken to Monterey Bay Aquarium, and subsequently released near San Diego. One adult female olive ridley turtle was found dead on Marina State Beach, Monterey County. Two unidentified hard-shelled turtles were observed swimming, one near Monterey Harbor and the other near Otter Pt., Pacific Grove.

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A STANDARD WEIGHT (W_s) EQUATION FOR WHITE STURGEON

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The relative weight index (W_r) contrasts with traditional condition assessments such as Fulton or Le Cren condition factors by facilitating comparisons among populations and among individuals of disparate lengths (Murphy et al. 1990, 1991, Willis et al. 1991). Relative weight values are obtained by dividing the actual weight of a fish by a standard weight (W_s) for fish of that length and then multiplying by 100 (Wege and Anderson 1978). This index thus requires a standard weight equation for the fish species of interest. This note describes a standard weight equation for white sturgeon (*Acipenser transmontanus*), a valuable fish in sport and commercial fisheries, and in commercial hatcheries, along the Pacific coast of North America.

Weight-length equations were compiled from the literature for 15 white sturgeon samples collected from locations representative of the geographical range of the species (Fig. 1, Table 1). Equations were standardized algebraically to the form:

$$W = \alpha L^b$$

where W = weight in kg and L = total length in cm. Fork lengths were converted to total lengths using a factor of 1.110. This conversion factor was derived from a linear regression of paired total length and fork-length data ($n = 1,750$) calculated for fork lengths from 1 cm to 250 cm in 1-cm intervals using each of seven conversion equations from various white sturgeon samples (Table 2). Fits of conversion equations were identical with ($b_0 = 2.216, b_1 = 1.096$) and without ($b_0 = 0, b_1 = 1.110$) the intercept term ($r^2 = 0.996$); however, omitting the intercept term simplified algebraic solution.

The standard weight-length relationship for white sturgeon (Table 3) was calculated from literature weight-length functions with the regression-line-75th-percentile technique (RLP) recommended as the standard by Murphy et al. (1991). The 15 weight-length functions (Table 1) were used to calculate mean weights for each 1-cm total length interval from 1 cm to 250 cm. The 75th-percentile weights for each 1-cm interval in this statistical population ($n = 3,750$) were then regressed on length to develop the standard weight equation. The standard weight function thus represents the condition that could be expected in a better than average white sturgeon population. Murphy et al. (1991) noted that W_s equations have been defined in most cases to represent populations in better-than-average condition, based on the assumption that attempting to produce fish populations that attain only average condition generally does not represent a typical management goal. All statistical analyses were performed with the Statistical Analysis System (SAS) for personal computers (SAS Institute 1988). Equivalent equations for English units and fork lengths were calculated

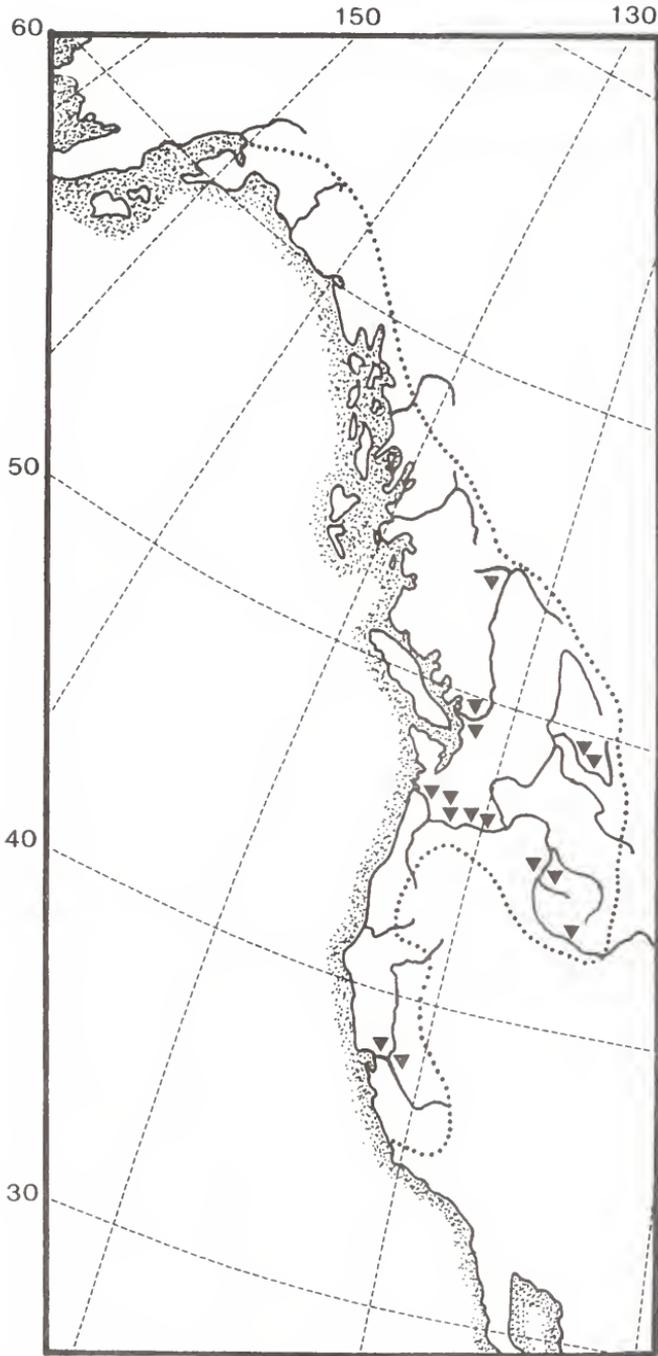


Figure 1. Geographical distribution of samples (denoted by triangles) of weight-length data used for estimation of a standard weight equation for white sturgeon, Pacific coast, North America. The range of white sturgeon (Scott and Crossman 1973) is circumscribed with a dotted line.

Table 1. Intercept (α), slope (β), and correlation coefficient for regression^a of weight (kg, dependent variable) on total length (cm) and mean relative weights (W_r) for 15 white sturgeon samples.

