Biological Report, 82(11.28)
February. 1985

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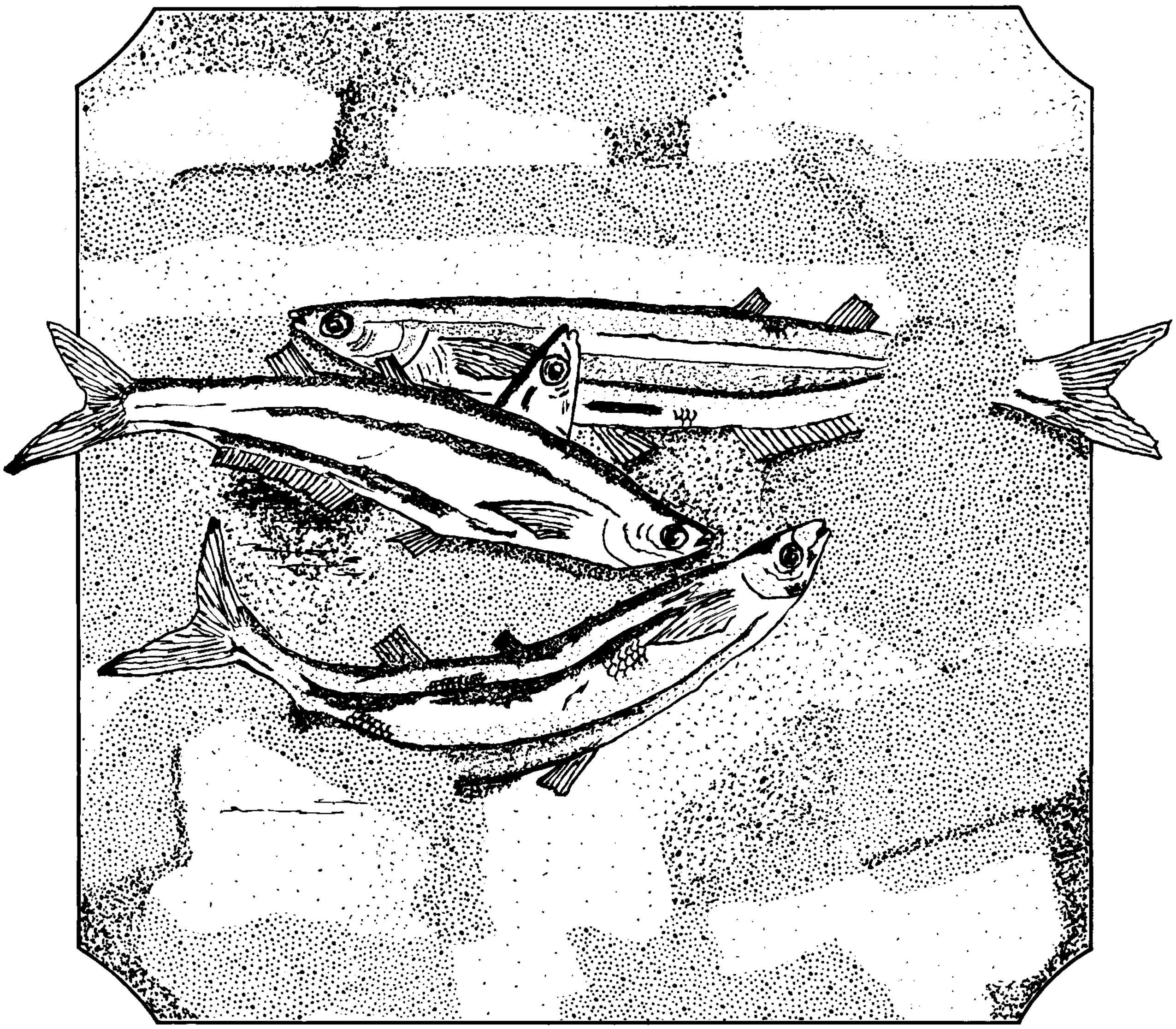
CALIFORNIA GRUNION



Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

This is one of the first reports to be published in the new "Biological Report" series. This technical report series, published by the Research and Development branch of the U.S. Fish and Wildlife Service, replaces the "FWS/OBS" series published from 1976 to September 1984. The Biological Report series is designed for the rapid publication of reports with an application orientation, and it continues the focus of the FWS/OBS series on resource management issues and fish and wildlife needs.

