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Biological Review and Commercial Whelk Fisheries Analysis of Busycon carica with Comments on B canaliculatum and B contrarium in Virginia

Jane DiCosimo
College of William and Mary - Virginia Institute of Marine Science

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BIOLOGICAL REVIEW AND COMMERCIAL WHELK FISHERIES ANALYSIS OF BUSYCON CARICA WITH COMMENTS ON B. CANALICULATUM AND B. CONTRARIUM IN VIRGINIA

A Thesis

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Jane DiCosimo

Jane DiCosimo

Approved, December 1986

William DuPaul

William D. DuPaul, Ph.D.

Herbert M. Austin

Herbert M. Austin, Ph.D.

Joseph G. Loesch

Joseph G. Loesch, Ph.D.

Michael Castagna

Michael Castagna, M.A.

Robert J. Huggett

Robert J. Huggett, Ph.D.

We judge ourselves by what we feel capable of doing, but others judge us by what we have already done.

Henry Wadsworth Longfellow

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ABSTRACT

Busycon carica, the knobbed whelk, *B. contrarium*, the lightning whelk, and *B. canaliculatum*, the channeled whelk, constitute the whelk fisheries of Virginia. *Busycon carica* is harvested primarily in a direct summer dredge fishery and as a by-catch from winter blue crab (*Callinectes sapidus*) dredging. Peak landings occurred in 1966 with 216,000 kg (476,000 lb), with a value of $70,500. *Busycon contrarium* is primarily landed by the surf clam (*Spisula solidissima*) fishery offshore of the Virginia/North Carolina boundary and *B. canaliculatum* primarily as a by-catch from crab pots, otter trawls, and surf clam dredges. Peak landings of *B. contrarium* and *B. canaliculatum* occurred in 1974 and 1975 with over 464,000 kg (1 million lb) at an ex-vessel value of $110,000 for each year, coincident with peak surf clam landings. Virginia landings for all species in 1984 totalled 64,000 kg (141,100 lb) with an ex-vessel value of $75,500.

Biological information for the three species are summarized from published and unpublished reports and theses to identify gaps in the scientific literature.

Species identification, size frequencies, sex ratios, movement on and off commercial fishing grounds and edible meat yields were determined from commercial catch samples from June 1983 through August 1984. *Busycon carica* occurred primarily in the Bay summer dredge fihsery, comprising 99 percent of the conch by-catch. Females predominated over males in size and sex frequencies. *Busycon canaliculatum* was caught in a variety of fisheries, but was landed primarily in the Bay crab pot and offshore surf clam dredge by-catch. It is distinguished from its congenics by its willingness to enter baited pots. Females also predominated over males in size and sex frequencies. *Busycon contrarium* is distinguished from the other Virginia whelk species by its greater size and sinistral orientation. It contributed nearly three fourths of the offshore surf clam dredge conch by-catch. Females also predominated over males in size and sex frequencies.

BIOLOGICAL REVIEW AND COMMERCIAL WHELK FISHERIES ANALYSIS OF *BUSYCON CARICA* WITH COMMENTS ON *B. CANALICULATUM* AND *B. CONTRARIUM* IN VIRGINIA

THESIS OBJECTIVES

Busycon carica, the knobbed whelk, *B. canaliculatum*, the channeled whelk, and *B. contrarium*, the lightning whelk, are commercially harvested along the north-western Atlantic Coast (Kent, 1981; Weinheimer, 1982; Edwards, 1985). Recent increases in product value, expansion of local products into foreign markets and the decline of other commercial shell and finfisheries may have contributed to increased interest in commercial whelk fisheries. Expansion of whelk fisheries in South Carolina in the late 1970's and Georgia in the early 1980's were possible because of conversion of shrimp trawlers to whelk trawlers (Weinheimer, 1984; Anderson and Eversole, 1982; Eversole and Anderson, 1982).

The dynamics of *Busycon* stocks in the Chesapeake Bay are not well understood. The whelk fisheries in Virginia appear not to be in crisis today but increasing fishing pressure could result in their decline. *Busycon* landings totalled over 464,000 kg (1,025,000 lb) in 1974 and 1975 as a by-catch of the surf clam (*Spisula solidissima*) fishery. Landings of this magnitude indicate the possibility of very high fishing pressure on the *Busycon* fisheries. Busycon landings for 1985 totalled 64,000 kg (141,000 lb). Current landings of *Busycon* as by-catch in the surf clam fishery may be as little as 1 or 2 bu/trip due to Mid-Atlantic Fisheries Management Commission restrictions on surf clam landings.

Neither the biology nor the commercial fisheries of any whelks have been thoroughly studied in the Chesapeake Bay or coastal Virginia waters.

The purpose of this investigation was to provide insight on population structure of the commercial fisheries. The objectives were to:

a) synthesize historical data from published articles and unpublished reports on the biology of *Busycon* species;

b) examine landings and licensing information from the Virginia Marine Resources Commission to describe the Virginia commercial conch fisheries; and

c) investigate the commercial fishery fluctuations of *Busycon* and determine population parameters such as species ratios, size frequencies, sex ratios and edible meat yields for each species.

PART I. BIOLOGICAL REVIEW AND VIRGINIA COMMERCIAL LANDINGS ANALYSIS OF *BUSYCON CARICA*, *B. CANALICULATUM* AND *B. CONTRARIUM*.

Introduction

There are few publications on the life history and population dynamics of *Busycon*, commonly known as conchs or whelks throughout its range from New England to Florida (Magalhaes, 1948; Edwards and Humphrey, 1981; Kent, 1981; 1983). Further, there are few additional unpublished accounts of Busycon (Sisson, 1972; Stevens, 1976; Davis and Mathiessen, 1978; Wood, 1979; LILCO, 1979; 1981; 1982; 1983; Walker et al., 1980; Walker, 1982; Weinheimer, 1982; Harasewych, 1982; Edwards, 1985; Anderson et al., 1985). This paper reviews these reports and investigates the Virginia *Busycon* fisheries.

The Virginia whelk fisheries are composed of three species, *B. carica*, the knobbed whelk, *B. canaliculatum*, the channeled whelk and *B. contrarium*, the lightning whelk. Differences among the species are listed in Table 1.

There have been no previous studies of the commercial fishery of these species in Virginia waters. An analysis of the Virginia whelk fisheries shows that commercial landings have decreased in recent years, due primarily to the decline of the offshore surf clam (*Spisula solidissima*) fishery of which *B. canaliculatum* and *B. contrarium* are a major by-catch. Offshore whelk landings peaked in 1974 and 1975 with catches of over 450,000 kg (1 million lb) each year. *Busycon carica* landings from the directed effort Chesapeake Bay dredge fishery peaked in 1966 with 215,628 kg (476,000 lb) and have since fluctuated widely.

Life History *Busycon carica* and *B. canaliculatum* are found on subtidal and intertidal flats in waters with salinity greater than 15°/oo, associated with beds of oysters (*Crassostrea virginica*) and hard clams (*Mercenaria mercenaria*) (Abbott, 1974; Eversole and Anderson, 1982). *Busycon canaliculatum* and *B. contrarium* are also caught by surf clam (*Spisula solidissima*) vessels working approximately 45 km off the Virginia/North Carolina state boundary.

Busycon carica populations in North Carolina consist of localized slow-growing, long-lived animals, with individuals continually migrating between adjacent intertidal populations (Magalhaes, 1948; Edwards and Humphrey, 1981). Migration occurs in response to food availability and to deeper water seasonally (Edwards and Humphrey, 1981; Walker, 1982).

Species Abundance The relative abundance of *Busycon* species along the eastern United States and Mexico has been determined (Figure 1). *Busycon* densities for different geographical areas range from 0.5/100 m^2 to 20/100 m^2 (Table 2). *Busycon canaliculatum* is more commonly harvested in the northern United States than *B. carica* or *B. contrarium*. A north-south cline in *Busycon* shell thickness also occurs along the east coast (Pulley, 1959), with thicker shelled species dominating over their thinner shelled congenics along a north-south orientation from Woods Hole, MA to Beaufort, NC (Paine, 1962). *Busycon carica* is more abundant than *B. canaliculatum* in their shared range, as *B. contrarium* is more abundant than *B. spiratum*, the pear whelk, in their shared range.

Feeding All three *Busycon* species are carnivorous gastropods as adults. Adult *Busycon* feed mostly on lamellibranch bivalves, including the American oyster, hard clam, surf clam; blue mussel (*Mytilus edulis*);

ribbed mussel (*Geukensis demissus*); bay scallop (*Argopecten irradians*); razor clam (*Tagelus plebeius*); and dog clam (*Chione cancellata*) (Magalhaes, 1948; Carriker, 1951; Menzel and Nichy, 1958; Paine, 1962; Peterson, 1982; Peterson et al., 1982).

Busycon canaliculatum will feed on carrion, and are attracted to baited traps in the New England whelk fisheries (Magalhaes, 1948; Sisson, 1972; Davis and Mathiessen, 1978; LILCO, 1981). The oyster and hard clam comprise the main diet for adult *B. carica*, with shell entry attained by chipping at the valves with the lip of the siphonal edge of the shell and inserting the proboscis to rasp out the flesh (Colton, 1908; Warren, 1916; Kent, 1983). *Busycon contrarium* is found in association with surf clams. Juveniles and adults of all three species feed primarily on small univalves and bivalves.

Busycon canaliculatum is unable to chip at the shell of its prey because of its thin shell (2 mm versus 4 mm of *B. carica* and *B. contrarium*) (Magalhaes, 1948; Paine, 1962; Kent, 1981). Paine (1962) studied ecological diversification of *B. contrarium* and *B. spiratum*, the pear whelk, in Florida. He suggested that when *Busycon* congenics live in the same geographic area there must be sufficient ecological differences to preclude interference competition. Shell thickness would be one such diversification.

Carriker (1949) reported that *B. carica* and *B. canaliculatum* have a tendency to open thinner shelled molluscs first. The whelk, by contracting the columellar muscle, slowly brings its outer lip to bear between the valves of thin shelled bivalves such as *Mytilus*, and either forces apart or chips away the edge of the valve.

Copeland (1918) investigated the olfactory response of B. canaliculatum exposed to crushed oysters. A chemical receptor, the osphradium, is situated within the siphon and mantle cavity. Analysis of movement patterns showed that the swinging of the siphon to the whelk's right and left while crawling precedes stimulation. This stimulation promotes a change in the direction of locomotion towards the food source. Therefore, these snails do not find food accidentally but react to chemical substances in the water.

Reproduction Fertilization occurs internally in B. carica, B. canaliculatum and B. contrarium (Magalhaes, 1948; Pulley, 1959; Weinheimer, 1982). Copulation was observed during March, August and September for B. carica and B. canaliculatum in North Carolina (Magalhaes, 1948). Spawning may occur primarily in the late summer and fall for B. canaliculatum in Rhode Island, although occasional ripe individuals are found in the spring (Betzer and Pilson, 1974). Stevens (1976) reported two spawning seasons for B. carica in South Carolina; in 1975-1976, the major spawning period began in late October or early November, while spring spawning began in April. Weinheimer (1982) reported gonadal indices for B. carica in South Carolina and suggested one spawning period of between six and ten months, in contrast to the two spawning periods reported by Betzer and Pilson (1974) and Stevens (1976).

On the Eastern Shore of Virginia, egg strings are laid from September to November and hatch in the spring, March to April (Kraeuter, 1977). Busycon carica and B. canaliculatum lay approximately 2,200 eggs per capsule with about half developing into embryos (Magalhaes, 1948; Davis and Mathiessen, 1978). A description of egg laying is given by Ram (1977). Ram (1977) and Ram, et al. (1982) observed that Busycon capsule strings always had empty capsules at the initially laid end. *Busycon carica* had 13-17 empty capsules and the *B. canaliculatum* string had 4-57 empty capsules. *Busycon carica* laid capsules in the laboratory at an average interval of 1.9 ± 1.5 hours/capsule. There is no evidence that a single female deposits more than one string in a single year. The scarcity of strings may indicate that mature females may produce eggs less frequently than once a year (Davis and Mathiessen, 1978).

In an early paper of *Busycon* embryology, Conklin (1907) reported that whelk eggs contain a great amount of yolk allowing the veliger stage to develop entirely within the egg capsule. *Busycon carica* eggs were reported to have a diameter of 1700u; those of *B. canaliculatum*, 1000u. Juveniles are approximately 4 mm in length when they hatch and begin their epibenthic existence immediately (Magalhaes, 1948).

In laboratory studies in Virginia, *B. carica* capsule production and hatching rates varied depending on: 1) the position of the capsule in the string; 2) capsule length and numbers of eggs; 3) difference in the time of development of eggs in capsules along the string; 4) temperature; and 5) differences in hatching time between strings (Kraeuter, 1977).

Activity Seasonal fluctuations in activity of *B. carica* and *B. canalicualtum* have been noted (Magalhaes, 1948; Betzer, 1972; Betzer and Pilson, 1974; Walker et al., 1980). Magalhaes (1948) reported that *B. carica* is active for a few hours a day for several days and then inactive for a longer time. Carriker (1951) reported that rest periods for *B. carica* and *B. canaliculatum* lasted as long as 16 days in aquaria; Colton (1908) found they remain buried about 65 percent of the time. The three *Busycon* species differ in daily active periods (Table 1). Commercial conch fishermen in Virginia dredge for *B. carica* at the mouth of the Chesapeake Bay at night, reporting reduced landings during periods of full moon.

Migration Busycon carica and B. canaliculatum are abundant from intertidal and subtidal flats with fine, elastic substrates to approximately the 50 m isobath (Harasewych, 1982; Walker, 1985) and are often associated with C. virginica and M. mercenaria, and are only rarely found on stiff clay or rocky bottom (Puffer and Emerson, 1954; Pulley, 1959; Vermeij, 1975) (Table 1). The substrate preference of any Busycon species in Virginia has not been determined.

Magalhaes (1948) observed two types of migration for B. carica and B. canaliculatum: horizontal migration, associated with reproduction and food availability from deep to shallow water; and vertical migration within the sediments, associated with reproduction, food availability, tides, predator avoidance and unfavorable environmental conditions. Horizontal locomotion averaged 4 m/hr, with small and medium size whelks generally moving faster than large.

Kent (1981; 1983) demonstrated that the crawling speed of B. contrarium was effected more by temperature and less with body size. He reported that B. contrarium showed little inclination for migration as most whelks were recaptured in their release area. Many whelks move vertically from their buried position to the substrate surface in a daily cycle. In a tag and recapture study, 57 percent of B. canaliculatum recaptured during 104 weeks of study were found near their area of release, with an average migration rate of 14 m/day (Sisson, 1972). Magalhaes (1948) determined a rate of horizontal migration of 18 m/day in North Carolina for B. carica.

Weinheimer (1982) found that B. carica females, males, and juveniles migrated independently in South Carolina. Monthly shell length frequency distributions indicated that stock recruitment of small males (55-75 mm) incurred in June, July and November 1979 and April 1980 while large males (125-155 mm) were not collected between October and November 1979. Recruitment of small females (60-80 mm) occurred in May 1979, July 1979 and October 1979 through March 1980, with the heaviest recruitment in May and July while a decrease in the numbers of large female whelks (145-187 mm) was seen between August 1979 and January 1980. The offshore location of any Busycon species has not been determined for any studied whelk population on the East Coast.

Sex Ratio Sex ratio variations of different Busycon spp. populations occur along the eastern coast of the United States (Table 3). Weinheimer (1982) reported that B. carica sex ratios varied monthly and according to size range. Three factors may influence the sex ratio variation: 1) different migration patterns for each sex; 2) different growth rates for each sex; and 3) greater female longevity (Wenner, 1972). Differential growth rates and migrational patterns influence sex ratios, while greater female longevity and reproductive periodicity had no apparent influence on the sex ratios of B. carica (Weinheimer, 1982). Sex ratio for B. carica and B. canaliculatum may also vary with bottom depth (Magalhaes, 1948). The male to female ratio of B. carica in Georgia differed from 1:1, 1:2, or 1:3 depending on location and time of year (Walker, 1982).

Growth Growth of any Busycon species does not increase in a linear fashion as small specimens grew the fastest (LILCO, 1983). No measurable growth occurred in most recaptures, even though a few were recaptured as long as three years after tagging (LILCO, 1981). Sisson (1972) reported that the mean growth of all returned tagged B. canaliculatum was 2.6 mm regardless of time at large. The mean growth rate for female and male _B. carica_ was 0.18 mm/day, estimated from median shell length and body weight values (Weinheimer, 1982). A mean growth rate of 0.44 mm/day for 10 medium sized (66-130 mm) and 0.034 mm/day for 5 large (131-180 mm) B. carica specimens in North Carolina was reported by Magalhaes (1948).

Size ranges of captured _Busycon_ spp. may be another clue to the lack of observable growth. The vast majority of measured whelks from all studies were adults. It is possible that most growth occurs in juveniles and that once maturity is reached growth slows to a rate not measurable because of either the time span involved or the lack of sensitivity of the current measuring techniques employed to detect small changes (LILCO, 1981).

Busycon carica growth rates are estimated in Table 4. Since growth is slow, the formation of a single spine can take between 3 and 17 months (Magalhaes, 1948). One spine is roughly equivalent to 10-20 percent of a body whorl (Kent, 1981). An average adult whelk approximately 100-120 mm in shell length has 10 to 12 spines on the body whorl. The formation of the last whorl could take 2 to 15 years (Pulley, 1959). Kent (1981) determined that spine formation occurred between late April and early October for _B. contrarium_ in northwest Florida when the water temperature was greater than 20°C. The fastest growing specimen added about one third of a whorl in one growing season, while most added 15 percent or less of a whorl during a season (Kent, 1981). _Busycon carica_ often displays abraasion because of chipping movements of the spire during feeding.

Age Determination Magalhaes (1948) states that age of _Busycon_ spp. cannot be determined through examination of growth lines on the shell as new growth covers old. Recovery of marked individuals has suggested that there are zero to three growth lines produced per year for B. carica and B. canaliculatum (Magalhaes, 1948; Davis and Mathiessen, 1978). Sisson (1972) used the growth layer on the shoulder of the main body whorl of B. canaliculatum for measurement of new growth, but not for aging. Growth layers may be more reliable in the temperate waters of Rhode Island where growth rings are laid down annually, probably during the winter months (Wood, 1979). Growth may be somewhat more continuous for B. canaliculatum in warmer waters, not allowing for the formation of a line marking the end of a period of growth (Wood, 1979).

A method of determining age via growth lines on the operculum has been suggested for gastropods (Kubo and Kondo, 1953). Kennish, Lutz and Rhoads (1981) described a method for preparation of acetate peels of fractured valve sections to observe growth patterns in bivalve shells.The acetate peel method for whelk age determination may be adaptable for the gastropod operculum. Alternatively, thin mounts of the operculum may be used to age Busycon whelks with a light microscope. Opercula from over 1000 Virginia whelks were collected during this study and inventoried with shell length, shell width and weight measurements for future age analysis.

PART II. CONCH FISHERY MANAGEMENT IN VIRGINIA

Whelks, or conchs as they are called commercially, are reported in the commercial landings of ten Atlantic Coast states (Table 5). *Busycon* fisheries have existed in New England for more than 25 years (Shaw, 1960; Sisson, 1972). *Busycon* fisheries are developing in South Carolina and Georgia. Abundant offshore whelk populations are reported in South Carolina since a whelk fishery began in 1978 (Anderson and Eversole, 1983; Eversole and Anderson, 1982; Anderson et al., 1985). Annual production has increased from 6,370 kg (14,040 lb) in 1978 to 20,400 kg (41,720 lb) in 1985 (K. Van Sant, South Carolina Div. of Fish and Wildlife, pers. commun., 1986). Large vessels landed in excess of 100 bushels/day from late winter to spring (Anderson and Eversole, 1982). Georgia shrimp fishermen have developed a conch fishery since 1981 for *B. carica* and *B. canaliculatum* from January through May. The recurrence of poor shrimp harvests in Georgia since 1977 has encouraged increased interest in a summer conch fishery. Landings rose from 3,100 kg (6,842 lb) worth $4,334 for 1981 and peaked at 224,150 kg (494,036 lb) worth $237,941 for 1984. Georgia landings for 1985 dropped to 97,900 kg (200,182 lb) (S. Shipman, Georgia DNR, pers. commun., 1986).

The Virginia *Busycon* fishery occurs both in the Chesapeake Bay and offshore Atlantic waters (Figure 2). The fishery is composed of landings of *B. carica*, *B. canaliculatum* and *B. contrarium* from conch dredge, crab dredge, crab pot, otter trawl and surf clam fisheries.

Incidental landings have also been reported from fish pots, gill nets, pound nets, oyster dredges and by hand.

BUSYCON CARICA FISHERY The *B. carica* dredge fishery is a directed effort fishery in the lower Chesapeake Bay approximately 3 miles above to 10 miles outside the Chesapeake Bay Bridge Tunnel and approximately 1 1/2 to 2 miles offshore in depths of 27 to 35 ft (Areas 2,3,5; Figure 2). The conch season between Cape Charles and Cape Henry occurs from 1 April to 30 September. The season extends from 1 May to 30 September west and north of the bridge to Wolf Trap Light. The summer conch dredge fishery is regulated by the Virginia Marine Resources Commission (VMRC) by Regulation XX.

A modified crab dredge is used, easing the transition to conching once the crab season ends. Conch dredgers dredge at night and report decreased catches even during periods of full moon. They leave the docks between 3 and 6 p.m., depending on their distance from the fishing grounds, and return between 7 and 9 a.m., depending on their fishing success. The conch dredging week begins Sunday evening and ends Saturday morning, weather permitting. One dredge tow will last between 10 to 15 minutes for a distance of approximately one mile. The dredger will then turn around and tow over the same area for the same distance to capture those individuals that were dislodged from the bottom but not caught during the first pass. A good conch dredge catch would consist of 40-50 bu/night (27 kg or 60 lb per bushel).

The number of conch licenses has fluctuated widely in the nine years the conch fishery has been monitored using VMRC licenses (Figure 3). The decline of whelk licenses from 24 in 1980 to 8 in 1982 has suggested decreased effort as the cause of reduced landings. Conch licenses totalled 18 for 1985.

Busycon carica contributes nearly three fourths of total Virginia conch landings in the conch dredge, crab dredge, pound net, otter trawl fisheries and by-hand (Table 6). *Busycon carica* comprises nearly 100 percent of landings in the Virginia conch dredge fishery. Additionally, *B. carica* comprises 96 percent of offshore otter trawl conch by-catch. Incidential landings are also observed in the inshore pound net fishery and by-hand (Table 6). Two Eastern Shore buyers purchased conch from the summer fishery dredgers and from 1982 to 1985 declined to report landings. VMRC currently employs a voluntary landings reporting system. Chesapeake Bay landings are known to be underreported as VMRC collected no landings for whelks harvested in the Bay by conch dredgers. This lack of reported landings occurred during the 1983/1984 when I was conducted dockside sampling of the Bay conch fishery.

BUSYCON CANALICULATUM FISHERY *Busycon canaliculatum* contributes significant conch landings in the crab pot and surf clam fisheries (Table 6). *Busycon canaliculatum* makes up one hundred percent of crab pot by-catch but less than one percent in the summer conch dredge fishery. Additionally, incidental landings of this species occurred in the conch dredge, pound net and otter trawl fisheries and by hand.

Peak landings of *B. canaliculatum* occurred with peak surf clam landings in 1972 to 1976. *Busycon canaliculatum*, contributed approximately 28 percent of conch landings in this fishery and totalled

327,000 kg (721,000 lb) for this five year period. This species currently averages 15 percent of all Virginia conch landings.

BUSYCON CONTRARIUM FISHERY Virginia conch landings have fluctuated markedly since 1963, peaking twice, in 1966 and 1974-75. The 1966 peak involved Chesapeake Bay dredge catch, but in 1974 to 1975, 95 percent and 97 percent, respectively, of the 498,000 kg (1 million lb) were taken by offshore surf clam dredge. Peak offshore B. canaliculatum and B. contrarium landings are matched with peak landings of the Atlantic surf clam, Spisula solidissima (Figure 4). The surf clam fishery was initiated in 1969/70 in a relatively small area off Cape Henry, VA (Ropes, 1982). An average of 15.6 percent of total conch landings were taken by the surf clam fishery from 1963-1971. Surf clam by-catch of conch increased to 94.9 percent from 1972-1975, and dropped to 52 percent of total catch from 1976-1982 when limitations on the surf clam industry were invoked.

Conch landings from the early years of the surf clam fishery may have been underreported because a market for the species had not yet been developed. The conch by-catch was given to the crew for "shack' money. Additionally, the Eastern Shore has many "mom and pop" seafood outlets and few big buyers, so much of the landings were probably unreported. By the mid-1970's, a conch processing facility had opened in Cape Charles, VA, which bought most of the conch landed on the Eastern Shore.

Federal and state management attention initially focused on the offshore surf clam fishery because industry overcapitalization, which may have encouraged overfishing, threatened the resource with economic extinction (Armitage, 1985). Federal regulations were promulgated for regional management of the surf clam fishery in 1977 (Federal Register, 1977). The plan established a variety of regulations, including an annual catch quota of 13.5 million kg (30 million lb) of meat and a 24 hour per week fishing limit. Surf clam landings dropped from 19.5 million kg (43 million lb) in 1977 to 14.2 million kg (31.4 million lb) in 1978. A fishing week in the Virginia surf clam fishery during this study consisted of three days, one day to and from the offshore fishing grounds back to Cape Charles, VA and one 24 hour period of fishing. Regulations passed in 1986 limit surf clam fishing to 6 hours every other week. Restrictions placed on the surf clam fishery also indirectly impact conch by-catches of *B. canaliculatum* and *B. contrarium*.

Busycon contrarium comprises almost three fourths of the Virginia surf clam dredge by-catch based on commercial catch analysis. *Busycon contrarium* landings are estimated at 862,000 kg (1,900,000 lb) for the period of peak surf clam landings, 1972-76. *Busycon contrarium* is also landed incidentally in the otter trawl fishery. *Busycon contrarium* currently contributes approximately 13 percent of all *Busycon* landings in Virginia (Table 6).

Total Landings Virginia conch landings were first reported by Fishery Statistics of the U.S. in 1940 (Figure 5). Landings for each species were calculated using landings data from Fishery Statistics of the United States, VMRC and species composition from field sampling (Figure 6). No landings were reported in 1942 and 1943 because of the suspension of data collection due to World War II. Landings averaged approximately 29,000 kg (63,000 lb) per year for 1940-59 (exclusive of 1942-43), 152,000 kg (335,000 lb) per year from 1960-79, less than half the 1960-79 figure with 57,000 kg (125,000 lb) per year for 1980-84.

Conch landings from 1963-1971 were produced mainly as the result of of by-catch from crab dredging. Landings ranged from a low of 45.1 percent of total landings in 1965 to a high of 83.3 percent of toal landings in 1971. Landings of around 500,000 kg (over 1 million lb) were obtained with the hydraulic surf clam dredge beginning in 1972. Conch bycatch in the surf clam fishery made up 80 percent of landings in 1972, compared to 6.6 percent of landings from crab dredging in the same year.

Conch landings have been considerably reduced since 1975. Overfishing, coupled with slow growth and the lack of size regulations, may cause depletion of local populations. Restrictions on the surf clam fishery has strongly reduced landings of B. canaliculatum and B. contrarium. The Chesapeake Bay B. carica fishery has not been similarly limited.

Dockside Value Average dockside value of conch in 1985 of between $10-12/bu approximates that of oysters ($11/bu) and blue crabs ($8/bu) Figure 5). Price paid for conch varies for each fishery, but the conch dredge fishery commands the highest prices.

Price paid for conch varies by species in Rhode Island where an extensive potting fishery for B. canaliculatum exists. Lower prices are paid for B. carica and B. contrarium since dredged conch are offten filled with mud and may have broken shell fragments in the meat (R. Borgnine, Rhode Island Seafood Council, pers. commun., 1983). Field samples purchased directly from the Virginia dredgers were covered with mud, but few specimens had broken shells.

Processing Four procedures for removing whelk meats from their shells have been investigated (Rippen, 1982). These methods include hand cracking, cutting of shell, steaming, and prefreezing and thawing

Prefreezing and thawing was found to be the most effective method, yielding meat weight of 39.1 percent of total live weight and eviscerated meat that was 28.5 percent of live weight. Subsequent hand shucking was easy, with less toughening of the meat than with the steam application. The next best yield came from hand cracking which resulted in meat yields and eviscerated meat yields of 32.7 percent and 21.9 percent total live weight, respectively.

A description of the above freezing method follows. Whelks were frozen, uncovered at 21^{o}C for 6-24 hours, then thawed at room temperature, shucked and weighed. The animals were easily pulled free from their shells after having been fully frozen after approximately 16 hours. The frozen/thawed animals were removed by inserting a knife under the operculum for leverage and then cutting the operculum off after removal. A marked protrusion of the foot muscle was observed in all frozen whelks handled in this manner. A drip loss of 2.6 percent and 0.7 percent was determined for one and two freeze/thaw cycles indicating a weight loss by the processor rather than the buyer if hand cracked (Rippen, 1982).

Many whelk processors in Rhode Island set a cut-off point for the minimum size animal they will accept (Wood, 1979). A minimum size of 6.0 mm shell width with its corresponding average yield of greater than eighteen percent would maximize the yield per individual upon recruitment into the fishery (Wood, 1979). The relationship between percent yield of edible weight and shell size for B. canaliculatum approaches an asymptotic curve with the asymptote being 25-27 percent edible weight at shell sizes greater than 8.5 mm. The yield for an average size animal of 7.2 mm wide is approximately 21 percent. Below this average shell size, the yield drops off quickly with decreasing animal size.

The minimum weight reported for efficient processing of B. canaliculatum in Rhode Island is 164 g with most animals having 4-5 shell growth layers (Sisson, 1972). Smaller animals yield less meat in proportion to shell weight, with the yield per 22 kg (50 lb) bushel also less (Sisson, 1972).

The smallest whelk in Virginia commercial field samples from July 1983 to August 1984 was 8.3 mm, a B. canaliculatum male. Minimum size restrictions allow most animals to spawn before being harvested, thereby increasing recruitment; however, little research has been done with B. to determine age or size at first reproduction. Any size restrictions set by industry reflect a minimum size for ease of shucking and not conservation measures.