River	n	Lengths	α	β	r^2	W_r	Reference
Sacramento-San Joaquin Rivers							
San Pablo Bay (1965-70)	209	102-203	1.18E-06	3.348	0.910	103	Kohlhorst et al. 1980
San Pablo Bay (1984-85)	124	31-224	2.19E-06	3.189	0.850	92	Brennan 1987
Columbia River							
Lower ^b	5,338	37-263	7.66E-06	2.958	0.961	117	Tracy, unpublished
Bonneville Res. (1976-78) ^b	2,516	34-269	1.63E-06	3.277	0.980	103	Malm 1979
Bonneville Res. (1988-90)	2,405	31-292	2.65E-06	3.161	0.958	99	Author, unpublished
The Dalles Res.	2,850	35-276	9.70E-07	3.376	0.968	96	Author, unpublished
John Day Res.	1,024	32-254	1.81E-06	3.249	0.982	100	Author, unpublished
Kootenai River							
(1980-82)	341	50-224	1.66E-06	3.26	0.980	97	Partridge 1983
(1989-91)	223	88-211	7.13E-07	3.394	0.841	77	Apperson, unpublished
Snake River							
Upper	560	46-270	3.0 E-07	3.612	—	91	Cochnauer 1983
Middle (1972-75)	602	45-274	1.14E-06	3.31	—	83	Lukens 1985
Middle (1982-84)	478	45-280	6.50E-07	3.43	—	83	Lukens 1985
Fraser River							
Lower (males) ^b	—	—	2.87E-06	3.13	—	93	Semakula and Larkin 1968
Lower (females) ^b	—	—	2.64E-06	3.15	—	94	Semakula and Larkin 1968
Upper	65	73-249	5.97E-07	3.444	0.998	82	Dixon 1986

^a $W = \alpha * TL^\beta$ ^b Converted from fork length using $TL = FL * 1.110$

Table 2. Fork length to total length (cm) conversion equations^a reported for several populations of white sturgeon.

Location	<i>n</i>	<i>b</i> ₀	<i>b</i> ₁	<i>r</i> ²	Reference
Sacramento-San Joaquin Estuary	366	1.343	1.093	0.922	Kohlhorst 1980
Columbia River (lower) ^b	2,039	2.06	1.09	0.994	Tracy, unpubl.
Columbia River (middle) ^c	3,612	1.240	1.095	0.972	Author, unpubl.
Columbia River (middle) ^d	2,516	5.06	1.08	--	Malm 1979
Fraser River	14	4.91	1.088	0.998	Dixon 1986
Kootenai River	341	0.77	1.104	--	Partridge 1983
Kootenai River	223	0.13	1.124	0.984	Apperson, unpubl.

^a $TL = b_0 + b_1 * FL$.

^b Downstream from Bonneville Dam.

^c Bonneville, The Dalles, and John Day Reservoirs.

^d Bonneville Reservoir.

algebraically from the standard metric equation based on total length (Table 3).

Weight-length parameters for the 15 samples were generally based on a broad range of fish sizes from minimum total lengths of 30 cm to maximum total lengths exceeding 200 cm (Table 1). Murphy et al. (1990, 1991) recommended using a comparison of the ratio of variance to mean \log_{10} weight for fish among 1-cm length intervals to specify minimum applicable lengths. This comparison for samples from Columbia River reservoirs (Fig. 2), indicated that restricting analyses to lengths of 70 cm or more will minimize effects of errors in weighing small fish and of developmental changes in body form from juveniles to adults.

Mean relative weights for the 15 samples ranged from 77 to 117 (Table 1). Samples with the lowest mean relative weights were all from headwaters of the Columbia and Fraser River systems, which often support unproductive white sturgeon populations because of limited food availability or poor recruitment (Cochner et al. 1985). The Kootenai River population, which is declining and in danger of extinction, had the lowest mean relative weight. White sturgeon with access to marine and estuarine resources in the lower Columbia River had the largest mean relative weight.

Murphy et al. (1991) suggested that condition factors provide an indirect means of evaluating ecological relations and the effects of various management strategies but that analyses limited to simple calculation of mean relative weight may conceal management problems in particular size classes of fish. Hence, size-specific comparisons within or among populations may provide more insight into factors affecting white sturgeon abundance and productivity.

Table 3. Standard weight-length equations^a for white sturgeon in metric and English units for total length and fork length measurements.

Length measurement	Length units	Weight units	α	β
Total	cm	kg	1.952E-6	3.232
Total	in	lb	8.747E-5	3.232
Fork	cm	kg	2.735E-6	3.232
Fork	in	lb	1.226E-4	3.232

