Biological Report 82(11.117)
December 1989

TR EL-82-4

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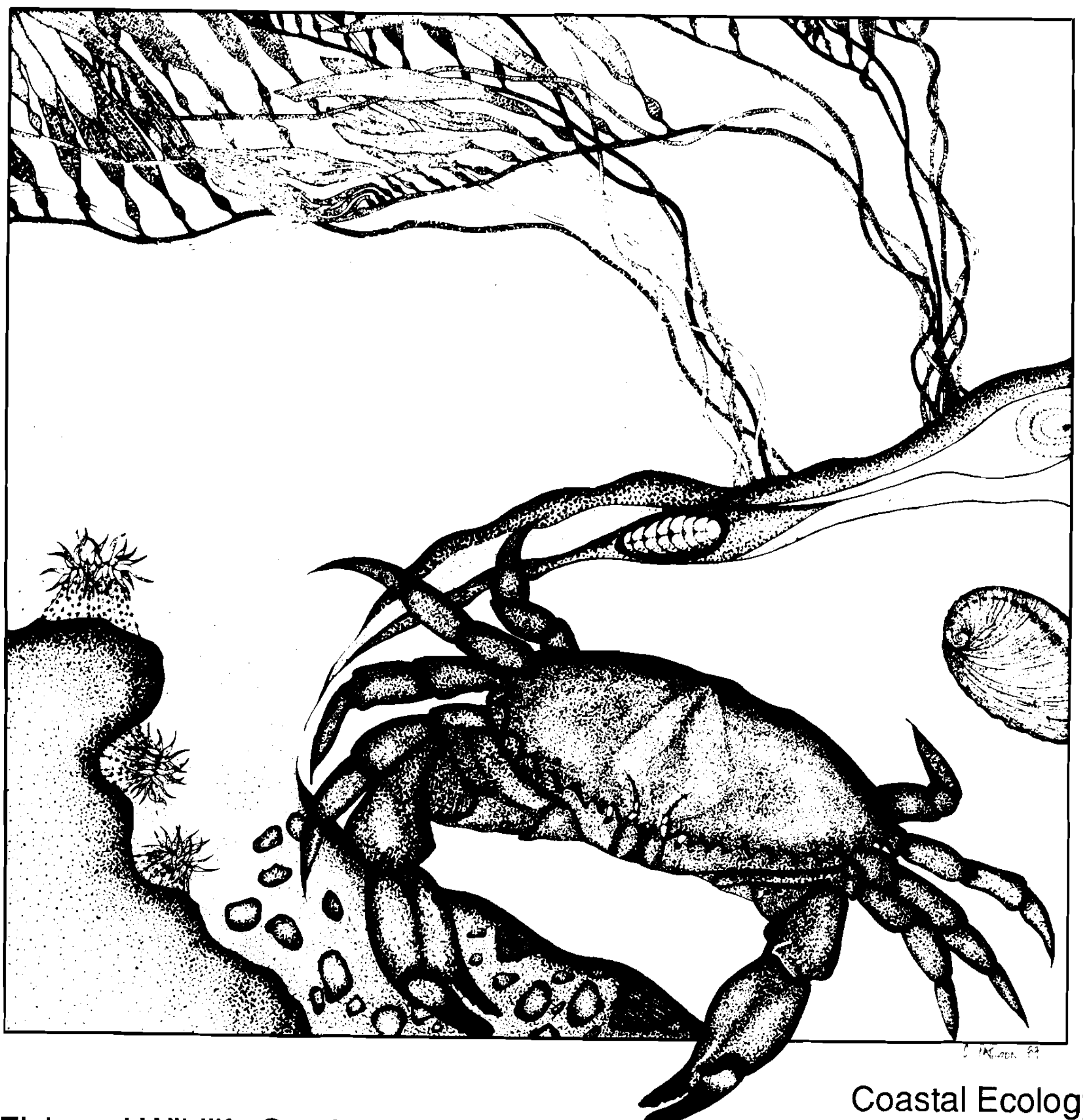
BROWN ROCK CRAB, RED ROCK CRAB, AND YELLOW CRAB



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

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

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

BROWN ROCK CRAB, RED ROCK CRAB, AND YELLOW CRAB

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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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Vicksburg, MS 39180

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
meters	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	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 (° C)	1.8 (° C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces	28.35	grams
pounds (lb)	0.4536	kilograms
pounds	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (° F)	0.5556 (° F - 32)	Celsius degrees

CONTENTS

FIGURES

ACKNOWLEDGMENTS

We gratefully acknowledge the reviews of this manuscript by Paul Reilly and David Parker of the California Department of Fish and Game, Jeffrey Shields of the University of California at Santa Barbara, and Christopher Toole of the California Sea Grant Marine Advisory Program.