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest)

CALIFORNIA GRUNION

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (1)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F - 32)	Celsius degrees

ACKNOWLEDGMENTS

We are grateful for the reviews by Robert N. Lea, California Department of Fish and Game, and Robert J. Lavenberg, Natural History Museum of Los Angeles County. Thomas Hassler (California Cooperative Fishery Research Unit) kindly acted as the liaison with the National Coastal Ecosystems Team and greatly facilitated the completion of this report.

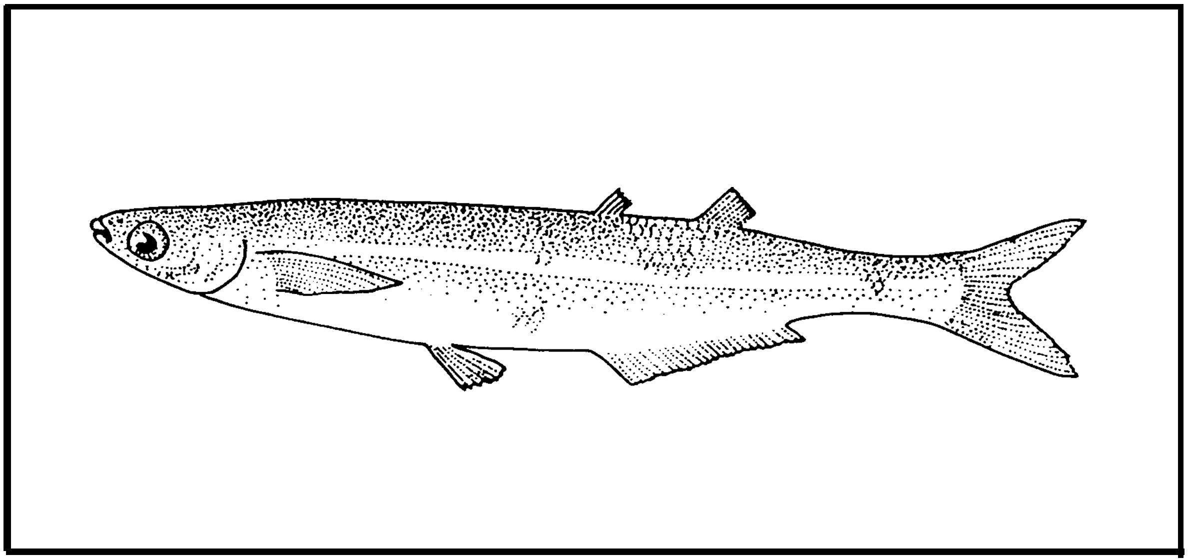

Figure 1. California grunion.

CALIFORNIA GRUNION

NOMENCLATURE/TAXONOMY/RANGE

Scientific name..........*Leuresthes tenuis* (Ayres)
Preferred common name.......California grunion (Figure 1)
Other common names......Grunion, smelt
Class.......................Osteichthyes
Order....................Atheriniformes
Family.......Atherinidae (Silversides)

Geographic range: coastal waters from San Francisco, California, to Magdalena Bay, Baja California; uncommon north of Point Conception (Figure 2).

MORPHOLOGY/IDENTIFICATION AIDS[1]

Dorsal fin V-VII + I,9-10; anal fin I,21-24; midlateral scales, 75 (Moffatt and Thompson 1978a); gill rakers 5-7 + 28-29; vertebrae 47-50. Body elongate and slender; eye diameter equal to snout length; maxillary not reaching pupil; premaxillary protrusible; jaw teeth lacking or minute; anal fin begins below 1st dorsal fin; scales between dorsal fins 7-9.

Color in life: greenish above, with a silver-blue lateral stripe; silvery below; bluish blotch on cheek.

REASON FOR INCLUSION IN SERIES

California grunion are caught by hand by sport fishermen during the

[1] Largely extracted from Jordan and Evermann (1896), Miller and Lea (1972), and Eschmeyer et al. (1983).