$$^a W = \alpha * L^\beta$$

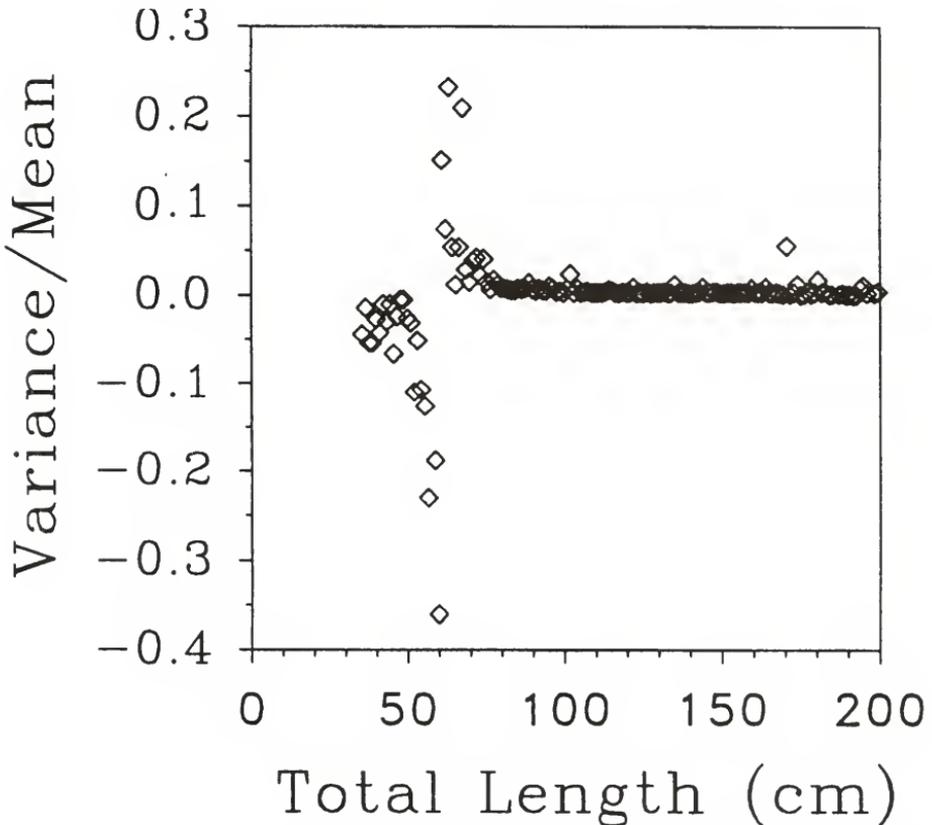


Figure 2. Variance/mean ratio for \log_{10} weight by centimeter length group for 6,279 white sturgeon collected from Bonneville, The Dalles, and John Day reservoirs in the Columbia River using techniques outlined by Elliott and Beamesderfer (1990).

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A COMPARISON OF MULE DEER SURVEY TECHNIQUES IN THE SONORAN DESERT OF CALIFORNIA

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Helicopter surveys, ground surveys, and interviews with hunters were compared as methods to obtain mule deer (*Odocoileus hemionus eremicus*) demographic data in the Sonoran Desert of southeastern California. No difference existed between results of aerial surveys and hunter interviews ($P > 0.50$), but samples from ground surveys were too small to allow a meaningful comparison. In our study area, it would not be practical to obtain an adequate sample using ground surveys, given the low observation rate and high cost associated with that technique. Interviews with hunters were conducted at no additional cost because public contacts were initiated as part of routine law enforcement activities during the deer season. Interviews may be a cost-effective method of obtaining demographic information for low-density deer populations where other sampling techniques are neither practical nor cost-effective.

INTRODUCTION

Mule deer (*Odocoileus hemionus eremicus*) are distributed widely over the Sonoran Desert of southeastern California (Bowyer and Bleich 1984). Low population densities (McLean 1940) and the reluctance of these deer to leave cover have hindered the acquisition of demographic data (Celentano and Garcia 1984). Interest in hunting these deer has increased substantially in recent years, thereby necessitating the development of efficient and economical methods of estimating population parameters. Our objectives were to: (1) compare demographic parameters obtained during aerial surveys, ground-based surveys, and hunter interviews; and (2) compare the costs associated with each of these techniques.

METHODS

The Sonoran Desert study area is located in and near the Chocolate Mountains, southeastern Riverside and eastern Imperial counties, California. The dominant vegetation type is creosote bush (*Larrea tridentata*) scrub (Paysen et al. 1980), and

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it is widespread in both mountainous and intermountain areas. Numerous large washes, supporting stands of palo verde (*Cercidium floridum*), ironwood (*Olneya tesota*), smoke tree (*Dalea spinosa*) and mesquite (*Prosopis* spp.), dissect the intermountain regions of the study area.

Annual precipitation averages approximately 7.5 cm, and occurs primarily during the summer (Bailey 1966). Naturally occurring water sources are few, but numerous man-made water sources have been developed to improve deer habitat within the study area. The Coachella Canal, on the west, and the Colorado River, on the east, also provide year-round sources of water. Deer densities in the study area are high compared to other areas within the geographic range of *O. h. eremicus* (Celentano and Garcia 1984).

We conducted our research from September to November, 1990. Temperatures are relatively high, and precipitation usually low during those months (Bailey 1966). We conducted aerial surveys in September and October, and ground surveys in September. To maximize public contact, interviews were conducted immediately before, and during, the deer hunting season (6 October-25 November).

Because sexual segregation is a phenomenon common among large, polygynous mammals (Bleich 1993, for review), it might be expected to influence the results of demographic surveys if not considered in survey design. With the exception of the breeding season, Scarbrough and Krausman (1988) observed sexual segregation throughout the year among desert-dwelling mule deer (*O. h. crooki*), and Bowyer (1984) noted that sexual segregation was maximized during the birthing season for *O. h. fuliginatus* inhabiting a mesic ecosystem. Deer in our study area breed during January and February, and fawns are born during August and September (Celentano and Garcia 1984); thus, our surveys occurred during a period of probable sexual segregation. Because sex ratios might be biased if surveys occurred in a single habitat type occupied preferentially by one sex or the other (Schaller and Junrang 1988), we sampled deer in creosote bush scrub as well as wash habitats, and in mountainous and intermountain areas.

We conducted September aerial surveys ($n = 6$) with a Bell 206 B-III turbine-powered helicopter and in October ($n = 2$) with a Bell UH-1 turbine-powered helicopter. Only experienced pilots (Bleich 1983) and observers participated in the aerial surveys. Because Hervert and Krausman (1986) did not observe deer come to water during mid-day, we assumed deer were not active at that time; hence, we conducted our surveys during periods when deer were thought to be most active (L. Lesicka, pers. comm.), primarily early morning and late afternoon. We pooled data from morning and evening flights prior to analysis.

For ground surveys, skilled observers drove predetermined routes during the early morning or late afternoon, and observations were made by the driver and one passenger. Distances driven, time and location of observations, and age and sex of all deer encountered were recorded. We pooled data from morning and evening ground surveys prior to analysis. Because part of the study area was closed to civilian aircraft, aerial and ground surveys were not coincident in all cases.