Market Market value for conch has increased dramatically since the early 1940's from approximately $0.80/kg ($0.36/lb) to $1.50/kg ($0.68/lb) in 1980 (Figure 7). Market value for 1983 and subsequent years dropped due to lack of reporting from the conch dredge fishery.

In addition to the Virginia Busycon species, U.S. conch exports also include B. spiratum from the southern U.S. and Strombus spp. (conch) from Florida and Caribbean Strombus imports. Conch are not promoted by regional and federal seafood councils as the supply fluctuates too widely for the international market (R. Borgnine, Rhode Island Seafood Council, pers. commun., 1983). United States Strombus imports fluctuate according to the marketplace as they are a principal export seafood product from the Caribbean. Busycon landings are strongly tied to the landings of other, larger fisheries (i.e., crabs, surf clams). Conchs for foreign export have been getting smaller due to

Oriental demand for smaller animals (R. Borgnine, Rhode Island Seafood Council, pers. commun., 1983).

The market for whelks began with the increased whelk landings as by-catch from the surf clam fishery on the Eastern Shore in the mid-1970's. One processor in Cape Charles, VA was processisng whelks and shipping the meat to a New Jersey cannery. In early 1986, another Eastern Shore buyer opened processing facilities for processing up to 300 bu/day, for a total volume of 40,000 bu/year. Both processors are selling the processed conch to a New Jersey cannery. Prior to 1986, this second buyer had shipped his entire supply "in the shell" to northern markets, primarily Fulton's Fish Market in New York City. From Fulton's, it had been sold locally, shipped to the New England market or shipped raw to the European and Oriental market. Foregoing the inconsistent price setting of Fulton's Market in New York will enable a steady supply of processed conch to the seafood industry, and maximize state benefit through employment and taxes. The proposed volume of conch to be handled by this processor (roughly 180,000 kg (400,000 lb) of meats) indicates that landings from 1982 to 1985 are probably underreported to the same degree. Reported landings of 141,000 lb (7,000 bu) in 1984 result from incidental shipments by truck to Fulton's Market along with other seafood products. The degree of underreporting can not be estimated for prior years, but is believed to be substantial given the low landings figures.

One Virginia wholesaler/retailer began purchasing conch in 1984 from the year round Eastern Shore buyer for local processing and shipping to the Orient. This contract lasted for less than six months due to the processor's inability to provide an adequate raw product for his Oriental buyers. The processing technique involved breaking the shell open with a hammer, removing the viscera and washing the shell from the edible product. He had tried the freezing technique I used for processing of field samples, but this method was not successful for undetermined reasons.

PART III. COMMERCIAL CATCH COMPOSITION OF THREE *BUSYCON* FISHERIES IN VIRGINIA.

Introduction

No study dealing with the biology or commercial fishery of any *Busycon* species has been reported for the Chesapeake Bay or coastal Virginia waters, although tens of thousands of bushels of whelks are harvested each year. This investigation aims to provide insight on population structure of the commercial fisheries.

In an attempt to characterize the specific *Busycon* fisheries, dockside sampling of the conch catches from Virginia's commercial fisheries was conducted from June 1983 through August 1984. Species ratio, sex ratio, size frequencies and edible meat yield were investigated for each commercial fishery.

Methods

Dockside Busycon specimens were collected from July 1983 through August 1984 except for November and December 1983 when commercial whelk catches were unavailable (Table 7). Samples were obtained from the conch dredge, crab dredge, crab pot and otter trawl fisheries (Table 8). Incidental specimens were collected by hand and in the pound net fishery.

One half bushel of whelks (approximately 50 animals) were collected from one to as many as three boats per sample date. These 50 specimen samples were provided by the boat captains, and were generally the last of the catch to be shoveled into bags for transportation to the buyer. Oneway ANOVA tests on length, width and weight means by sex and species were run for all samples collected per sample date. All statistics were tested at the 95 percent probability level. No significant differences were detected from samples from a given month and all specimens per month were pooled by species and sex for additional analyses. Significant differences did occur between species and sexes.

All whelks were collected while alive and kept frozen at approximately -30^{o}C for ease in shucking. Samples were thawed overnight before measurements were taken. Species were identified by gross morphological examination of the shell surface and determination of sinistral or dextral orientation. Shell length was measured from the tip of the spire to the tip of the siphonal canal. Shell width was measured directly below the shoulder spines with the aperture facing down. Shell length measurements were taken to the nearest millimeter using a measuring board and shell width, opercula length and opercula width were measured by calipers to 0.1 mm. Total weight (shell, body and operculum), meat weight and foot weight were measured on a Mettler top loading balance. Specimens were removed from their shells to determine meat weight by tugging on the mantle along the siphonal canal until the animal slipped out of the shell. If this method did not free the body, the claw end of a hammer was used to crack a hole in the shell so that the collumellar muscle attachment could be cut. This attack was necessary only with the largest specimens. Sex was determined by the presence or absence of a penis, on the right shoulder behind the head for right-handed whelks and left shoulder for left-handed whelks, after the animal was shucked. Foot weight, or edible meat yield, was measured after separating the viscera and defacing the animal by cutting away the siphon and eyestalks. Opercula weights were measured on a digital Sartorius balance. Twelve hundred and sixty three *Busycon* specimens were analyzed.

Chi-square tests were performed on each monthly sample to determine if sex ratios significantly differed from 1:1.

Frequency distributions were determined to examine seasonal/monthly fluctuations in shell length, shell width, total weight, meat weight, foot weight, opercula length, opercula width, and opercula weight.

Model I oneway analyses of variance with an *a posteriori* Scheffe tests were performed on females and males separately to examine monthly fluctuations in these parameters.

Analyses of covariance were used to determine if data for regressions of shell length against shell width, total weight against meat weight, shell length against total weight, and shell length against opercula length could be pooled for females and males.

Regressions were calculated using SPSS. Tests of regression coefficients were performed to test for differences between females and males.

Analyses of edible meat yields (foot weight/total weight) used an arcsin transformation of data for paired t-test analyses with an *a posteriori* Scheffe test. The Scheffe test was chosen for *a posteriori* analyses for its conservative nature, as sample sizes varied widely.

Results

BUSYCON CARICA

Sex Ratios Chi-square tests showed that females significantly outnumbered males for sampled months between July 1983 and July 1984, except for August and September 1983 (Table 9). There were few males in October 1983 (n=1) and June and July 1984 (n=2).

Morphometrics Frequency distributions showed that females analyzed in this study had wider size ranges than males (Figures 8 - 15). Student's t-tests showed that female and male *B. carica* significantly differed for all parameters tested indicating that females and males were morphometrically different, with females having greater mean sizes than males (Table 10). Means and standard deviations for these parameters were calculated by month (Table 11). Overall, July 1983 had the lowest mean value for all parameters tested for each sex, while October 1983 and June 1984 had significantly higher values. Morphometrics will be discussed in more detail later.

Monthly Size Distributions The monthly shell length frequency distribution for *B. carica* indicates that small males (<80 mm) did not occur in the Virginia commercial fishery. Males remained at a fairly constant size between 120-160 mm and peaked in the late summer months, August and September 1983, when sex ratios were approximately 1:1 as a percentage of the catch. The monthly female shell length frequency distribution indicates that females less than 100 mm did not occur in the conch dredge fishery. Large females (>200 mm) occurred in the fishery in October 1983, June and July 1984, the three months of lowest male frequencies.

The male meat weight histogram shows a pattern similar to shell length, with smaller males present from July 1983 to March 1984. Males with higher weights (>100 g) began to enter the fishery in September 1983; males greater than 200 g appeared in July 1984. Small females (<40 g) did not appear in the commercial fishery. Females 50-150 g dominated the July, August, September 1983 and January 1984 catch. Larger females (>200 g) appeared in October 1983, February, March and June 1984. Females greater than 400 g appeared in July 1984.

Regressions Regression analyses revealed significant differences for only shell width on shell length between the sexes (Figures 16 - 19). A summary of the results of regression analyses are listed in Table 12.

Edible Meat (Foot) Yield The relationship between female and male regression lines of edible meat yield (EMY) or foot weight onto total weight shows that females generally produce more edible meat yield than do males (Figure 20). Foot weights as a percentage of total weight were also examined for each sex meat yield. A monthly yield of 15 percent or greater was determined throughout the sampling period (Figure 21). Paired t-tests with an *a posteriori* Scheffe test of EMY showed that September and October 1984 were siginificantly different from all other months.

BUSYCON CANALICULATUM

Sex ratio Chi-square tests showed that females significantly outnumbered males in October 1983 and July and August 1984 (Table 13). No differences occurred for the two remaining months sampled, April and May 1984.

Morphometrics Frequency distributions showed that females analyzed in this study had wider size ranges than males (Figures 22 - 29). T-tests results indicated that females and males significantly differed for only shell length and shell width of the eight parameters tested (Table 14). Model I oneway analysis of variance showed that January 1984 had the lowest mean value for all parameters tested for *B. canaliculatum* females; July 1984 had the highest values. October 1983 had the lowest value, and June 1984 had the highest value, for all parameters analyzed for *B. canaliculatum* males (Table 15).

Monthly Size Distributions Monthly shell length frequency distribution for *B. canaliculatum* indicates that few males less than 100 mm occurred in the Virginia commercial fisheries (Figure 22). Males were of a fairly steady size distribution of between 80-180 mm. The monthly female shell length frequency distribution indicated that small females (<100 mm) and large females (>200mm) did not occur in the Virginia conch fisheries.

The male meat weight histogram shows a pattern similar to shell length, with smaller males (70-170 g) present in October 1983 and April 1984 (Figure 25). Larger males (130-180 g) occurred in May, July and August 1984. Small females (<100 g) did not appear in the commercial fishery. Females in the 200-400 g range dominated the October 1983 and April and May 1984 catch. Larger females (400-800 g) appeared in April, May, July and August 1984, but with frequencies of only one or two. The largest females (180-210 g) occurred in July 1984.

Regressions Analyses of covariance revealed significant differences between the sexes so that data for the sexes could not be pooled. A summary of comparisons between female and male functional regression lines are listed in Table 12.

Edible Meat (Foot) Yield The regression relationship of foot weight onto total weight between female and male regression lines shows no significant differences occurred between the sexes (Figure 35). A yield of 25 percent or greater was determined throughout the sampling period (Figure 36).

BUSYCON CONTRARIUM

Sex ratios Chi-square tests showed that females significantly outnumbered males in April, May and June 1984, but not in July and August 1984 (Table 16). Due to the scarcity of B. contrarium conch bycatch in this fishery all samples sizes, cumulative for both sexes, were under thirty individuals.

Morphometrics Frequency distributions showed that females analyzed in this study had wider size ranges than males and significantly differed for all eight parameters tested using t-tests (Table 17; Figures 36 - 43). Model I oneway analysis of variance showed that no differences occurred for any parameters for female or male B. contrarium tested separately.

Monthly Size Distributions The monthly shell length frequency distribution for B. contrarium indicates that small males (<140 mm) did not occur in the surf clam fishery bycatch (Table 18). Males were of a fairly steady size distribution of between 140-210 mm. Males were less frequent than females throughout sampling. Monthly female shell length frequencies indicated that small females (<120 mm) also did not occur in the fishery. Large females (>250 mm) occurred in the fishery on every sampling date. Sample sizes were less small (< 30); therefore, a reliable description of B. contrarium size frequencies was not attained.

Monthly size frequencies for B. contrarium show a siginificant difference between female and male shell length. Male shell length frequencies ranged between 14 and 20 mm. Female shell length frequencies ranged generally between 20 and 26 mm. This pattern occurred throughout the sampling period, although August 1984 contained two female specimens one each at 12 and 13 mm.

Most males occurred between 150-300 g meat weight range throughout the sampling period (Table 18). Small females (<200 g) did not occur in the commercial fishery. Most females occurred in the 300-500 g meat weight range. Females in excess of 200 g appeared in April and August 1984.

Regressions Analyses of covariance revealed that no significant differences occurred between the sexes. A summary of comparisons between female and male functional regression lines are listed in Table 12.

Edible Meat (Foot) Yield The relationship of foot weight onto total weight was demonstrated (Figure 48). The relationship between female and male regression lines shows that foot weight correlates with total weight equally between the sexes.

Foot weight as a percentage of total weight were examined for each sex. A yield of 20 percent or greater was determined throughout the sampling period (Figure 49). Males yielded a higher but not significantly different percentage of edible product than females.

Discussion

Management Concerns

The exceptionally high catches of conch in 1974 and 1975 together with increasing interest in underutilized species in the early 1980's and their slow growth rate led to scientific interest in the basic biological characteristics of these species. Preliminary work on hatching and growth rates of B. carica was performed in the late 1970's by Kraueter and Castagna (1979). The investigators made population estimates for one barrier island, Cedar Island, of between 19,000 and 25,000 individuals. The Virginia Marine Resources Commission (VMRC), the state agency with regulatory authority of the Commonwealth's marine fisheries passed Regulation XX, Pertaining to the Taking of Conchs in 1979. Regulation XX designated commercial fishing areas for conchs with seasonal and gear type restrictions (Figure 2). VMRC was contacted in 1980 by a major conch buyer and two conch fishermen to request an extension of the season for Area 4 by one month and boundary changes for Areas 2 and 4. Regulation XX was accordingly amended in 1981. Regulation XX was amended in September 1986 to extend the conch dredging season in Areas 2 and 4 by one month, through October 1986.

VMRC staff also began to notice increased exploitation and interest in Virginia's conch fishery through landings information and inquiries to field office personnel. In an attempt to quantify landings, VMRC staff sought to amend Section 28.1-119.1 of the Code of Virginia which does not require conch buyers to obtain a seafood buyer's license. This ommission also occurs for buyers of lobsters and horseshoe crabs. VMRC plans to offer a legislative amendment in 1987 to require all seafood buyers to purchase a VMRC license.

The true extent of the past, present and potential annual harvest of *Busycon* is unknown because a substantial volume of whelks are sold directly to small volume retailers and one big volume wholesaler and shipper who do not consistently keep or report quantity or value handled.

In 1983 VMRC staff proposed to initiate conch fishery record-keeping by: 1) implementing daily logbook requirements of all licensed conch fishermen in January 1984 whereby I would collect and quantify this information to determine catch-per-unit-effort; 2) implementing a daily logbook for crab dredgers for the collection of daily crab landings, as specified by Regulation XII which would include a request for by-catch landings for Virginia fishermen selling to unlicensed buyers and non-resident licensed buyers; and 3) collecting historical conch catch data from the one wholesaler. Unfortunately, none of these objectives were attained due to the low management priority given this species by VMRC.

In an attempt to provide basic biological information on the three *Busycon* species landed in Virginia's commercial fisheries, a sampling program was undertaken. Most of the sampling was directed at the Chesapeake Bay conch dredge fishery for *B. carica* as it contributes nearly 75 percent of current Virginia conch landings.

Discussion of dockside sampling results will focus primarily on *B. carica*. The small sample sizes of *B. canaliculatum* and *B. contrarium* analyzed in this study preclude analysis related to seasonal size changes, movement or reproduction, but do indicate sex and size frequencies in the bycatch of different commercial fisheries.

Size Frequencies An increase or decrease in size over the sampling period is not evident for female or male *B. carica*, as might have been expected due to growth or fishing pressure. Monthly means do, however, increase and decrease.

Preliminary examination of conch catches indicated that overfishing might seriously deplete the resource by eliminating the females from the population. Additionally, the location of males and juveniles outside of the commercial fishing grounds is unknown. The resource could be easily depleted by a moderate, yet constant fishing effort given the sex composition of the catch and slow growth rates. No evidence of overfishing of the commercially harvestable portion of the population occurred based upon measurements from this study.

The lack of trend for shell lengths, shell widths or total, meat or foot weights may indicate that *B. carica* is very mobile on and off the commercial fishing grounds. A mark and recapture rate of four percent for *B. carica* was reported by Kraeuter and Castagna (unpub. data) for a Virginia barrier island population. Low tag returns were also reported for Georgia and South Carolina *B. carica* populations (Walker, 1982; Edwards, 1985; Anderson et al; 1985). Low movement, between 12 and 18m/day, and low recapture rates are also reported for *B. canaliculatum* (Magalhaes, 1948; Menzel and Nichy, 1958; Sisson, 1972; Wood, 1979; LILCO; 1982).

Kraeuter and Castagna (unpub. data) determined a population estimate of 328 *B. carica* for Cedar Island, VA in 1977/78 from 82 tagged individuals. This estimate was thought to be artificially low because: 1) loss of marks depressed recapture rates; 2) two populations were utilizing the flats at different times; or 3) continuous loss and replacement of individuals was occurring. The investigators assumed that the recapture rate should have been about 18 percent and that harvesting rates of marked individuals approached 21 percent. The Cedar Island population estimate was revised to between 19,000 and 25,000 individuals. It was observed, however, that the numbers of whelks on the flats remained about the same. If 21 percent of the population was being harvested, approximately 5,000 individuals, a rapid rate of turnover was occurring.

A significant increase in monthly means did not occur for _B_. _carica_ over the ten months sampled, for _B_. _canaliculatum_ over five months or for _B_. _contrarium_ over four month's sampled. Lack of growth may indicate the limited size range sampled, but it is also possible that movement on and off fishing grounds accounts for the lack of a stable sampled commercial population.

Reproduction Reproductive periodicity may be indicated by the monthly fluctuations in body weight in sampled _Busycon_. Increased EMY in September and October 1983 for _B_. _carica_ indicates reduction in percentage of gonad weight to total weight due to egg laying. Kraeuter and Castagna (unpub. data) reported that egg-string laying was observed in Virginia from September to November; hatching was observed from March to April. Size frequencies from this study indicate that egg-laying may have occurred in October 1983 and June-July 1984.

Sex Ratios One aspect of the reproductive capacity of a bisexual species is its sex ratio. A 1:1 sex ratio results from natural selection if an equal amount of parental energy is required to produce offspring. Differences in sex ratios may be caused by differential survival rates, differential growth rates, different migration patterns, greater female longevity and gear selctivity.

Males made up 30 percent of the B. carica commercial landings, 35 percent of B. canaliculatum and 39 percent of B. contrarium bycatches. Field samples collected by hand on Cedar Island, VA resulted in only 6.9 percent males of 350 individuals collected (Kraeuter and Castagna, unpubl. data). Weinheimer (1982) determined that sex ratios had no influence on Busycon reproductive capacity. High values for female and male reproductive indices occurred whether females were more frequent than males, were equal in numbers with males or were less frequent than males.

When B. carica sex ratios returned to 1:1 in August and September 1983, the males were still significantly smaller in size. Therefore, previous decreases in relative numbers of males may be due to an increase in male mortality. Different growth rates may be responsible for some of the variations sex ratios, but this could not be determined from data collected by this study. Weinheimer (1982) suggested that female growth rates were often higher than for males. Additional evidence of encrusting organisms present on the largest female and male shells also indicated that the age of the largest shells for both sexes were approximately equal, although the male shells were significantly smaller.

It is possible that if males grow at a slower rate than females as size frequencies indicate, natural mortality from causes such as predation could be higher for males than for females of the same year class. Sex and size ratios might shift toward more males, more females, or remain constant, depending on the removal rates of males by harvest relative to the combined migration and harvest rates of females.

Edible Meat (Foot) Weight The foot is the edible portion of the whelk and is marketed commercially. Expansion of the commercial fishery may make a minimum size restriction beneficial to both the fisherman and the fishery. At present, however, there are no indications of over exploitation of the commercial whelk population.

The lack of small specimens of all three Busycon species in the sampled catches precludes determination of a minimum size recommendation. Size ranges may have been too narrow, and sample sizes may have been too small for B. canaliculatum and B. contrarium.

The meat yield for a 60 lb (22 kg) bushel of average size whelks is 10 lb (3.7 kg) or sixteen percent and is the approximate yield necessary to make a profit. Yields determined in this study approached thirty percent but could include sampling error. The minimum size for B. canaliculatum in Rhode Island was determined to be 163g for maximum yield/animal (Sisson, 1972), and meat yield dropped off quickly below this average shell size.

Minimum Size Little work has been done on minimum size at which whelks can be commercially processed (Wood, 1979; Rippen, 1972). Whelk processors generally accept any size conchs to ensure their supply. South Carolina has enforced a 4 1/2 inch minimum size limit on their commercial conch fishery (Anderson et. al, 1985). One important aspect of a fisheries management strategy is to maximize the yield per recruit into a fishery. A minimum size restriction would also allow most whelks the opportunity to spawn before being harvested. Recruitment to the fishery should increase since more animals would be available to the commercial fishery from that spawn.

RECOMMENDATIONS FOR FUTURE RESEARCH

The naturally occurring populations of these species must be sampled to determine availability and vulnerability of juveniles to the commercial industry, along with estimates of EMY from the entire population size range before a minimum size restriction could be recommended.

1. The extent to which whelks move is unknown. Inshore populations may become quite sensitive to an increase in fishing effort above the current levels with little in-migration. Further study designed to investigate both the commercial fishery at dockside and the natural population would provide important information on population structure, movement, recruitment and the role of whelks in benthic communities.

2. A tagging study is necessary to identify B. migration patterns to understand the monthly/seasonal variations in population movement, sex and size frequencies for Virginia populations.

3. Developing a valid aging technique would provide information on differences in growth rates betwen the sexes, and among species, age at first reproduction, age at first recruitment and differential survival between sexes.

4. Additional investgations should include B. canaliculatum and B. contrarium as a substantial proportion of whelk catch is dependent on the effort expended in other commercial fisheries.

MANAGEMENT RECOMMENDATIONS

5. VMRC should enforce Regulation XX to require conch dredge license holders to report daily catch for at least one season to

determine catch rates. Catch-per-unit-effort data, in combination with tagging results, would allow for estimation of fishing pressure on the commercial fishery.

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Table 1. Biological characteristics of *Busycon* spp. as reported in published literature. All information from Magalhaes (1948) except as noted (*).

	B. carica	*B. canaliculatum*	*B. contrarium*
range	So. end Cape Cod, MA Cape Canaveral, FL	Cape Cod, MA to Augustine, FL; introduced to San Fran. Bay	NJ to FL and Gulf States
preferred temp.; range	30°C; 10.5-35.0°C	17.5°C; 8.5-31.5°C (Shaw, 1960)	20-25°C (Kent, 1983)
substrate	sandy	muddy (Walker et al., 1980)	sandy
location	intertidal	inshore and offshore	offshore
daily active period	daily and nocturnal	nocturnal only	daily and nocturnal (Paine, 1962)
food	all bivalves	all except *Mercenaria*	all bivalves
carrion feeder	no	yes	no
orientation	dextral	dextral	sinistral
shell	smooth	hirsute periostracum	smooth
size differences	female > male	female > male	female > male
activity	March-December	March-December	Dec-April (Paine, 1962)
fecundity (Davis and Mathiessen, 1978)	2200 eggs	2200 eggs	unknown
spawning	spring and fall (Stevens, 1976); spring through fall Weinheimer, 1982)	spring and fall (Betzer and Pilson, 1984	unknown
shell thickness (mm)	4.0	2.0	4.0

Table 1. (cont'd).

	B. carica	*B. canaliculatum*	*B. contrarium*
length (mm) (range)*	7.5-25.0	8.0-20.0	14.0-27.6
width (mm) (range)*	4.0-12.0	4.0-11.0	7.7-13.0
weight (g) (range)*	50-550	65-370	257-1530

*from Virginia commercial catch, July 1983-August 1984

Table 2. Densities of *Busycon* spp. along the eastern United States.

SOURCES	LOCATION	DENSITY (per 100 m^2)	SPECIES
Sisson (1972)	Narragansett Bay, RI	1.0	*B. canaliculatum*
Davis and Mathiessen (1978)	Cotuit Bay, RI	3.7	*B. canaliculatum*
		20.0	*B. carica*
	Nantucket Sound, RI	0.5	*B. canaliculatum*
		1.5	*B. carica*
	Buzzards Bay, RI	0.66	*B. canaliculatum*
Wood (1979)	Quonset Point, RI	1.2	*B. canaliculatum*
		4.0	*B. carica*, *B. canaliculatum*
	General Rock, RI	1.7	*B. canaliculatum*
		6.7	*B. carica*, *B. canaliculatum*
	America's Ledge, RI	1.2	*B. canaliculatum*
		1.8	*B. carica*, *B. canaliculatum*
Carriker (1951)	Little Egg Harbor, NJ	11.1	*B. carica*, *B. canaliculatum*
Kraeuter and Castagna (unpubl. data)	Cedar Island, VA	4.9	*B. carica*
Magalhaes (1948)	Beaufort, NC	14.3	*B. carica*, *B. canaliculatum* *B. contrarium*
Walker et al. (1980)	Savannah, GA	2.2	*B. carica*, *B. canaliculatum* *B. contrarium*
Menzel and Nichy (1958)	Alligator Harbor, FL	4.0	*Busycon* spp.

Table 3. Sex ratios of _Busycon_ spp. along the eastern United States.

Source	Location	Sex Ratio (F:M)	
Magalhaes (1948)	Beaufort, NC	59:41	_Busycon_ spp.
Betzer (1972)	Rhode Island	36:64	_B_. _canaliculatum_
Ram (1977)	Woods Hole, MA	98:2	_B_. _canaliculatum_ (>300g)
		79:21	_B_. _canaliculatum_ (250-300g)
		55:45	_B_. _canaliculatum_ (<250g)
Kraeuter (1977)	Cedar Island, VA	24:326	_B_. _carica_
this paper	Virginia	653:283	_B_. _carica_
		126:69	_B_. _canaliculatum_
		96:62	_B_. _contrarium_
Wood (1979)	Narragansett Bay, RI	59:31	_B_. _canaliculatum_
		36:64	_B_. _carica_
Walker (1982)	Wassaw Sound, GA	7:1	_B_. _canaliculatum_
		11:1	_B_. _carica_
		57:0	_B_. _contrarium_

Table 4. Age and growth data for *Busycon carica*, adapted from Sisson (1972).

Age (months)	Length (mm)	
	*B. carica***	*B. carica****
1	1.0	11.0
2	-	22.5
4	-	33.4
6	-	36.4
12	2.1-4.0	37.2
18	4.1-8.0	-
18-24	8.1-16.0	-
24-30	16.1-32.0	-
>30	32.1-64.0	-

* data from Magalhaes (1948)

** data from Kraueter and Castagna (unpubl. data)

Table 5. Commercial landings of B. carica, B. canaliculatum, and Strombus gigas.*

YEAR	KG	TOTAL VALUE	VALUE PER KG	# OF STATES
1962	346,000	$ 86,669	$0.25	8
1963**	495,009	$180,921	$0.59	8
1964	305,700	$ 93,552	$0.31	8
1965	288,200	$120,863	$0.42	8
1966	571,200	$258,953	$0.45	8
1967	368,800	$133,352	$0.36	8
1968	362,100	$120,576	$0.33	8
1969	448,200	$192,172	$0.43	8
1970**	434,000	$211,084	$0.49	7
1971	266,100	$142,674	$0.54	8
1972**	350,800	$195,782	$0.56	8
1973	432,100	$283,265	$0.66	9
1974**	821,800	$298,972	$0.36	8
1975	849,500	$373,547	$0.44	10
1976	566,000	$308,284	$0.54	9
1977**	349,400	$330,167	$0.94	8
1978**	655,700	$945,801	$1.44	10
1979**	529,000	$783,106	$1.48	10
1980**	241,600	$327,439	$1.36	8
1981**	427,700	$366,519	$0.86	9
1982**	499,700	$615,934	$1.23	9
1983**	483,000	$791,759	$1.64	9
1984**	644,300	$1,022,460	$1.59	8

*National Marine Fisheries Service Data Management and Statistics Division, personal communication; NMFS Commercial Landings Bulletins, 1962-1980. Data from 1980 are incomplete, due to lack of reports from Connecticut and Delaware. Adapted from Weinheimer (1982).

**No S. gigas reported.

Table 6. Landings (%) of *Busycon* species reported by gear from monthly samples from July 1983 to August 1984 for inshore and offshore Virginia waters.

Location	*B. carica* %	*B. canaliculatum* %	*B. contrarium* %
Inshore			
crab/conch dredge (n=871)	99.3	0.7	0.0
crab pot (n=119)	1.7	98.3	0.0
pound net (n=2)	50.0	50.0	0.0
hand (n=12)	66.7	33.3	0.0
Inshore Average	87.3	12.7	0.0
Offshore			
otter trawl (n=75)	96.0	2.7	1.3
surf clam dredge (n=229)	0.0	27.5	72.5
Offshore Average	23.6	21.4	55.3

Table 7. Number of *Busycon* specimens by species by sample month.

Sample Date*	*B. carica*	*B. canaliculatum*	*B. contrarium*
July 1983	206		
August 1983	195		
September 1983	93		
October 1983	26	118	
January 1984	97		
February 1984	88		
March 1984	77		
April 1984		17	30
May 1984		11	32
June 1984	48	0	45
July 1984	35	16	26
August 1984		19	25
Total	865	181	158

*No November or December samples taken.

Table 8. Female and male B. carica landings by gear type from July 1983 to July 1984.

	crab/conch dredge		crab pot		pound net		otter trawl		hand		surf clam dredge	
	F	M	F	M	F	M	F	M	F	M	F	M
July 1983	136	70							8*			
August	102	93										
September	42	51										
October			1				24	1				
November	no samples taken											
December	no samples taken											
January 1984	72	25										
February	62	26										
March	61	16										
April												
May												
June	46	2										
July	33	2										
August												
Total	579	286	1	0	0	0	24	1	8	0	0	0

*8 B. carica of undetermined sex

Female and male B. canaliculatum landings by gear type from July 1983 to July 1984.

	crab/conch dredge F	crab/conch dredge M	crab pot F	crab pot M	pound net F	pound net M	otter trawl F	otter trawl M	hand F	hand M	surf clam dredge F	surf clam dredge M
October 1983	87	31										
April 1984											7	10
May											6	5
July											12	4
August											7	12
Total	87	31	0	0	0	0	0	0	0	0	119	62

Female and male B. contrarium landings by gear type from July 1983 to July 1984.

	crab/conch dredge F	crab/conch dredge M	crab pot F	crab pot M	pound net F	pound net M	otter trawl F	otter trawl M	hand F	hand M	surf clam dredge F	surf clam dredge M
April 1984											18	12
May											22	10
June											28	17
July											14	12
August											14	11
Total	0	0	0	0	0	0	0	0	0	0	96	62

Table 9. *B. carica* sex ratios (female:male) by month.

