NOTES

MORTALITIES AND EPIBIOTIC FOULING OF EGGS FROM WILD POPULATIONS OF THE DUNGENESS CRAB, *CANCER MAGISTER*[1,2]

Cultured crustaceans have been found to be susceptible to fouling by a variety of epibionts. Nilson et al. (1975) recently described mortalities attributed to epibiotic fouling in the eggs and larvae of the American lobster, *Homarus americanus,* the larvae of the prawn, *Pandalus platyceros,* and larvae of the Dungeness crab, *Cancer magister* Dana. This same type of fouling has also been found on juveniles of Penaeid shrimp, where it causes death in rearing ponds with low oxygen content by inhabiting the gill filaments and suffocating the animal (Johnson et al. 1974; Lightner et al. 1975). The organisms most commonly encountered have been filamentous bacteria and algae.

Work on the larval cultivation of the Dungeness crab at the Bodega Marine Laboratory, Bodega Bay, Calif., revealed heavy fouling on the eggs of oviposited female crabs held in rearing tanks. Further investigation showed that the condition also existed on eggs of crabs obtained from local fishermen. Egg masses with extensive fouling also showed a large number of empty egg cases, although eyespot development on the remaining embryos showed the time until hatching to be distant. Similar fouling of the eggs of wild caught Atlantic blue crabs, *Callinectes sapidus,* has been observed and well documented (Sandoz et al. 1944; Rogers-Talbert 1948). With *Callinectes*, however, the predominant fouling organism appears to be the fungus *Lagenidium callinecti.*

These observations of fouling and mortality in the natural population suggest a possible explanation for the decline in Dungeness crab catches recorded in the San Francisco Bay region since 1960 (Biostatistical Section 1961, 1963, 1964, 1965; Greenhood and Mackett 1965, 1967; Heimann and Frey 1968a,b; Heimann and Carlisle 1970; Pinkas 1970; Bell 1971; Oliphant 1973). In order to investigate this possibility, a distributional study was undertaken, comparing mortalities and epibiotic

fouling of crab eggs from various locations along the coast of northern California.

Materials and Methods

Egg samples of *C. magister* were obtained from fishermen along the northern California coast during the period from 27 November 1974 to 30 January 1975. A total of 105 samples of eggs from individual crabs were obtained from six regions which included the following localities (Figure 1): region I — Pacifica (4 samples); region II — Drake's Bay (18 samples); region III—Point Reyes (39 samples); region IV—Bodega Bay, Russian River, and Gualala (10 samples); region V — Fort Bragg (20 samples); region VI — Eureka (14 samples).

In the field, a portion of eggs were removed from the Dungeness crab egg masses and placed in vials
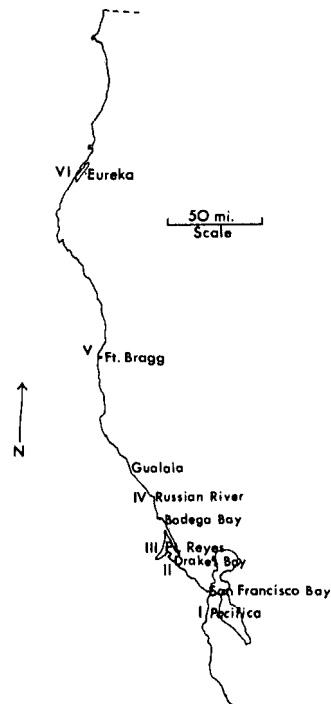

FIGURE 1.—The coast of northern California showing the Dungeness crab collection sites: I - Pacifica; II - Drake's Bay; III - Point Reyes; IV - Bodega Bay, Russian River, and Gualala; V - Fort Bragg; VI - Eureka.

containing 10% Formalin[3] in seawater. The sample size was variable—all exceeded 100 eggs, usually several hundred. The vials were then shipped to the laboratory for examination with the aid of a dissecting microscope. The epibiotic organisms were clearly visible using transmitted light for illumination (Fisher et al. 1975). Closer examination of the egg cases was carried out with a phase microscope to aid in the characterization of the fouling organisms. Portions of the samples were categorized as to the comparative developmental state of the eggs, extent of epibiotic fouling, and egg mortality by the following methods:

1. The following observations of the eyespots which develop as the embryos develop were used to give a comparative estimate of the time the eggs had been carried externally on the female:

    D1. No visible eyespot.
    D2. Emerging eyespot.
    D3. Full eyespot.