Hunters were interviewed by California Department of Fish and Game (CDFG)

wardens, or by other qualified personnel. The interviews consisted of a short series of questions about the number of deer seen, their relative ages, and the sex of those deer. Animals were classified as female or male adults based on the presence or absence of antlers, or as juveniles (fawns, sex undetermined). Additional data, including the date, location, time, and number of hunters in each party, were recorded. Interviews were conducted on an informal basis, during routine public contacts, and interviewees were not told how their responses would be used. Consistent with the hunting regulations in this area, we assumed that deer hunters could distinguish mature antlered deer from mature antlerless deer, and young-of-the-year (newborn fawns) from antlerless adults (including yearlings). Interviews were conducted in areas coincident with those surveyed by ground observers or aerial observers.

We compared total overall costs, as well as cost ratios (dollars/deer classified) as measures of survey efficiency. We compared relative frequencies of the ages and sex of deer classified during aerial surveys and hunter interviews using a log-likelihood ratio statistic appropriate for contingency tables (Zar 1984).

RESULTS

During 13.4 hours of helicopter surveys, we classified 77 deer in 42 groups (Table 1), for an overall observation rate of 5.7 deer/rotor-hour. For aerial surveys, the mean group size was 1.8 deer. Helicopter costs (actual survey time, ferry time, travel expenses, logistical support [Bleich 1991] and observer salaries and travel expenses) totaled \$7,863 for September. Although no expenses were incurred for helicopter services during October (because helicopter time was donated), we estimated the value of that service to be \$1,499 based on costs incurred during September. Using these figures, we estimated a cost of \$122/deer classified for aerial surveys.

Twelve deer in four groups were classified during 13 ground surveys (Table 1). The average group size was 3.0, and the overall observation rate was 0.04 deer/mile driven. No costs were incurred for ground surveys because vehicles, fuel, and personal services were donated by volunteers. However, we estimated the total value of these surveys to be \$1,900, and the cost/deer classified to be \$158.

Table 1. Frequency (and percent) of male, female, and juvenile mule deer in samples obtained during aerial surveys, ground surveys, and through hunter interviews, Imperial and Riverside counties, California, September–November, 1990.

Source of Data	Deer Classification ^a		
	Male	Female	Juvenile
Helicopter	17 (22.1)	48 (62.3)	12 (15.6)
Ground	2 (16.7)	7 (58.3)	3 (25.0)
Interview	34 (18.7)	110 (60.4)	38 (20.9)

^a Juveniles are fawns (generally < 4 months of age).

A total of 101 public contacts yielded observations of 182 deer (Table 1); it was not possible to calculate the mean size of deer groups because, in most cases, hunters reported total numbers of animals seen, by sex and age categories. No costs were incurred while obtaining these data, because interviews were conducted during the course of routine patrol and resource assessment activities.

The percentages of male, female, and juvenile deer classified during three types of surveys were remarkably similar (Table 1). Indeed, samples obtained from helicopter sampling and hunter interviews (Table 1) did not differ ($G = 1.16, P = 0.56, 2 \text{ df}$). Samples from the ground surveys were too small to be compared in a statistically meaningful manner.

DISCUSSION

Our objective was to compare aerial surveys, ground surveys, and hunter interviews as methods of estimating population parameters of mule deer inhabiting a Sonoran Desert ecosystem in southeastern California. We found no significant differences between demographic data resulting from aerial surveys and hunter interviews, and the latter technique may be an appropriate alternative for estimating population parameters of low-density deer populations. We attempted to avoid biases by sampling in the 2 vegetation types occurring in the hunt zone, by minimizing the probability of sampling an individual animal > 1 time during any survey (Wehausen 1990), and by interviewing "parties" of hunters, rather than individuals, that composed hunter groups.

Ground surveys yielded observations of only 12 deer, despite the expenditure of > 40 person-days of effort, and > 330 vehicle-miles. Given the low return per unit effort, we do not consider vehicle-based ground surveys a viable method of obtaining demographic data in our study area. For example, if the ground observation rate remained constant, it would require approximately 250 person-days and 2,300 vehicle-miles to accumulate a sample equivalent to that obtained using a helicopter. It is unreasonable to assume that amount of effort would be available to us on an annual basis; however, we encourage other investigators to explore ground surveys, in lieu of aerial surveys, as a means of obtaining demographic data.

Relatively low aerial observation rates (5.7 deer/hour) during September and October probably reflect the low density of deer inhabiting the study area. During Autumn, deer may be more widely dispersed than during Summer, a result of somewhat lower ambient temperatures that allow deer to disperse farther from sources of free water. Aerial observation rates (J. R. Thompson, unpubl. data) during June 1990 (before any summer thundershowers had occurred, and a very hot time of the year) were 1.4 x those obtained during our Autumn surveys. Mean group size during June was 1.3 x that during Autumn, possibly a reflection of the less gregarious nature of mule deer during the birthing season (Bowyer 1985). Larger groups may be more easily seen from the air (Samuel et al. 1987), but the advantages of higher observation rates in June may be more than offset by the difficulty associated with distinguishing adult male and female deer, as antlerogenesis has only recently begun.

Aerial survey data are expensive, with a cost of \$122/deer observed. Demographic data obtained during interviews were indistinguishable from results obtained during aerial surveys, but confidence intervals of high precision could not be calculated. Interviews were conducted at no additional cost to CDFG, because they were obtained during other previously scheduled activities. Interviews appear to be a valid method for estimating demographic parameters for low-density deer populations inhabiting the Sonoran Desert of southeastern California. Moreover, this technique may be applicable to other deer populations where aerial or ground surveys are neither efficient nor cost-effective, and we encourage investigators faced with similar logistical and fiscal constraints to explore its utility.

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HARVEST SLOT LIMIT RATIONALE FOR LAHONTAN CUTTHROAT TROUT AT PYRAMID LAKE, NEVADA

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In the past, Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) at Pyramid Lake, Nevada were protected by a 483 mm minimum size limit. These protected fish showed stunted growth and dominated recent spawning runs. We implemented the slot limit harvest regulation based on creel census, creel interview, spawning run, and gillnetting data. Protected slots are fish under 406 mm and from 483 to 610 mm. The rationale behind the present slot limit regulation has been that by harvesting the surplus of small fish, and protecting the largest fish, spawn collection will be enhanced.