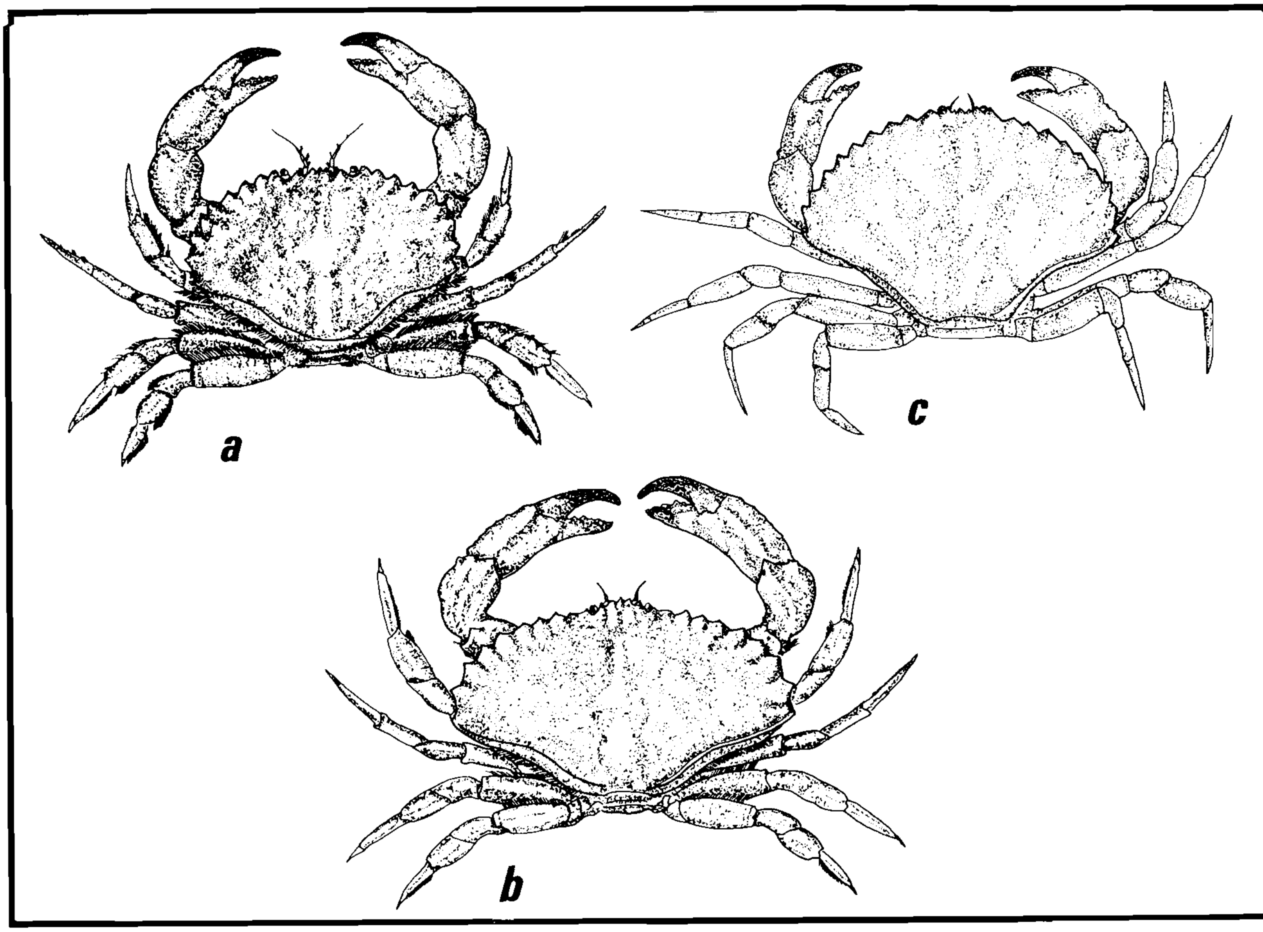

Figure 1. Rock crabs: a) brown rock crab (after Rathbun 1930); b) red rock crab (after Rathbun 1930); c) yellow crab (after Johnson and Snook 1955).

BROWN ROCK CRAB , RED ROCK CRAB , AND YELLOW CRAB

NOMENCLATURE/TAXONOMY/RANGE

Scientific name.........*Cancer antennarius* Stimpson 1856
Preferred common name.......Brown rock crab (Figure 1a)
Other common names............................Rock crab, brown crab, red rock crab, spot-bellied crab

Scientific name...............*Cancer productus* Randall 1839
Preferred common name...........Red rock crab (Figure 1b)
Other common names.........................Rock crab, red crab

Scientific name................*Cancer anthonyi* Rathbun 1897
Preferred common name..............Yellow crab (Figure 1c)
Other common names.......................Rock crab, gold crab

Class..Crustacea
Order..Decapoda
Infraorder..Brachyura
Family..Cancridae

Geographical ranges (Figure 2): rock crabs are distributed in coastal waters of the west coast of North America (Nations 1975). *Cancer antennarius* ranges from Sequim, Washington (Jensen and Armstrong 1987), to Baja California, Mexico, including Islas de Todos Santos (Schmidt 1921; Garth and Abbott 1980). Its habitat extends from the low intertidal zone to depths greater than 100 m, and includes substrates of

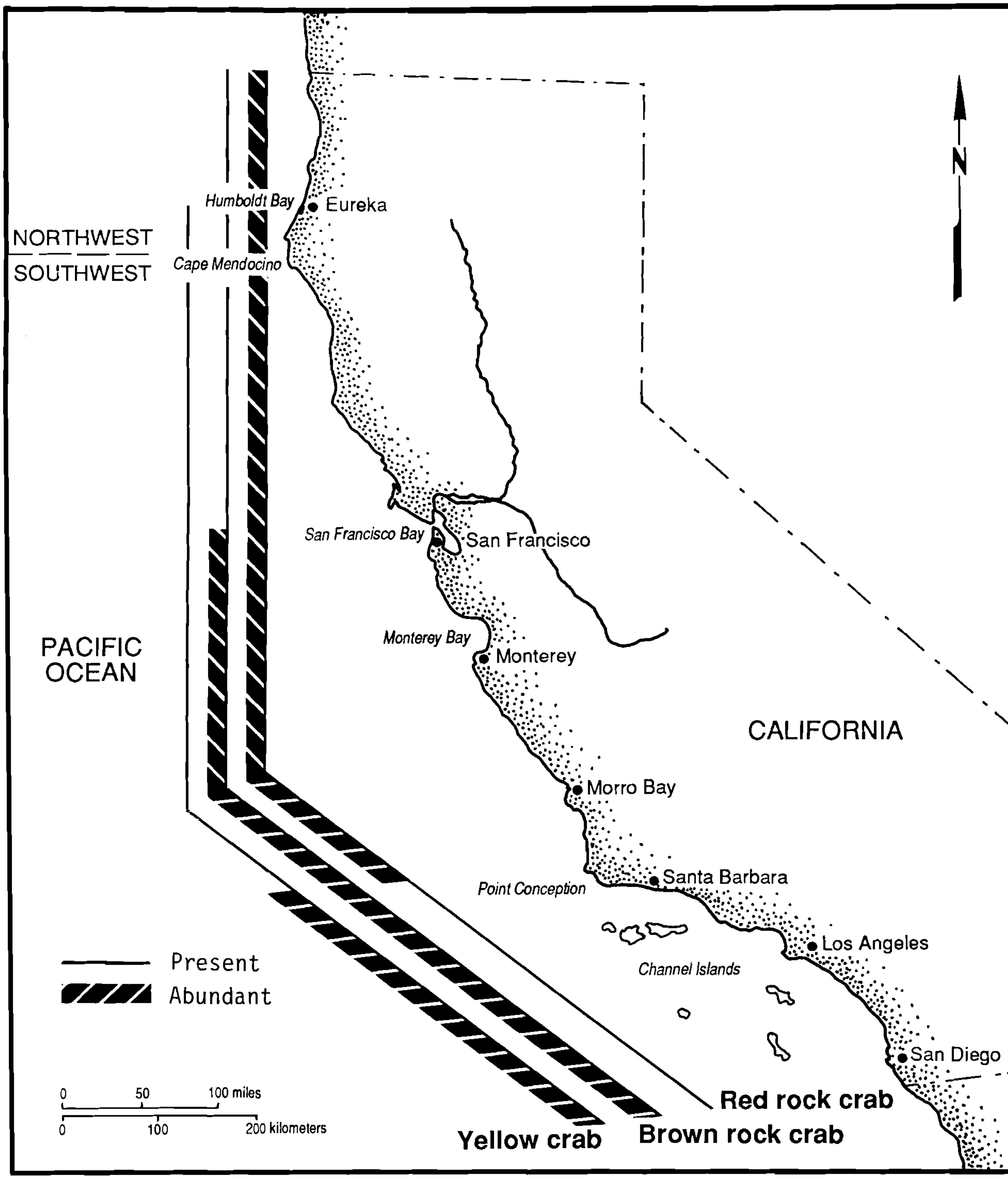

Figure 2. Distribution of brown rock crab, red rock crab, and yellow crab in the Pacific Southwest.

rocky shores, subtidal reefs, and coarse to silty sands (Winn 1985).