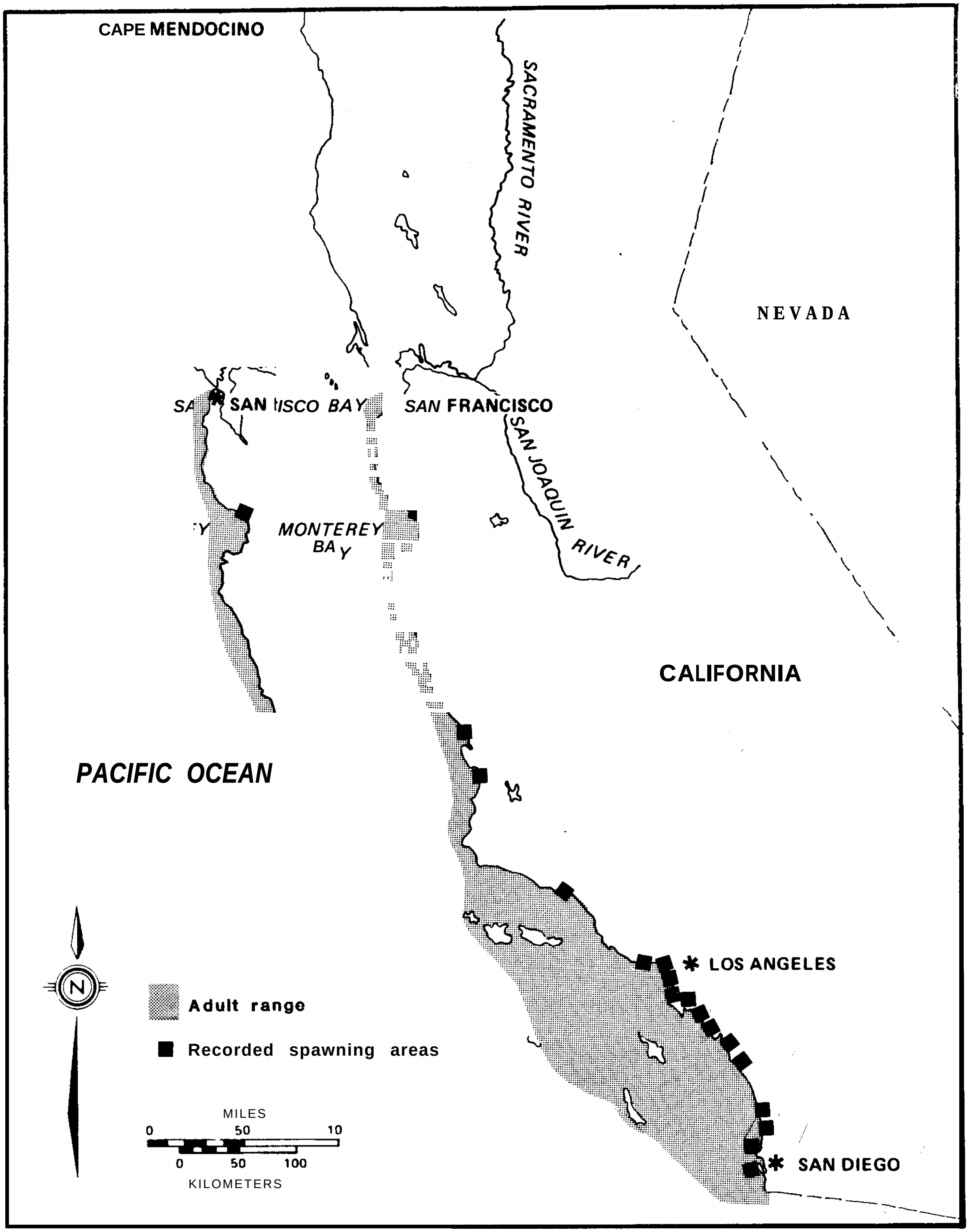

Figure 2. Distribution of the California grunion along the California coast of the United States.

open season when the fish spawn on beaches above the surf line at night (see LIFE HISTORY). The commercial catch of grunion is taken incidentally while fishing for other species and is marketed fresh as "smelt." Limited quantities are used for live bait.

LIFE HISTORY

Spawning

The grunion's unique spawning habits have long been recognized and it has been called the "fish that spawns on land." Through this unusual behavior, the California grunion has traded numerous marine perils for fewer terrestrial hazards, and thereby improved the probability of egg survival (Thompson 1919). The spawning season begins in late February or early March and may extend to early September; peak spawning is in April and May (Clark 1925). The protracted season may vary from year to year by several months (Walker 1952). Most females in their third year of life (age-group II) begin spawning early in the season (April-May), whereas fish in their second year of life (age-group I) spawn somewhat later (May-June). According to Clark (1925), about 30% of the females will have spawned in March, 75% by late April, and 90% by early May. The remaining 10% spawn from May to September. In late July, only 7% of the females examined contained mature ova, and in late August only immature ova were observed (Clark 1925).