Sample	Females	Males	Total	Sex Ratios
July 1983	136	70	206	1:0.51*
August	102	93	195	1:0.91
September	42	51	93	1:1.21
October	25	1	26	1:0.04*
January	72	25	97	1:0.34*
February	62	26	88	1:0.41*
March	61	16	77	1:0.26*
June	46	2	48	1:0.04*
July	33	2	35	1:0.06*
	579	286	865	1:0.49

*Significantly different from 1:1 at =0.05.

Table 10. Summary of t-test analyses of female and male *B. carica* for selected characteristics.

Variable	Females			Males				
	N	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	t-Stat.	Probability
Shell Length (mm)	581	15.233	2.151	287	12.449	1.042	20.753	<0.0001
Shell Width (mm)	581	7.746	1.213	287	6.168	0.637	20.676	<0.0001
Total Weight (g)	579	294.447	129.522	287	162.923	42.582	19.045	<0.0001
Meat Weight (g)	575	107.065	72.853	285	53.767	17.980	16.210	<0.0001
Foot Weight (g)	571	60.117	35.810	285	32.833	11.088	14.637	<0.0001
Opercula Length (mm)	449	5.279	0.750	224	4.277	0.454	18.556	<0.0001
Opercula Width (mm)	449	2.684	0.379	224	2.202	0.238	4.635	<0.0001
Opercula Weight (g)	449	1.894	0.759	224	1.304	0.298	11.217	<0.0001

Significantly different at =0.05.

Table 11. Female and male *B. carica* mean ($\bar{x}$), standard deviation (s.d.) and sample size (N) by month for shell length, shell width, total weight, meat weight, foot weight, opercula length, opercula width and opercula weight.

Shell length (mm)

Females	$\bar{x}$	s.d.	N
July 1983	13.696	1.713	136
August 1983	14.816	1.518	102
September 1983	15.240	1.841	42
October 1983	19.536	2.208	25
January 1984	15.199	1.053	72
February 1984	14.908	1.873	62
March 1984	15.507	1.868	61
June 1984	17.778	1.531	46
July 1984	16.173	1.236	33

Males	$\bar{x}$	s.d.	N
July 1983	11.976	0.978	70
August 1983	12.390	0.839	93
September 1983	12.733	0.935	51
October 1983	16.100	-	1
January 1984	12.904	1.205	25
February 1984	12.596	1.012	26
March 1984	12.425	1.108	16
June 1984	14.700	-	2
July 1984	13.650	-	2

Shell width (mm)

Females	$\bar{x}$	s.d.	N
July 1983	7.019	1.028	136
August 1983	7.314	0.834	102
September 1983	7.533	0.963	42
October 1983	9.828	1.181	25
January 1984	7.574	0.597	72
February 1984	7.661	0.986	62
March 1984	7.857	1.051	61
June 1984	9.561	0.711	46
July 1984	8.585	0.702	33

Males	$\bar{x}$	s.d.	N
July 1983	6.043	0.647	70
August 1983	5.971	0.473	93
September 1983	6.314	0.530	51
October 1983	8.100	-	1
January 1984	6.400	0.579	25
February 1984	6.446	0.725	26
March 1984	6.119	0.723	16
June 1984	8.300	-	2
July 1984	6.900	-	2

Table 11 (cont.)

Total weight (g)

Females	$\bar{x}$	s.d.	N
July 1983	230.354	76.174	136
August 1983	278.288	65.858	100
September 1983	158.302	26.768	42
October 1983	389.000	73.198	25
January 1984	269.785	40.257	72
Febuary 1974	290.158	62.549	62
March 1984	330.693	106.284	61
June 1984	513.556	100.837	46
July 1984	398.109	92.149	33

Males	$\bar{x}$	s.d.	N
July 1983	152.987	35.994	70
August 1983	168.417	29.600	93
September 1983	124.539	8.949	51
October 1983	304.400	-	1
January 1984	177.248	36.580	25
Febuary 1974	197.219	47.315	26
March 1984	178.787	47.761	15
June 1984	342.700	-	2
July 1984	231.950	-	2

Meat weight (g)

Females	$\bar{x}$	s.d.	N
July 1983	73.336	31.545	134
August 1983	80.978	20.921	99
September 1983	88.833	25.053	42
October 1983	203.144	68.434	25
January 1984	84.187	23.922	72
February 1984	124.863	49.219	62
March 1984	119.170	43.953	61
June 1984	195.082	41.852	45
July 1984	146.542	41.069	33

Males	$\bar{x}$	s.d.	N
July 1983	46.617	13.299	70
August 1983	49.022	10.628	93
September 1983	60.175	17.070	51
October 1983	101.100	-	1
January 1984	53.096	15.978	24
February 1984	64.031	26.813	25
March 1984	60.900	17.917	15
June 1984	125.450	-	2
July 1984	82.900	-	2

Table 11 (cont.)

Foot weight (g)

Females	$\bar{x}$	s.d.	N
July 1983	43.369	18.959	134
August 1983	44.677	12.840	98
September 1983	53.129	18.235	42
October 1983	127.112	43.131	25
January 1984	47.633	13.623	72
February 1984	73.152	29.406	60
March 1984	66.586	25.909	59
June 1984	97.898	21.429	46
July 1984	71.248	22.270	33

Males	$\bar{x}$	s.d.	N
July 1983	28.446	8.618	69
August 1983	30.684	6.895	93
September 1983	35.359	9.791	51
October 1983	55.800	-	1
January 1984	31.864	10.496	25
February 1984	41.196	17.512	26
March 1984	36.150	11.037	16
June 1984	70.500	-	2
July 1984	52.450	-	2

Opercula length (mm)

Females	$\bar{x}$	s.d.	N
July 1983	4.486	0.769	48
August 1983	5.097	0.481	71
September 1983	5.078	0.588	42
October 1983	6.477	0.783	25
January 1984	5.140	0.368	72
February 1984	5.187	0.665	58
March 1984	5.259	0.620	60
June 1984	6.176	0.471	39
July 1984	5.625	0.421	32

Males	$\bar{x}$	s.d.	N
July 1983	4.015	0.519	30
August 1983	4.218	0.380	72
September 1983	4.328	0.347	50
October 1983	6.775	-	1
January 1984	4.310	0.327	25
February 1984	4.400	0.438	25
March 1984	4.284	0.399	16
June 1984	5.475	-	2
July 1984	4.695	-	2

Table 11 (cont.)

Opercula width (mm)

Females	$\bar{x}$	s.d.	N
July 1983	2.291	0.392	48
August 1983	2.643	0.371	71
September 1983	2.570	0.286	42
October 1983	3.175	0.348	25
January 1984	2.600	0.193	72
February 1984	2.620	0.316	58
March 1984	2.684	0.332	60
June 1984	3.090	0.223	39
July 1984	2.936	0.202	32

Males	$\bar{x}$	s.d.	N
July 1983	2.190	0.378	30
August 1983	2.157	0.172	72
September 1983	2.196	0.155	50
October 1983	3.160	-	1
January 1984	2.243	0.202	25
February 1984	2.228	0.277	25
March 1984	2.211	0.217	16
June 1984	2.625	-	2
July 1984	2.452	-	2

Opercula weight (g)

Females	$\bar{x}$	s.d.	N
July 1983	1.221	0.536	48
August 1983	1.685	0.379	71
September 1983	1.652	0.518	42
October 1983	3.172	0.850	25
January 1984	1.685	0.374	72
February 1984	1.706	0.572	58
March 1984	1.935	0.706	60
June 1984	2.902	0.778	39
July 1984	2.188	0.549	32

Males	$\bar{x}$	s.d.	N
July 1983	0.921	0.248	30
August 1983	1.000	0.175	72
September 1983	1.022	0.250	50
October 1983	3.210	-	1
January 1984	1.039	0.317	25
February 1984	1.096	0.308	25
March 1984	1.059	0.289	16
June 1984	1.831	-	2
July 1984	1.424	-	2

Table 12. Summary of regression coefficients (B), coefficients of determination (R), and F values (F) for regression analyses for *B. carica*, *B. canaliculatum*, and *B. contrarium*. Significant differences between female and male regression coefficents are noted (*).

	Shell width vs. shell length			Meat weight vs. total weight			Total weight vs. shell length			Opercula length vs shell length			Foot weight vs. total weight		
	B	R	F	B	R	F	B	R	F	B	R	F	B	R	F
B. carica															
Female	.90	.81	2341.8*	.84	.71	1369.5*	.79	.62	929.9	.79	.89	1710.6	.77	.59	831.4
Male	.74	.55	336.7*	.61	.38	169.9*	.66	.44	216.0	.72	.89	235.6	.60	.36	155.8
B. canaliculatum															
Female	.93	.87	839.0	.91	.82	578.1	.89	.78	453.7	.85	.72	323.6	.88	.77	415.5
Male	.89	.79	236.2	.98	.96	1356.3	.89	.79	237.0	.58	.34	30.9	.97	.93	168.5
B. contrarium															
Female	.81	.66	181.5	.88	.77	308.4	.77	.60	140.2	.77	.60	138.2	.86	.74	267.8
Male	.69	.48	54.6	.93	.87	391.1	.78	.60	91.4	.71	.50	58.8	.92	.85	327.6

Table 13. B. canaliculatum sex ratios (female:male) by month.

Sample	Females	Males	Total	Sex Ratios
October 1983	87	31	118	1:0.35*
April 1984	7	10	17	1:1.43
May 1984	6	5	11	1:0.83
July 1984	12	4	16	1:0.33*
August 1984	7	12	19	1:1.71*
	119	62	181	1:0.52*

*Significantly different at =0.05.

Table 14. Summary of t-test results of female and male *B. canaliculatum* for selected characteristics.

Variable	Females N	Females $\bar{x}$	Females s.d.	Males N	Males $\bar{x}$	Males s.d.	t-Stat.	Probability
Shell Length (mm)	126	15.148	2.608	65	14.131	2.116	6.090	<0.0001
Shell Width (mm)	126	8.023	1.492	65	7.351	1.229	3.125	$.005<P<0.0002$
Total Weight (g)	126	272.245	166.070	65	235.145	116.059	1.609	$0.02>P>0.10$
Meat Weight (g)	126	145.900	107.250	65	126.277	73.090	1.331	$0.02>P<0.10$
Foot Weight (g)	126	80.045	52.110	65	73.494	43.260	0.875	$0.50<P<0.20$
Opercula Length (mm)	122	5.178	0.981	62	5.190	1.160	-0.074	>0.50
Opercula Width (mm)	122	2.894	0.631	62	2.833	0.593	0.635	>0.50
Opercula Weight (g)	122	1.271	0.843	62	1.326	0.884	-0.414	>0.50

Table 15. Female and male *B. canaliculatum* mean ($\bar{x}$), standard deviation (s.d.) and sample size (N) by month for shell length, shell width, total weight, meat weight, foot weight, opercula length, opercula width and opercula weight.

Shell length (mm)

Females	$\bar{x}$	s.d.	N
October 1983	14.364	2.221	87
April 1984	15.300	2.285	7
May 1984	15.450	1.754	6
July 1984	19.267	0.944	12
August 1984	16.643	3.206	7

Males	$\bar{x}$	s.d.	N
October 1983	12.671	1.393	31
April 1984	14.820	2.622	10
May 1984	14.900	1.382	5
July 1984	15.745	0.443	4
August 1984	15.833	1.242	12

Shell width (mm)

Females	$\bar{x}$	s.d.	N
October 1983	7.583	1.290	87
April 1984	7.443	1.037	7
May 1984	8.683	1.019	6
July 1984	9.942	0.587	12
August 1984	9.386	1.859	7

Males	$\bar{x}$	s.d.	N
October 1983	6.452	0.781	31
April 1984	7.390	1.186	10
May 1984	8.660	0.976	5
July 1984	8.475	0.591	4
August 1984	8.308	0.456	12

Table 15 (cont.)

Total weight (g)

Females	$\bar{x}$	s.d.	N
October 1983	196.176	77.859	87
April 1984	308.800	138.287	7
May 1984	348.417	93.712	6
July 1984	617.750	84.375	12
August 1984	450.100	220.096	7

Males	$\bar{x}$	s.d.	N
October 1983	132.261	39.499	31
April 1984	289.510	95.496	10
May 1984	311.100	81.093	5
July 1984	358.650	45.355	4
August 1984	338.567	47.748	12

Meat weight (g)

Females	$\bar{x}$	s.d.	N
October 1983	97.668	45.955	87
April 1984	178.057	105.018	7
May 1984	177.767	53.126	6
July 1984	367.667	74.663	12
August 1984	277.200	142.844	7

Males	$\bar{x}$	s.d.	N
October 1983	62.542	18.965	31
April 1984	163.830	62.957	10
May 1984	169.740	60.064	5
July 1984	189.675	42.514	4
August 1984	191.525	33.154	12

Table 15 (cont.)

Foot weight (g)

Females	$\bar{x}$	s.d.	N
October 1983	57.353	28.121	87
April 1984	104.229	61.228	7
May 1984	101.683	29.742	6
July 1984	165.183	29.159	12
August 1984	156.414	79.220	7

Males	$\bar{x}$	s.d.	N
October 1983	36.219	11.586	31
April 1984	97.090	39.467	10
May 1984	97.080	31.260	5
July 1984	89.925	15.554	4
August 1984	118.392	23.350	12

Opercula length (mm)

Females	$\bar{x}$	s.d.	N
October 1983	4.809	0.765	85
April 1984	5.436	0.404	7
May 1984	5.532	0.754	6
July 1984	6.838	0.406	10
August 1984	6.020	1.049	7

Males	$\bar{x}$	s.d.	N
October 1983	4.250	0.456	31
April 1984	6.199	1.428	10
May 1984	6.105	0.317	4
July 1984	6.186	0.353	4
August 1984	5.969	0.413	10

Table 15 (cont.)

Opercula width (mm)

Females	$\bar{x}$	s.d.	N
October 1983	2.656	0.496	85
April 1984	3.045	0.409	7
May 1984	3.149	0.540	6
July 1984	3.924	0.206	10
August 1984	3.526	0.510	7

Males	$\bar{x}$	s.d.	N
October 1983	2.329	0.297	31
April 1984	3.130	0.371	10
May 1984	3.369	0.182	4
July 1984	3.436	0.316	4
August 1984	3.402	0.248	10

Opercula weight (g)

Females	$\bar{x}$	s.d.	N
October 1983	0.956	0.539	85
April 1984	1.239	0.600	7
May 1984	1.311	0.548	6
July 1984	2.898	0.486	10
August 1984	2.088	0.977	7

Males	$\bar{x}$	s.d.	N
October 1983	0.603	0.200	31
April 1984	1.703	0.792	10
May 1984	2.478	0.788	4
July 1984	1.889	0.475	4
August 1984	2.138	0.567	10

Table 16. *B. contrarium* sex ratios (female:male) by month.

Sample	Females	Males	Total	Sex Ratios
April 1984	18	12	30	1:0.67*
May 1984	22	10	32	1:0.45*
June 1984	28	17	45	1:0.61*
July 1984	14	12	26	1:0.86
August 1984	14	11	25	1:0.79
	96	62	158	1:0.65*

*Significantly different =0.05.

Table 17. Summary of t-test results of female and male *B. contrarium* for selected characteristics.

Variable	Females			Males				
	N	$\bar{x}$	s.d.	N	$\bar{x}$	s.d.	t-Stat.	Probability
Shell Length (mm)	96	22.051	2.190	62	17.103	1.729	15.131	<0.0001
Shell Width (mm)	96	11.485	1.172	62	8.729	0.838	16.117	<0.0001
Total Weight (g)	96	1066.062	289.386	62	442.797	118.607	16.197	>0.0001
Meat Weight (g)	96	486.253	137.675	62	195.823	52.043	15.981	<0.0001
Foot Weight (g)	96	261.811	75.927	62	115.169	36.157	40.077	<0.0001
Opercula Length (mm)	95	8.578	0.897	61	6.767	0.617	13.931	<0.0001
Opercula Width (mm)	95	4.306	0.491	61	3.369	0.322	13.197	<0.0001
Opercula Weight (g)	95	7.393	2.549	61	3.484	1.185	11.298	<0.0001

Table 18. Female and male *B. contrarium* mean ($\bar{x}$), standard deviation (s.d.) and sample size (N) by month for shell length, shell width, total weight, meat weight, foot weight, opercula length, opercula width and opercula weight.

Shell length (mm)

Females	$\bar{x}$	s.d.	N
April 1984	22.706	1.608	18
May 1984	22.300	1.532	22
June 1984	22.250	1.713	28
July 1984	21.386	4.038	14
August 1984	21.086	4.038	14

Males	$\bar{x}$	s.d.	N
April 1984	16.867	1.890	12
May 1984	17.580	1.432	10
June 1984	17.288	2.043	17
July 1984	16.467	1.702	12
August 1984	17.336	1.304	11

Shell width (mm)

Females	$\bar{x}$	s.d.	N
April 1984	11.850	0.796	18
May 1984	11.736	0.794	22
June 1984	11.507	0.975	28
July 1984	11.243	1.010	14
August 1984	10.821	2.091	14

Males	$\bar{x}$	s.d.	N
April 1984	8.692	0.934	12
May 1984	8.980	0.676	10
June 1984	8.671	0.935	17
July 1984	8.450	0.820	12
August 1984	8.936	0.755	11

Table 18 (cont.)

Total weight (g)

Females	$\bar{x}$	s.d.	N
April 1984	1137.817	264.832	18
May 1984	1076.595	251.553	22
June 1984	1054.975	240.714	28
July 1984	1043.621	268.644	14
August 1984	1001.871	461.484	14

Males	$\bar{x}$	s.d.	N
April 1984	438.750	144.106	12
May 1984	472.380	92.441	10
June 1984	437.906	122.740	17
July 1984	396.075	109.769	12
August 1984	478.845	113.736	11

Meat weight (g)

Females	$\bar{x}$	s.d.	N
April 1984	533.328	113.638	18
May 1984	477.891	114.638	22
June 1984	471.441	106.459	28
July 1984	471.843	136.519	14
August 1984	482.964	233.074	14

Males	$\bar{x}$	s.d.	N
April 1984	197.642	57.575	12
May 1984	201.880	43.180	10
June 1984	197.829	50.929	17
July 1984	167.633	50.204	12
August 1984	215.982	53.168	11

Table 18 (cont.)

Foot weight (g)

Females	$\bar{x}$	s.d.	N
April 1984	306.533	69.453	18
May 1984	261.782	57.127	22
June 1984	249.218	59.122	28
July 1984	226.636	57.273	14
August 1984	264.721	124.722	14

Males	$\bar{x}$	s.d.	N
April 1984	118.225	41.067	12
May 1984	121.270	22.470	10
June 1984	110.559	32.326	17
July 1984	89.542	31.653	12
August 1984	141.373	35.541	11

Opercula length (mm)

Females	$\bar{x}$	s.d.	N
April 1984	8.689	0.559	18
May 1984	8.674	0.651	22
June 1984	8.531	0.676	28
July 1984	8.632	0.736	13
August 1984	8.329	1.780	14

Males	$\bar{x}$	s.d.	N
April 1984	6.640	0.664	11
May 1984	6.904	0.550	10
June 1984	6.789	0.544	17
July 1984	6.465	0.694	12
August 1984	7.067	0.568	11

Table 18 (cont.)

Opercula width (mm)

Females	$\bar{x}$	s.d.	N
April 1984	4.315	0.377	18
May 1984	4.367	0.301	22
June 1984	4.275	0.406	28
July 1984	4.414	0.459	13
August 1984	4.163	0.911	14

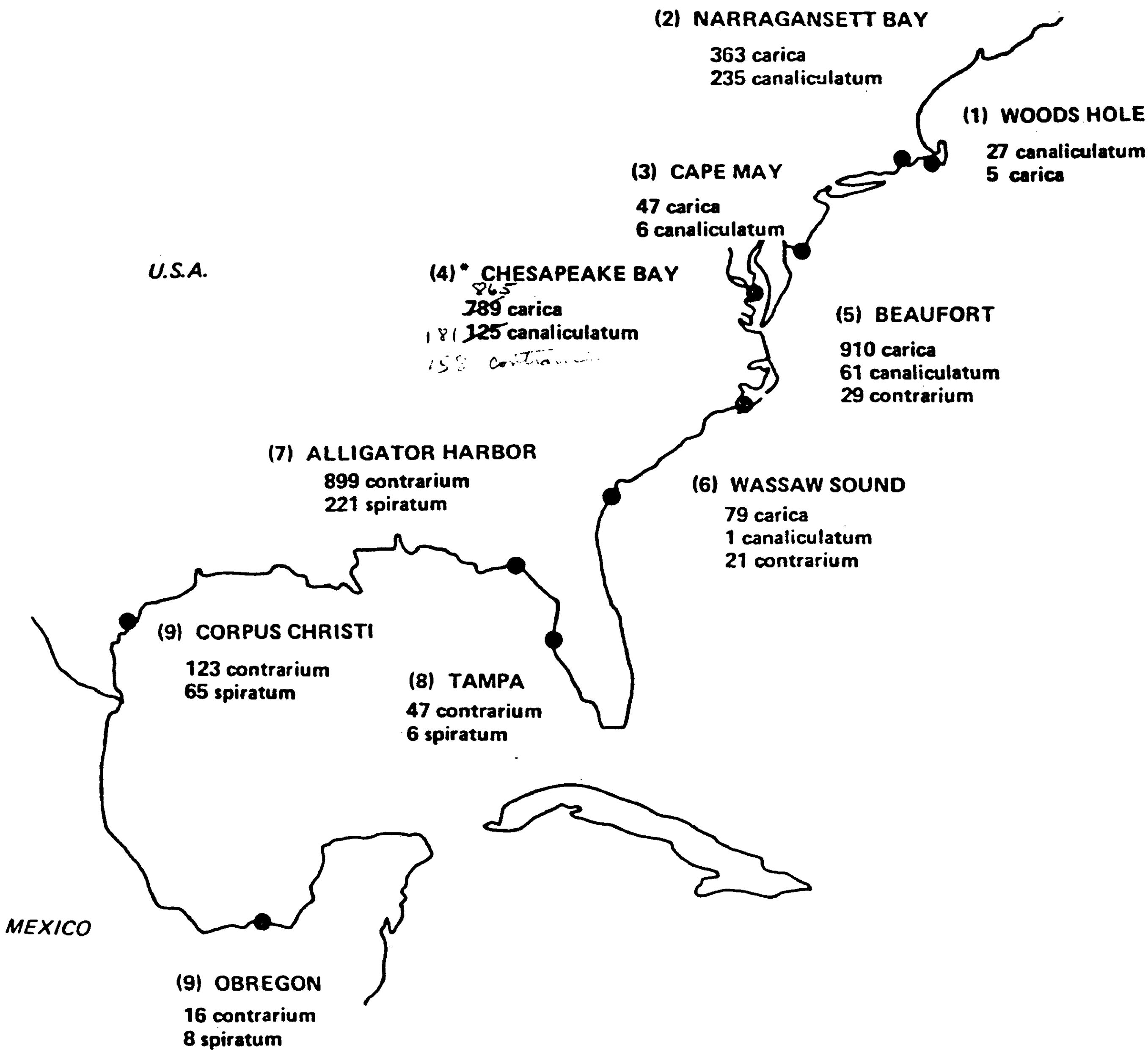
Males	$\bar{x}$	s.d.	N
April 1984	3.287	0.421	11
May 1984	3.433	0.213	10
June 1984	3.364	0.279	17
July 1984	3.252	0.260	12
August 1984	3.529	0.387	11

Opercula weight (g)

Females	$\bar{x}$	s.d.	N
April 1984	7.395	2.271	18
May 1984	7.258	2.424	22
June 1984	7.244	1.943	28
July 1984	7.436	2.177	13
August 1984	7.862	4.267	14

Males	$\bar{x}$	s.d.	N
April 1984	3.462	1.530	11
May 1984	3.576	0.737	10
June 1984	3.214	0.836	17
July 1984	3.055	0.868	12
August 1984	4.309	1.598	11

Figure 1. Abundance of _Busycon_ species at locations along the eastern United States and coast of Mexico (adapted from figures by Paine (1962) and Wood (1979)). Data from: (1) Sumner et al., 1913; (2) Wood (1979); (3) Wood and Wood, 1928; (4) this report (5) Magalhaes, 1948; (6) Walker et al., 1980; (7) Paine, 1962; (8) Post, 1899; (9) Hildebrande, 1954.



*from commercial landings July '83 – ~~March~~ August '84.

Figure 2. Commercial fishing areas for *Busycon* whelks as designated by the Virginia Marine Resources Commission, Newport News, VA.

Area 1: same as for crab dredging season
conventional dredge only

Area 2: 1 April through 30 September
convnetional dredge only
catch limited to conch

Area 3: year round; no gear restriction

Area 4: 1 May through 30 September
conventional dredge only
catch limited to conch

Area 5: 1 January through 31 August and
1 November through 31 December
no gear restrictions

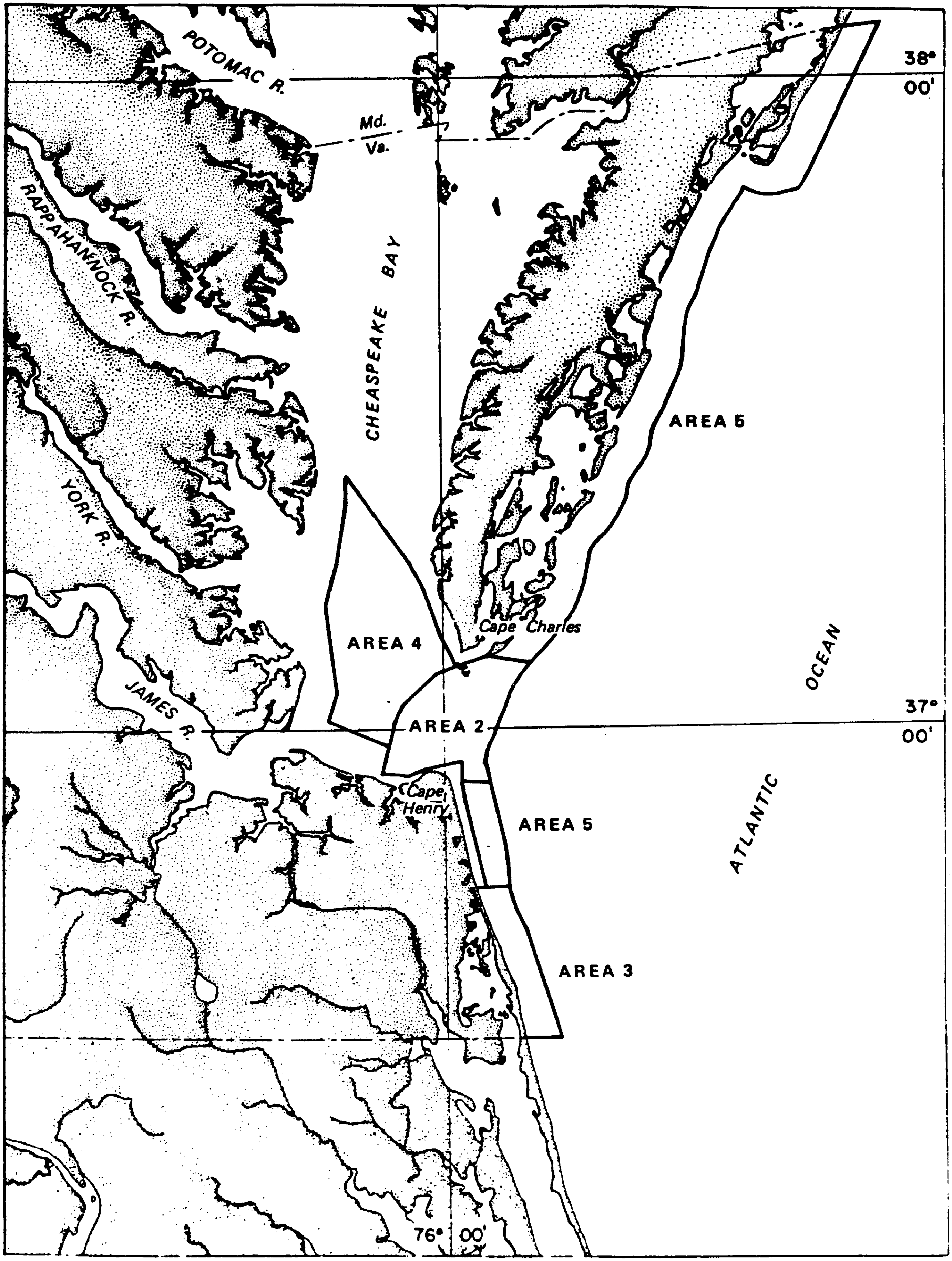

POTOMAC R.
38°
00'
Md.
Va.
RAPPAHANNOCK R.
CHEASPEAKE BAY
YORK R.
AREA 5
Cape Charles
AREA 4
OCEAN
JAMES R.
37°
AREA 2
00'
Cape Henry
AREA 5
ATLANTIC
AREA 3
76° 00'

Figure 3. Virginia conch dredge landings and licenses for 1978-1985.


POUNDS
LICENSES
100,000
80,000
60,000
40,000
20,000
0
1976
1978
1980
1982
1984
1986
YEAR
LEGEND
POUNDS
LICENSES

Figure 4. Virginia landings of *B*. *canaliculatum* and *B*. *contrarium* with the surf clam, *Spisula solidissima*, for 1940-1985.