Cancer productus occurs from Kodiak Island, Alaska, to San Diego, California (Schmidt 1921). San Diego is the margin of the southern range limit though the species has been reported at Bahia Magdalena, Baja California, Mexico (Garth and Abbott 1980). The habitat of the red rock crab extends from the low intertidal zone, including bays and estuaries, to a depth of at least 91 m, and includes gravel and rocky substrates, subtidal reefs, coarse sands, and muds (Schmidt 1921).

Cancer anthonyi ranges from Humboldt Bay, California (Willis 1968) to Magdalena Bay, Baja California, Mexico (Schmidt 1921). Its habitat extends from the low intertidal zone, including bays and estuaries, to a subtidal depth of 140 m; it inhabits mostly silty sand to mud substrates and the sand-rock substrate ecotone of rocky reefs (Garth and Abbott 1980; Winn 1985).

MORPHOLOGY/IDENTIFICATION AIDS

Taxonomic keys to the species of *Cancer* in California were provided by Carlton and Kuris (1975). The following morphological descriptions are adapted from Rathbun (1930). All *Cancer* species are recognized by their broad, oval, uneven but not highly sculptured carapace which has numerous anterolateral teeth. Males are distinguished by a slender abdomen and mature females by a broad abdomen that is often hirsute on the margin. Lawton and Elner (1985), who studied the morphological relationships of 10 northern temperate *Cancer* species, considered the brown rock crab, red rock crab, and yellow crab closely related primarily on the basis of similarities in claw shape.

The brown rock crab is mottled dark brown dorsally (rarely uniformly orange or gray), and has red spotting over a white background ventrally. There are nine anterolateral teeth, and the carapace is widest at the eighth tooth. Characteristic long and stout paired antennae (from which the species name is derived) arise between the retractable stalked eyes. Legs are generally rough along the edges and may be hairy, especially in females and juveniles. The claws are black tipped with a single tooth or spine on the wrist.

Adult red rock crabs are mottled brick-red dorsally, and dirty white or yellowish white ventrally, but there are no red spots such as those on the brown rock crab. The carapace is widest at the eighth of 10 anterolateral teeth; the teeth become larger and more acute posteriorly. Red rock crabs are distinguished from other *Cancer* species by the characteristic frontal margin of the carapace between the eyes which is markedly produced as five equally-spaced teeth beyond the orbital angles (to which the species name refers). The red rock crab has a greater carapace width:carapace length ratio compared to that of brown rock crab and yellow crab. The claws are rough above and black tipped. Color of juveniles is often extremely variable ranging from pure white to a variety of color patterns including bands of brown and white, stripes of red and white, and brown stripes (Garth and Abbott 1980). The produced frontal margin is also distinct in juvenile crabs.

Adult yellow crabs are light brown to pale yellow dorsally and uniformly light yellow ventrally, without red spotting beneath. The carapace is widest at the ninth of 10 anterolateral teeth. The tips of the claws are partly or almost entirely darkened and the walking legs are generally without hair. Coloration of juveniles tends to be darker than that of adults, ranging from brown to gray. Yellow crabs are allied to the brown rock crabs, but have broader and less projecting anterolateral teeth, and less hairy legs.

Two other large *Cancer* species, the Dungeness crab (*C. magister*), and the slender crab (*C. gracilis*) also occur in the coastal areas of California. In both species the tips of the claws lack dark coloration. The Dungeness crab is widest at the 10th or last anterolateral tooth and is light brown-yellow dorsally. Additionally, it is the only species of *Cancer* in which the tip of the last abdominal segment is rounded rather than pointed (P. Reilly, California Department of Fish and Game [CDFG], Menlo Park; pers. comm.). The slender crab has a light olive coloration, slender walking legs, and only nine low anterolateral teeth.

A small species of *Cancer* in the Pacific southwest region, the hairy cancer crab (*C. jordani*), may be confused with the juvenile brown rock crab. The hairy cancer crab, however, has 10 sharp anterolateral teeth, alternately large and small, and lacks red spotting ventrally.

REASON FOR INCLUSION IN THE SERIES

The three rock crab species treated here contribute to a commercial fishery that has grown unevenly but steadily from 1963 to 1986. Rock crabs had been fished previously at a low level of effort since at least 1930 (Heimann and Carlisle 1970). Commercial fishery landings statistics of CDFG showed that annual landings in the mid-1980's approached 2 million lb with an ex-vessel value exceeding $1.6 million. Declines in the stocks of other commercially important nearshore species have stimulated interest in further use of rock crab species; continued growth of the fishery is expected (D. Parker, CDFG, Long Beach; pers. comm.). The three species also support a small recreational fishery.

Rock crabs occupy a variety of coastal habitats and are an ecologically important component of the nearshore environment. As juveniles, they are important prey of numerous invertebrates and many commercially and recreationally important fishes (Van Blaricom 1982; Roberts et al. 1984). Adult rock crabs are a major food of the threatened southern sea otter (*Enhydra lutris*) along the contral California coast (Benech 1986).

LIFE HISTORY

Mating

Details on seasonal and regional variability in mating for each of the three species are lacking, although a generalized description of reproduction known from other *Cancer* species may be reasonably applied (see Warner 1977). The female mates in the soft-shell condition, after molting. Soft-shell female rock crabs are most common in spring and fall, though they may be found throughout the year (Reilly 1987; CDFG, unpubl. data). A pheromone released in the urine of females before they molt attracts males and stimulates mating behavior. Yellow crabs and brown rock crabs are stimulated to pre-copulatory position and activity by pheromone concentrations as low as 10^{-8} moles/l and 10^{-10} moles/l, respectively (Kittredge et al. 1971). The male carries the female, before her ecdysis, through insemination, and until initial hardening of her shell occurs. Mating involves insertion of the male gonopod into the spermatheca of the female and deposition of a spermatophore. Spermatophores contain sperm that is potentially viable for a year or longer, for multiple spawnings. Mated females (in the "plugged" condition) may be identified by the presence of the hardened spermatophore deposited in the spermatheca by the male, which presumably blocks further mating and prevents loss of sperm. Plugged yellow crabs have been most commonly found from spring to early summer in southern California (CDFG, unpubl. data). The plug is ejected during the first oviposition; multiple ovipositions may occur but no record of them has been published.