Grunion spawn as far north as New Brighton State Beach, Monterey Bay (Spratt 1981) and as far south as Mexico. The largest grunion spawning runs reported by Spratt (1971) are typically along the beaches in southern California (Figure 2).

In grunion spawning waters there are two high and two low tides daily. The higher of the high tides is at night in spring and summer. Each month, these higher tides reach their peak at the full and new moon. California grunion spawn every 4 weeks during the full moon tidal series (Thompson 1919). Apparently an individual grunion may spawn about every 2 weeks during both the full and new moon cycles. Female grunion are known to spawn as many as eight times a season on consecutive runs (Clark 1925). Grunion begin spawning two to six nights after the peak tides of each cycle, when each succeeding tide is lower than that of the previous night (Thompson 1919). Only three or four nights are suitable for spawning during each cycle. The spawning runs begin immediately after high tide. At first, several fish, normally males, are swept up the beach and become temporarily stranded on the sand as they swim against the receding water. Gradually increasing numbers of both sexes beach themselves with succeeding waves. Spawning begins about 20 minutes after the first fish appear, peaks in one hour, and lasts 30 to 60 minutes. During peak spawning, thousands of grunion litter the beach (Walker 1952). When the tide has ebbed about one foot, the night's run terminates as suddenly as it began.

Typically, females are accompanied by one or more males as they swim toward shore (Walker 1952). Using a beach seine, Thompson (1919) captured twice as many males as females during a spawning run. If males are not present when the female is ready to spawn, she returns to the sea without laying eggs (Walker 1952). During spawning, the female arches her body, keeping the head up while the caudal fin vigorously excavates the semifluid sand (Walker 1952). As the tail sinks, the female twists her body and digs tail first until she is buried up to her pectoral fins. Occasionally females completely bury themselves in the nest (Thompson 1919). After the female is in the nest, up to eight males attempt to mate with her (Walker 1952). The males curve around the female, placing their vents close to or in contact with her body. Concurrently, the female emits eggs 50 to 75 mm below the surface of the sand. The males discharge their milt into the sand near the female and immediately retreat toward the ocean. The milt flows down the female's body until it reaches the eggs below. The female then twists free and returns to the sea with the next wave. Generally about 30 seconds elapse from "nest" digging to egg laying but some fish remain on the beach for several minutes.

Waves tend to erode sand from the beach as the tide rises and to deposit sand as it falls; consequently, falling tides deposit more sand (41-46 cm) over previously buried eggs, which helps protect the eggs during low tides. The eggs remain in the sand for about 10 days, until the higher tide of the next lunar series erodes the sand and washes the eggs free. Eggs do not hatch until they are uncovered and agitated by the surf (Thompson 1919). Eggs of a single clutch hatch within 2 to 5 minutes. Agitation is necessary because larval movement does not aid in escape from the egg shell. Seawater and agitation probably stimulate the release of an enzyme that softens the covering of the egg (Daugherty 1962). A study by Thompson (1919) demonstrated that egg capsules effectively protect developing embryos from freshwater and desiccation for at least 8 days. Eggs do not usually hatch prematurely unless the eggs are washed free. For example, eggs 1 aid on a calm night were washed free the next night by high waves during a storm; the result was complete mortality.

Fecundity

Fecundity is positively correlated with the size of the female. One female 137 mm long (all lengths are total lengths) contained 1,475 eggs and one 171 mm long had 2,528 (Thompson 1919). Six grunion nests examined by Thompson (1919) contained from 1,149 to 2,705 eggs (mean, 2,200). Counts of 1,600 to 3,600 eggs in eight females were made by Daugherty (1962); in several, larger females produced more eggs.

Ova Development

Ovaries of females collected before January contain only immature eggs (mode, 0.08 mm; largest diameter, 0.27 mm). In January the eggs form an intermediate size class which by the end of February attains a maximum diameter of 0.78 mm. Fish taken in February with less fully developed ova probably begin spawning later in the season. A maturing egg size class, 0.74 to 1.29 mm, arises from the intermediate class and is usually spawned in March. Immediately after the fish spawn, a second maturing class of eggs begins differentiating and is spawned 15 days later. This 15-day cycle cont nues throughout the period of spawn ng; therefore, as the season progresses, a slight time lag is established between the 2-week tidal peaks and the spawning dates (Clark 1925).