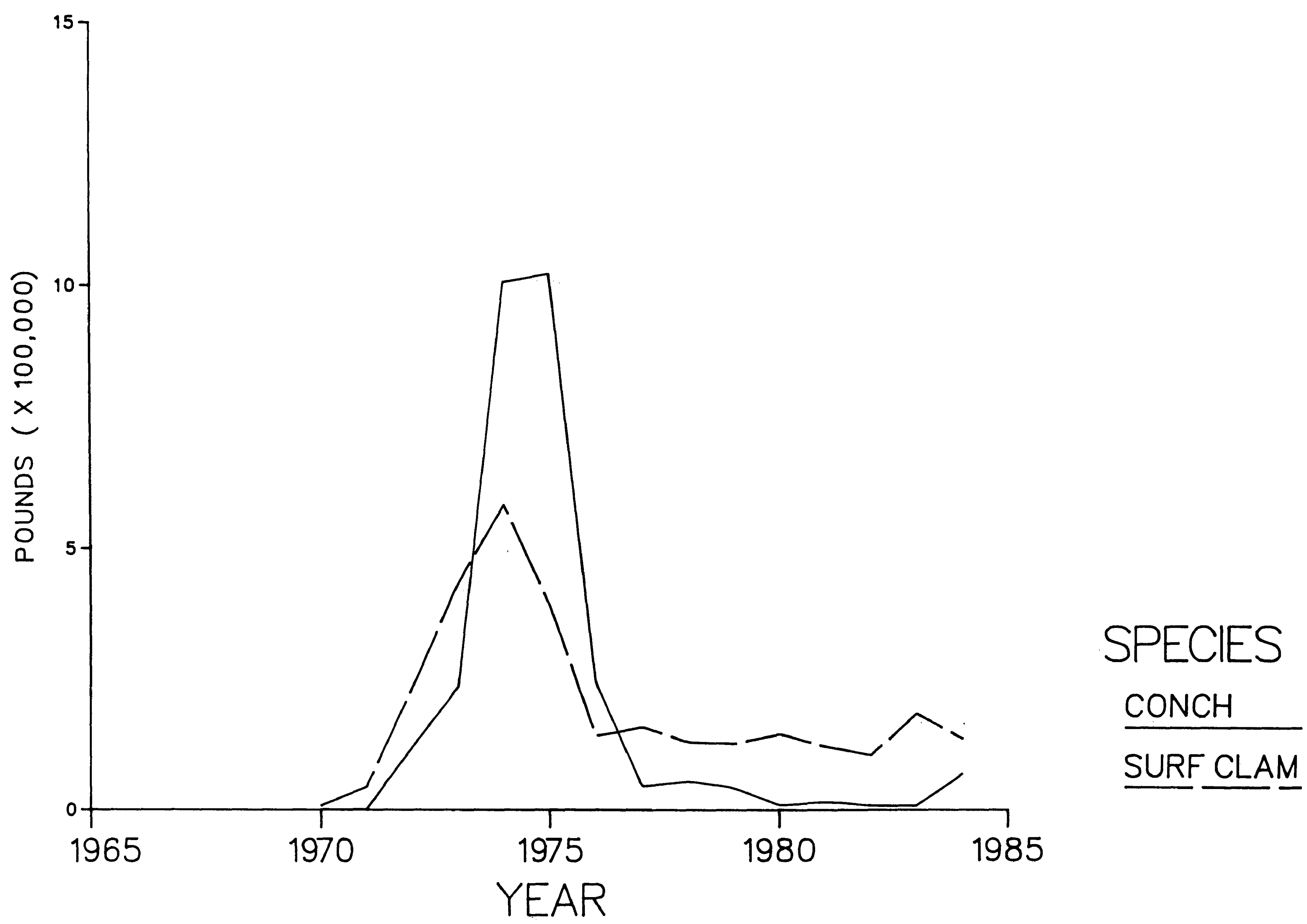

POUNDS (X 100,000)
15
10
5
0
1965
1970
1975
1980
1985
YEAR
SPECIES
CONCH
SURF CLAM

Figure 5. Total Virginia *Busycon* landings for 1940-1985.

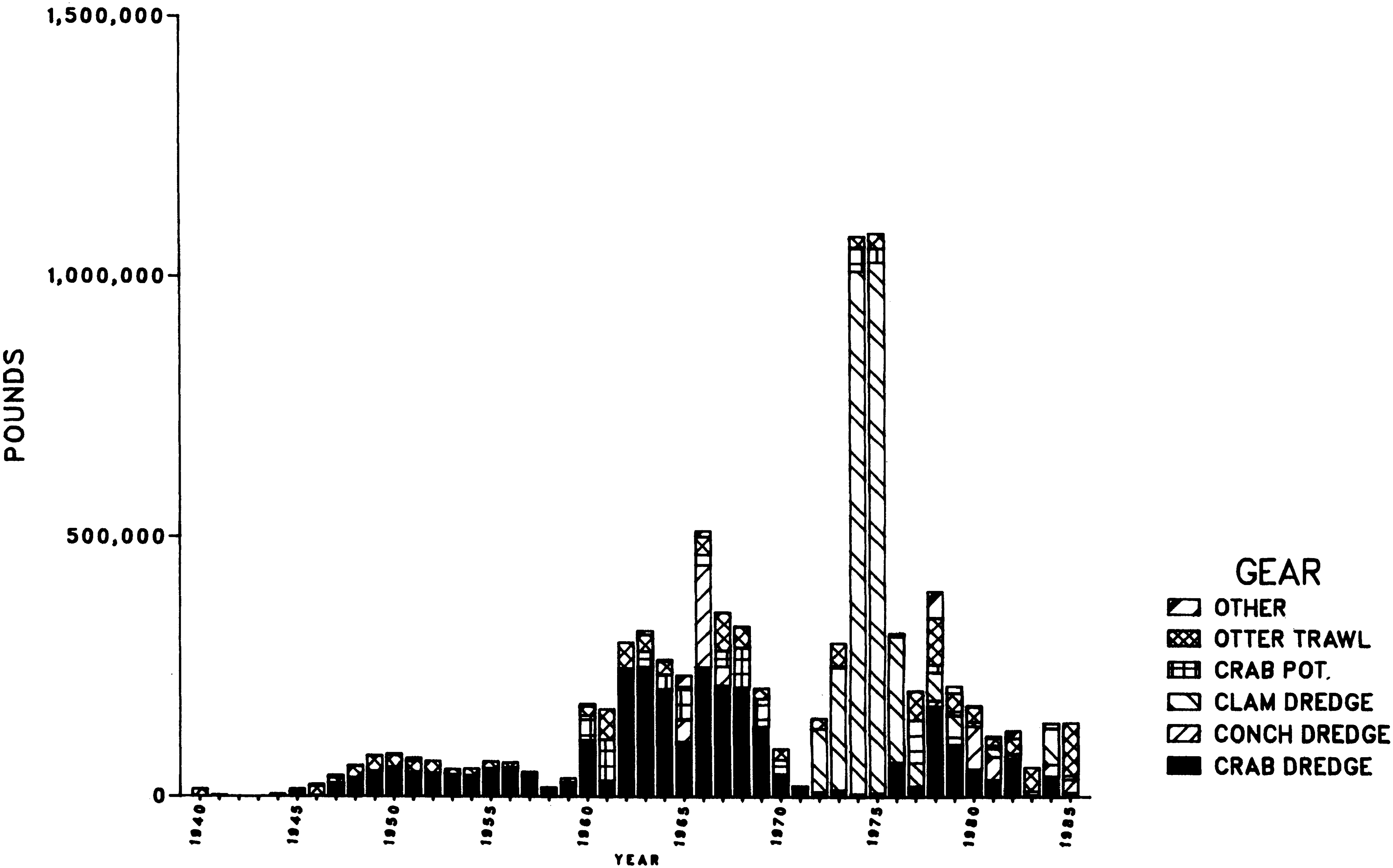

1,500,000
1,000,000
500,000
0
POUNDS
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
YEAR
GEAR
OTHER
OTTER TRAWL
CRAB POT.
CLAM DREDGE
CONCH DREDGE
CRAB DREDGE

Figure 6. Total landings of *B. carica*, *B. canaliculatum* and *B. contrarium* estimated from sampling and annual landings for 1940-1985.

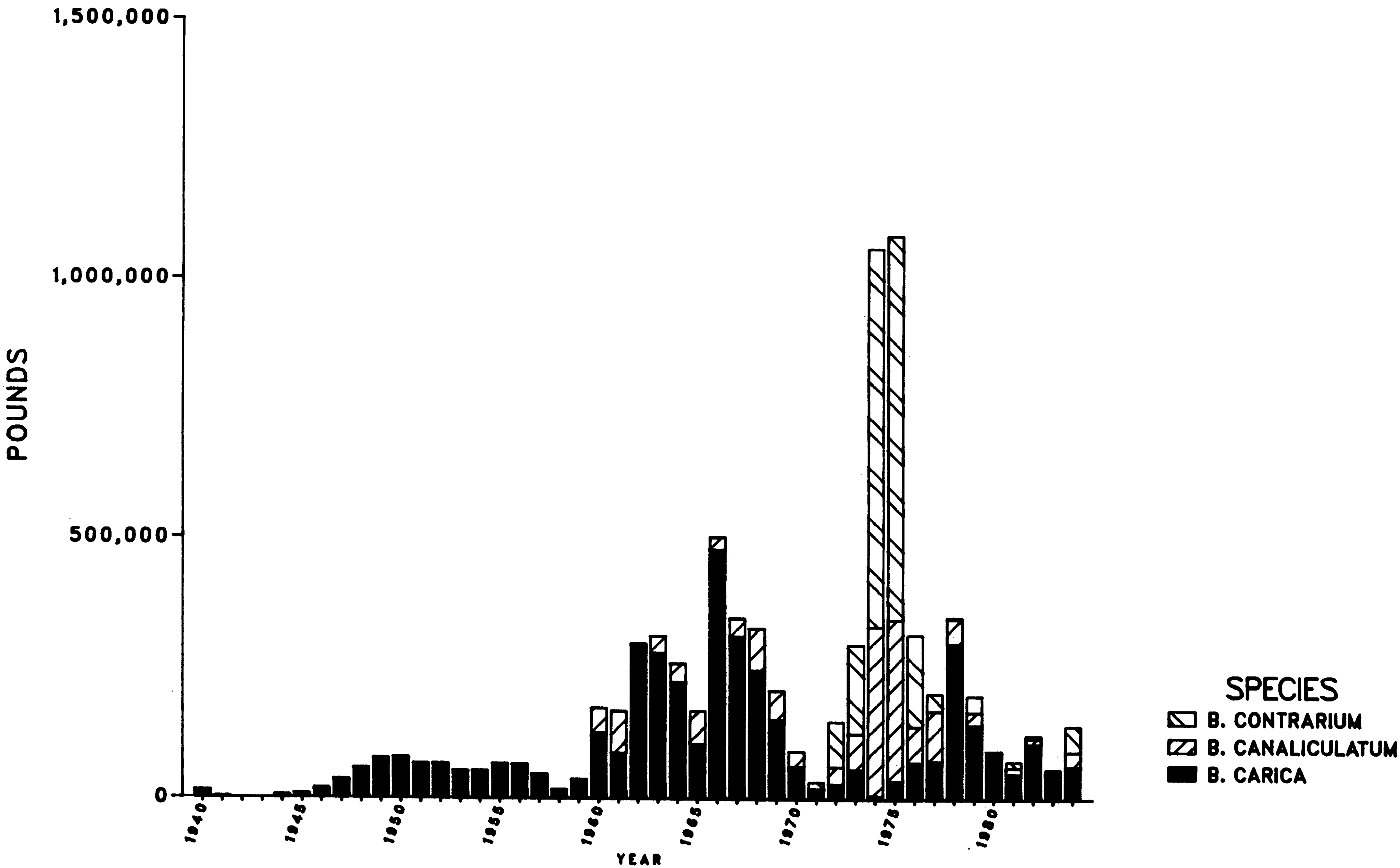

POUNDS
1,500,000
1,000,000
500,000
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
YEAR
SPECIES
B. CONTRARIUM
B. CANALICULATUM
B. CARICA

Figure 7. Average price for Virginia *Busycon* landings 1940-1985.

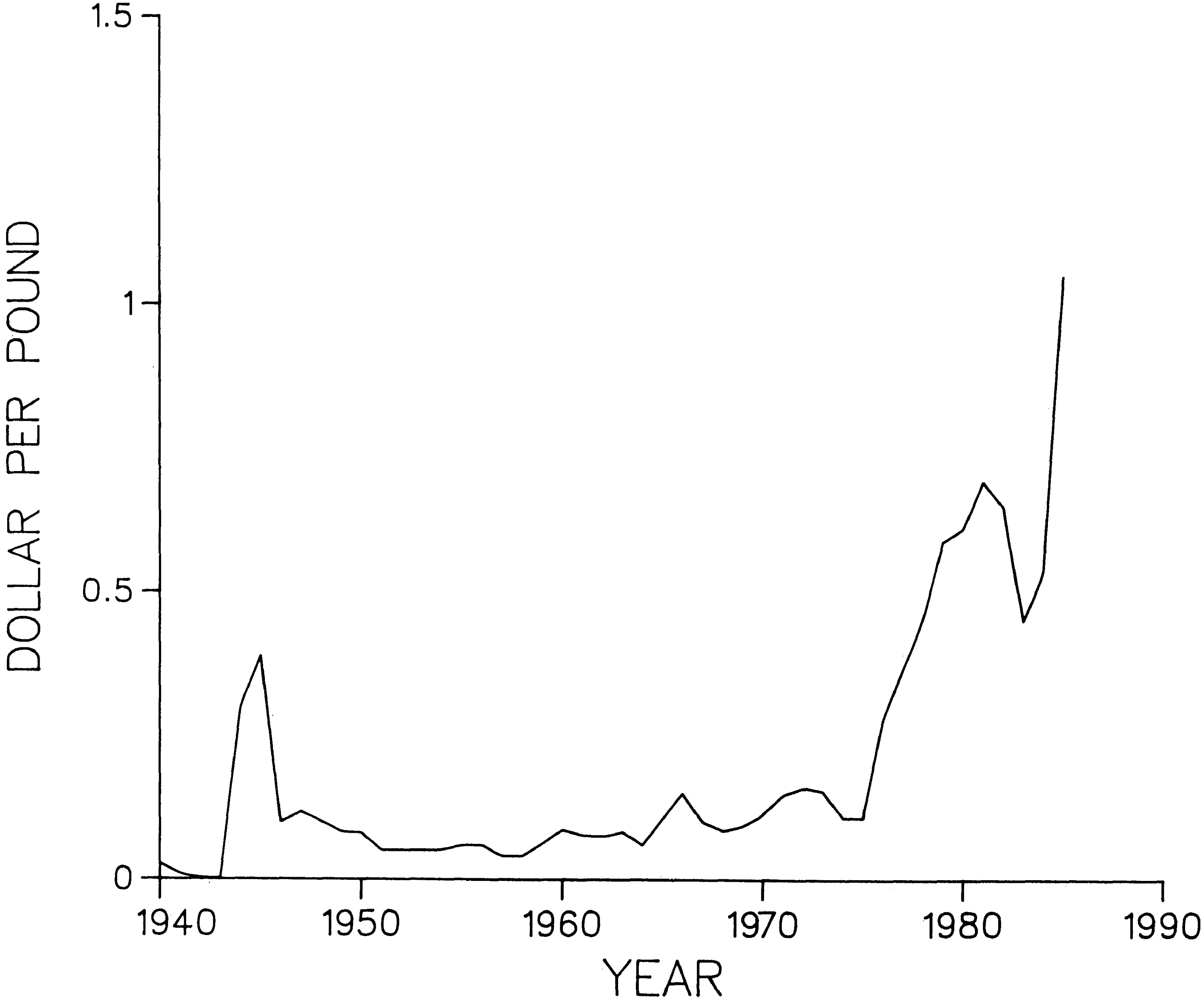

DOLLAR PER POUND
1.5
1
0.5
0
1940
1950
1960
1970
1980
1990
YEAR

Figure 8. Female and male *B. carica* shell length (mm) by month.

SHELL LENGTH

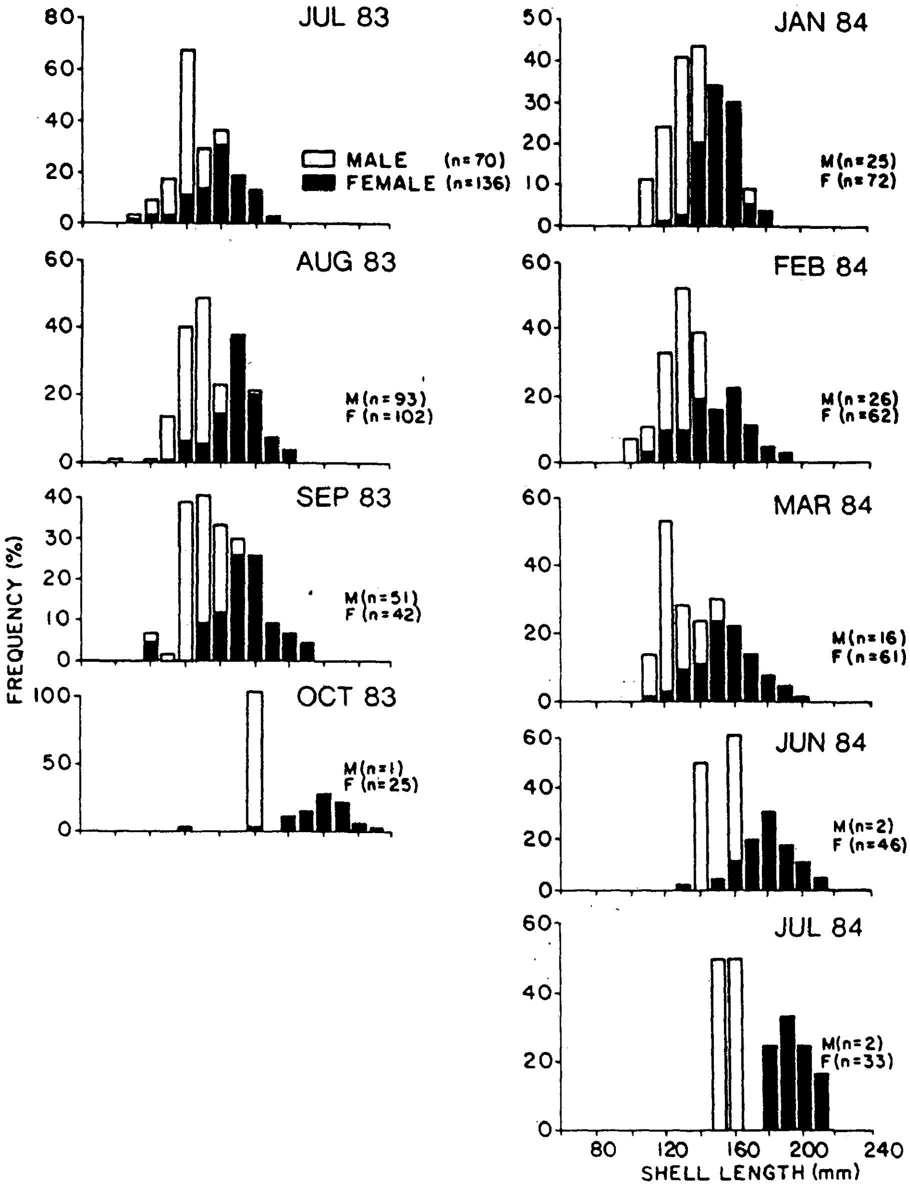
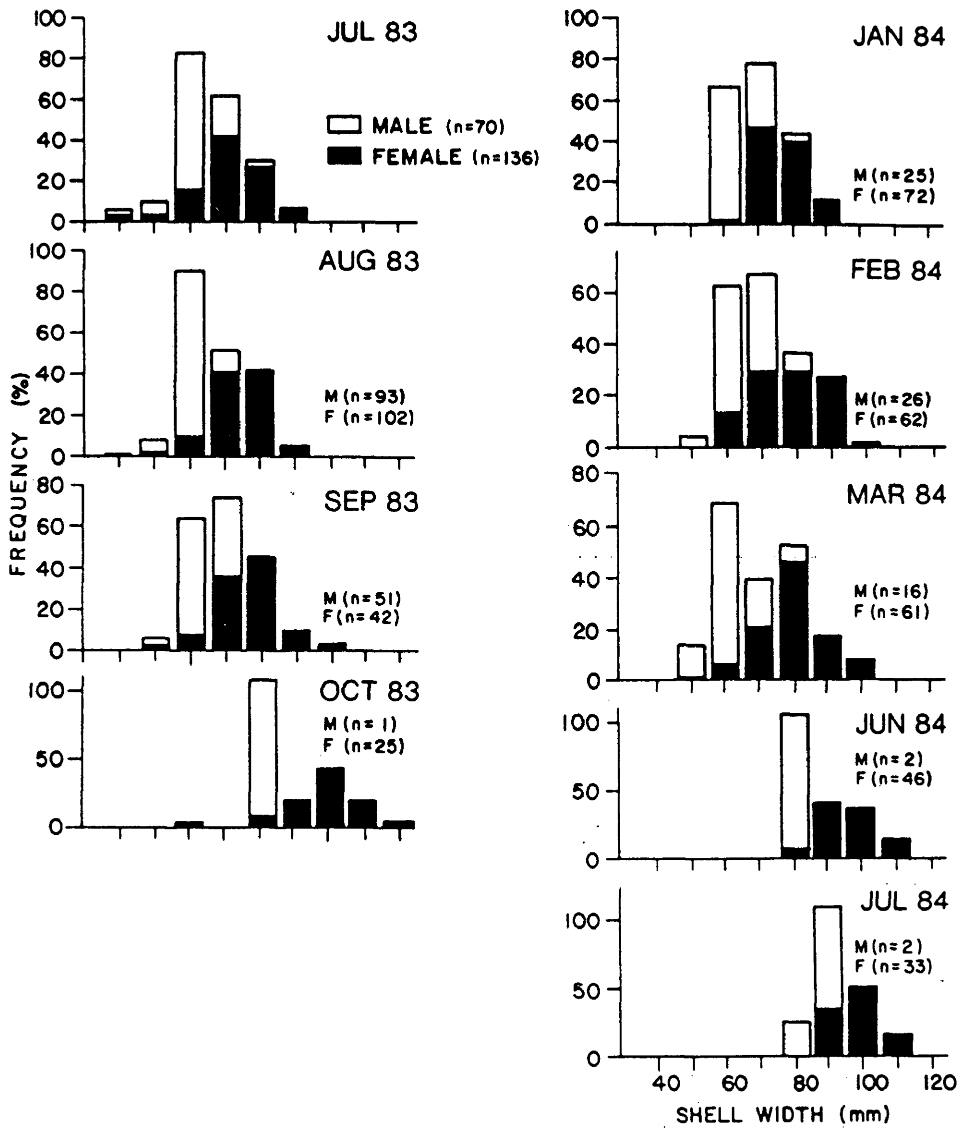


Figure 9. Female and male B. *carica* shell width (mm) by month.

SHELL WIDTH



JUL 83
MALE (n=70)
FEMALE (n=136)
AUG 83
M (n=93)
F (n=102)
SEP 83
M (n=51)
F (n=42)
OCT 83
M (n=1)
F (n=25)
FREQUENCY (%)
JAN 84
M (n=25)
F (n=72)
FEB 84
M (n=26)
F (n=62)
MAR 84
M (n=16)
F (n=61)
JUN 84
M (n=2)
F (n=46)
JUL 84
M (n=2)
F (n=33)
40 60 80 100 120
SHELL WIDTH (mm)

Figure 10. Female and male B. *carica* total weight (g) by month.

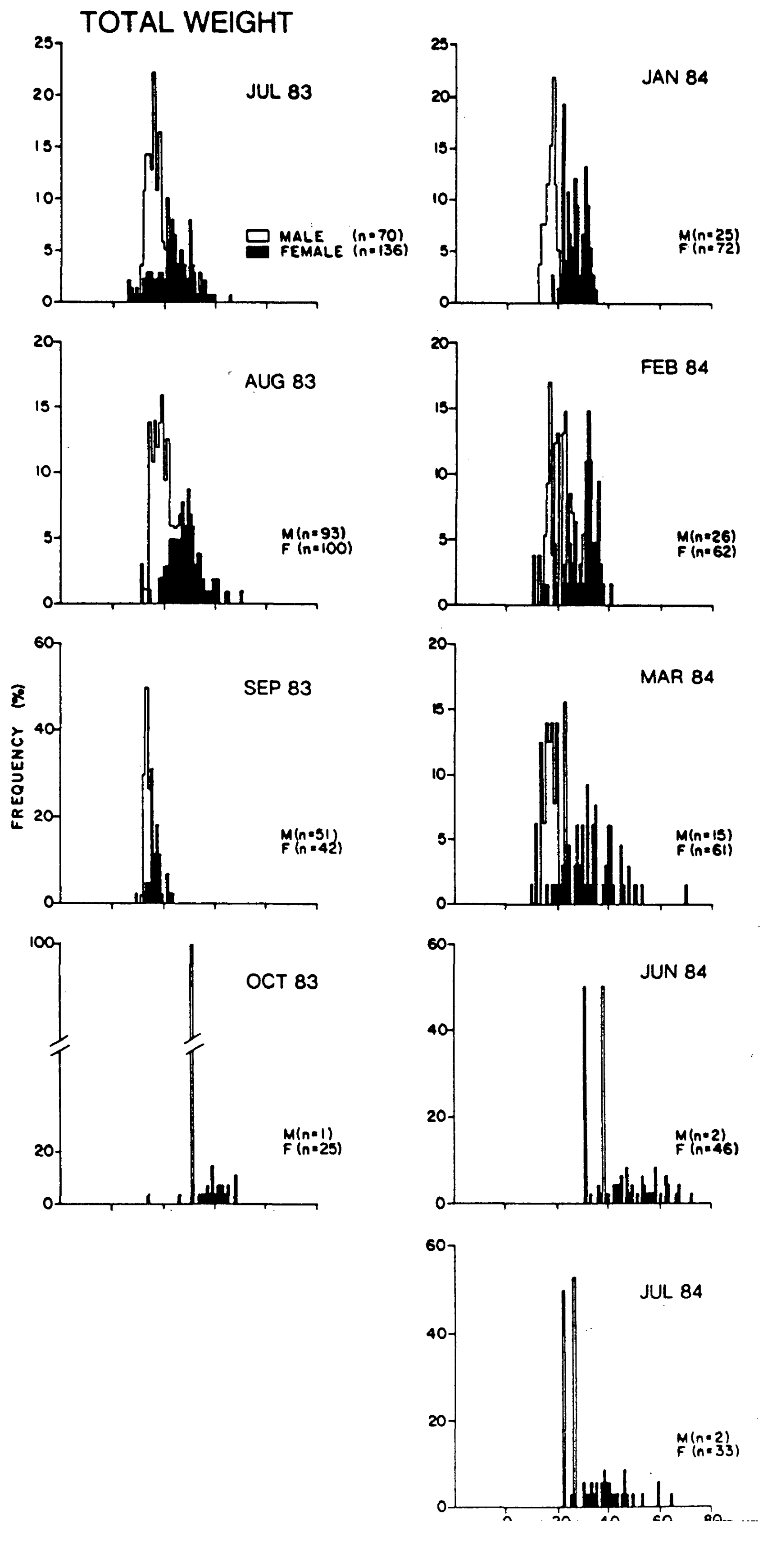

TOTAL WEIGHT
JUL 83
MALE (n=70)
FEMALE (n=136)
AUG 83
M(n=93)
F (n=100)
SEP 83
M(n=51)
F (n=42)
OCT 83
M(n=1)
F (n=25)
JAN 84
M(n=25)
F (n=72)
FEB 84
M(n=26)
F (n=62)
MAR 84
M(n=15)
F (n=61)
JUN 84
M(n=2)
F (n=46)
JUL 84
M(n=2)
F (n=33)
FREQUENCY (%)

Figure 11. Female and male *B. carica* meat weight (g) by month.

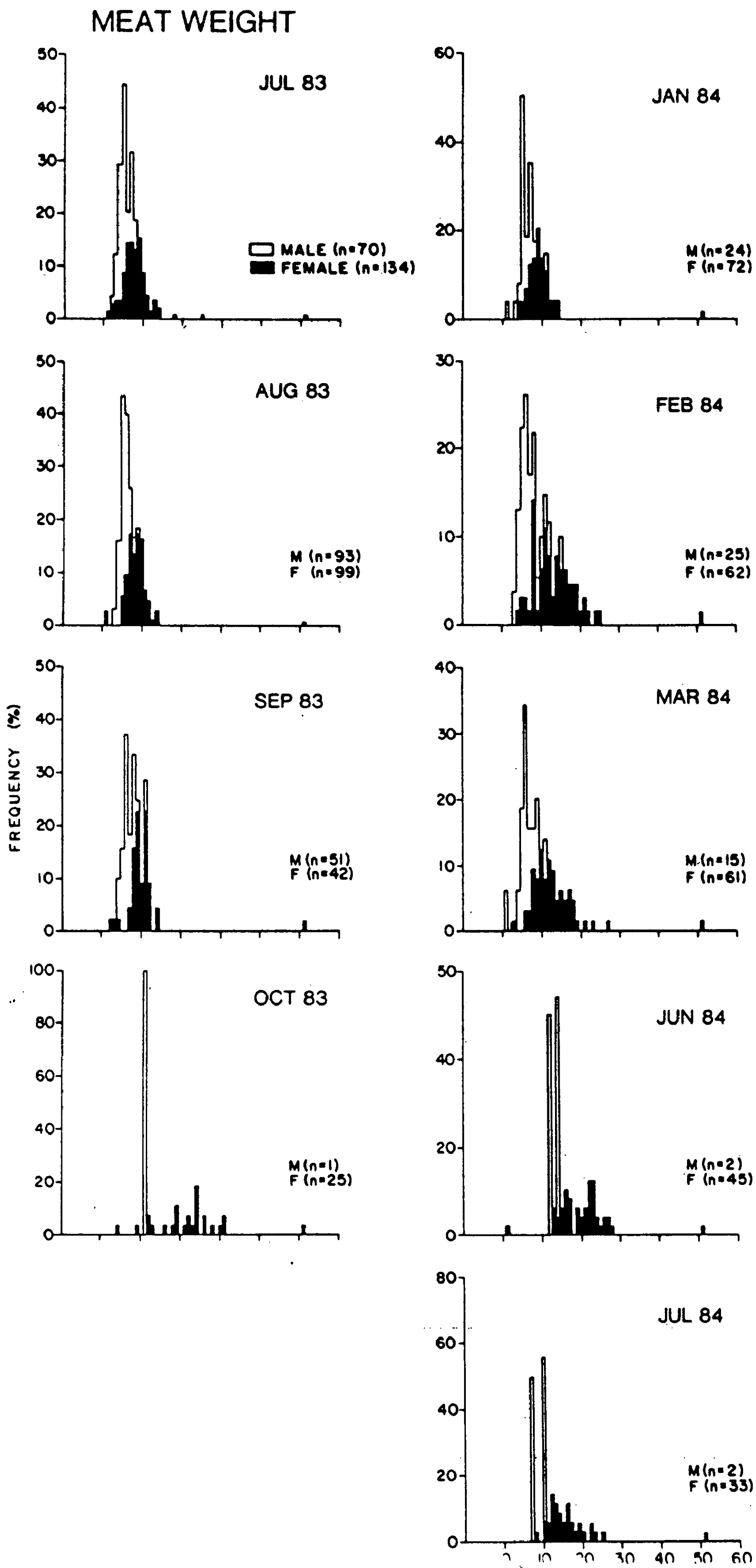

MEAT WEIGHT
JUL 83
MALE (n=70)
FEMALE (n=134)
AUG 83
M (n=93)
F (n=99)
SEP 83
M (n=51)
F (n=42)
OCT 83
M (n=1)
F (n=25)
JAN 84
M (n=24)
F (n=72)
FEB 84
M (n=25)
F (n=62)
MAR 84
M (n=15)
F (n=61)
JUN 84
M (n=2)
F (n=45)
JUL 84
M (n=2)
F (n=33)
FREQUENCY (%)
10
30
40
50
60

Figure 12. Female and male *B. carica* foot weight (g) by month.