INTRODUCTION

The application of size limits is a commonly employed technique in recreational fisheries management (Fox 1975). Some of the major justifications for establishing size limits are to maximize the yield or weight harvested (Ricker 1945), increase the catch of large fish (Anderson 1974), and protect potential spawners (Serns 1978, Elser 1986). Size limits for Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) at Pyramid Lake were primarily used as a tool to obtain large fish for the anglers, and to protect fish until they sexually matured and had an opportunity to spawn at least once (Sigler et al. 1983). However, size limits may produce undesirable as well as desirable results (Fox 1975).

The minimum size limit for Lahontan cutthroat trout at Pyramid Lake, Nevada from 1954 to 1982 varied from 381 to 483 mm (Coleman and Johnson 1988), and remained at 483 mm from 1983 to 1991 (Pyramid Lake Fisheries unpubl. data 1991). Large fish of both sexes are preferentially sought by anglers for their food value and trophy size. Little emphasis was placed on protecting large, sexually mature Lahontan cutthroat trout females, which can have average fecundities of 3,815 eggs (Sigler et al. 1983).

Most historical spawning habitats of Lahontan cutthroat trout have been altered and lost because of dams, intentional channel modifications and sedimentation of the Truckee River (Sigler et al. 1983). Due to the loss of natural spawning habitat, Pyramid Lake's trout population is supported by hatchery propagation. Limited data on the maturation of female trout in Pyramid Lake suggest that they mature sexually at age IV, and that consecutive year spawning does not occur (Sigler 1978). In the past, slow growing fish have been protected by the minimum size limit and have dominated recent spawning runs. In such situations, the protection of large fish from harvest becomes particularly important so that large, fast growing, and highly fecund fish are

available for spawning. The rationale behind a slot limit regulation has been that by protecting the fecund fish, spawn collection will be enhanced.

In this paper, we present data supporting the implementation of a harvest slot limit for trout in Pyramid Lake. The proposed slot limit would protect large trout entering the protected slot, resulting in more fecund fish for spawning.

METHODS

Three sources of data were used to evaluate the previous minimum size limit. The first data set was obtained from creel census, collected at a fixed creel station by the methods described by Robson (1960). The creel station was five miles (9 km) away from Pyramid Lake on the Pyramid Lake Highway leading to Reno. Information collected from each fisherman included hours fished, composition of catch, length and weight of the catch, and recovery of coded-wire micro-tags. Most survey data were collected between October and April when most trout fishing occurs. Census hours usually were between noon and sunset during the weekends. Since 1988, the creel station extended its hours to one hour past sunset in order to census late evening fishermen, who were found to comprise a significant portion of the successful fishing effort. In addition to creel census, 465 creel interviews were conducted in 1983, and a self-administered questionnaire was distributed to 600 licensed fishermen during 1986. The questionnaire consisted of 12 questions including number of years fished at Pyramid Lake, mode of fishing (boat, shore), and management preferences (type of fishery, closed seasons, gear restrictions, and size and bag limit). Other questions addressed angler's opinion about the present fishery status and suggestions for its improvement.

The second data set was obtained from the spawning run of trout at Sutcliffe. Coded-wire micro-tagged fish were sacrificed from the spawning population for age data collection. Length and weight measurements were taken from micro-tagged fish to determine the growth rates for the tagged fish.

The third data set was obtained from gillnetting which began in 1984 applying techniques designed by Sigler (1978). Experimental gill nets, 1.8 X 76 m, built of white multi-filament nylon, were used. Each net was composed of 10 panels (1.8 X 7.62 m each) of the following mesh size: 25 mm (twine #210/2), 38 mm, 51 mm, 64 mm, 76 mm, 89 mm and 102 mm (each with twine #69) 127 mm (twine # 104) and 152 mm and 178 mm (twine #139). When first initiated, a monthly sampling schedule was followed, but since 1986, quarterly sampling was conducted.

Six sampling stations were selected on both sides of the lake. The exact depth of each site varied from south to north along both sides of the lake, with shallow (approximately 50 feet) and deep (approximately 150 feet) sites at each station. The nets were set at two depths (shallow and deep) at each of two stations, and were lifted the following morning, then reset at the next two stations. Trout sampled from 1984 through 1990 were measured to the nearest millimeter in fork length.

RESULTS AND DISCUSSION

In the past, slow growing fish were protected by the 483 mm minimum size limit and dominated spawning runs. Analysis of micro-tagged fish indicates that many fish were only reaching a size of 457 mm by age eight, the average maximum lifespan. These fish were not achieving a harvestable size, and were not desirable as spawners.

Fishing effort as measured by angler days (determined by the number of seasonal permits sold multiplied by the mean number of trips per permit plus daily fishing permit sold) at Pyramid Lake have increased since 1977 (Coleman and Johnson 1988), and Lahontan cutthroat trout catch increased with the fishing effort from 1983 to 1991 (Fig. 1). Under the 483 mm minimum size limit the anglers selectively removed large individuals from the population, leaving very few large fish surviving to return to the spawning run. At the same time released fish increased from 75% to 92% of the total catch (Table 1).

Some actions have been taken to minimize the affects of selective harvest. A slot limit regulation was implemented in October 1991 to allow a harvest of the large surplus of small fish, including the slow-growing older individuals, and to protect large fish desired for spawning. The protected slots are fish under 406 mm and from 483-610 mm. Ideally all large fish (> 610 mm) should be protected to maximize their number in the spawning population. However, harvest of only one fish over 610 mm is allowed to ensure that the angling interest is not seriously impacted. Total bag limit is maintained at two fish per day.