Eggs and Fecundity

The eggs are fertilized internally as they are extruded, about 11 weeks after the mating, and are carried by the female during development. They appear as a bright orange mass ("sponge") attached to setae on the endopodites of the pleopods, beneath the abdominal flap. Egg-bearing ("berried" or "ovigerous") female brown rock crabs are most common in central California in winter (Carroll 1982), although ovigerous yellow crabs and brown rock crabs are present throughout the year in nearshore waters (Toole 1985; Winn 1985; Reilly 1987). Ovigerous brown rock crabs have been observed buried in sand at the base of rocks in shallow water, and are found more commonly in water less than 18 m deep in southern California (Reilly 1987). The color of the eggs progressively darkens from orange to dark brown as embryos absorb the yolk during development. A single egg mass in brown rock crabs may contain from 0.41 million to 2.79 million eggs, red rock crabs from 0.56 million to at least 1.01 million eggs, and yellow crabs from 0.68 to 3.85 million eggs (A. Hines, Smithsonian Environmental Research Center, Edgewater, MD; pers. comm.). Clutch size in the yellow crab averages over 2.6 million eggs (J. Shields, University of California, Santa Barbara; pers. comm.).

In brown rock crabs and yellow crabs, 7-8 weeks are required for development and hatching of eggs at ambient temperatures of 10-18 °C (Anderson and Ford 1976; Carroll 1982). Yellow crab eggs hatched in about 43 days at 17 °C (J. Shields, pers. comm.).

Developmental times for red rock crabs are not available in the literature.

Larvae

Larval development in the brown rock crab was described by Mir (1961) and Roesijadi (1976), in the red rock crab by Trask (1970), and in the yellow crab by Mir (1961) and Anderson and Ford (1976). Development is similar in the three species. Larvae hatch as prezoeae and molt to first stage zoeae in less than 1 h. They advance through six stages of successive increases in size--five zoeal and one megalopal (Figure 3).

Anderson and Ford (1976) described the effects of temperature, diet, and culture systems on the growth and survival of larval and juvenile yellow crab reared in the laboratory. Average larval development times (from hatching through completion of the megalopal stage) were 33 days at 22 °C and 45 days at 18 °C. There are no data in the literature on total development time for yellow crabs reared at cooler ambient temperatures. For red rock crabs, development time to the megalopal stage was 97 days at 11 °C; however, none of the larvae survived to the first crab instar (Trask 1970). Total development time for Dungeness crab larvae in situ was estimated to be 80-95 days for completion of the five zoeal stages and 25-30 days for the megalopal stage (Reilly 1983). Larval development time in the Dungeness crab has been shown to be inversely related to water temperature (Poole1966).

During their planktonic existence, crab larvae become widely distributed over the continental shelf. Reilly (1983) found that, in central California, estuarine runoff and upwelling probably dispersed Dungeness crab zoeae offshore, and the northward flowing Davidson current dispersed larvae upcoast in winter. Shanks (1986) presented evidence that early stage larvae of rock crabs generally occurred on the bottom, or in depths up to 80 m, during the day; late stage larvae, however, were more abundant near the surface. He suggested that a combination of physical factors, primarily wind-generated surface currents and tidally forced internal waves, caused megalopae to be transported shoreward (Shanks 1983). Late stage larvae generally begin to recruit to the nearshore habitat in spring (Lough 1976; Reilly 1983; Winn 1985), a season of strong onshore sea breezes along the California coast. Densities of *Cancer* spp. zoeae as high as 336/m^3 and averaging 80/m^3 have been recorded from nearshore waters in central California in spring (B. Russell, TERA Environmental, Berkeley, CA; pers. comm.).

Juveniles

Most megalopae molt into juveniles (first crab instars) in late spring or summer months (Winn 1985). Despite a

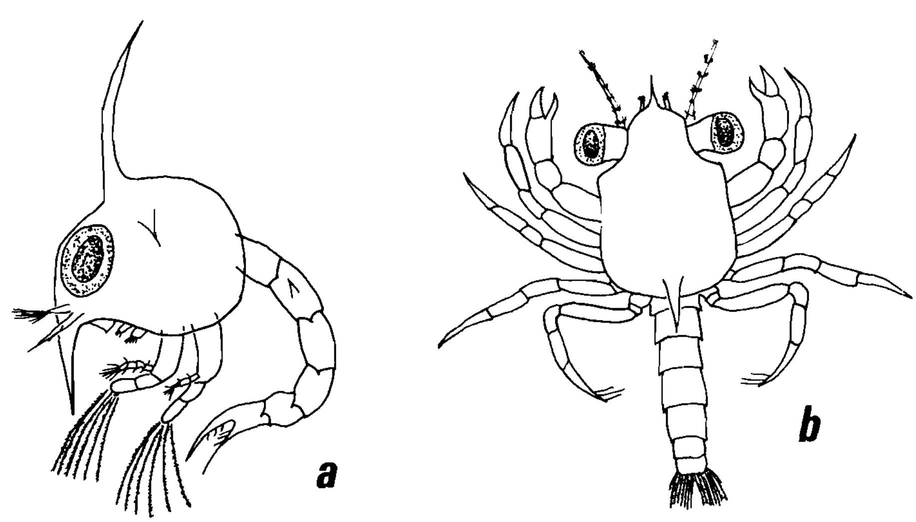

Figure 3. Larval stages of yellow crab: a) stage II zoea; b) megalopa.

widespread spatial and temporal overlap of larval distribution in coastal waters, certain species-specific patterns of recruitment vary with depth and substrate (Winn 1985). In southern California the densities of juvenile yellow crabs were higher than those of the other two species; the young were collected almost exclusively from sand substrata in depths less than 33 m. Juvenile brown rock crabs, which had a more generalized pattern of substrate and depth preference, settled on both rock and sand substrata; among the two substrate types and various depths, however, their densities were greatest on rock substrata that were at 13 m. Red rock crabs had the lowest juvenile densities on all substrata.