Throughout the spawning season the three egg size classes remain distinct. As the number of maturing eggs differentiated from the intermediate class increases during the spawning season, immature eggs are probably recruited to this intermediate group. The number of intermediate eggs in each female decreases from one spawning to the next. After the last spawning, the remaining intermediate eggs are resorbed; the immature eggs are carried over to the next year (Clark 1925).

The California grunion egg is spherical and about 1.6 mm in diameter at hatching (David 1939). A range of 1.75 to 2.20 mm was reported by Moffatt (1977). The eggs lack the filaments attached to eggs of many atherinid species (Clark 1925). Newly deposited eggs have many oil globules

(David 1939). The size and number vary during development until only one large uncolored oil globule remains in the yolk sac of the larva. Cleavage is usually complete 12 hours after fertilization. The embryonic axis is formed about 18 hours after fertilization, but the lenses and auditory capsules do not form until about 34 hours. The heart begins beating at about 46 hours and the head and tail are free at about 62 hours. Blood circulation can also be observed at this time and the formation of the somites is nearly complete. At about 84 hours the eyes of the embryo are pigmented, there are two otoliths in each auditory capsule, the myomere count is 45 or more, and melanophores are present on the head, upper sides, and above the gut. At about 184 hours, the embryo has reached its full length, its pigmentation is complete, and it is ready to hatch. In one study, Thompson (1919), who collected eggs from a spawning beach daily to observe development, reported that most eggs hatched on the 10th day (240 hours) after spawning (and collection), 1 day before the next series of high tides. The remaining eggs hatched on the next day, showing that the rate and duration of egg development is in synchrony with the tidal cycle. The evolution of egg size and yolk volume in grunion has apparently been influenced by the tides more than by temperature or any other factor (Moffatt and Thompson 1978b).

Larval, Postlarval, and Juvenile Stages

In contrast to larvae of other marine fishes, California grunion are large and well-developed when hatched. They are 6.5 to 6.8 mm long at hatching and 7.8 to 8.0 mm long after three days (David 1939). According to May (1971), the average length of 9 recently-hatched larvae was 9.0 mm and that of 20 4-day olds was 9.4 mm. Newly-hatched grunion are extremely active and the eyes and jaws are functional (Thompson 1919; May 1971). The larvae are capable of immediate feeding but retain a yolk sac for 4 to 6 days (David 1939; May 1971). In laboratory feeding studies, May (1971) showed that grunion larvae can live for a relatively long time without food -- some as long as 3 weeks. In one experiment, all larvae that survived 16 days without food began feeding when offered food and were alive at the end of the study 20 days later (May 1971).

Newly hatched larvae usually live at or near the water surface (David 1939). The mouth is open then, and the first buds of the gill filaments are visible. Larvae do not begin active feeding until the second day after hatching. Between the fifth and ninth day, swimming activity increases and they descend slightly below the surface film (David 1939). The average length of 10 larvae 16 days old was 12.2 mm, and that of 10 25-day-old larvae was 15.1 mm (May 1971).

Larval atherinids live predominately in the neuston (surface) layer (Lindsay et al. 1978); however, in collections from California coastal waters, Kauffman et al. (1981) could not identify to species the atherinid larvae less than 15 mm long. Most postlarval and juvenile atherinids longer than 15 mm were identified as grunion. Large larvae (>15 mm) were captured exclusively at night using sampling gear fished near the surface. Their mean density was 10/m. Grunion larvae longer than 15 mm were scarce near the surface during the day and absent at mid and bottom depths during day or night. Grunion larvae are strong swimmers and may simply avoid the sampling gear during the day. According to Kauffman et al. (1981), atherinid larvae longer than 10 mm accounted for more than 90% of the larvae sampled during the day (density up to $90/m^3$). All larvae caught at mid-depth and near-bottom were less than 10 mm long (density $0.5/m^3$). The percentage increase of the smaller larvae in mid-depth samples taken at night indicates they disperse at night (Kauffman et al. 1981). The young fish grow rapidly and are about 127 mm long at the end of their first year of life (Walker 1952).

Adults

Except for spawning habits and behavior, little is known about the adult stage in the coastal zone. Grunion populations seemingly move little along the shoreline (Walker 1952), but seasonal inshore-offshore movements not associated with spawning are well-documented.