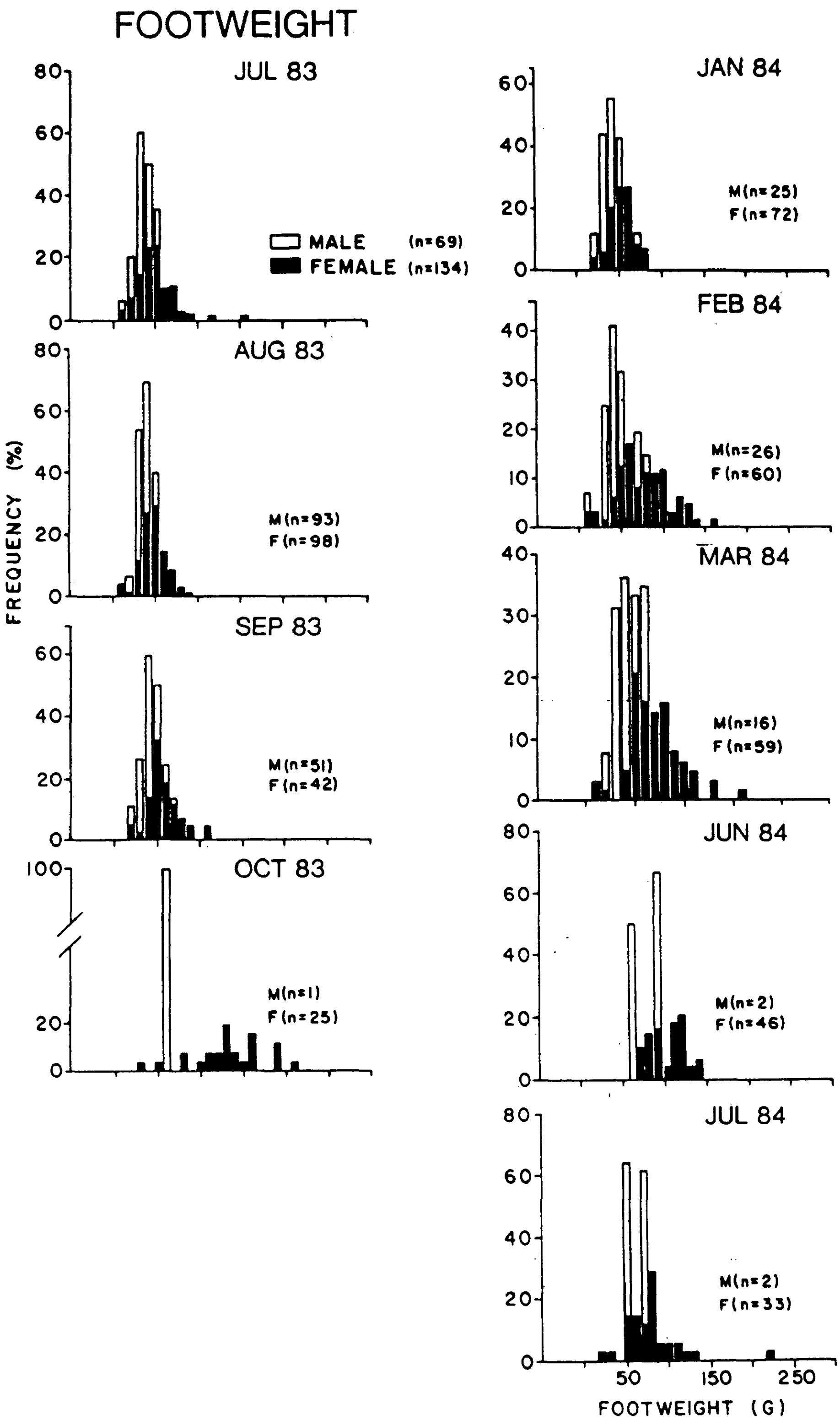
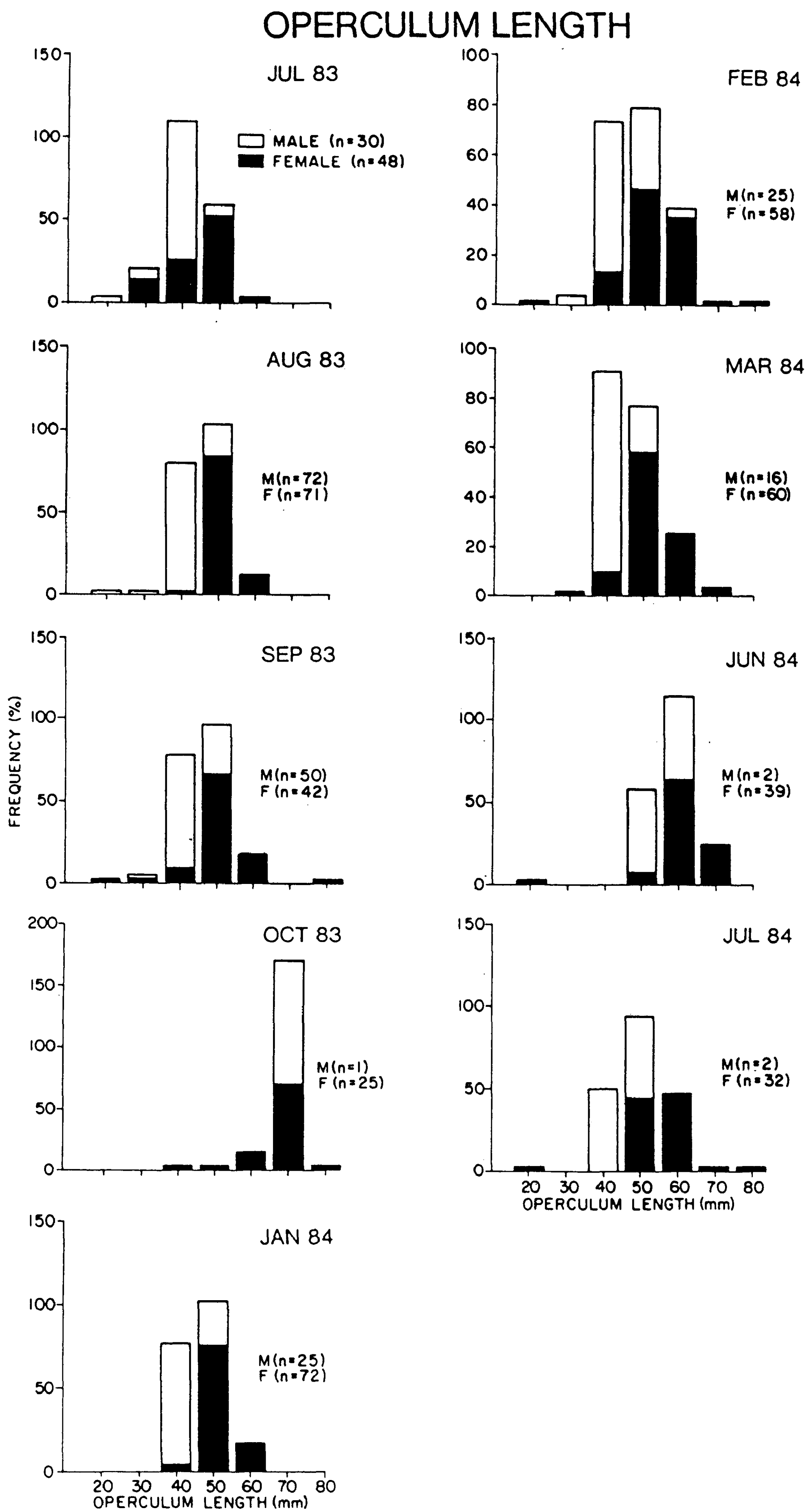

FOOTWEIGHT
JUL 83
MALE (n=69)
FEMALE (n=134)
AUG 83
M(n=93)
F(n=98)
SEP 83
M(n=51)
F(n=42)
OCT 83
M(n=1)
F(n=25)
FREQUENCY (%)
JAN 84
M(n=25)
F(n=72)
FEB 84
M(n=26)
F(n=60)
MAR 84
M(n=16)
F(n=59)
JUN 84
M(n=2)
F(n=46)
JUL 84
M(n=2)
F(n=33)
50
150
250
FOOTWEIGHT (G)

Figure 13. Female and male *B. carica* opercula length (mm) by month.



OPERCULUM LENGTH
JUL 83
MALE (n=30)
FEMALE (n=48)
FEB 84
M(n=25)
F (n=58)
AUG 83
M(n=72)
F (n=71)
MAR 84
M(n=16)
F (n=60)
SEP 83
M(n=50)
F (n=42)
JUN 84
M(n=2)
F (n=39)
FREQUENCY (%)
OCT 83
M(n=1)
F (n=25)
JUL 84
M(n=2)
F (n=32)
JAN 84
M(n=25)
F (n=72)
20 30 40 50 60 70 80
OPERCULUM LENGTH (mm)

Figure 14. Female and male *B. carica* opercula width (mm) by month.

OPERCULUM WIDTH

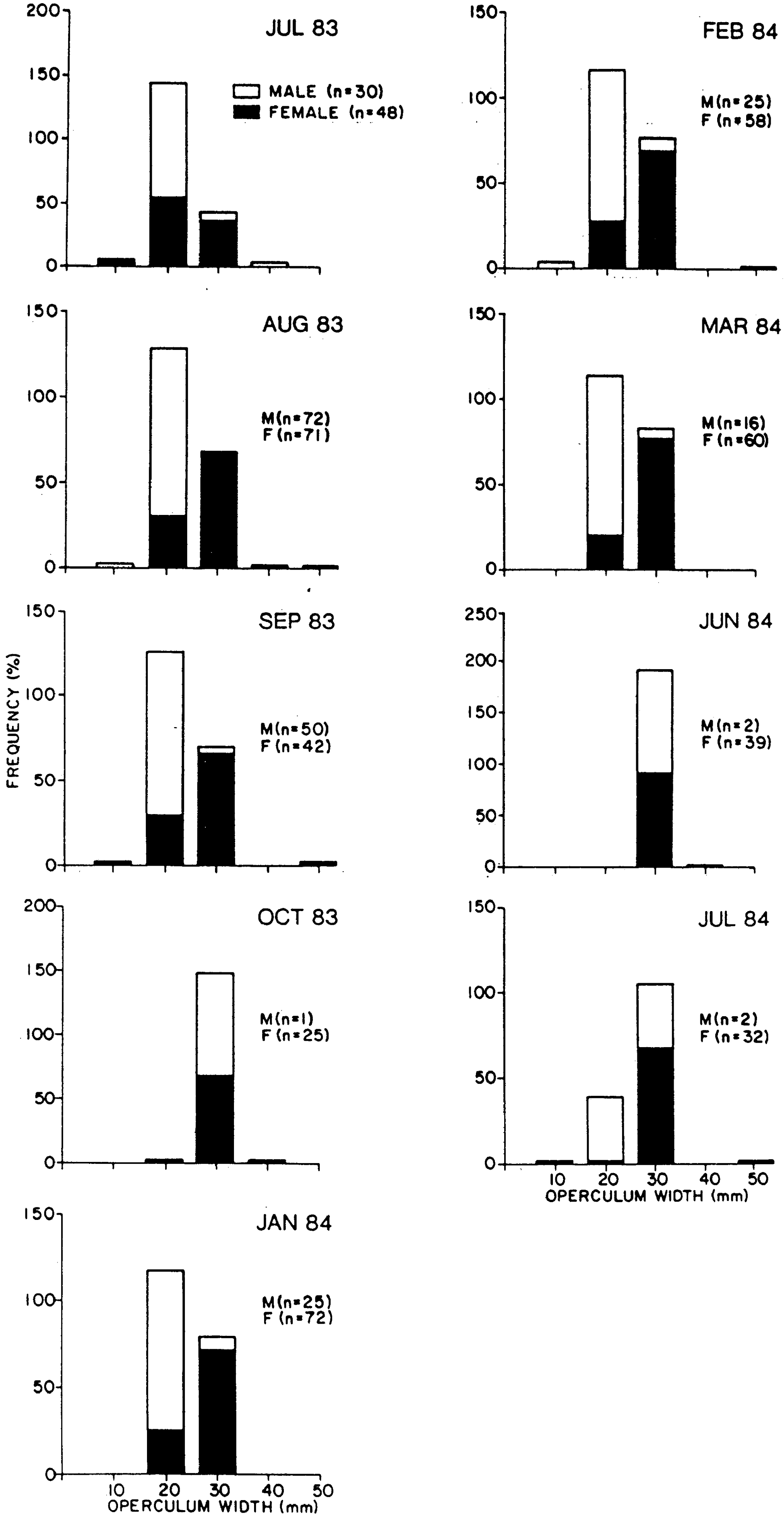


Figure 15. Female and male B. *carica* opercula weight (g) by month.

OPERCULUM WEIGHT

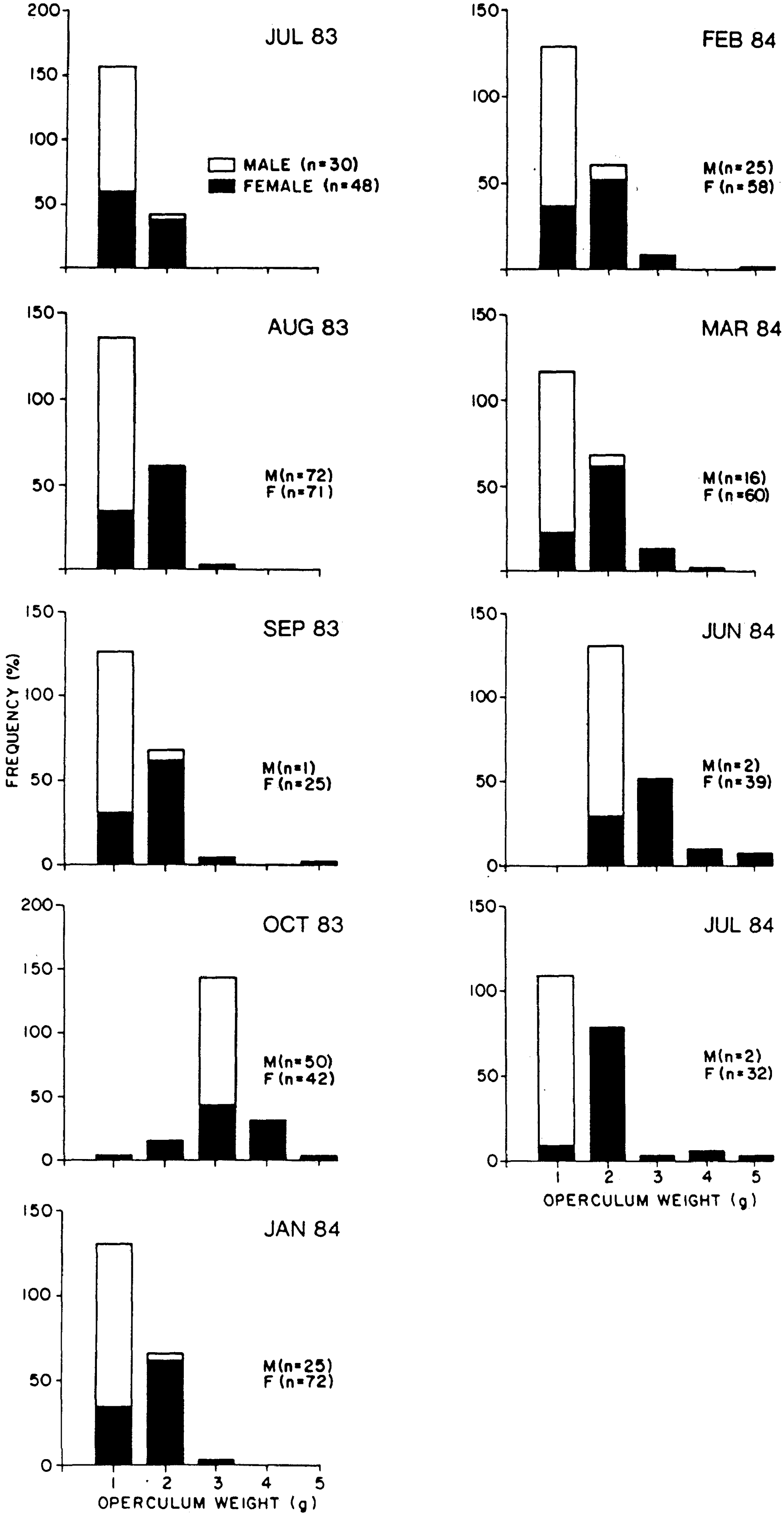
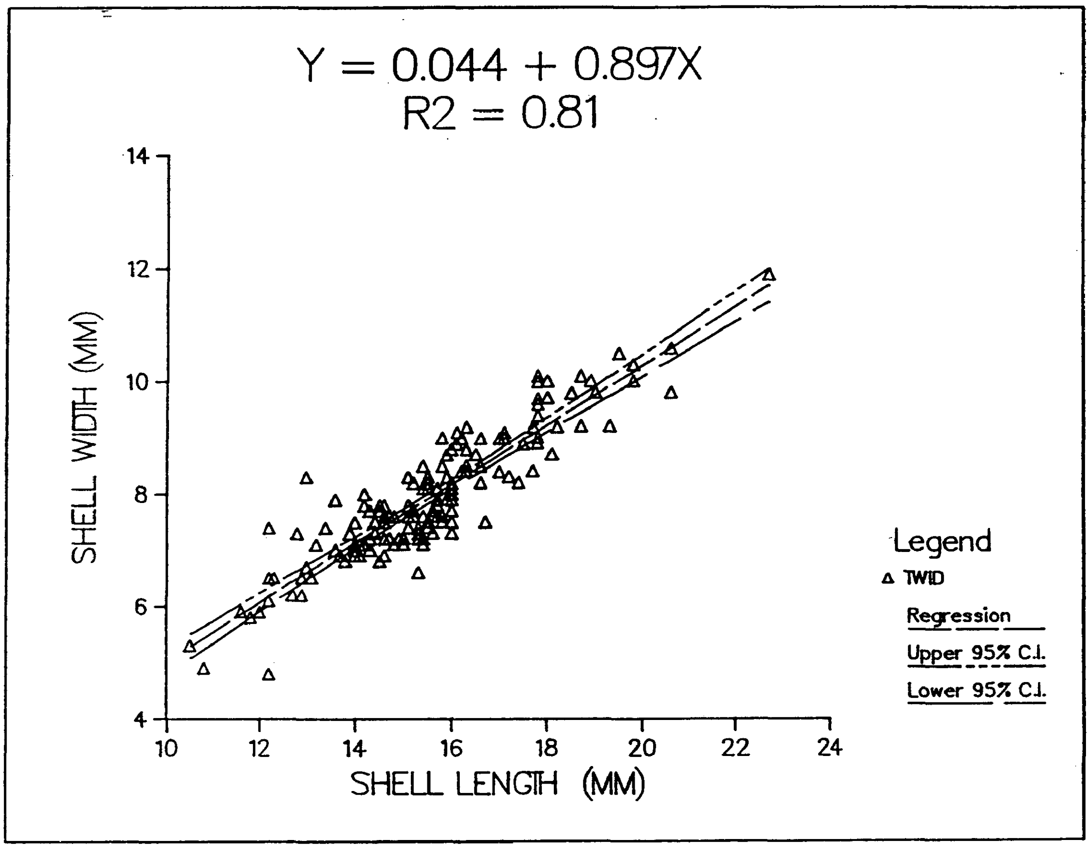
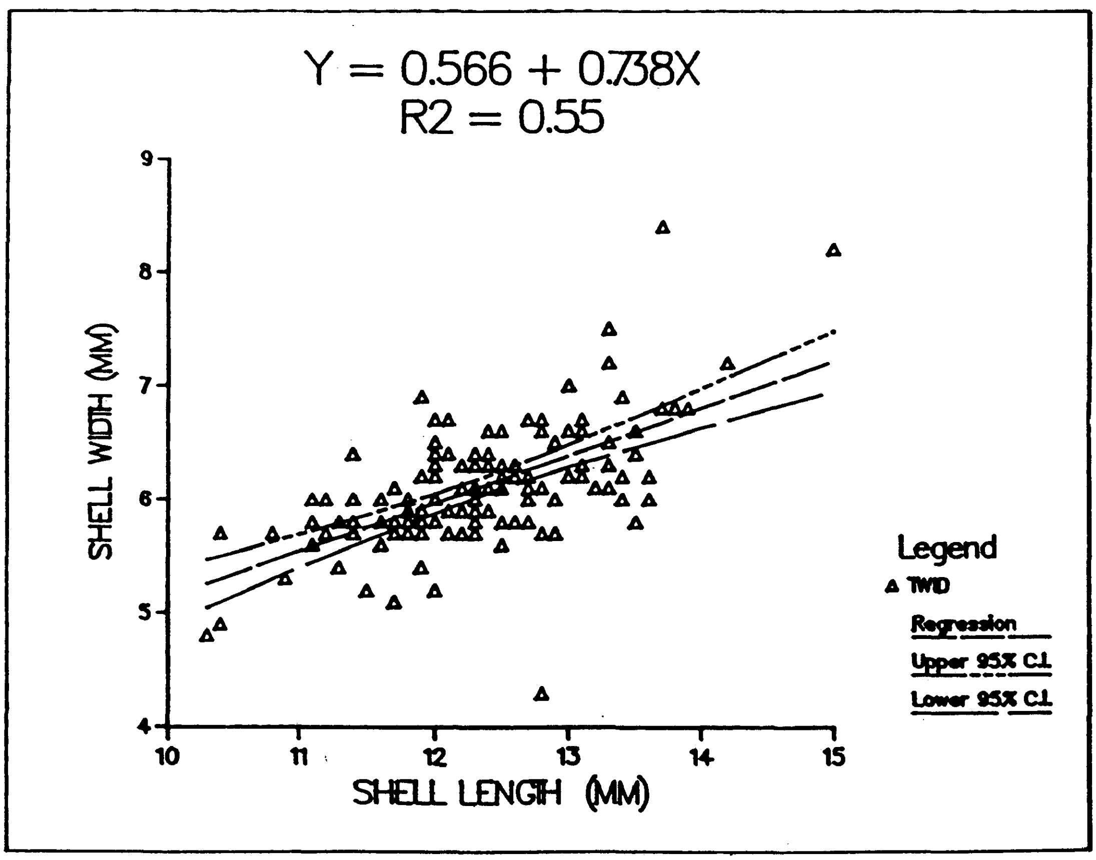


Figure 16. Female (above) and male (below) *B. carica* regression of shell width (mm) on shell length (mm).

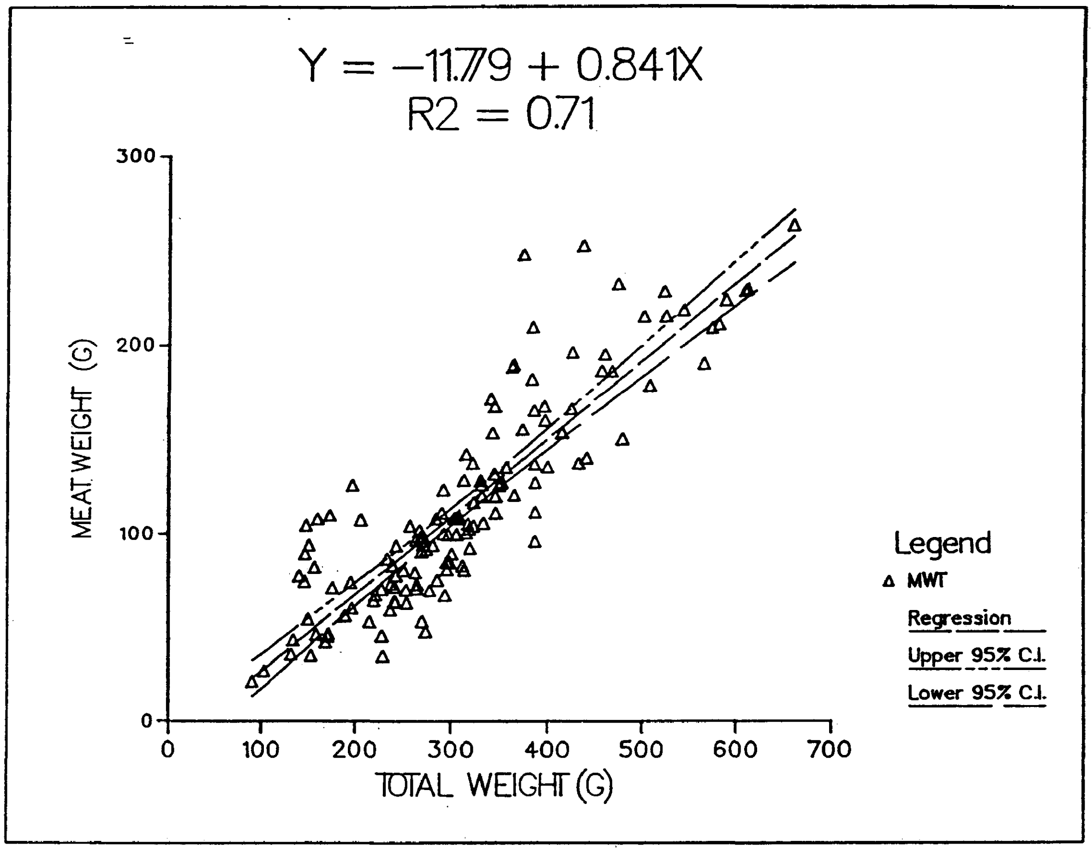


Y = 0.044 + 0.897X
R2 = 0.81
SHELL WIDTH (MM)
SHELL LENGTH (MM)
4
6
8
10
12
14
10
12
14
16
18
20
22
24
Legend
TWID
Regression
Upper 95% C.I.
Lower 95% C.I.

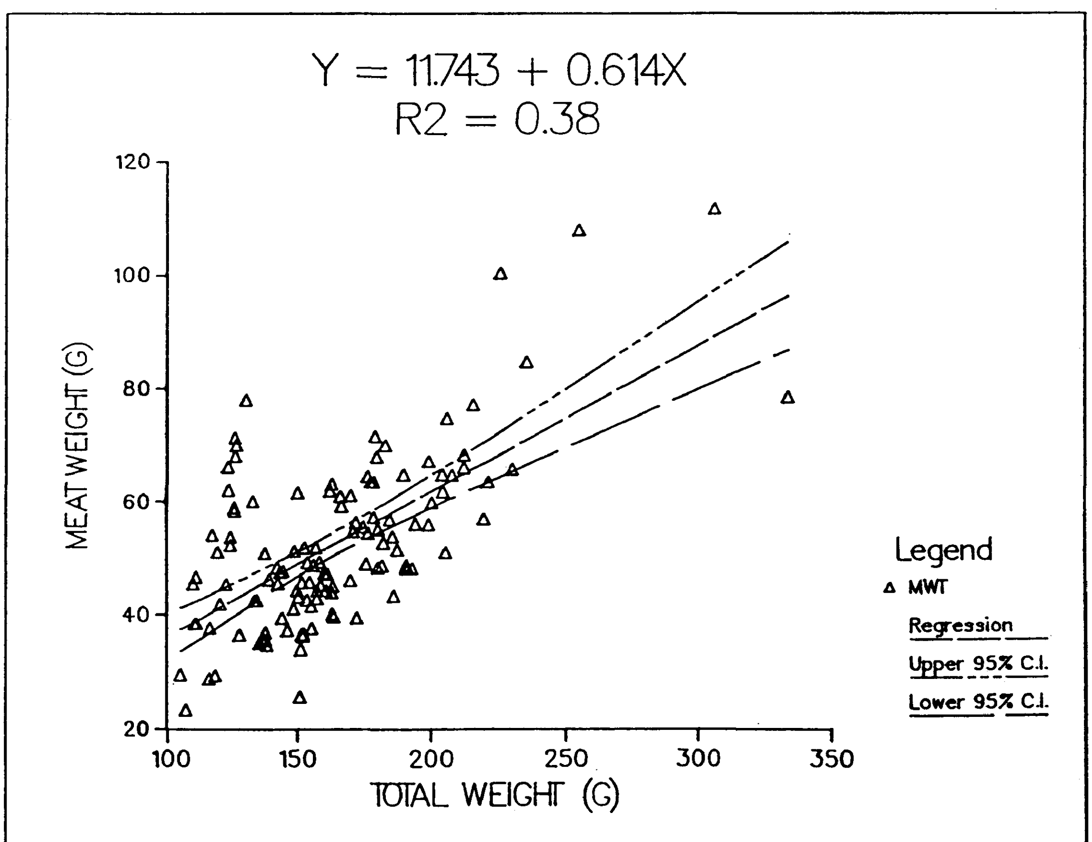


Y = 0.566 + 0.738X
R2 = 0.55
SHELL WIDTH (MM)
SHELL LENGTH (MM)
4
5
6
7
8
9
10
11
12
13
14
15
Legend
TWID
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 17. Female (above) and male (below) _B. carica_ regression of meat weight (g) on total weight (g).