Any samples which showed evidence of hatching were not used. Occasionally, there was variation in the degree of development of the eggs from a single sample, in which case the eggs that had developed furthest were used for observation.

2. The extent of epibiotic fouling was determined by the following observations of the external egg membrane:

    F1. None—no evidence of epibionts at 100× (Figure 2A).
    F2. Light—occasional short filaments.
    F3. Moderate—the majority of the surface covered with short filaments and occasional long filaments (Figure 2B).
    F4. Heavy—the surface extensively covered with short and long filaments (Figure 2C).
    F5. Very heavy—the surface extensively covered with short filaments, long filaments, and detrital material.

3. The number of empty egg cases was used as an estimate of mortality.

    M1. <10% mortality.
    M2. 10-25% mortality.

    M3. 26-50% mortality.
    M4. 51-75% mortality.
    M5. 76-100% mortality.

Only empty egg cases (Figure 3) were considered mortalities. Other abnormal conditions, such as discolored eggs which might have eventually led to mortalities, were observed but not used in the estimates. All developmental stage D3 samples were checked for emerging embryos to ensure that the empty egg cases were not due to hatching.

In addition to the field samples, seven ovigerous females from the Point Reyes area were examined before being placed into flow-through seawater tanks at the laboratory. After 25 days the eggs were reexamined to determine the progress of the infestation. In addition, one complete egg mass from an ovigerous female was examined to determine the homogeneity of the fouling condition throughout the egg mass.

Results

Observation of eyespot development placed 10.5% of the samples into category D1, 35.2% into D2, and 54.3% into D3. Fouling was observed in all developmental categories, but mortalities were generally higher in the more developed eggs. The histograms presented in Figure 4 show the percent of samples from each region placed in each mortality category (M1-M5) and fouling category (F1-F5) after combining the developmental categories.

The eggs of the seven females held in the laboratory for 25 days showed an average increase in their development, fouling and mortality of one level in each category. The greatest observed change was on an egg mass in developmental stage 2 which originally showed light fouling (category 2) and were in mortality category M2. After 25 days it was in developmental stage 3 and showed very heavy fouling (category 5) and had advanced to mortality category, M5. Another showed no increase in fouling as it matured from developmental stages 1 to 3, but the egg mortality category advanced from M1 to M3.