Since the goal of the fishery is to produce large numbers of big fish, a selective breeding program can also be implemented to complement the selection processes affected by fishing regulations. Large size is influenced by both environmental factors

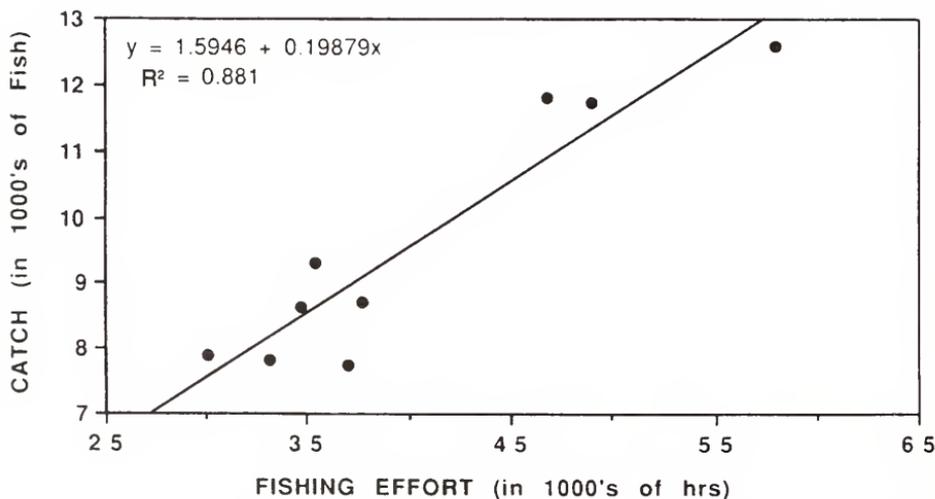


Figure 1. Fishing effort and number of Lahontan cutthroat trout caught at Pyramid Lake, Nevada (1983-1991).

Table 1. Creel survey data of Lahontan cutthroat trout at Pyramid Lake, Nevada from 1983 to 1991.

Year	Number of fish caught	Fish released (%)	Mean length of catch (mm)
1983	8651	75	523
1984	8708	76	544
1985	9312	78	564
1986	7825	77	579
1987	7747	79	572
1988	11800	85	586
1989	12600	86	593
1990	11717	89	559
1991	7913	92	556

as well as hereditary factors like age of first maturation, longevity, food habit preference and energy conversion efficiency (Coleman and Johnson 1988). Large adult size is usually related to late maturation (5-7 years), moderate to fast growth after maturation, and increased longevity. Small maximum size is related either to reduced energy conversion efficiency and lack of piscivory, or to fast initial growth, early maturation, and shorter life span.

The most obvious strategy for a selective breeding program will be to spawn only the large individuals. However, in recent years less than 5% of the spawning run has consisted of fish over 560 mm. The new fishing regulations at Pyramid Lake will allow more large fish (483 to 610 mm) to survive and enter the spawning run in years to come.

Management Considerations of the Slot Limit

The harvest slot limit regulation was designed to increase the number of large Lahontan cutthroat trout spawners, and provide more large fish for the anglers.

Anglers play a key role in any fishery management program. Their compliance is considered before any change in angling restrictions is implemented. In a survey of 536 anglers at Pyramid Lake, 67% wanted a trophy fishery (> 610 mm), 76% were satisfied with a 483 mm minimum size limit, and 82% were satisfied with a two fish daily bag limit (Fig. 2). The angler's main motivations were attaining a bag limit, and the status associated with a trophy harvest. We believe that the slot limit will achieve these goals.

Lahontan cutthroat trout mortalities range widely among fish captured and released. Hooking mortality of lure-caught cutthroat trout in Yellowstone Lake was relatively low (< 6.5%); however, the combination of natural baits and high water temperature resulted in significantly high mortality (Marnell 1969, Marnell and Hunsaker 1970). Legal tackle is limited to artificial lures and flies only at Pyramid Lake. Summer deepline mortality of unharvested trout at Pyramid Lake was determined

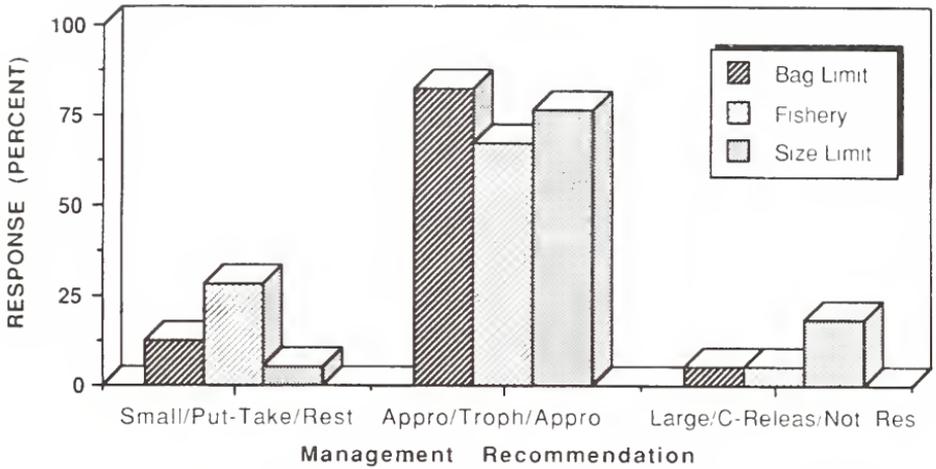


Figure 2. Pyramid Lake fishermen's response to bag limit, type of fishery, and size limit. Bag limit: 2 fish/day is too small (Small), appropriate (Appro), or too large (Large); Fishery: put and take (Put-Take), trophy (Troph) (>610 mm), or catch and release (C-Releas); and Size limit: 483 mm is too restrictive (Rest), appropriate (Appro), or not restrictive enough (Not Res)

to be 0.09 fish per hour in 1984 (Pyramid Lake Fisheries unpublished data). Since 1990 the trout season is closed from 1 July through 30 September each year, which is expected to reduce released fish mortalities.