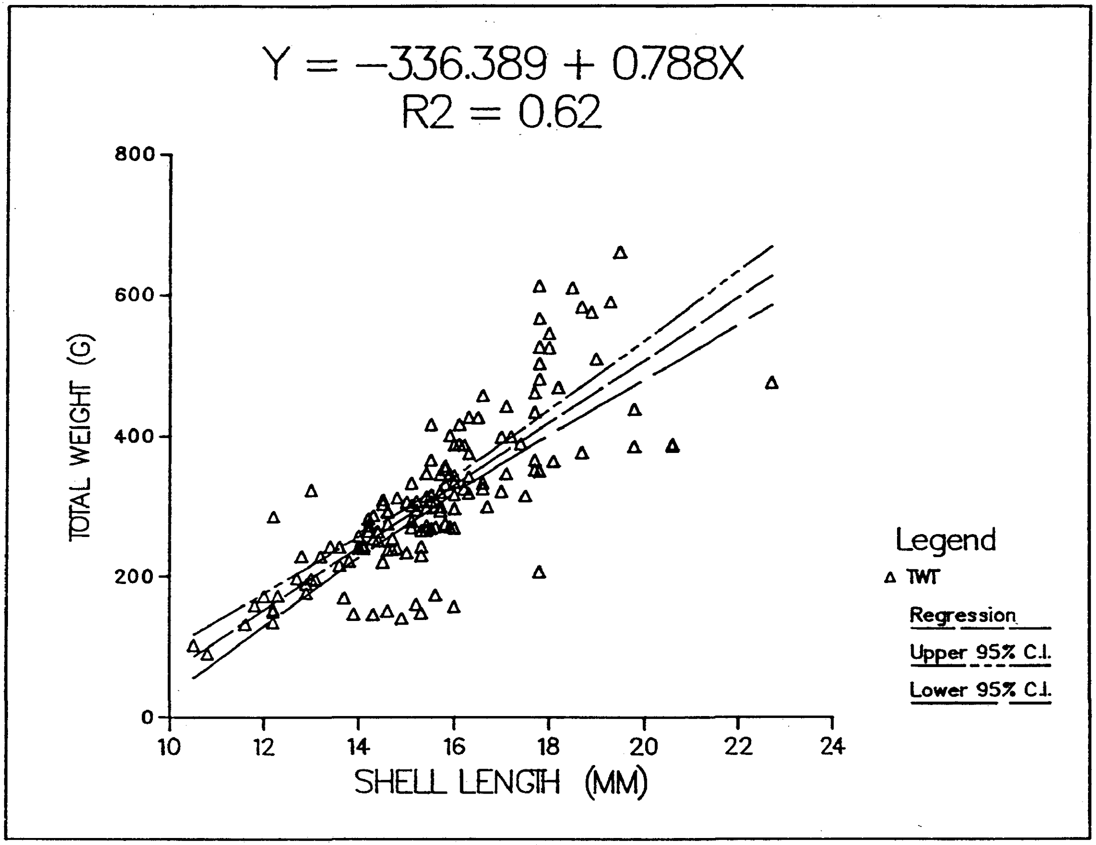


Y = −11.779 + 0.841X
R2 = 0.71
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
0
100
200
300
0
100
200
300
400
500
600
700
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

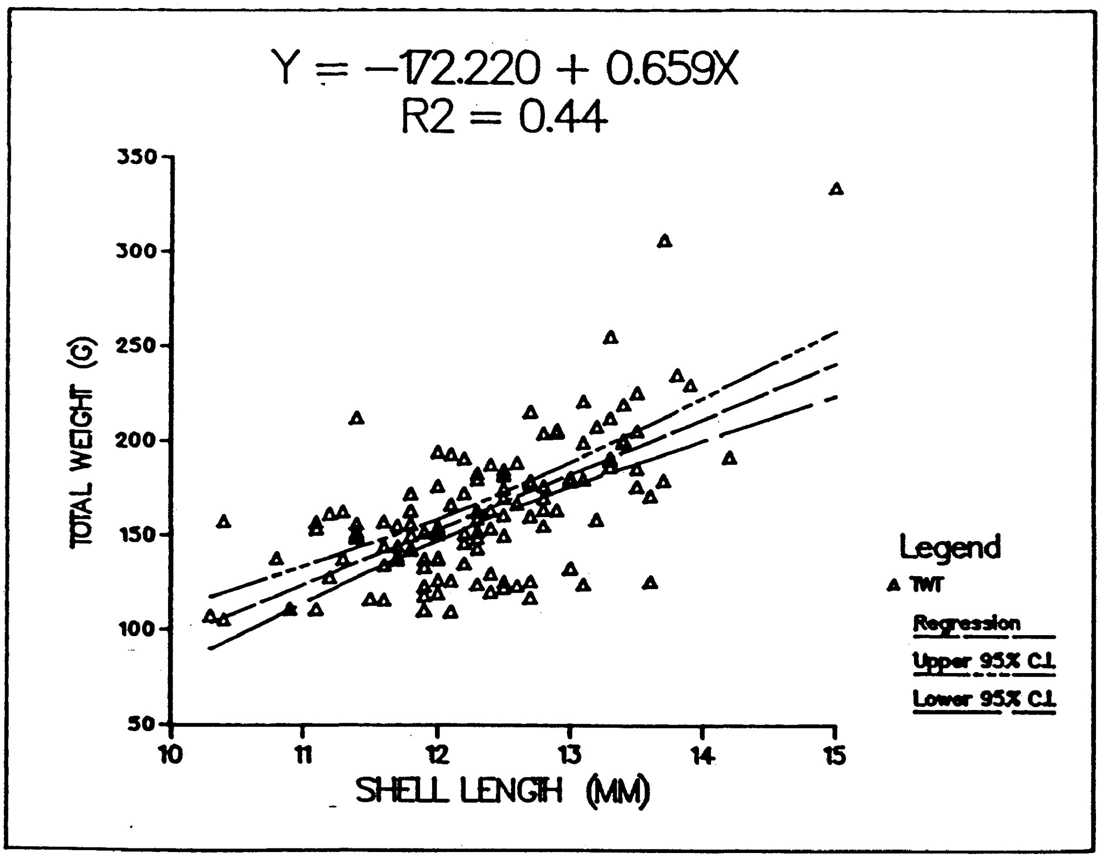


Y = 11.743 + 0.614X
R2 = 0.38
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
20
40
60
80
100
120
100
150
200
250
300
350
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 18. Female (above) and male (below) _B. carica_ regression of total weight (g) on shell length (mm).

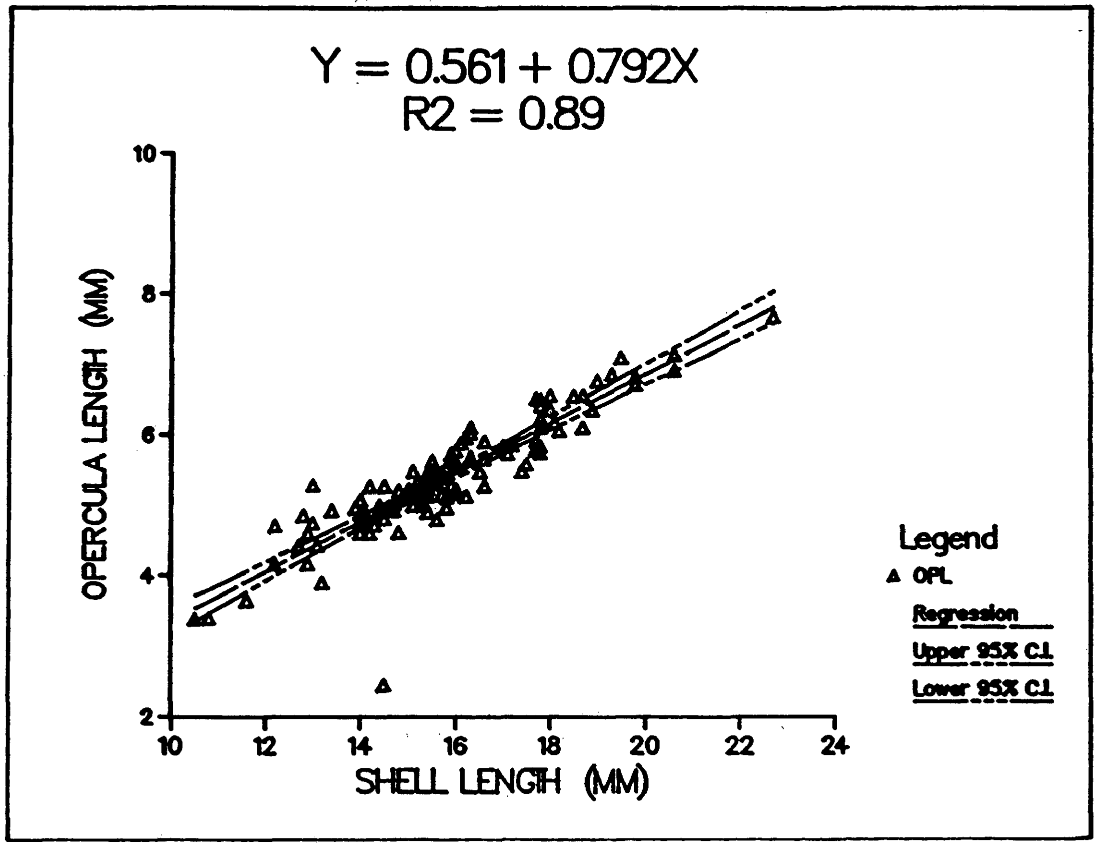


Y = −336.389 + 0.788X
R2 = 0.62
TOTAL WEIGHT (G)
SHELL LENGTH (MM)
800
600
400
200
0
10
12
14
16
18
20
22
24
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.



Y = −172.220 + 0.659X
R2 = 0.44
TOTAL WEIGHT (G)
SHELL LENGTH (MM)
350
300
250
200
150
100
50
10
11
12
13
14
15
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 19. Female (above) and male (below) B. *carica* regression of opercula length (mm) on shell length (mm).


Y = 0.561 + 0.792X
R2 = 0.89
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
10
8
6
4
2
10
12
14
16
18
20
22
24
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

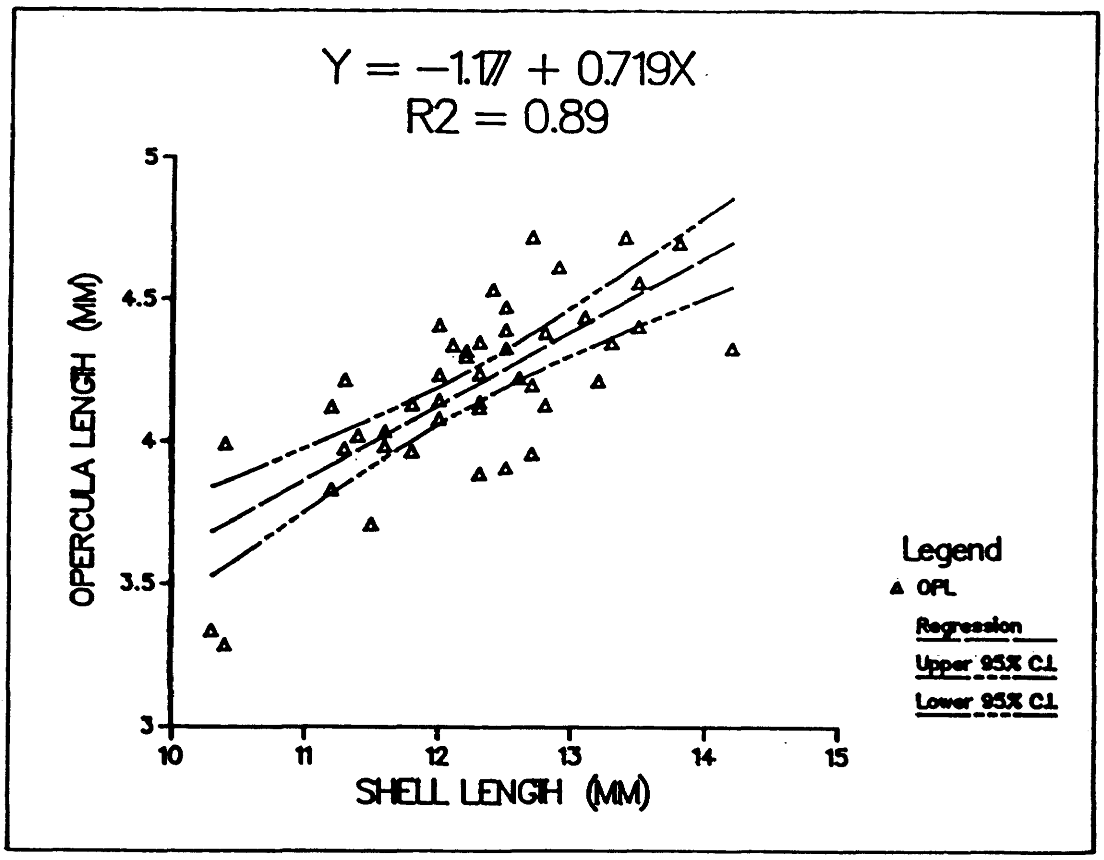
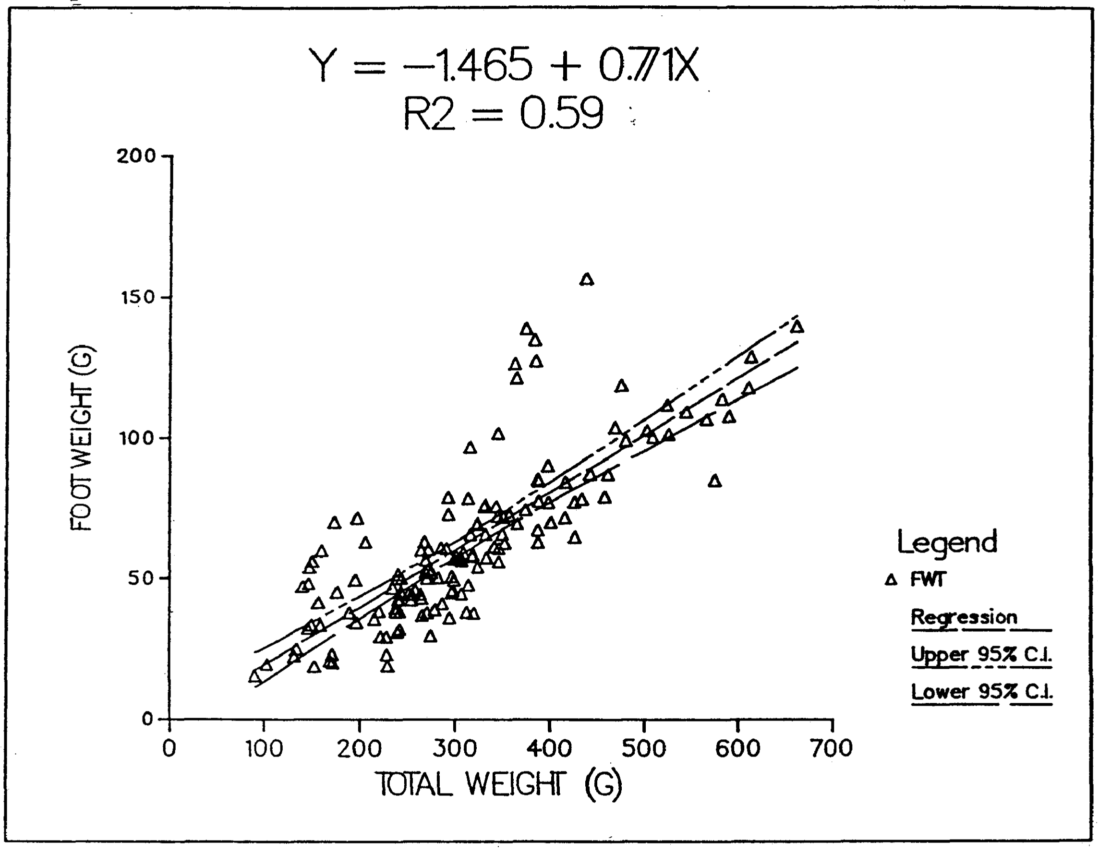

Y = −1.17 + 0.719X
R2 = 0.89
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
5
4.5
4
3.5
3
10
11
12
13
14
15
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 20. Female (above) and male (below) B. *carica* regression of foot weight (g) on total weight (g).


Y = −1.465 + 0.771X
R2 = 0.59
FOOTWEIGHT (G)
TOTAL WEIGHT (G)
0
50
100
150
200
0
100
200
300
400
500
600
700
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.

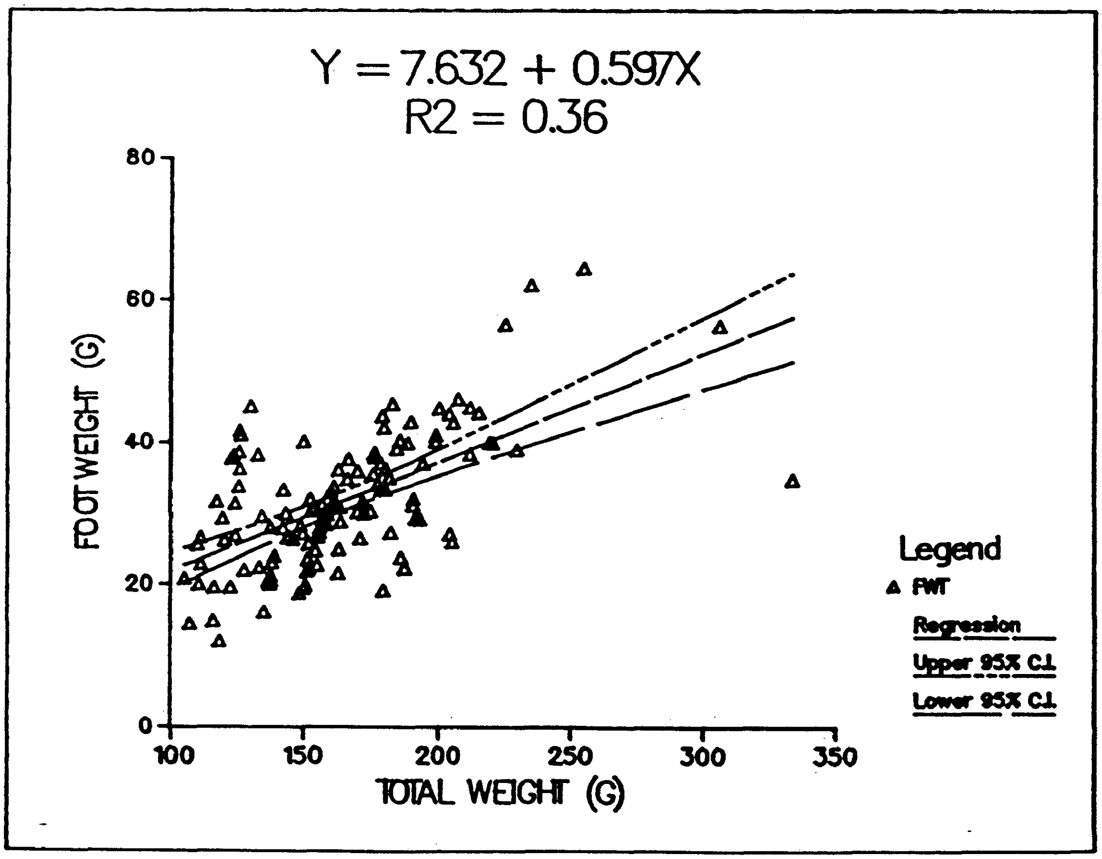
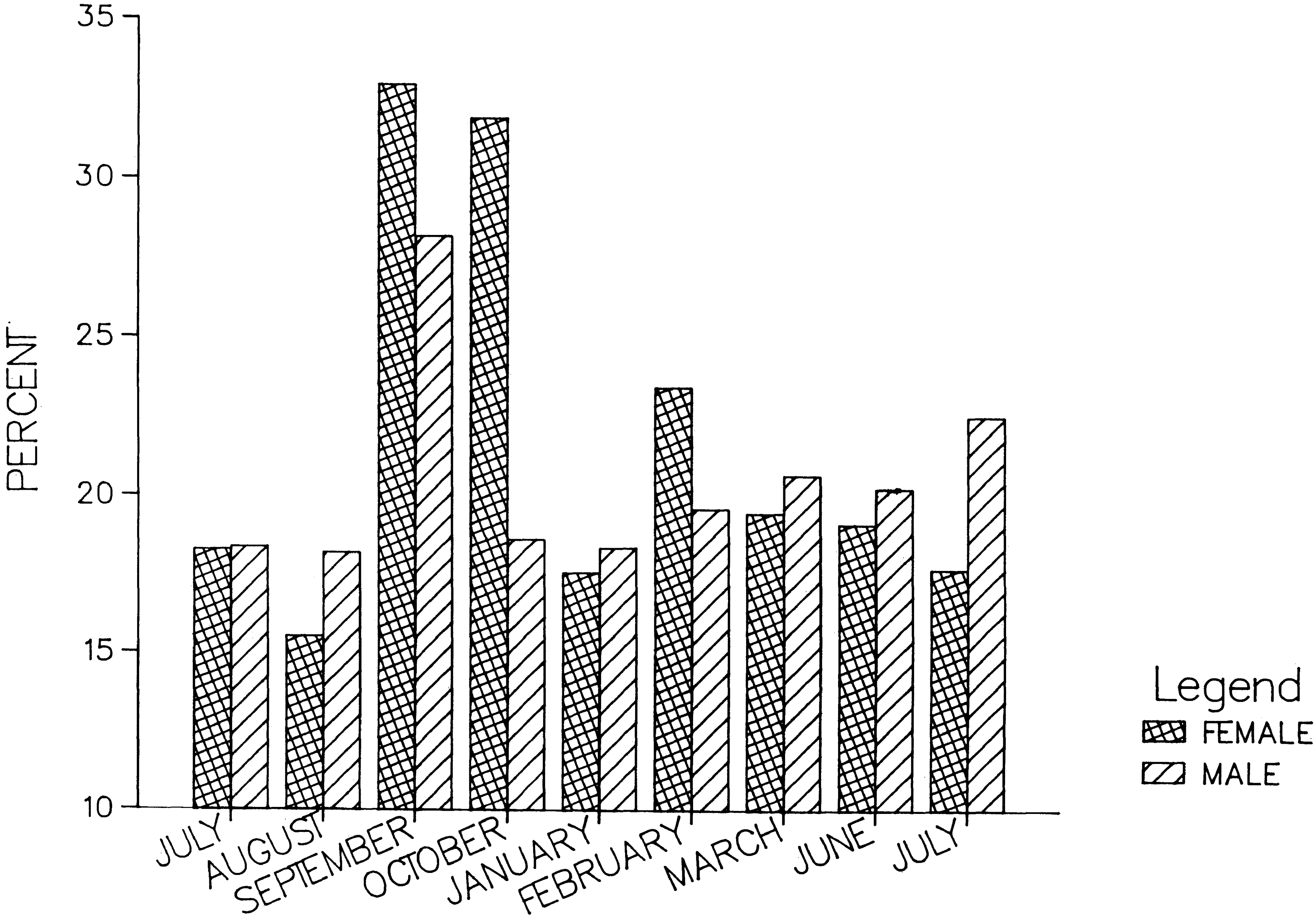

Y = 7.632 + 0.597X
R2 = 0.36
FOOTWEIGHT (G)
TOTAL WEIGHT (G)
0
20
40
60
80
100
150
200
250
300
350
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.

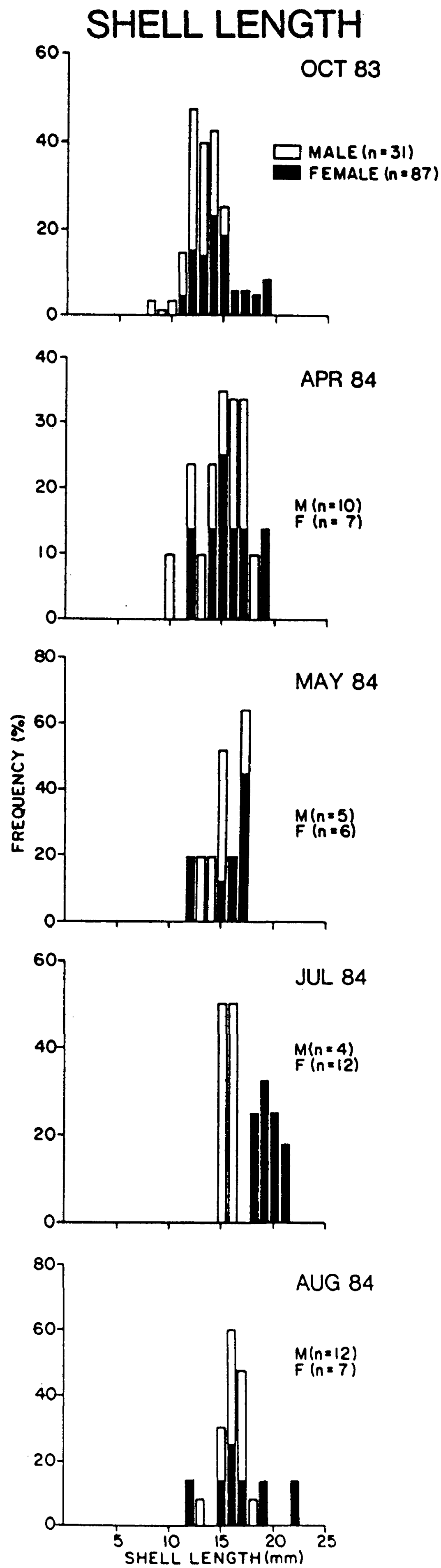
Figure 21. Edible meat yield (foot weight/total weight) for

B. carica.



PERCENT
35
30
25
20
15
10
JULY
AUGUST
SEPTEMBER
OCTOBER
JANUARY
FEBRUARY
MARCH
JUNE
JULY
Legend
FEMALE
MALE

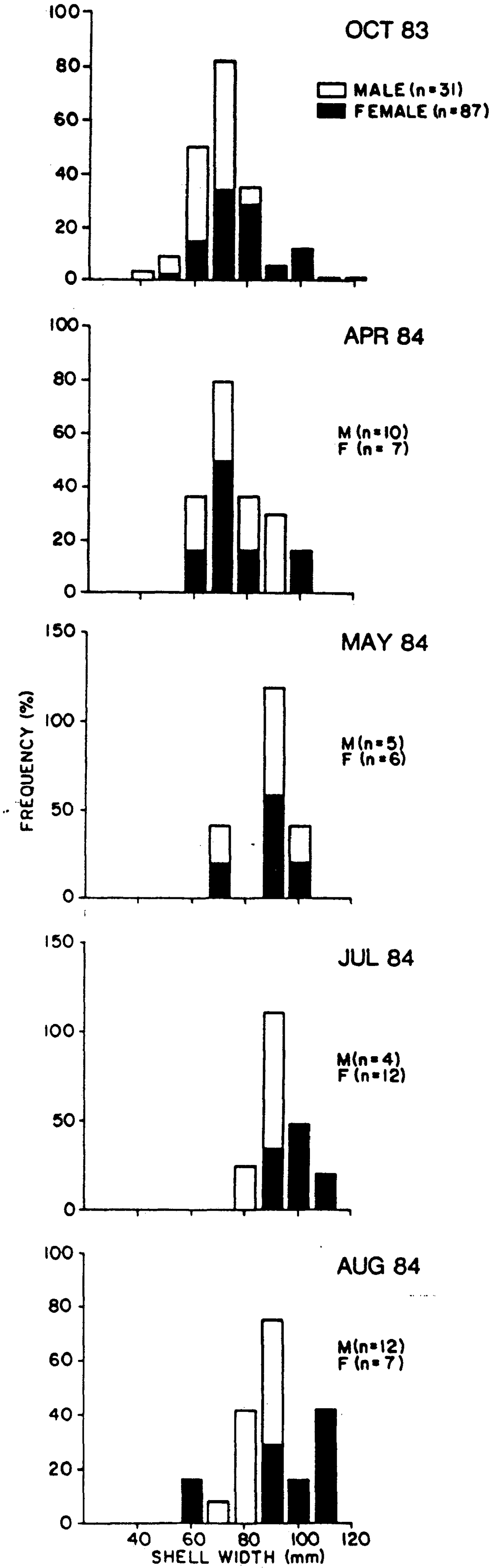
Figure 22. Female and male B. *canaliculatum* shell length (mm) by month.



SHELL LENGTH
OCT 83
MALE (n=31)
FEMALE (n=87)
APR 84
M (n=10)
F (n= 7)
MAY 84
M (n=5)
F (n=6)
JUL 84
M(n=4)
F (n=12)
AUG 84
M(n=12)
F (n=7)
FREQUENCY (%)
SHELL LENGTH (mm)

Figure 23. Female and male *B. canaliculatum* shell width (mm) by month.

SHELL WIDTH



OCT 83
MALE (n=31)
FEMALE (n=87)
APR 84
M (n=10)
F (n= 7)
MAY 84
M (n=5)
F (n=6)
JUL 84
M (n=4)
F (n=12)
AUG 84
M (n=12)
F (n=7)
FREQUENCY (%)
SHELL WIDTH (mm)
40 60 80 100 120

Figure 24. Female and male B. canaliculatum total weight (g) by month.

TOTAL WEIGHT

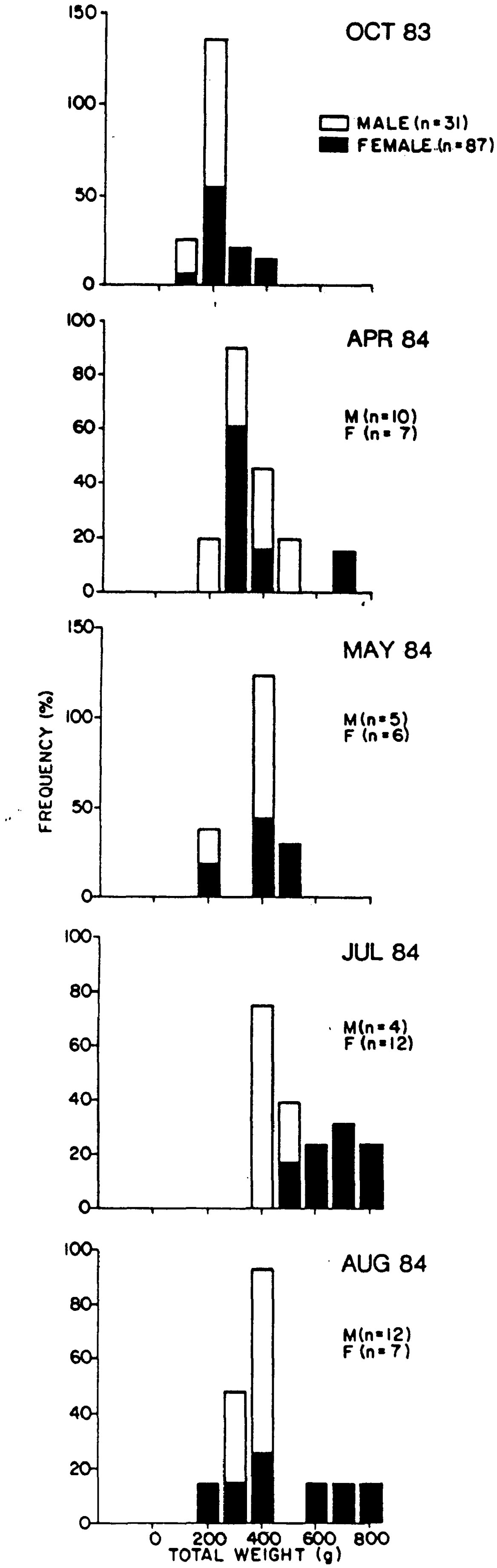


Figure 25. Female and male _B_. _canaliculatum_ meat weight (g) by month.