In central California, juvenile brown rock crabs and red rock crabs are commonly found from the intertidal zone to depths exceeding 30 m, and in summer may be especially common in shallow stands of surfgrass (*Phyllospadix* spp.) along the open coast, or partly buried in sand beneath rocks.

Adults

Detailed information on adult rock crab patterns of abundance, depth, substrate, and habitat type are lacking over much of the crabs' ranges. Generally, rock crabs co-occur over a wide range of nearshore substrata in depths less than 55 m at the interface of rock and sand substrate (Winn 1985). The three species, however, show some degree of distributional segregation according to substrate type, depth, and latitude (Figure 4).

Trapping studies in southern California by Winn (1985) and CDFG (unpubl. data) identified the habitats and relative abundances of the three species in several areas. The yellow crab was the most prevalent of the *Cancer* species on the extensive sand bottom habitat in southern California, where it often made up 70%-95% of the total crab catches. Toole (1985) reported that only 1.5% of experimental catches of rock crab in Humboldt Bay, in northern California, were yellow crabs.

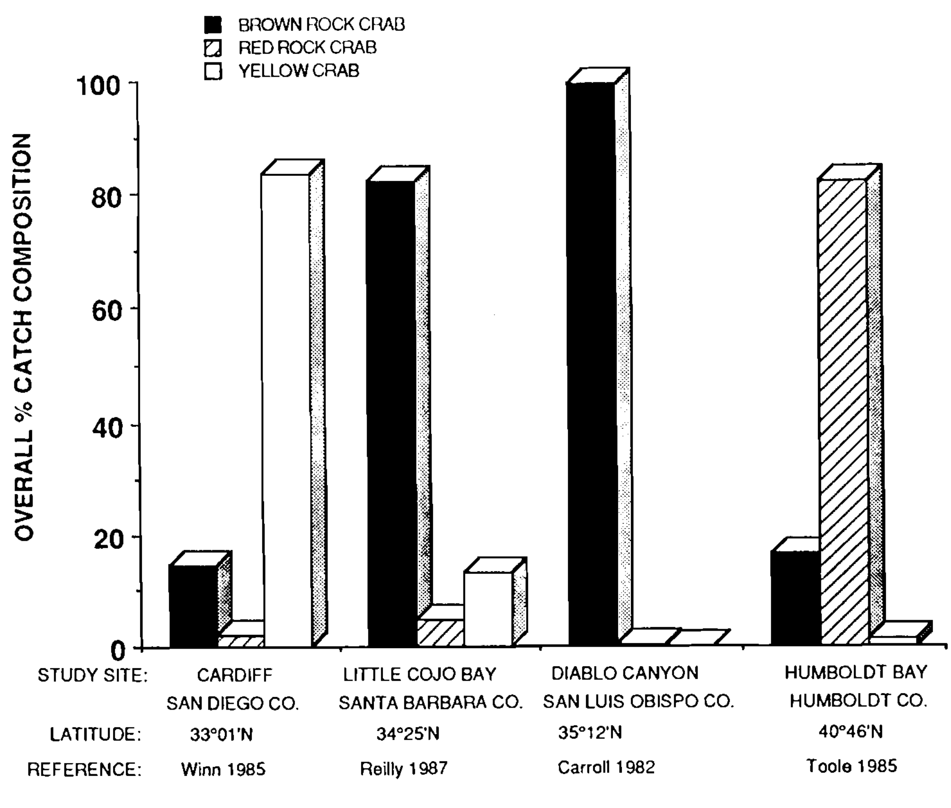

Figure 4. Relative abundance of brown rock crab, red rock crab, and yellow crab in four areas of the Pacific Southwest.

Humboldt Bay is near the northern limit of the species' range. The yellow crab lives almost exclusively on sandy substrata; consequently the "rock crab" designation is somewhat misleading although the species is often found at the interface of rock and sand habitats, and adjacent to artificial reefs (Turner et al. 1969). Adult yellow crabs were most common at depths of 18-55 m.

The brown rock crab ranked second in abundance in southern California and was most abundant in traps set on sand adjacent to rocky habitats, or on extensive rocky reefs at depths less than 55 m. In samples taken along a depth gradient between 8 and 18 m, relative abundances decreased, proceeding seaward, for brown rock crabs and increased for yellow crabs (Reilly 1987). Central California, north of Point Conception, appears to be the geographical center of brown rock crab distribution, where the species predominates in commercial rock crab catches (S. Meyer, commercial fisherman, Morro Bay, CA; pers. comm.).

The red rock crab ranked third in relative abundance in southern California and was most common on rocky substrata in mixed association with brown rock crabs. There is a trend toward markedly reduced abundance of the red rock crab in the southern regions of California. The species was exceptionally rare in catches from San Diego County (Winn 1985). In contrast, red rock crabs predominated in crab catches from certain areas in the more northern extent of the region, and especially in shallow embayments in northern California (Toole 1985).

Movements

The few tag-and-recapture data available indicate that adult rock crabs remain fairly close inshore; localized movements rarely exceed several kilometers from their release sites (Carroll 1982; Winn 1985). From a total of over 17,000 tagged crabs released and nearly 2,000 recaptured during a 10-year study (1976-86) in central California, the greatest distances traveled by brown rock crabs were less than 8 km over an 8-month period (J. Carroll, unpubl. data). Toole (1985), however, reported that two red rock crabs moved 3.1 km in 6-10 days, indicating that long-distance movements occur but perhaps have not been detected in limited experimental trapping. Boulding and Hay (1984), who attached radio tags to two red crabs and located them repeatedly over a 3-week period, recorded only local movements; the animals often remained in one location for several days.

Although the few studies thus far do not permit verification of seasonal migration patterns, the occurrence of larger numbers of female brown rock crabs and red rock crabs in traps during fall than in other seasons suggests that onshore-offshore movements in some areas may be related to annual cycles of molting and mating (Selby 1980; Carroll 1982). Trap placement and fishing success may strongly bias the interpretation of recapture or movement data (Diamond and Hankin 1985). Miller (1979), who studied the entry of red rock crabs into baited traps, concluded that trap orientation was significantly correlated to catch per unit of effort. Crabs were more likely to enter a trap if the opening was perpendicular to prevailing currents.

GROWTH CHARACTERISTICS

Growth in rock crabs, as in all crustaceans, progresses as a step function through a series of molts. In brown rock crabs the maximum carapace width is at least 155 mm in males (measured at the widest point on carapace, excluding the anterolateral spines) but does not exceed 145 mm in females (Carroll 1982). Red rock crabs are the largest of the three species treated here; maximum carapace widths are 190 mm in males and 168 mm in females, respectively (CDFG, unpubl. data). Maximum carapace width in yellow crabs is 165 mm for males and 148 mm for females (CDFG, unpubl. data). Longevity has been estimated to be about 5-6 years for brown rock crabs (Carroll 1982).