Examination of the entire egg mass of one specimen showed that the extent of the fouling was variable and concentrated mostly on the periphery of the mass and on the inner eggs near the fold of the abdomen. This raises the possibility of sampling error; however, it would probably be insignificant since the field samples came primarily from the exterior of the egg masses.
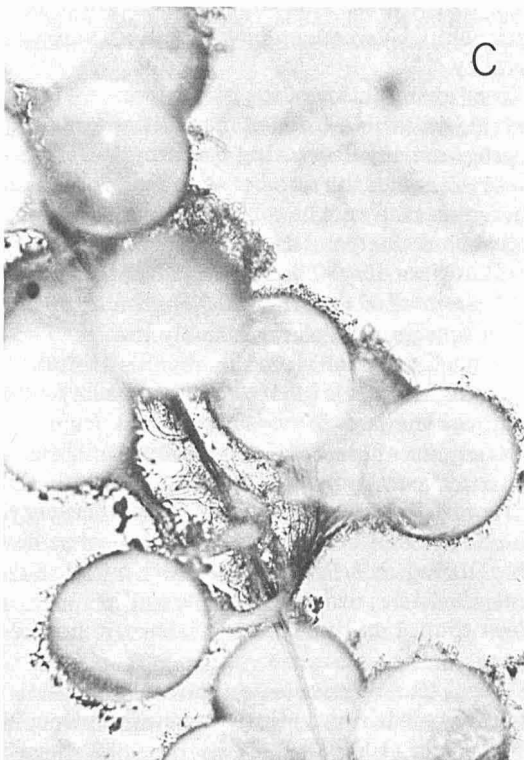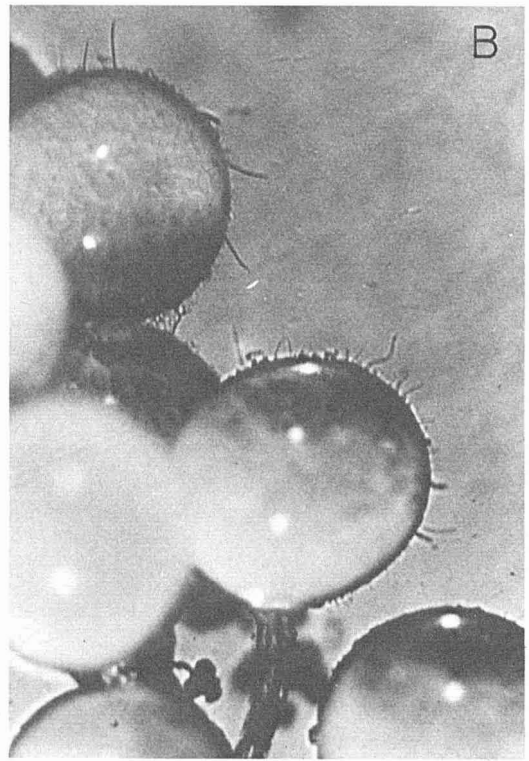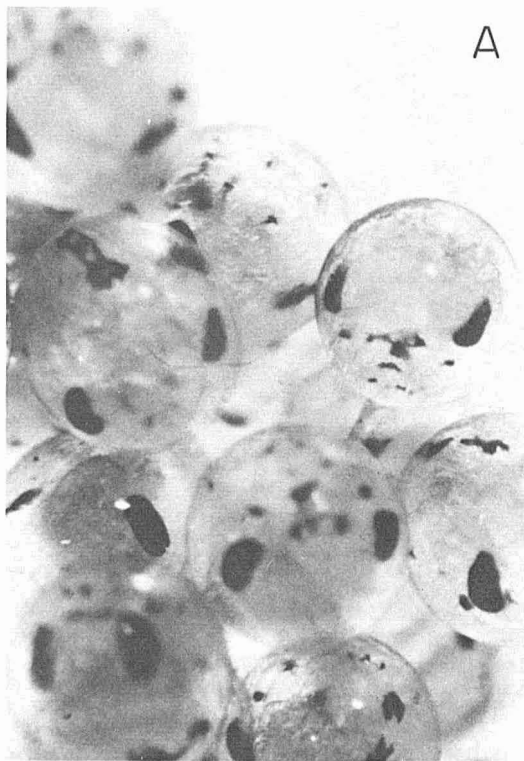
FIGURE 2.—Dungeness crab egg samples showing (A) no epibiotic fouling on the egg membrane (78×), (B) moderate epibiotic fouling on the egg membrane (96×), and (C) very heavy epibiotic fouling on the egg membrane (57×).

The epibiotic fouling organisms found were similar to those noted on other crustaceans by Nilson et al. (1975). Particularly prominent were the long filamentous cyanophytes which resembled *Oscillatoria* and bacterial filaments similar to *Leucothrix*. In heavily fouled samples stalked protozoans (vorticellids) were also observed. These and the filamentous organisms trapped detrital material, which added to the overall contamination of the eggs. Fouling on the egg stalk was often more extensive than fouling on the egg membrane proper. Empty egg cases also showed heavier fouling than those containing embryos. In many cases where fouling was observed, worms were found, and the population of worms was generally larger on egg samples with heavier fouling. The worms were identified as the nemertean egg predator *Carcinonemertes epialti* as described by Kuris (1973).
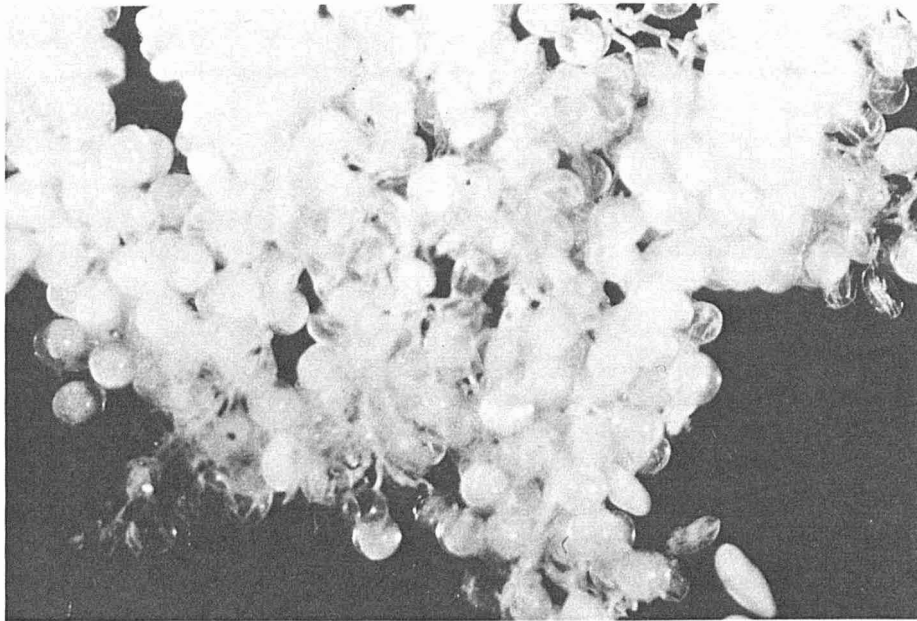
FIGURE 3.—Dungeness crab egg sample showing empty egg cases representing egg mortalities alongside viable eggs from the same egg mass (24.5×).