Under the present harvest slot limit, it will be important to monitor catches to make sure that sufficient numbers of fish move through the first harvest slot to the protected status. The small protected fish would enter the first harvest slot at age III⁺ and remain there until approximately age IV⁺, then enter the protected slot and remain there until age VI⁺. Because of the long life span of the trout and the difficulty in checking the mortality rate of the young released, it will be several years after the regulation's enactment before any changes in stock status will be evident.

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PREDATION ON SMALL NORTHERN ANCHOVY (*ENGRAULIS MORDAX*) BY LARGE SILVERSIDES (ATHERINIDAE)

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Silversides (*Atherinops affinis* and *Atherinopsis californiensis*) are common species of fish found in coastal waters and estuaries along the west coast of North America. They are surface-schoolers, inhabiting the open areas over sandy substrates, within and adjacent to beds of giant kelp (*Macrocystis pyrifera*), and throughout estuaries (Quast 1968, Feder et al. 1974, Cailliet et al. 1977, Yoklarich 1991). Until now, silversides were thought to be diurnal planktivores, feeding exclusively on algae or small crustaceans associated with giant kelp and/or in the plankton (Limbaugh 1955, Quast 1968, Ruagh 1976, Cailliet et al. 1977, Cailliet et al. 1979). Frey (1971), however, mentions that *A. californiensis* readily pursue a moving spinner or lure and that small fish form part of their diet, although no data are presented. Our observations document predation by silversides on northern anchovy (*Engraulis mordax*), a feeding behavior previously undescribed.

During a mid-afternoon (1515-1600) dive on 24 June 1992, we observed silversides attacking a school of anchovy and witnessed two silversides ingesting a separate anchovy. The event occurred near Frenchy's Cove, Anacapa Island, California over a flat, muddy-silt substratum dominated by urchins and polychaetes, 250 m from the nearest bed of giant kelp. Water depth was 10 m, visibility was 9-10 m, and temperature was 13°C. As field identification of silversides is difficult unless specimens are in hand, we were unable to determine genus or species of attacking silversides.

Initially, a school of several thousand small anchovies (40-50 mm TL) extending from <1 m to 3-4 m above the substratum and spanning 4-5 m in length, swam into view. After about 10 min, the school suddenly contracted into a dense aggregation approximately 3 m in all dimensions and began to swirl around us in a highly-agitated manner. We could feel individuals bounce off our wetsuits and were able to capture several by cupping our hands together.

At this point, 50-60 silversides (250-300 mm TL) were noted at the upper edges of the swirling anchovy school. A trailing tongue of 100-200 anchovies was created as the main school swirled back-and-forth; the tongue was attacked repeatedly by 10-

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15 silversides. Cooperative foraging (Schmitt and Strand 1982) was not apparent, either in forming or attacking the tongue. Swallowing behavior was noted in several of the attacking silversides and two silversides were observed to catch and ingest an anchovy. Many anchovy scales were present in the water column surrounding the attacking silversides.

After 2-3 min, the silversides left. The anchovy school then expanded to a larger and less-dense configuration and resumed its normal swimming behavior. After an additional 5-10 min, however, the school again contracted to a dense swirling aggregation in response to the presence of a mixed-school of 30-40 silversides and 5-10 jack mackerel (*Trachurus symmetricus*) (250-300 mm TL). Although the anchovy school reacted in the same way as during the previous attack, neither silversides nor jack mackerel were observed to ingest anchovies during the second encounter.

After the second encounter, a single anchovy was observed thrashing within the grasp of tentacles from a benthic terebellid polychaete. The captured anchovy (47 mm TL) and polychaete were collected and preserved.

The importance of small anchovy in the diet of large silver-sides remains to be determined, but our observations establish that large silversides prey on small anchovies. Virtually all prior studies investigating food habits of silversides report a diet of small crustaceans and algae (including diatoms). Measurements of preserved silversides (Moss Landing Marine Laboratory fish collection) revealed a mean gape of 15 x 9 mm for *A. californiensis* ($n = 5$, 230-270 mm TL) and 14 x 8 mm for *A. affinis* (230 mm TL). Thus, preserved individuals of both species that are approximately the size of silversides observed consuming anchovies in the field, have gapes sufficiently large to accommodate a 6 x 3 mm anchovy (47 mm TL). Large silversides are opportunistic piscivores; however, piscivory may be relatively unimportant, as not all of the silversides we observed actually participated in the attacks on anchovy.

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GROUND SQUIRRELS FEEDING ON EELGRASS

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On 7 August 1992, along the harbor waterfront in Morro Bay, San Luis Obispo County, California, four California ground squirrels (*Spermophilus beecheyi*) were seen retrieving blades of eelgrass (*Zostera marina*) from the salty waters of the bay, and then eating them. This activity was again observed on 10 August 1992, at which time photographs were taken (Fig. 1). There are several interesting aspects to this observation.

At many waterfront sites, rocks have been placed on slopes to form a revetment which reduces erosion by waves and tides. Personal observations at Point Lobos, Ventura, and Long Beach, California, as well as at Morro Bay, indicate that squirrels can establish sea level colonies in the revetments of urban or harbor locations. At the west end of Beach Street in Morro Bay, such a revetment has been further strengthened by pouring concrete over the rocks, leaving a few holes through which the squirrels can get down under cover. The use of such an artificial site was not described by Grinnell and Dixon (1918), or by subsequent authors.

No natural food supply exists at most man-made littoral habitats. At Morro Bay the only plants growing in the vicinity are unpalatable species: tree tobacco (*Nicotiniana glauca*), coast golden bush (*Isocoma menziesii*), and sweet alyssum (*Lobularia maritima*). Squirrel colonies in tide level revetments depend almost entirely on food brought to the site by humans. At Morro Bay, this food supply includes peanuts,



Figure 1. (Left) Adult California ground squirrel reaching for a floating blade of eelgrass. (Right) Subadult ground squirrel eating eelgrass

pistachio nuts, french-fried potatoes, bread, various brands of salty chips, and candy. This is totally different from the typical ground squirrel diet (seeds and vegetative parts of many grasses and herbaceous plants), but appears to include the essentials necessary for their survival. Squirrels inhabiting revetments are usually fat, with glossy coats, and reproduce successfully.