Incremental increases per molt of 7%-26% in width and 50%-70% in body weight have been measured in adult brown rock crabs in field growth studies (Carroll 1982; C. Toole, California Sea Grant, Foot of Commercial Street, Eureka; pers. comm.); the width and weight increases are proportionately greater in smaller crabs (Carroll 1982). Size increases are slightly greater in males than in females. A similar pattern was identified in a field study of growth in yellow crabs that were tagged and subsequently molted while at liberty (CDFG, unpubl. data). Presumably more energy is allocated by females than males to reproductive output, and less to somatic growth.

In brown rock crabs, size difference in claws is a sexually dimorphic characteristic that occurs at the pubescent molt, males attaining larger claws than females (Carroll 1982). Unsexed juveniles had a constant ratio of claw height to carapace width up to a width of 65 mm. Beyond this size, the ratios in males and females diverged from juvenile proportions. Discontinuities in growth rates of appendages were more distinct in males than in females.

Anderson and Ford (1976) reared yellow crabs in laboratory aquaria from the larval stages to sexual maturity. Crabs grew significantly faster at 22 °C than at 16 °C, but were larger at each instar in the 16 °C experimental treatment. One 13th instar female crab reared at 22 °C became sexually mature when carapace width was 98 mm, 400 days after hatching. Sexually mature yellow crabs as small as 85 mm have been collected in the field, however, a size which corresponds to the 11th or 12th instar (Anderson and Ford 1976). The approximate growth curves of brown rock crabs indicate that the pubertal molt is at a carapace width of 60-80 mm, or within the 10th to 12th instar, and at an age of about 18-24 months (Carroll 1982). No comparable growth estimates have been published for red rock crabs.

Molting appears to occur most frequently in rock crabs during fall and early winter, although it may occur throughout the year (Selby 1980; CDFG, unpubl. data). Brown rock crabs in the 80-105 mm size range may have a 5-8 month interval between molts, whereas large crabs (>135 mm) have a 12-16 month intermolt period (Carroll 1982). The lengthening of the successive intermolt periods is a general feature of many decapods (Passano 1960) and has been documented in other *Cancer* species (Butler 1961; Hancock and Edwards 1967; Anderson and Ford 1976).

Spaziani et al. (1981) were able to accurately classify stages of the molting cycle (i.e., premolt, intermolt, postmolt) in brown rock crabs by measuring various characteristics of shell composition and blood chemistry. Female rock crabs can also be staged by examining the pleopod tips (P. Reilly, pers. comm.). The specific hormonal mechanisms that control molting cycles in brown rock crabs and yellow crabs have also been elucidated (McConaugha 1977; Hinsch et al. 1980; Spaziani et al. 1982).

ECOLOGICAL ROLE

Rock crabs as a group are both scavengers and predators, feeding on a wide variety of snails, clams, echinoderms, and crustaceans. Powerful crusher claws enable adult crabs to eat thick-shelled snails (Fotheringham 1971; Geller 1982); cockles, *Protothaca staminea* (Boulding 1984; Boulding and LaBarbera 1986); barnacles and hermit crabs (Ricketts et al. 1985); abalone, *Haliotis* spp. (Schiel and Welden 1987); and a variety of thin-shelled infaunal and epifaunal species (Petersen 1983). Cannibalism, as observed in Dungeness crabs (Gotshall 1977), may also occur within the three species. Rock crabs are extremely sensitive to the scent of potential food in the water (Case 1964; Zimmer-Faust and Case 1982) and can detect amino acid concentrations as low as 10^{-11} moles/l (Fuzessery and Childress 1975).

Larval red crabs have been observed in laboratory cultures feeding on barnacle nauplii and sea urchin larvae, indicating that they are active planktivores (Rumrill et al. 1985). Yellow crab larvae, however, have been successfully reared on a mixture of dinoflagellates and diatoms, suggesting that they are feeding generalists during their planktonic existence (McConaugha 1985).

Benthic fishes are major predators on juvenile rock crabs; among the many that are known are scorpionfish (*Scorpaena guttata*), cabezon (*Scorpaenichthys marmoratus*), barred sand bass, and several species of rockfishes (Turner et al. 1969; Roberts et al. 1984; Love et al. 1987). The sand star *Astropecten verilli* has been identified as a major invertebrate predator on juvenile yellow crabs (Van Blaricom 1982). Larger crabs eventually attain a size large enough to preclude predation by most fishes, except when the shell is soft, just after molting. Rock crabs may fall prey to southern sea otters (Benech 1986) which ranged in the mid-1980's from Ano Nuevo Island, San Mateo County, south to Point Conception, California. Rock crabs are also the preferred prey of octopuses in southern California (Ambrose 1984), and have been found in the gut of bottom-foraging sharks in Elkhorn Slough, central California (Talent 1982).

Krekorian et al. (1974), who studied behavioral interactions between brown rock crabs and California spiny lobsters (*Panulirus interruptus*) in laboratory experiments, concluded that the generally non-aggressive behaviors observed during interspecific encounters were adaptations to sharing the same refuges in the natural habitat.

The polychaete worm *Iphitime holobranchiata* infests the gills of brown rock crabs and can be potentially detrimental to its host (Pilger 1971). The nemertean egg predator *Carcinonemertes epialti* often occurs in the egg masses of rock crabs (Wickham and Kuris 1985). Further information on the ecological role of each rock crab species is presented in the life history section.

THE FISHERY

Commercial Harvest

Rock crabs have historically supported only a relatively minor fishery in California, particularly when compared with the fishery of the Dungeness crab. The rock crab fishery has grown steadily since landings of about 20,000 lb were reported in 1950 (Heimann and Carlisle 1970). Annual landings exceeded 1.2 million lb in 1976 and approached 2 million lb in 1986 (Figure 5).

The three species are harvested commercially throughout the Pacific Southwest region, from the ports of Eureka, northern California, to San Diego, southern California; the highest landing totals are generally recorded from the Santa Barbara-Los Angeles area (Table 1). The south central California fishery, however, expanded into previously unfished areas north of Point Conception during the early 1980's and contributed an increasing share of the total California landings. Lower relative fishing effort out of some ports in the central and northern California regions, rather than the paucity of crabs, is probably responsible for the lower landing totals from these ports. The extensive fishing effort expended preferentially on the Dungeness crab also contributes to the lower relative landing totals for these three species north of Morro Bay. In the mid-1980's, rock crabs were trapped in Washington and Oregon and shipped to California for sale, presumably because the selling price was higher there.