Discussion

Various workers have attributed mortalities (Johnson et al. 1974; Lightner et al. 1975; Nilson et al. 1975; Fisher et al. 1975) in cultured crustaceans to epibiotic fouling. These reports suggest that death may be caused either by mechanical interference in larval molting or restriction of gaseous exchange across the egg or gill membrane. The fouling organisms may also consume a great deal of the available oxygen from the environment. The dramatic effect of this condition may be seen in Figure 5 where the moderately fouled egg case is entirely intact, yet the embryo is atrophied and nonviable.

Infestation with fouling organisms presumably does not begin until the eggs are oviposited. Although heavy fouling may occur, few mortalities are observed in the early developmental periods. Fouling on the eggs held in rearing tanks progressed as the eggs developed. The progression was an increase in the number or filament length of any one type of the organisms or the addition of other types of organisms. By the second and third developmental categories, mortalities were regularly encountered where fouling occurred.

The samples obtained from regions II and III showed the heaviest epibiotic fouling, as well as the highest levels of mortality. In comparison, region V showed the least extensive fouling and the fewest mortalities. This suggests that there is a relationship between epibiotic fouling and egg mortality.

Closer examination of the histograms in Figure 4 reveals a possible trend of mortalities and fouling progressively decreasing from region II to region V. Although the number of samples obtained from region I may not be conclusive evidence, they suggest that the trend may not continue south of San Francisco Bay. The region VI data show a slight reversal of the trend although mortalities and fouling are still comparatively low.

The mortalities observed in regions II and III are particularly relevant when the coastal crab catch over the last 25 yr is considered. Figure 6 shows a general coast-wide decline in Dungeness crab catch commencing in 1958. In 1965, the northern fishery areas began a strong recovery, whereas the San Francisco area remained at low level. During this decline, the catch of the San Francisco fishery dropped from 8½ million pounds to less than 1 million pounds where it has remained.

Several studies have investigated the potential impact of overfishing on the Dungeness crab population. Poole (1962) and Cordier (1966) showed
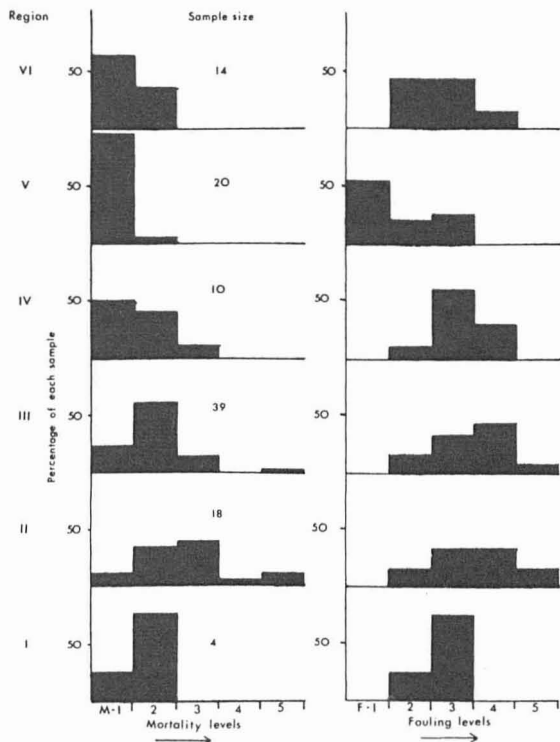
FIGURE 4.—Histograms representing the percent of Dungeness crab samples from each region found in the mortality and fouling categories. The arrows represent increasing mortalities and increasing fouling. Sample sizes from each region are shown.
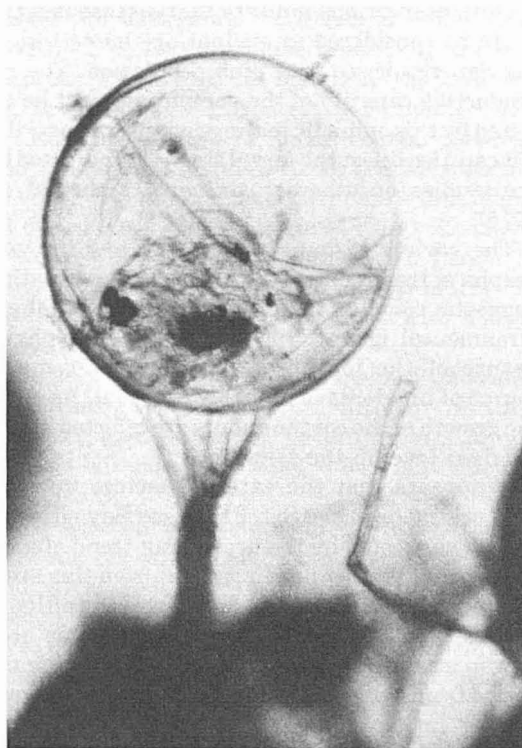