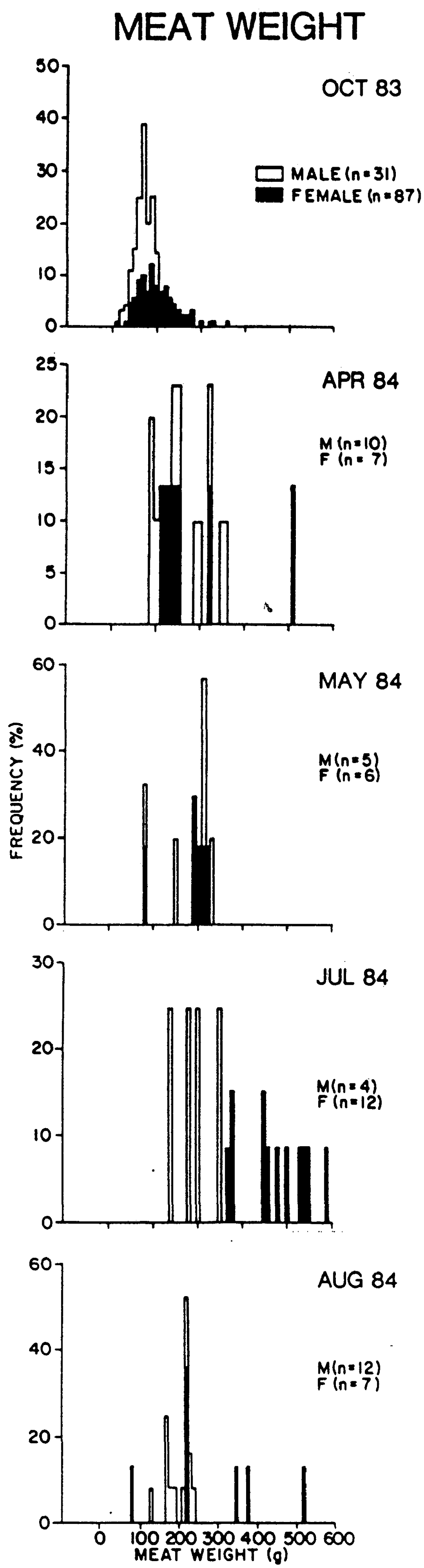

MEAT WEIGHT
OCT 83
MALE (n=31)
FEMALE (n=87)
APR 84
M (n=10)
F (n= 7)
MAY 84
M (n=5)
F (n=6)
JUL 84
M(n=4)
F (n=12)
AUG 84
M(n=12)
F (n=7)
FREQUENCY (%)
0 100 200 300 400 500 600
MEAT WEIGHT (g)

Figure 26. Female and male *B. canaliculatum* foot weight (g) by month.

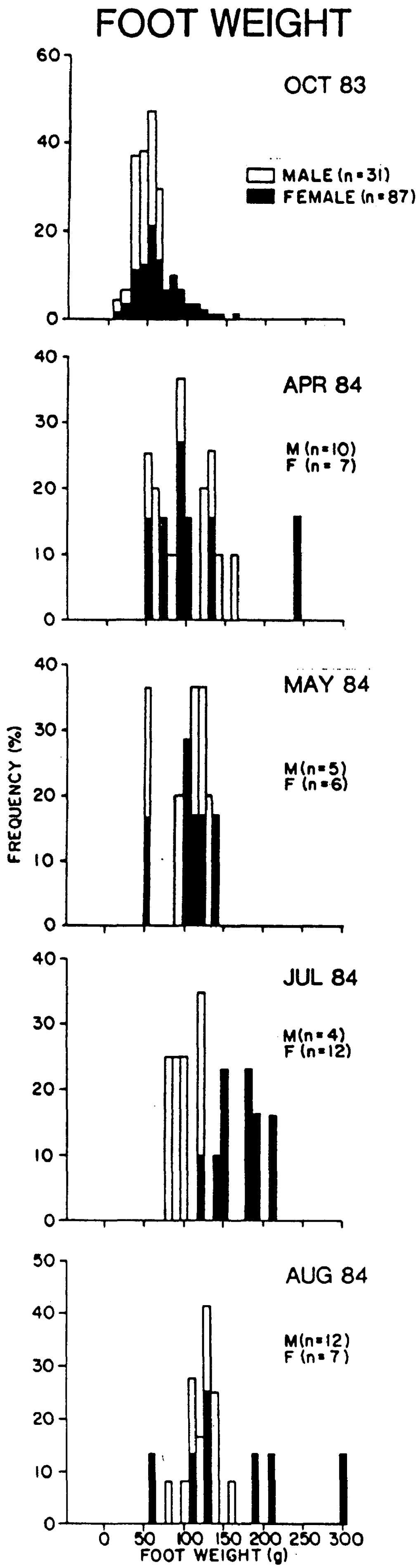

FOOT WEIGHT
OCT 83
MALE (n=31)
FEMALE (n=87)
APR 84
M (n=10)
F (n= 7)
MAY 84
M(n=5)
F (n=6)
JUL 84
M(n=4)
F (n=12)
AUG 84
M(n=12)
F (n=7)
FREQUENCY (%)
FOOT WEIGHT (g)
0 50 100 150 200 250 300

Figure 27. Female and male *B. canaliculatum* opercula length (mm) by month.

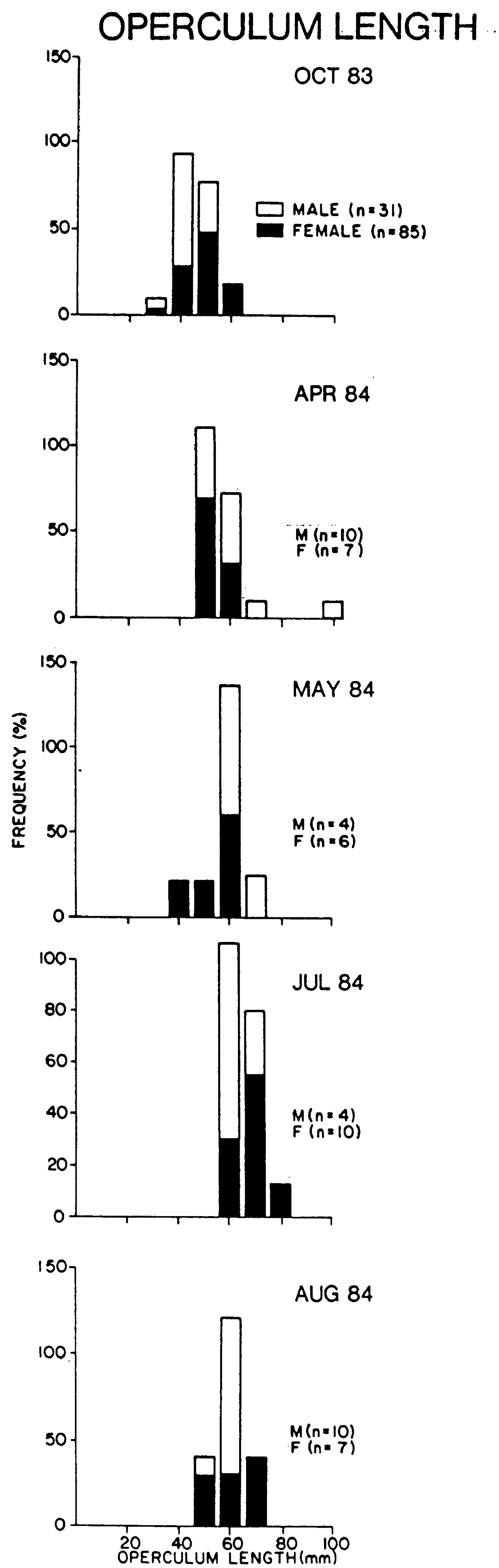

OPERCULUM LENGTH
OCT 83
MALE (n=31)
FEMALE (n=85)
APR 84
M (n=10)
F (n=7)
MAY 84
M (n=4)
F (n=6)
JUL 84
M (n=4)
F (n=10)
AUG 84
M (n=10)
F (n=7)
FREQUENCY (%)
OPERCULUM LENGTH (mm)
0
50
100
150
20
40
60
80
100

Figure 28. Female and male B. *canaliculatum* opercula width (mm) by month.

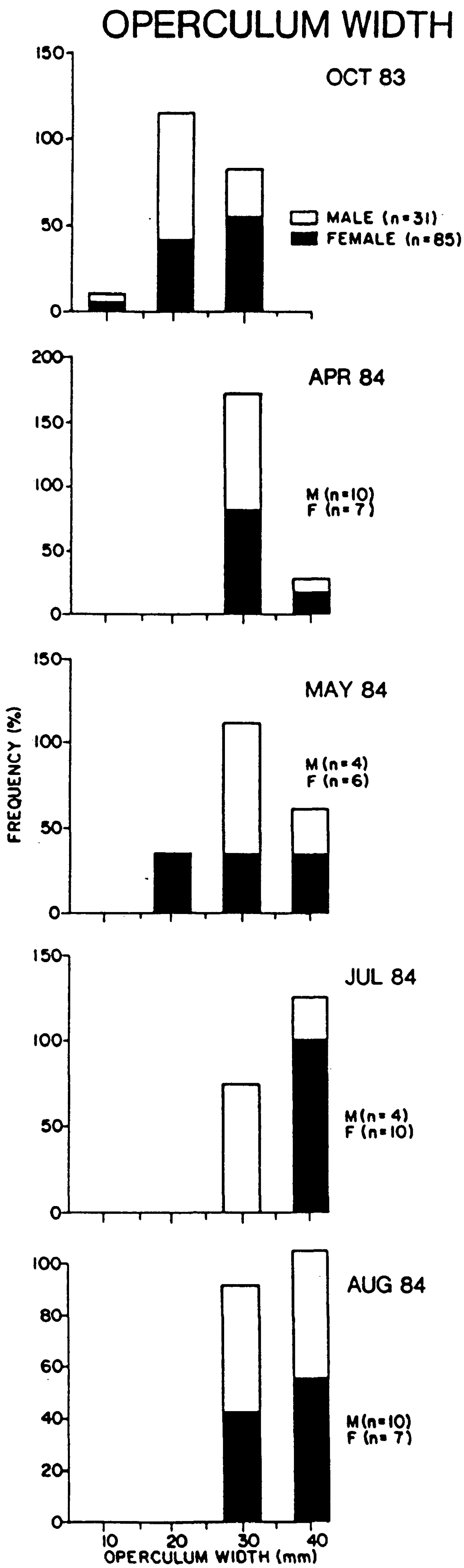

OPERCULUM WIDTH
OCT 83
MALE (n=31)
FEMALE (n=85)
APR 84
M (n=10)
F (n=7)
MAY 84
M (n=4)
F (n=6)
JUL 84
M (n=4)
F (n=10)
AUG 84
M (n=10)
F (n=7)
FREQUENCY (%)
OPERCULUM WIDTH (mm)
150
100
50
0
200
80
60
40
20
10
30

Figure 29. Female and male *B. canaliculatum* opercula weight (g) by month.

OPERCULUM WEIGHT

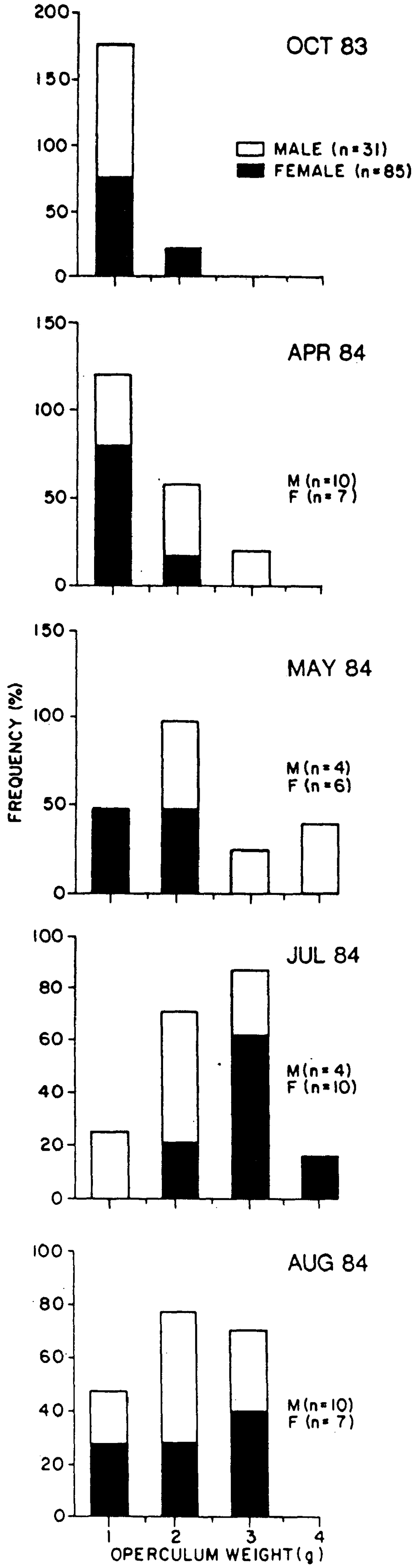
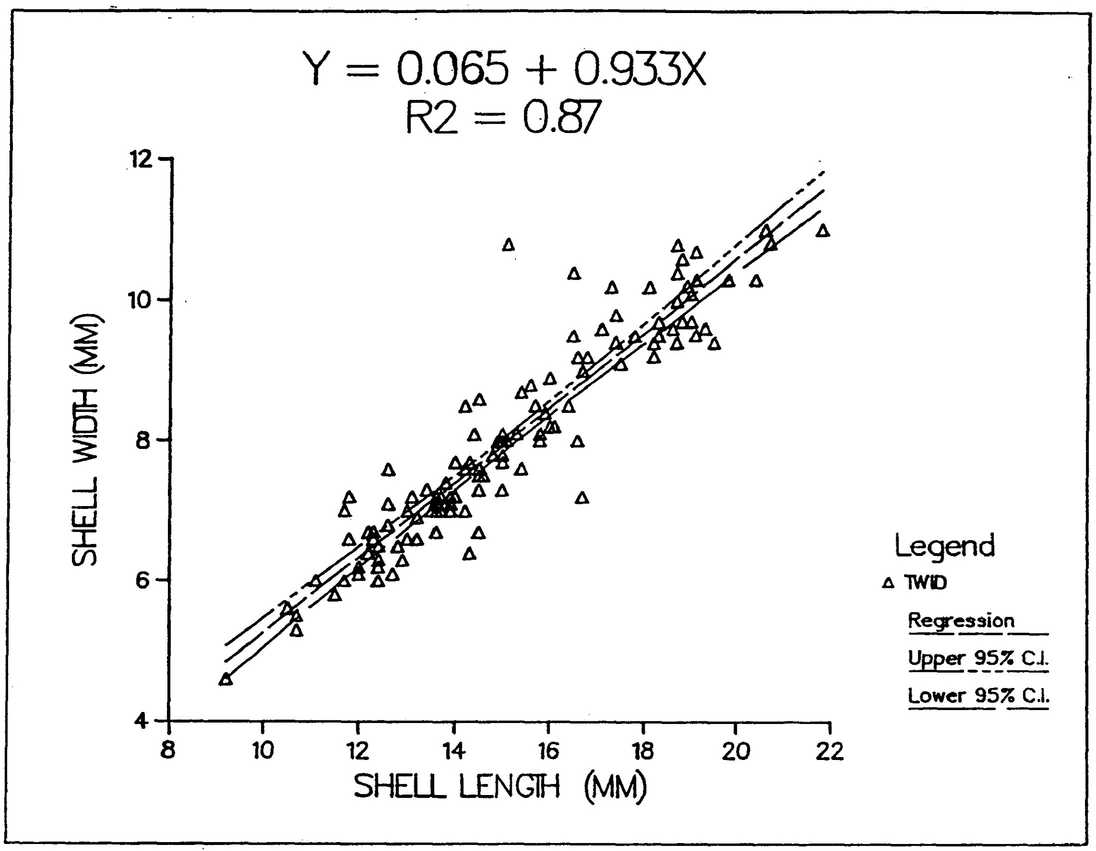


Figure 30. Female (above) and male (below) *B. canaliculatum* regression of shell width (mm) on shell length (mm).


Y = 0.065 + 0.933X
R2 = 0.87
SHELL WIDTH (MM)
SHELL LENGTH (MM)
Legend
TWD
Regression
Upper 95% C.I.
Lower 95% C.I.

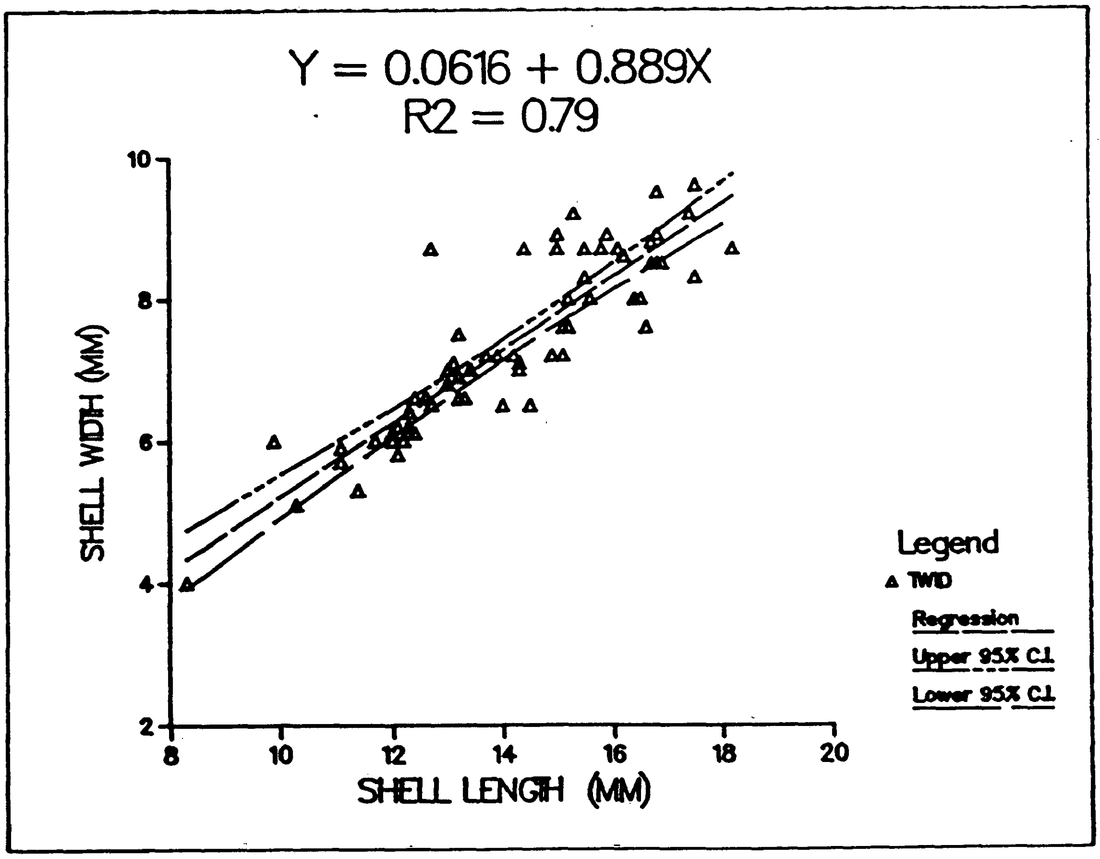
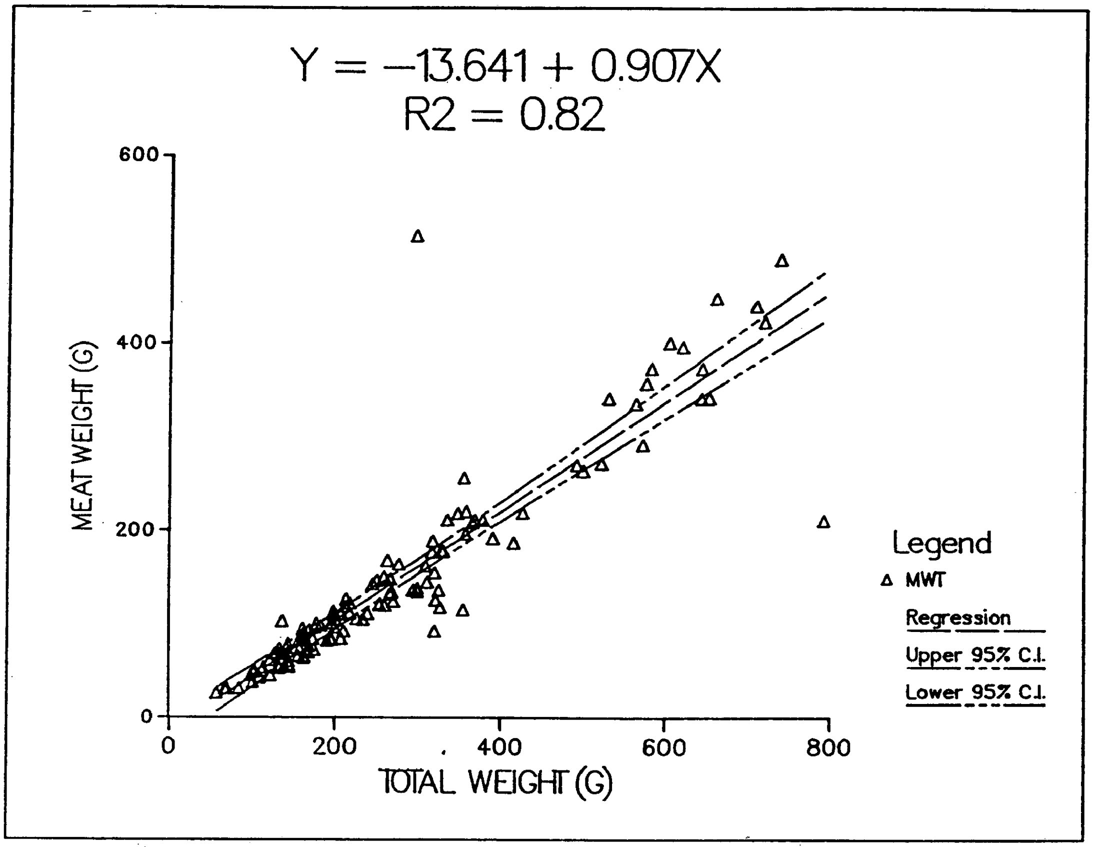
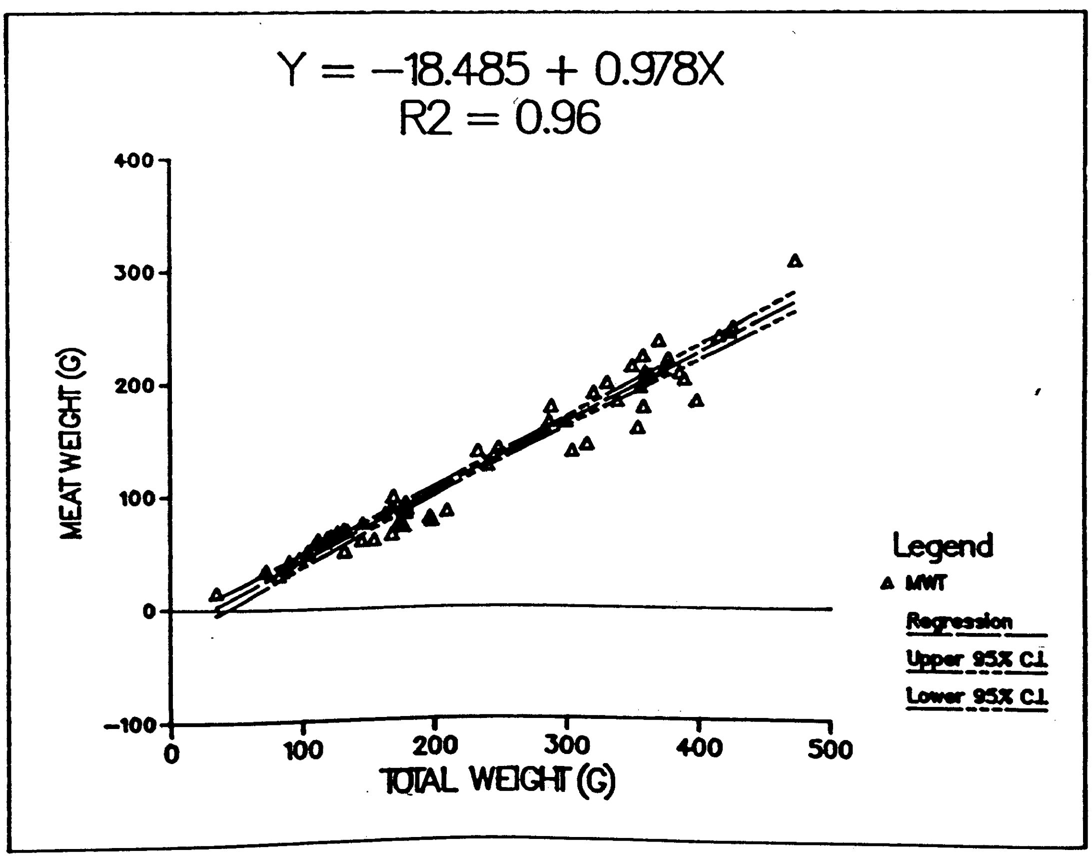

Y = 0.0616 + 0.889X
R2 = 0.79
SHELL WIDTH (MM)
SHELL LENGTH (MM)
Legend
TWD
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 31. Female (above) and male (below) *B. canaliculatum* regression of meat weight (g) on total weight (g).

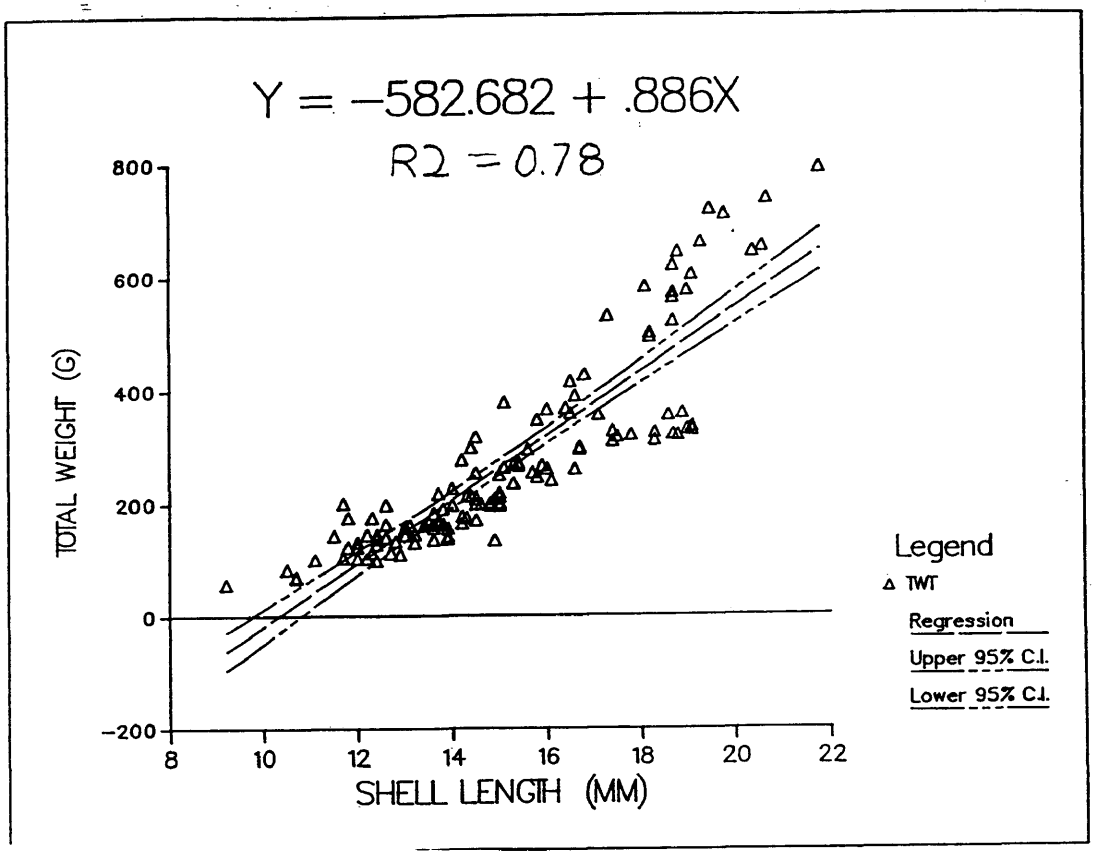


Y = −13.641 + 0.907X
R2 = 0.82
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
0
200
400
600
800
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

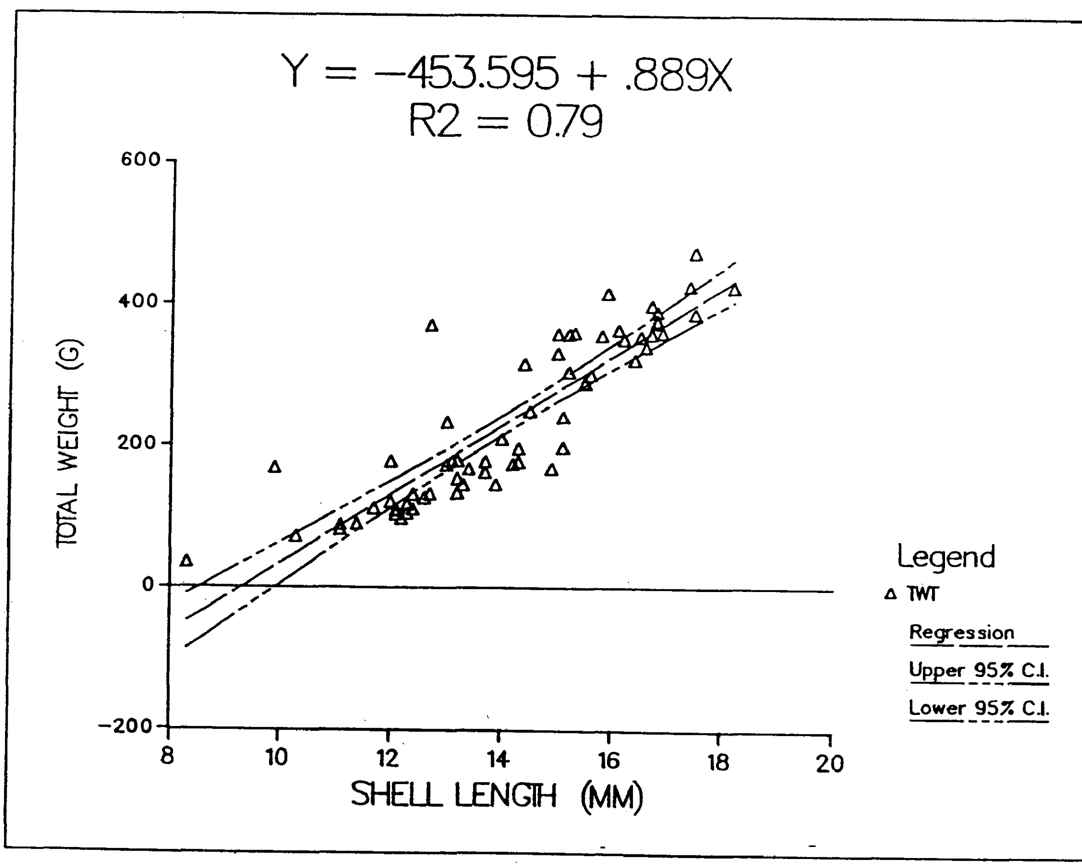


Y = −18.485 + 0.978X
R2 = 0.96
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
−100
0
100
200
300
400
500
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 32. Female (above) and male (below) *B. canaliculatum* regression of total weight (g) on shell length (mm).