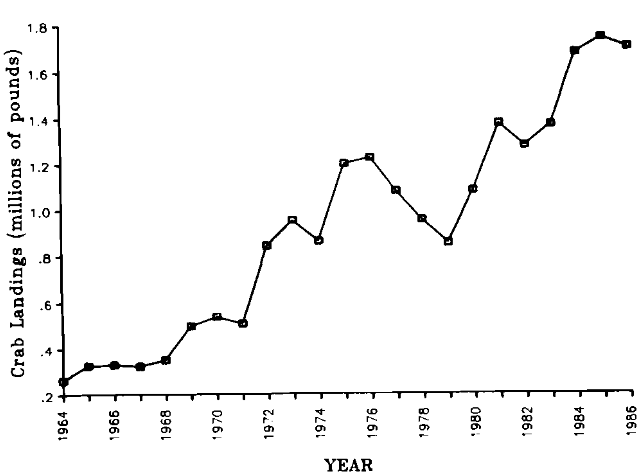

Figure 5. Annual rock crab landings in California, 1964-86 (CDFG, unpubl. data).

The harvest on the species-by-species basis has been difficult to assess because the statistics have been combined in the general "rock crab" category. Although this practice simplifies many aspects of marketing and management as a single species fishery, the nonspecific statistics thwart an understanding of the relation between available stocks and landings of the individual species.

Commercial landings show no well-defined trends in seasonal crab abundance. Monthly landing totals may be a misleading indicator of seasonal abundance because total fishing effort varies and marketable crab size may fluctuate with consumer demand (S. Meyer, pers. comm.). Experimental trapping studies, however, indicate a trend toward the catches being highest in fall and lowest in summer. This pattern of increased seasonal abundance has been noted for red rock crabs in Coos Bay, Oregon (Selby 1980), and in Humboldt Bay, northern California (C. Toole, unpubl. data), and for brown rock crabs in central California (Carroll 1982). Higher catches in central California were positively correlated with annual maximum water temperatures and an increased proportion of female crabs in the catches.

Recreational Harvest

Accurate data on the sport fishery for rock crabs are lacking. The crabs are taken mainly in small numbers with baited hoop nets near piers and jetties, and by hand by sport divers. This harvest is insignificant compared with the total commercial harvest (D. Parker, pers. comm.). In California, the sport catch limit on all *Cancer* species in combination (excluding the Dungeness crab) is 35 crabs per day, and the minimum legal carapace width is 4 inches.

Table 1. Percent contribution to total annual rock crab landings by California fisheries origin blocks, 1965-85 (CDFG, unpubl. data).

Year	San Diego/ Orange	Los Angeles/ Santa Barbara	Morro Bay	Monterey	San Francisco	Eureka/ Crescent City
1965	2.3	95.2	2.4	0.1	-	-
1966	5.7	91.2	3.0	0.1	-	-
1967	3.4	95.6	0.8	0.1	-	0.1
1968	2.3	92.8	4.7	0.1	-	0.2
1969	17.7	55.7	25.6	0.1	-	0.9
1970	42.3	41.7	15.5	0.2	-	0.3
1971	42.9	49.2	7.5	0.2	-	0.3
1972	45.8	45.0	8.8	0.1	0.1	0.2
1973	41.6	46.2	11.8	0.1	0.1	0.2
1974	45.6	41.1	13.2	0.1	-	-
1975	19.3	51.9	28.7	-	-	0.1
Average 1965-75	24.4	64.1	11.2	0.1	-	0.2
1976	21.2	58.0	20.8	-	-	-
1977	19.5	52.3	27.8	0.1	-	0.3
1978	10.5	38.4	49.8	0.1	0.8	0.4
1979	13.3	65.9	19.2	-	0.9	0.7
1980	14.2	71.4	12.7	-	0.2	1.5
1981	23.2	54.9	21.0	-	0.7	0.2
1982	17.7	55.5	24.7	0.3	1.2	0.6
1983	19.3	49.7	28.3	0.1	1.9	0.7
1984	11.2	40.8	43.8	1.0	1.6	1.6
1985	7.7	29.5	58.3	0.1	1.7	2.6
Average 1976-85	15.8	51.6	30.6	0.2	0.9	0.9

Factors Affecting Commercial Landings

The variability in the harvest of crabs in southern California has been historically linked to the changing success of other commercial fisheries (Winn 1985). In particular, the rock crab fishery is closely associated with the California commercial fishery for spiny lobsters, in terms of seasonal effort, gear, and methods. Fishermen can easily switch to trapping crabs in the "off-season" or when catches of lobsters are low. Lobster gear has been widely used for harvesting crabs.

In the mid-1980's, a controversy developed regarding trap design and crab size limits, due to the elimination of the size limit of 4 inches in carapace width from the California Fish and Game Code. Many fishermen subsequently used a more efficient small-mesh trap design (1 x 2 inch mesh) that resulted in catches composed of higher relative numbers of females and subadults.

Mean size comparisons from trapping studies in Santa Monica Bay, which has been closed to commercial fishing, indicated a significantly larger overall size distribution there than in adjacent sites open to fishing (CDFG, unpubl. data). Similarly, in Humboldt Bay, crabs were significantly smaller where oyster growers trapped large numbers of crabs (to curb predation on oyster seed) than in adjacent areas where crab fishing was less intense (C. Toole, pers. comm.). Cumulative impacts by the fishery would thus be seen as reduced overall catches, greater percentages of females, and smaller size classes. Fishermen have also found a high demand for egg-bearing females in some markets (W. Hall, commercial fisherman, Long Beach, CA; pers. comm.)--a demand that could result in a significant negative impact on the stocks.

The exploitation of relatively localized areas can be assessed by following catch statistics within specific fishery blocks over several years (Figure 6). These statistics do not include the number of boats fishing or number of traps per boat, and thus do not allow comparison on the basis of catch per unit of effort. Also, changes in reporting requirements since 1983 have resulted in increased use of port of landing rather than specific fishery blocks, resulting in an apparent catch decrease in some blocks (D. Parker, pers. comm.). Nevertheless, the data illustrate the decline of crab catches in an easily accessible area near a major port of landing (Long Beach), and the more recent exploitation of two areas (Point Conception and Point Purisma), which are less accessible to major ports of landing (Santa Barbara and Port San Luis, respectively). This evidence, coupled with the observation that rock crabs generally do not move long distances, suggests that overfishing has occurred in certain areas, despite a long-term increase in total statewide landings.