FIGURE 5.—A single Dungeness crab egg showing an intact membrane, an atrophied and nonviable embryo (168×).
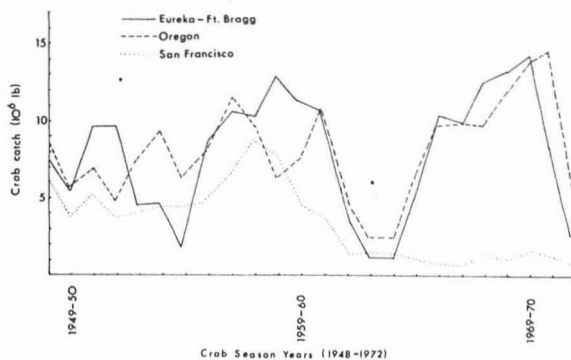

FIGURE 6.—A graph comparing the Dungeness crab catches reported from 1948 to 1972 in three areas. Note that the San Francisco crab catch did not increase from the 1961-62 level.

that 99% and 98%, respectively, of the adult female population had been inseminated, indicating that the fishing industry (which only legally catches males greater than 6¼ inches across the carapace) is not significantly reducing the reproductive capabilities of the crab population. Also, tagging studies have shown that an estimated 90 to 100% of the legal-size males in fishing areas of the California coast have been caught each year since 1929 (Pacific Marine Fisheries Commission 1965). Cleaver (1949) and Peterson (1973) stated that the fishing pressure has been similar in Washington and Oregon. It therefore appears that fisheries along the coast are capable of maintaining production despite the virtually maximum fishing pressures. Poole and Gotshall (1965) concluded that the fishing regulations at that time were sufficient to protect the crab from depletion through overfishing.

Physical factors may be responsible for periodic fluctuations in crab abundance. The Pacific Marine Fisheries Commission (1965) suggested that shifting currents played a role in these fluctuations by disturbing larval settlement. Lough (1974) found a correlation between rainfall during salinity-sensitive larval stages and crab catch 4 yr later when those larvae were to enter the fishery. Peterson (1973) and Botsford and Wickham (1975) have found a positive correlation between upwelling intensity and crab catch.

205

Our observations indicate that disease is a factor to be considered in evaluating the decline of the San Francisco area crab population. The reproductive capacity of the population must be affected by this epibiotic fouling condition especially if it can also infest the larval stages as indicated by the studies on other crustaceans (Fisher et al. 1975).

The variety of fouling organisms and the geographical trends observed in this disease situation suggest a complex relationship with external environmental factors. In view of the saprophytic nature of the fouling organisms, their major source of nutrients is probably external. As such, the growth of the contaminants are affected by the nutrient level in the seawater.

It appears that the external factors involved may originate in the San Francisco Bay effluent. This is suggested by the decreasing trend of mortalities and fouling heading north from this area, presumably reflecting the dilution of the effluent waters. The normal water currents in this area flow in a southerly direction; however, during the period from November through February, the prevailing inshore flow is the northerly Davidson Current (Reid et al. 1958). During the egg-bearing season, the effluent from San Francisco Bay is carried northward.