Maturity and Life Span

Grunion mature in their second year of life and have a short life span. In January some yearling females contained immature eggs, and others intermediate-sized eggs. In February nearly all young females had both immature and intermediate eggs, and young males appeared to be nearing maturity. They apparently spawn in their second year of life (age group I). The largest grunion collected by Clark (1925) was a 3-year-old male 170 mm long. She collected no grunion older than age II.

GROWTH CHARACTERISTICS

Scales can be used to study the age and growth of grunion. In contrast to many fish, grunion form an annulus in July and August rather than in the spring (Clark 1925). Growth data given here, however, are based largely on length distribution rather than the scale method. In September, at an age of about 2 months, average lengths were 79 mm for males and 81 mm for females. Until September, their mean daily growth rate was 0.73 mm (Clark 1925). From September to the end of January, the growth rate declined because of low winter temperatures but accelerated again in early February through April. In September, young-of-the-year females were only slightly longer than young-of-the-year males, but by April the females were about 10 mm longer. This difference was maintained throughout adult. life. The growth of age-groups I and II also accelerated in late winter and spring, then tended to decline in early May with little growth evident in late May, June and July (Clark 1925). Growth began again in August.

Growth of grunion was most rapid during the first year of life and then declined in following years (Clark 1925). At the end of the first year the mean total length was about 110 mm for males and 119 mm for females. After the second year's growth, average lengths were 129 and 140 mm. For the few fish reaching the beginning of a second spawning season, the average lengths were I43 mm (males) and 154 mm (females). The largest fish reported was 191 mm long (Miller and Lea 1972). Among spawning fish caught in a beach seine in April, average lengths of males and females were 129.5 and 142.5 mm (Thompson 1919). According to Clark's (1925) findings, the fish measured by Thompson (1919) were probably entering their second spawning season.

The rate of weight gain was not as proportionately rapid as the corresponding increase in length during the first year (Clark 1925). In following years, as growth in length slowed, the rate of weight increase diminished only slightly. In February, the mean weight of yearling fish was 11.8 grams for fish 110 mm long, and 15.2 grams for fish 120 mm long (Clark 1925). Fish in age group II and older, which were 130 to 140 mm long, averaged 19.3 to 23.0 grams; and those 145 to 155 long averaged 26.7 to 32.3 grams. Calculated weights, based on the formula Weight (g)=0.0089 Length^3 (mm), differed only slightly from the mean measured weights.

COMMERCIAL AND SPORT FISHERIES

California grunion are sought by sportsmen, nature lovers, and curious observers during grunion spawning runs, yet accurate estimates of the sport catch and the contribution to the economy are lacking. Despite their high concentration on beaches during spawning, grunion are not abundant (Walker 1952). A few are landed commercially by round haul nets and lamparas and are sold for bait or marketed as smelt in the fresh-fish market (Clark 1928; Young 1949; Daugherty 1962; Frey 1971). Most grunion landed commercially are taken in late winter and in spring just before the spawning season (Clark 1928). In February 1927 the Los Angeles County grunion catch for the fresh-fish market peaked at about 6,000 lb and averaged about 2,759 lb monthly in January-March. The highest catch reported was 9,573 lb from October 1926 to October 1927. No commercial landings of grunion have been reported since (Frey 1971), probably because they are caught largely by smelt fishermen and reported in the smelt catch. Grunion are occasionally taken in pure hauls of up to 4 or 5 tons (Daugherty 1962). Only then are grunion sold as fresh fish and then only if smelt are relatively scarce. Otherwise, the mixed catch is sold as bait or to canners of pet food (Daugherty 1962).

In the 1920's the grunion fishery began showing signs of depletion (Clark 1928), which was probably due to overfishing and habitat alteration (Walker 1952). From 1927 to 1946, the fishing season in California was closed from April to June. By 1947, abundance had increased and the restriction was eased. Grunion may now be taken by sportsmen only by hand throughout the year except in April and May. Although the population size is unknown, the resource appears to be maintaining itself under the present sport fishing intensity (R. Klingbeil, California Department of Fish and Game; pers. comm., 1983); Since grunion populations seldom move laterally along the shoreline, local controls may be adequate for management (Walker 1952).

ECOLOGICAL ROLE

In spite of the publicity given to the unique spawning behavior of the grunion, little attention has been given to its ecological role.