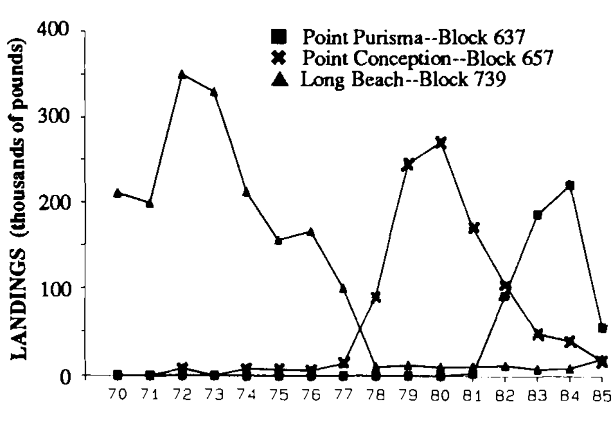

Figure 6. Annual rock crab catches from three fisheries origin blocks in California, 1970-85 (CDFG, unpubl. data).

A fishery based on the sale of claws only has been largely replaced by that of whole crabs in recent years, although claws remain a specialty item in many markets. The claws are taken from dead or dying crabs at the markets, and by fishermen who remove claws and return the de-clawed crab to the sea. Apparently, it is a common belief that, because crabs regenerate lost limbs, the practice of claw removal at sea contributes to the renewal of the resource. Avoidance of mortality, however, requires a clean separation at the fracture plane, which is difficult to obtain without damaging the body. In addition, regeneration of full-sized claws takes two to three molts (up to two years for large adult crabs). A claw fishery alone, nevertheless, results in less overall mortality than a whole-crab fishery.

Mortality from handling, transportation, and continued fishing of lost traps also occurs (Winn 1985), but there are no reliable estimates of the magnitude of these additional factors.

ENVIRONMENTAL REQUIREMENTS

In a study of survival and recruitment of *Cancer* spp. larvae off southern California, Shanks (1986) showed that prevailing current patterns influenced the onshore and offshore drift of larvae, and was critical in determining successful nearshore settlement. Winn (1985), who conducted field experiments to determine preferred substrate types of newly settling rock crab larvae in southern California, observed that first crab instar yellow crabs were most abundant on sand and least abundant on rock substrates, and that brown rock crabs were equally abundant on both substrate types; recently settled red rock crabs were too scarce to provide conclusive results.

Anderson and Ford (1976) found that a temperature increase of about 4 °C significantly accelerated the rate of larval development of yellow crabs reared in the laboratory. The average duration of each instar was longer at 18 °C than at 22 °C, resulting in an average total development time of 45 days at 18 °C but only 33 days at 22 °C.

In laboratory thermal tolerance studies on brown rock crabs, mortality was 100% in adult crabs exposed for 1 h to acute temperatures above 31.1 °C, and nil in crabs similarly exposed to 29.2 °C (Pacific Gas and Electric Company 1982). Chronic exposure (96 h) of crabs to several test temperatures yielded a median effective 50% mortality at a theoretical value of 25.4 °C. Although such temperatures are unlikely along the open coast in California, they sometimes occur near the cooling water discharges of coastal power plants. Adams (1970) observed both juvenile and adult brown rock crabs in the discharge canal of the Morro Bay (California) Power Plant, where temperatures exceeded 26 °C.

Fishermen commonly hold crabs in submerged receivers for several days before transporting them to market. Losses of penned crabs may be up to 30%-40% during summer and fall, when water temperatures approach 20 °C (Winn 1985). Crabs missing limbs or in soft-shell condition are especially susceptible to warmer temperatures (S. Meyer, pers. comm.). Mortality can sometimes be reduced by lowering the receivers into cooler bottom water.

Juvenile red rock and brown rock crabs are common in the intertidal zone, where they may be exposed to the air daily for several hours (Ricketts et al. 1985). Mortality is unlikely, however, provided they are shaded from direct sunlight beneath algae, or protected in rock crevices.

Selby (1980) found that the distribution and abundance of red rock crabs in Coos Bay, Oregon, was correlated with changes in salinity; because red rock crabs are osmoconformers, survival was low at salinities below 13.1 ppt. No tolerance levels have been established for the larval life history stages of rock crabs, but Buchanan and Milleman (1969) found that low salinities impaired the molting process in larvae of the closely related Dungeness crab.

Toxicities of 11 metals found in drilling muds to embryos and prezoeae of the yellow crab have been measured. The distribution of this crab overlaps significantly with current and planned offshore oil drilling and production platforms. Lethal concentrations to embryos after 7 days were 1 g/l of iron or barium (sulfate), two of the most common contaminants. Increased mortality of embryos resulted from longer exposure. Exposure of embryos to chromium VI, copper, or zinc actually protected zoeae from those metals, possibly as a result of induction of biochemical pathways of metal inactivation (MacDonald et al. 1988).

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15. Supplementary Notes

*U.S. Army Corps of Engineers Report No. TR EL-82-4.

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, distribution, life history, habitats, and environmental requirements of coastal species of fishes and aquatic invertebrates. They are designed to assist in environmental impact assessment. "Rock crab" is the common name designating three similar species of edible crabs: brown rock crab (*Cancer antennarius*), red rock crab (*C. productus*), and yellow crab (*C. anthonyi*). The three species co-occur in shallow coastal waters throughout the Pacific Southwest region. The yellow crab is most common in southern California on sand substrate, and the red rock crab in northernmost areas on rock or gravel substrates; the brown rock crab occurs on rock or sand substrates in all areas. Rock crabs are sought commercially to fill an increasing market demand for whole crabs that approached 2 million pounds annually in 1986. Most of the catch comes from the region of Morro Bay south to Los Angeles, including the Channel Islands. Egg-bearing females are commonly found during winter, although they may occur throughout the year. Rock crabs go through five zoeal stages and one megalopal stage during a larval period that generally requires 90-120 days. Metamorphosis and settlement of the first crab stage is on either sand or rock, and crabs may reach maturity within 1-2 years. All three species are predators on a variety of shelled mollusks, but are also considered scavengers. They are a major food for many commercially and recreationally important fishes, as well as for the threatened southern sea otter, *Enhydra lutris*.

17. Document Analysis a. Descriptors

Fisheries
Feeding habits
Growth
Temperature
Crabs
Life cycles

b. Identifiers/Open-Ended Terms

Rock crab
Cancer antennarius
Cancer productus
Cancer anthonyi
Ecological role
Habitat requirements

c. COSATI Field/Group

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