The observations of this study were limited by the collection of samples during only the 1974-75 crab season. Because of the potential relationship of these findings to a valuable natural resource, we felt that it was important to communicate the available information. It is clear that further studies during the next season will enhance our understanding of the situation.

Acknowledgments

Literature Cited

BELL, R. R.
1971. California marine fish landings 1970. Calif. Fish Game, Fish Bull. 154, 50 p.
BIOSTATISTICAL SECTION, MARINE RESOURCES OPERATIONS.
1961. The marine catch of California for the year 1960. Calif. Fish Game, Fish Bull. 117, 45 p.

1963. The California marine fish catch for 1961. Calif. Fish Game, Fish Bull. 121: 1-47.
1964. The California marine fish catch for 1962. Calif. Fish Game, Fish Bull. 125, 45 p.
1965. The California marine fish catch for 1963. Calif. Fish Game, Fish Bull. 129, 45 p.
BOTSFORD, L. W., AND D. E. WICKHAM.
1975. Correlation of upwelling index and Dungeness crab catch. Fish. Bull., U.S. 73:901-907.
CLEAVER, F. C.
1949. Preliminary results of the coastal crab (Cancer magister) investigation. Wash. Dep. Fish., Biol. Rep. 49A:47-82.
CORDIER, P.
1966. Cruise report 66-N-9 crab. Calif. Dep. Fish Game, Mar. Resour. Oper.
FISHER, W. S., E. H. NILSON, AND R. A. SHLESER.
1975. Diagnostic procedures for diseases found in egg, larval, and juvenile cultured American lobsters (Homarus americanus). Proc. 6th Annu. Workshop World Maricult. Soc., Seattle, Wash., 1975.
GREENHOOD, E. C., AND D. J. MACKETT.
1965. The California marine fish catch for 1964. Calif. Fish Game, Fish Bull. 132, 45 p.
1967. The California marine fish catch for 1965. Calif. Fish Game, Fish Bull. 135:1-42.
HEIMANN, R. F. G., AND H. W. FREY.
1968a. The California marine fish catch for 1966. Calif. Fish Game, Fish Bull. 138:1-48.
1968b. The California marine fish catch for 1967. Calif. Fish Game, Fish Bull. 144, 47 p.
HEIMANN, R. F. G., AND J. G. CARLISLE, JR.
1970. The California marine fish catch for 1968 and historical review 1916-1968. Calif. Fish Game, Fish Bull. 149, 70 p.
JOHNSON, S. K., J. C. PARKER, AND H. HOLCOMB.
1974. Control of Zoothamnium sp. on penaeid shrimp. Proc. 4th Annu. Workshop World Maricult. Soc., Monterrey, Mexico, 1973.
KURIS, A.
1973. Population interactions between a shore crab and two symbionts. Ph.D. Thesis, Univ. California, Berkeley.
LIGHTNER, D. V., C. T. FONTAINE, AND K. HANKS.
1975. Some forms of gill disease in penaeid shrimp. Proc. 6th Annu. Workshop World Maricult. Soc., Seattle, Wash., 1975.
LOUGH, R. G.
1975. Dynamics of crab larvae (Anomura, Brachyura) off the central Oregon coast, 1969-1971. Ph.D. Thesis, Oregon State Univ., Corvallis, 229 p.
NILSON, E. H., W. S. FISHER, AND R. A. SHLESER.
1975. Filamentous infestations observed on eggs and larvae of cultured crustaceans. Proc. 6th Annu. Workshop World Maricult. Soc., Seattle, Wash., 1975.
OLIPHANT, M. S.
1973. California marine fish landings for 1971. Calif. Fish Game, Fish Bull. 159, 49 p.
PACIFIC MARINE FISHERIES COMMISSION.
1965. Discussion that followed the report on Dungeness crabs. 16th and 17th Annu. Rep. Pac. Mar. Fish. Comm., p. 38-39.
PETERSON, W. T.
1973. Upwelling indices and annual catches of Dungeness crab, Cancer magister, along the west coast of the United States. Fish. Bull., U.S. 71:902-910.