Gut content analysis indicated that grunion fed primarily during the day (Kauffman et al. 1981). Food found in larvae less than 10 mm long consisted largely of copepod nauplii and tintinnid protozoans. Cyclopoid copepods, Oithona sp., numerically dominate the gut contents of larvae 10-28 mm long. The harpactacoid copepod Euterpina acutifrbns and the cyclopold copepod Corycaeus anglicus are much less abundant (Kauffman et al. 1981). The relatively low densities of these animals in California's coastal waters suggest that most grunion larvae must search for prey.

Adult grunion eat food similar to that eaten by larvae and juveniles. Stomach contents consisted of microscopic and slightly larger planktonic organisms (Fitch and Lavenberg 1971).

All life stages of grunion are preyed upon by a number of predators. Eggs buried in the beach sand are fed upon by sand worms, shore birds, and even ground squirrels (Fitch and Lavenberg 1971). Walker (1949) reported that shorebirds, including marbled godwit (Limosa fedoa) and whimbrel (Numenius phaeopus) actively probe the sand in search of grunion eggs. An isopod, two species of flies, and a beetle also preyed on buried grunion eggs (Frey 1971). Juvenile and adult grunion are preyed upon by halibut (Paralichthvs californicus), sand bass (Paralabrax), white croakers (*Genyonemus lineatus*), and other large predators including man (Fitch and Lavenberg 1971).

ENVIRONMENTAL REQUIREMENTS

Tidal Cycle

Tidal cycles may have influenced the evolution of egg size in the grunion. In possible response to the more irregular tides of California, the eggs of the California grunion are much larger than those of their closest congener *Leuresthes sardina* from the Gulf of California (Moffatt and Thompson 1978b).

Cyclic tides also deposit additional sand over the developing eggs. This provides protection from thermal, osmotic, and desiccation stresses as well as predation (Middaugh et al. 1983).

Temperature

Grunion eggs hatch over a water temperature range of 14.0 °C to 28.5 °C. Water temperatures of 29.8 °C and above reduced the viability of grunion larvae (Hubbs 1965; Ehrlich and Farris 1971). An increase of about 9 °C is required to double the development rate (Hubbs 1965). Yolk-sac larvae showed a preference for water temperatures near 25 °C (Ehrlich and Muszynski 1981), well above the range that produced maximum growth. Feeding larvae apparently select relatively high temperatures for growth. The ability of larvae to metabolize food (protein) decreased above 25 °C and below 16 °C (fat) (Ehrlich and Muszynski 1981). Growth rates are positively correlated with temperature between 18 °C and 25.4 °C (Ehrlich and Farris 1972).

Salinity

Only half of the grunion eggs placed in freshwater by Hubbs (1965) hatched. Lower and upper lethal salinities for prolarvae were 4.2 and 41 ppt and for 20-day-old post larvae these salinities were, respectively, 9 and 30 ppt (Reynolds et al. 1976). A decrease in salinity tolerance with age was also reported.

Light

Exposure to light seems to reduce hatching success of grunion eggs (Hubbs 1965). Young grunion are positively phototactic and can be attracted to light as bright as 10,000 lux (Reynolds et al. 1977). The strength of the gathering response is apparently related to the strength of the light stimulus.

Other Environmental Factors

Grunion eggs require moisture to prevent desiccation. Interstitial water (g water/kg sand) in grunion nests can range from 1% to 19% (Middaugh et al. 1983).

An unidentified nonthermal component of power plant effluents significantly reduces hatching success of grunion (Ehrlich 1977). At all test temperatures the percentage of eggs hatched in effluent water was lower than the percentage hatched in sea water collected before passage through the power plant.

Exposure of eggs to benzo(a)pyrene levels of 24 ppb or more decreased hatching percentage and increased morphological anomalies (Winkler et al. 1983).

There is no published information on dissolved oxygen or turbidity requirements for the California grunion.