A variety of micro-organisms grow on eelgrass blades (Ricketts et al. 1985) and possibly the Morro Bay squirrels were eating this encrusted food source. However, the squirrels were observed eating the whole blade, not just removing material from its surface. Further, they have not eaten the small crabs and molluscs which live in shallow water and on wet rocks at the lower edge of the revetment; these marine animals are still present locally. The squirrels avoided entering the water, although they did get their front feet wet when pulling in the eelgrass.

California ground squirrels do not require free fresh water, although they will drink if it is available (Grinnell and Dixon 1918). Murie and Michener (1984) reported that ground squirrels obtain water from the moist plant material which they eat, but the xeric, unpalatable plants at most sea level sites do not provide such a natural source. Ungar (1991) stated that eelgrass tissue fluid had a higher sodium concentration than sea water, so it is unlikely that the squirrels were eating eelgrass for its water content. Finally, eelgrass is not known to be a food plant for any other mammals except humans (Armstrong and Thorne 1989) and dugongs (*Dugong dugon*); Dorst and Dandelot (1969). Martin et al. (1951) list only several waterfowl species as consumers of eelgrass.

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BOOK REVIEW

GUIDE TO NORTHEAST PACIFIC ROCKFISHES

Genera *Sebastes* and *Sebastolobus*

by Donald E. Kramer and Victoria M. O'Connell. 1988. Alaska Sea Grant College Program. Marine Advisory Bulletin #25. Fairbanks. vii + 78 p. \$10.00.

Alaska Sea Grant College Program has produced a very fine publication titled "Guide to Northeast Pacific Rockfishes Genera *Sebastes* and *Sebastolobus*," by Donald E. Kramer and Victoria M. O'Connell. The title is somewhat of a misnomer in that the guide is a regional treatise to the species of rockfishes and thornyheads known to occur in Alaskan waters. The book is printed on heavy coated card stock that is semi-water resistant, is spiral bound, and totals 78 pages. Its contents include: Preface, Introduction, a page portraying important morphological characteristics of a generalized rockfish, a second page illustrating head structures which enumerates the cranial spine pattern, the main text, Selected references, and indices to common and scientific names. The main body of the text, the Rockfish Guide, consists of two pages devoted to each listed species. One (typically) to three photographs of the species occupies the first page while the second page consists of a diagrammatic illustration delineating important morphological characters and textual information which encompasses: description, size, range/habitat, and remarks. The photographs of the included species vary from excellent to fair, but all appear to be of freshly caught specimens and typify what one might normally encounter. Thirty-seven species are covered of which most are well known from Alaska. Two species, the dusky rockfish, *Sebastes ciliatus*, and blue rockfish, *S. mystinus*, require further study from this geographic area. Three species (chilipepper, *S. goodei*; shortbelly rockfish, *S. jordani*; and blackgill rockfish, *S. melanostomus*) are extralimital but are included based on records from British Columbia or unconfirmed Alaskan reports.

The authors state: "The primary purpose of this guide is to simplify the identification of rockfish found along the Alaska coast. It is intended for those who do not have the experience or the time to use a key for rockfish identification." The method required to identify a fish is to match the specimen in question with a photograph in the guide and then corroborate its identity by using the associated diagrams and description from the text. This technique should usually prove successful.

The information presented in this volume is general and accurate; few errors were found. However, several are worthy of discussion. The illustration of head structures and spines (p. vii) is of primary importance as an aid in correct identification. One should learn the terminology and position of the cranial spines to effectively identify rockfishes. The spines labeled supracleithral and cleithral are in fact the post-temporal and supracleithral spines, respectively. This is primarily an error of perpetuation as most historic keys to Pacific rockfishes have used this nomenclature, although erroneous and in need of rectification.

Under silvergray rockfish, *S. brevispinis*, the primary character listed to separate this species from the bocaccio, *S. paucispinis*, is dorsal spine count [*sic* - in reality the character is dorsal soft-rays]. The statement "*S. brevispinis* has 15 to 17 spines [soft-rays] on dorsal fin while *S. paucispinis* has 13 to 15, usually 14" is not valid. The normal dorsal soft-ray count for both species is 13 to 15; the modal value for both is 14. Pectoral rays (17-18 vs. 14-16), anal fin rays (7, rarely 8 vs. 8-10), and total gill rakers (33-36 vs. 27-32) are characters that are reliable in distinguishing *brevispinis* and *paucispinis*, respectively.

Two species of thornyhead (genus *Sebastolobus*) are included: *S. altivelis* and *S. alascanus*. It would have been useful to mention *Sebastolobus macrochir*, the broadbanded thornyhead,

which is known from the Aleutian Islands. This species is of commercial importance in Japan and the comparison of the three species of thornyhead would be of value to fishery biologists working on groundfish resources in the North Pacific. It would not surprise me to see the broadbanded thornyhead captured off British Columbia or northern California for that matter, as other boreal species have occasionally been taken from these areas (e.g., roughscale sole, *Clidoderma asperrimum*). The statement under remarks for shortspine thornyhead, "... not important commercially due to small size," is contradictory. The shortspine is the largest of the three thornyheads and size is given as "To 75 cm (30 inches)," certainly a species of marketable dimension. The shortspine thornyhead has achieved considerable importance in the California trawl fishery where it is primarily exported to Japan; the remainder is marketed domestically as ocean catfish and ocean perch.

Kramer and O'Connell have done a fine job and have provided new insight into rockfish biology and identification. Biologists, marine resource managers, fishermen, divers, and fish processors from Alaska and British Columbia will find this guide invaluable. Persons from Washington, Oregon, and California will also find it a useful supplement to the standard rockfish references for these areas. The guide can be ordered from Alaska Sea Grant College Program, University of Alaska, Fairbanks, AK 99775-5040. The \$10 price tag, which includes shipping and handling, is a bargain in this age of spiraling book prices.

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