PINKAS, L.
    1970. The California marine fish catch for 1969. Calif. Fish Game, Fish Bull. 153, 47 p.
POOLE, R.
    1962. Cruise report 62-N-2g, h, i and l crab. Calif. Dep. Fish Game, Mar. Resour. Oper.
POOLE, R., AND D. GOTSHALL.
    1965. Regulations and the market crab fishery. Outdoor Calif. 26(9):7-8.
REID, J. L., JR., G. I. RODEN, AND J. G. WYLLIE.
    1958. Studies of the California Current System. Calif. Coop. Oceanic Fish. Invest. Rep. 1 July 1956 - 1 January 1958, p. 27-56.
ROGERS-TALBERT, R.
    1948. The fungus Lagenidium callinectes Couch (1942) on eggs of the blue crab in Chesapeake Bay. Biol. Bull. (Woods Hole) 94:214-228.
SANDOZ, M. D., R. ROGERS, AND C. L. NEWCOMBE.
    1944 Fungus infection of eggs of the blue crab Callinectes sapidus Rathbun. Science (Wash., D.C.) 99:124-125.

WILLIAM S. FISHER

Department of Food Science and Technology
University of California
Davis, CA 95616

DANIEL E. WICKHAM

Department of Zoology
University of California
Berkeley, CA 94620

SECOND RECORD OF BLACK SKIPJACK, *EUTHYNNUS LINEATUS*, FROM THE HAWAIIAN ISLANDS

Matsumoto and Kang (1967) reported the first capture of the black skipjack, *Euthynnus lineatus* Kishinouye, in the Hawaiian Islands. Recently (14 July 1975), a second black skipjack was taken in these waters by a Hawaiian pole-and-line skipjack tuna fishing vessel, the *Marlin*, skippered by Walter Asari. The fish was noticed by a fish receiver at Hawaiian Tuna Packers, Richard Howell, who contacted Robert T. B. Iversen, Southwest Region Representative stationed at the Southwest Fisheries Center Honolulu Laboratory. Iversen brought the fish to me for identification.

The specimen, 454 mm fork length, and weighing 1.53 kg, was caught from a school of small skipjack tuna, *Katsuwonus pelamis*, at the extreme tip of Penguin Banks, about 40 km south of the eastern end of Oahu. The specimen is deposited in the U.S. National Museum collection (USNM 214683).

Measurements in millimeters taken according to the methods described by Godsil and Byers (1944) are as follows: Fork length - 454; head length - 126; 1st dorsal insertion - 144; 2d dorsal insertion - 271; anal fin insertion - 306; ventral fin insertion - 144; greatest body depth - 112; greatest body width - 73; dorsal-ventral distance - 108; dorsal-anal distance - 188; ventral insertion to vent - 160; length 1st dorsal base - 130; length 2d dorsal base - 29; length anal base - 25; length pectoral - 70; height 1st dorsal - 61; height 2d dorsal - 28; height anal - 28; diameter of iris - 19; maxillary length - 50; snout to posterior margin of eye - 54.

Counts: 1st dorsal spines - 14, plus 1 imbedded; 2d dorsal rays - 12; dorsal finlets - 8; anal rays - 12; anal finlets - 7; pectoral rays - 26; gill rakers - left side $9 + 1 + 24 = 34$, right side $9 + 1 + 25 = 35$.

The external characters agree with that of the previous capture (Matsumoto and Kang 1967) and with Godsil's (1954) description of the species. Five black unbranched stripes run parallel to the longitudinal axis of the body on the back from the corselet to the caudal fin, and five or six faint unbranched stripes run horizontally on the belly. Two black thoracic spots are located on each side at the indentation of the corselet near the ventral margin of the body.

The vertebral count is $20 + 17 = 37$. As in the previous capture, four large protuberances are present on the 31st vertebra, a characteristic of this species (Godsil 1954).

Although this is only the second specimen recorded, an interview with the skipper of the vessel disclosed that fish similar to this are often caught but are not reported. The question posed in 1967 as to whether this is a chance migrant from the eastern Pacific Ocean still stands.

Literature Cited

GODSIL, H. C.
    1954. A descriptive study of certain tuna-like fishes. Calif. Dep. Fish Game, Fish Bull. 97, 185 p.
GODSIL, H. C., AND R. D. BYERS.
    1944. A systematic study of the Pacific tunas. Calif. Dep. Fish Game, Fish Bull. 60, 131 p.
MATSUMOTO, W. M., AND T. KANG.
    1967. The first record of black skipjack, *Euthynnus lineatus*, from the Hawaiian Islands. Copeia 1967:837-838.

WALTER M. MATSUMOTO

Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, HI 96812