The grunion is the host of several crustaceans and digenetic trematodes. The six known crustacean parasites are the copepods *Bomolachus pectinatus*, *Caligus olsoni*, and *Clauellopsis*; the brachiuran *Argulus* *melanostictus*; and the isopods *Nerocila californica* and *Lironeca californica* (Olson 1972). Metacercariae with the characteristics of *Bucephalopsis lebiatus* (Trematoda: Bucephalidae) infect the grunion heart muscle (Olson 1975). Among the trematodes, *Asymphylodora atherinopsidis* occurs in the posterior intestine of the grunion while *Lepocredium manteri* occurs in the expanded. anterior intestine (Olson 1977, 1978). The effects of these parasites on growth and survival are not known.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, range, life history, environmental requirements, and importance of coastal aquatic species. They are prepared to assist in environmental impact assessment. The California grunion (Leuresthes tenuis) has little commercial importance but is one of the most popular sport fish along the beaches of southern California. California grunion spawn on sand beaches about every 2 weeks (as many as eight spawnings per female) during full and new moon high tide cycles. The spawning season begins in February-March and may extend to early September. The eggs hatch in about 2 weeks. California grunion mature at a young age and have a life span of about 3 years. Larvae and adults prey on planktonic organisms, primarily copepods. Eggs are preyed upon by beach scavengers; adults are forage for larger piscivores. The California grunion exhibits a wide tolerance of salinity and temperature. They host several crustacean and digenetic trematode parasites.

17. Document Analysis a. Descriptors

Fishes, Growth, Spawning, Feeding, Sand beaches

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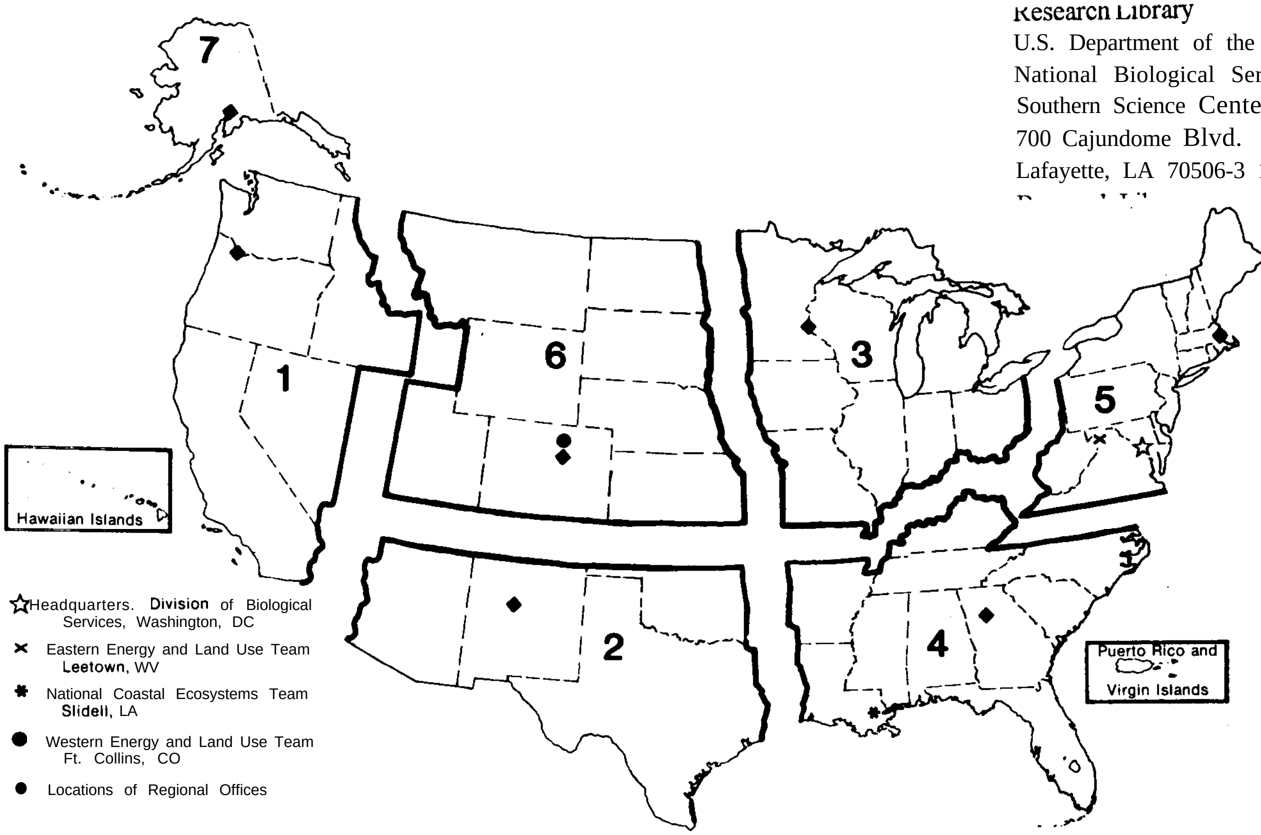

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