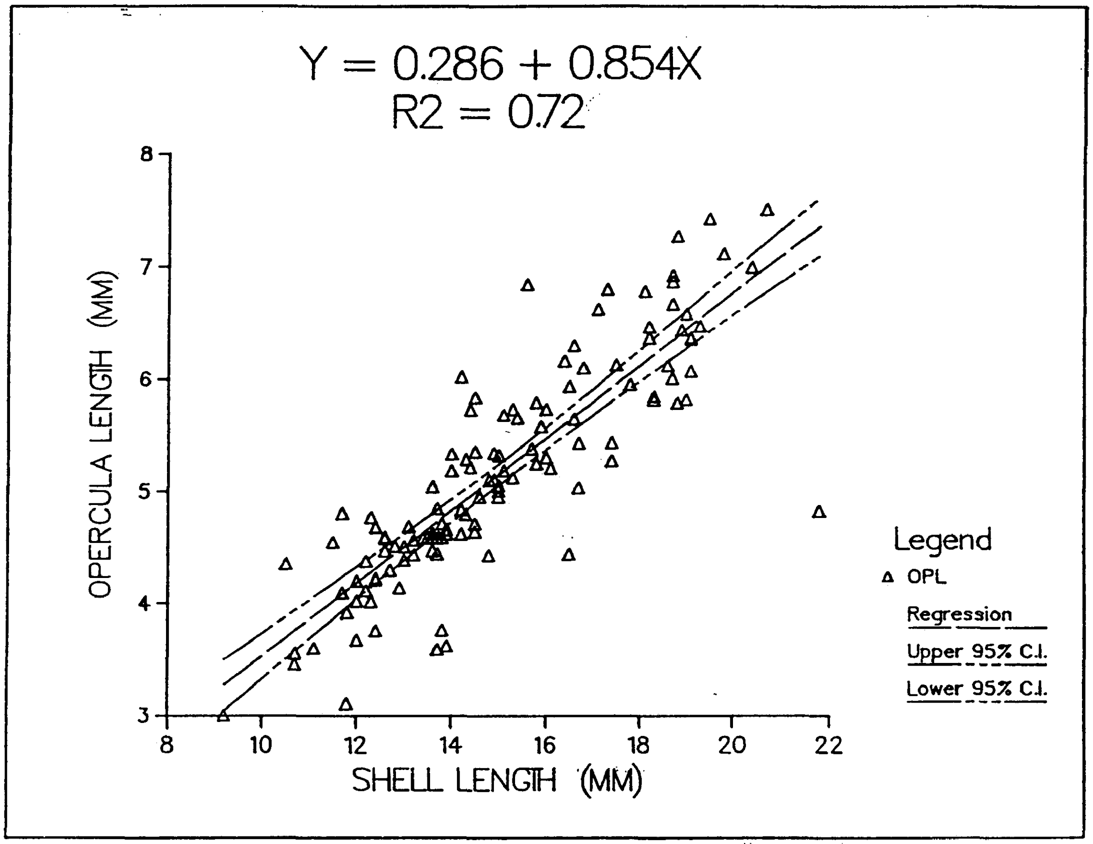


Y = −582.682 + .886X
R2 = 0.78
TOTAL WEIGHT (G)
800
600
400
200
0
−200
8
10
12
14
16
18
20
22
SHELL LENGTH (MM)
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.



Y = −453.595 + .889X
R2 = 0.79
TOTAL WEIGHT (G)
600
400
200
0
−200
8
10
12
14
16
18
20
SHELL LENGTH (MM)
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 33. Female (above) and male (below) *B. canaliculatum* regression of opercula length (mm) on shell length (mm).


Y = 0.286 + 0.854X
R2 = 0.72
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
8
7
6
5
4
3
8
10
12
14
16
18
20
22
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

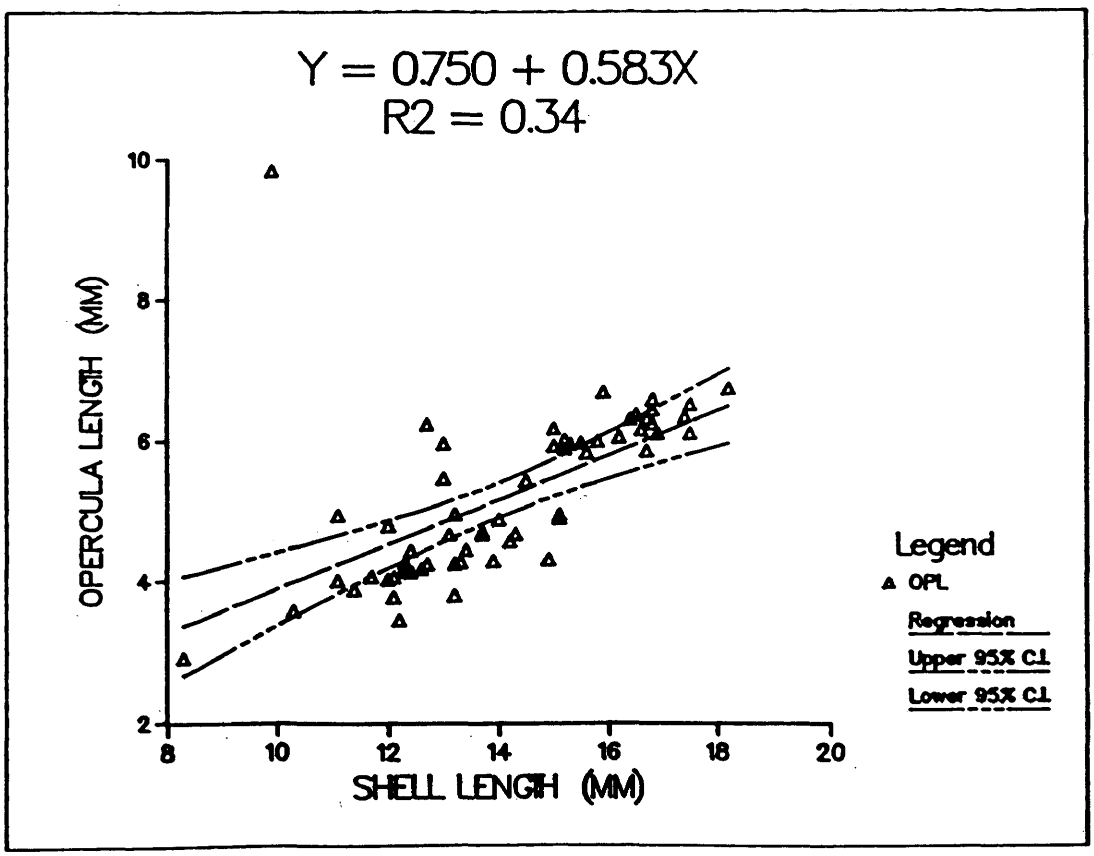
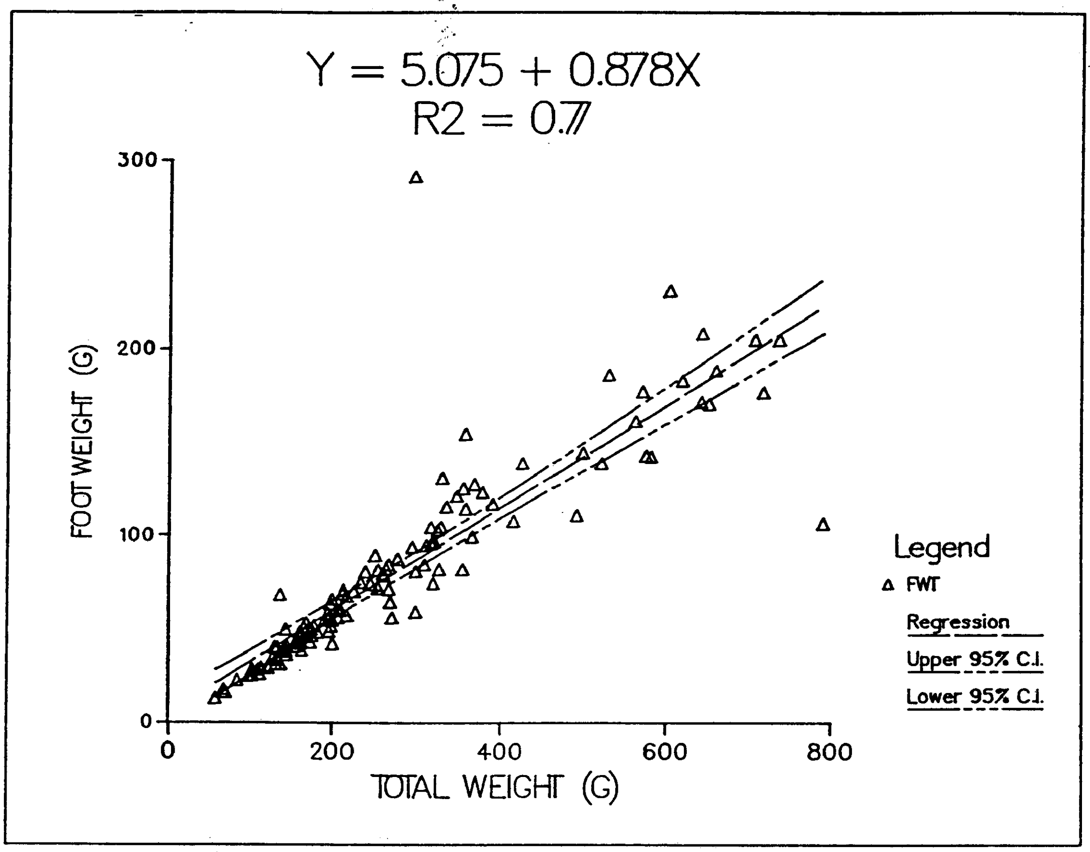

Y = 0.750 + 0.583X
R2 = 0.34
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
10
8
6
4
2
8
10
12
14
16
18
20
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 34. Female (above) and male (below) _B_. _canaliculatum_ regression of foot weight (g) on total weight (g).


Y = 5.075 + 0.878X
R2 = 0.77
FOOT WEIGHT (G)
TOTAL WEIGHT (G)
300
200
100
0
0
200
400
600
800
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.

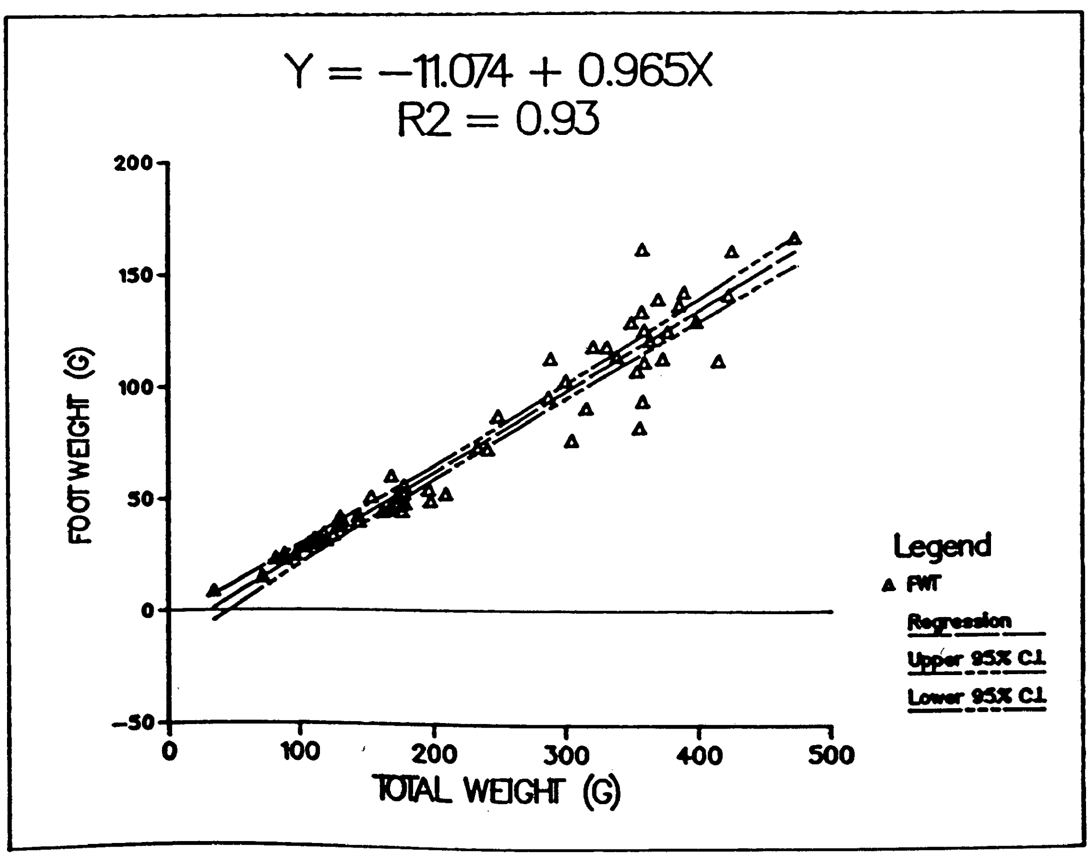

Y = −11.074 + 0.965X
R2 = 0.93
FOOT WEIGHT (G)
TOTAL WEIGHT (G)
200
150
100
50
0
−50
0
100
200
300
400
500
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 35. Edible meat yield (foot weight/total weight) for

B. canaliculatum.

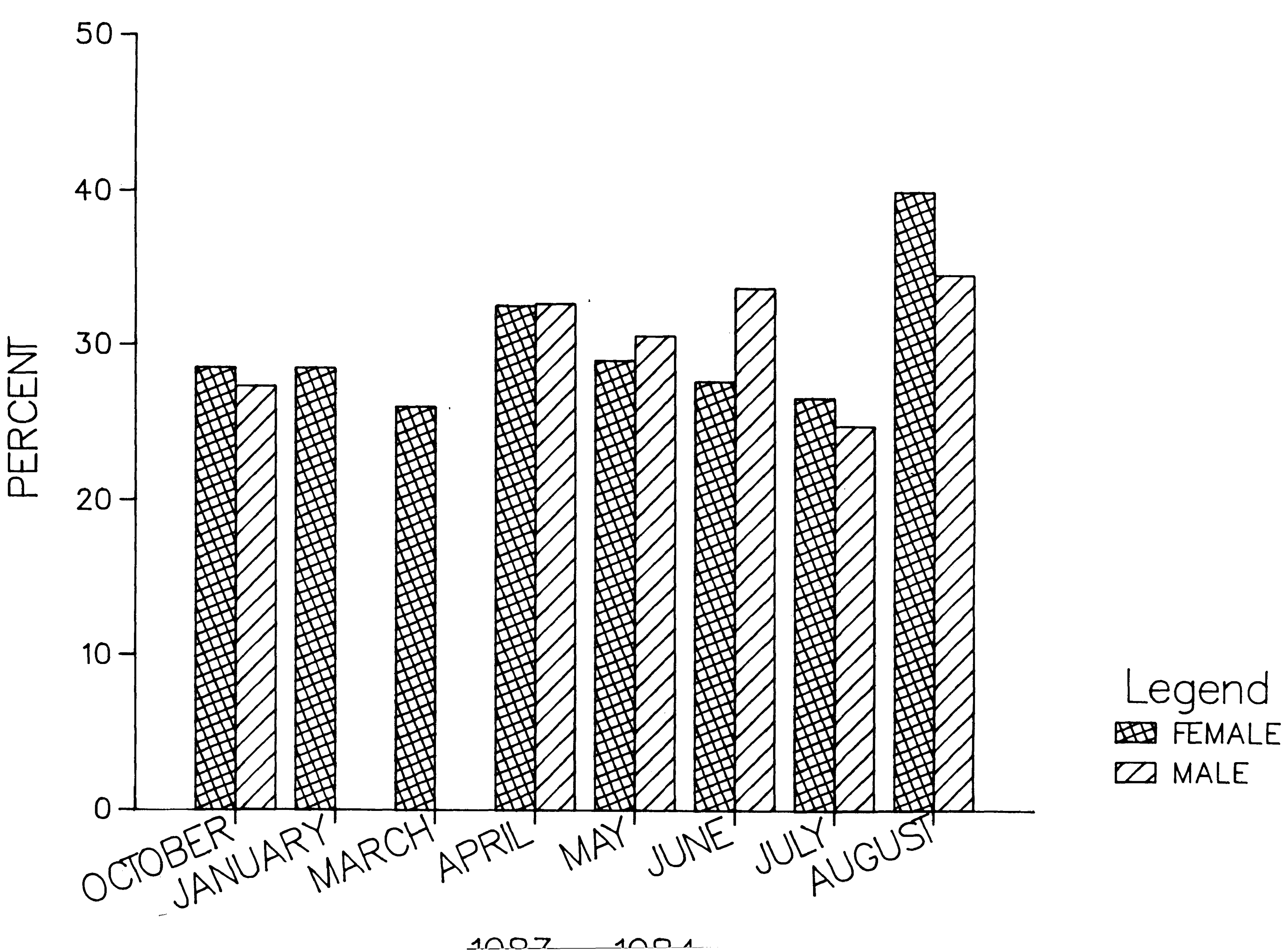

PERCENT
50
40
30
20
10
0
OCTOBER
JANUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
Legend
FEMALE
MALE

Figure 36. Female and male B. contrarium shell length (mm) by month.

SHELL LENGTH

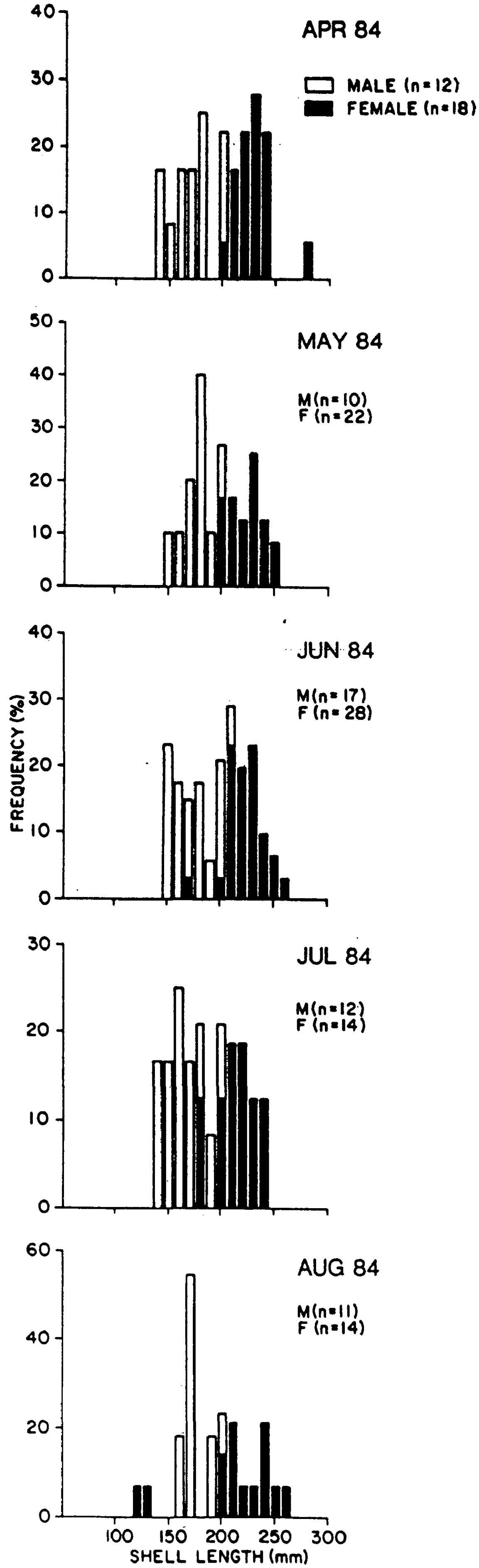


Figure 37. Female and male *B. contrarium* shell width (mm) by month.

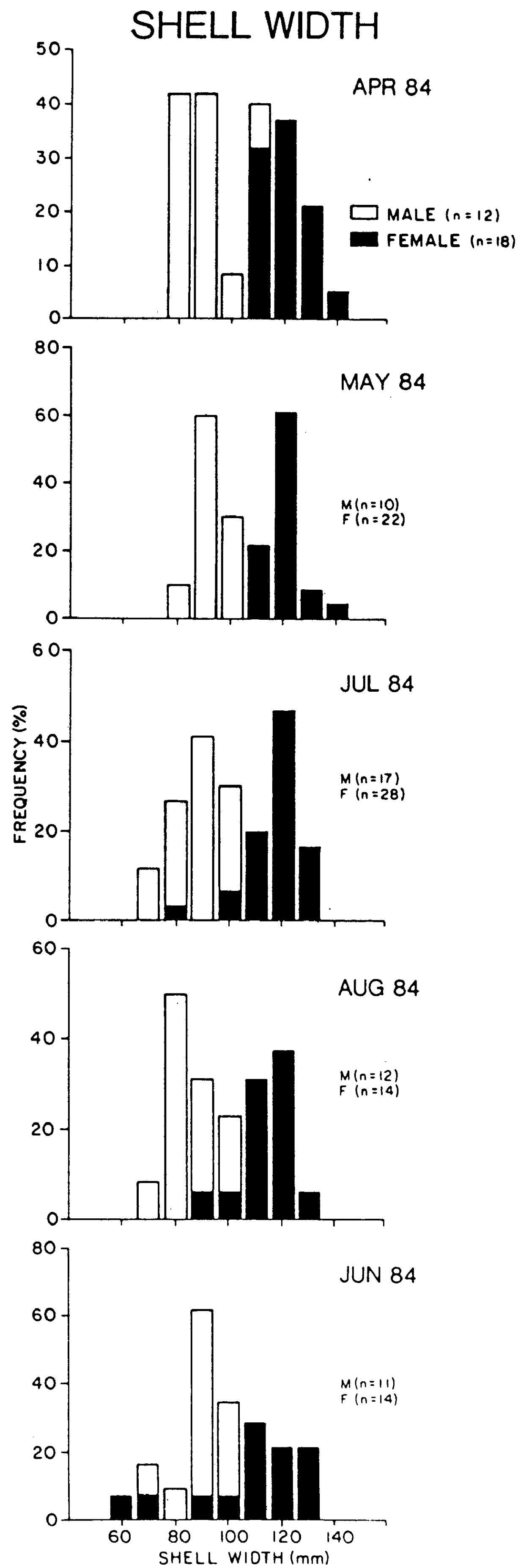

SHELL WIDTH
APR 84
MALE (n=12)
FEMALE (n=18)
MAY 84
M(n=10)
F (n=22)
JUL 84
M(n=17)
F (n=28)
AUG 84
M(n=12)
F (n=14)
JUN 84
M(n=11)
F (n=14)
FREQUENCY (%)
SHELL WIDTH (mm)
0
10
20
30
40
50
60
80
100
120
140

Figure 38. Female and male B. *contrarium* total weight (g) by month.

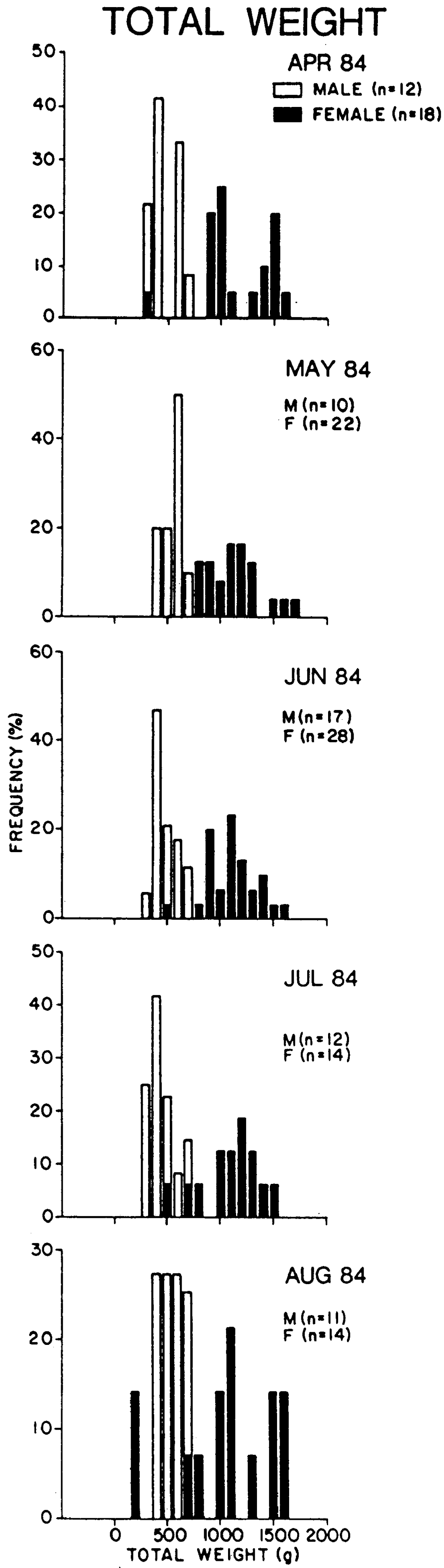

TOTAL WEIGHT
APR 84
MALE (n=12)
FEMALE (n=18)
MAY 84
M (n=10)
F (n=22)
JUN 84
M(n=17)
F (n=28)
JUL 84
M(n=12)
F (n=14)
AUG 84
M (n=11)
F (n=14)
FREQUENCY (%)
0
500
1000
1500
2000
TOTAL WEIGHT (g)

Figure 39. Female and male *B. contrarium* meat weight (g) by month.

MEAT WEIGHT

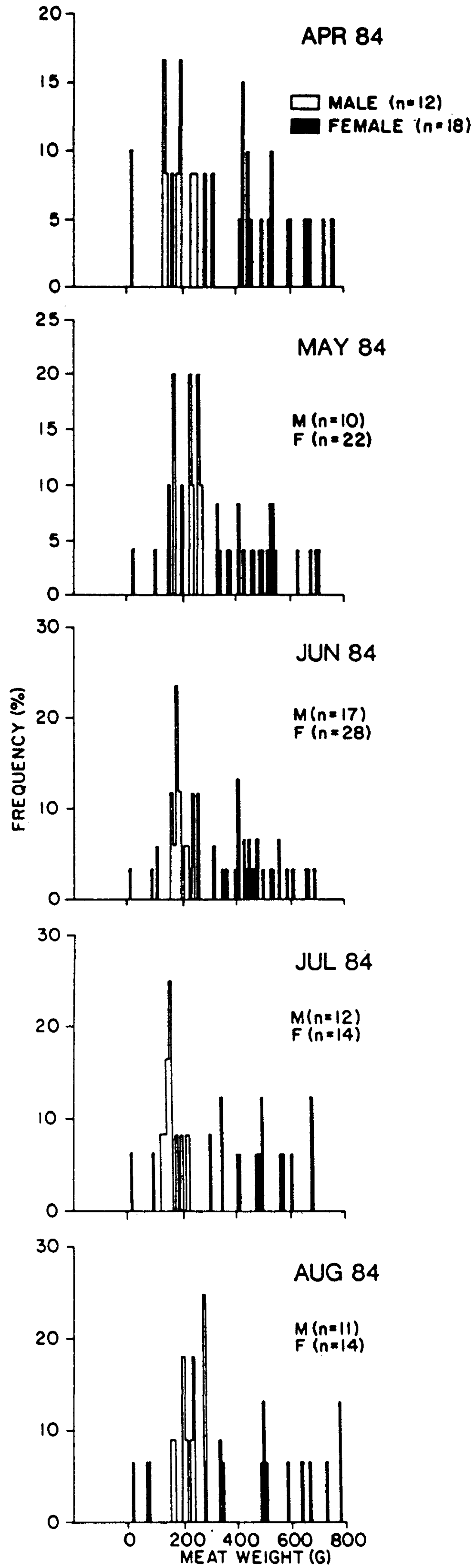

APR 84
MALE (n=12)
FEMALE (n=18)
MAY 84
M (n=10)
F (n=22)
JUN 84
M (n=17)
F (n=28)
JUL 84
M (n=12)
F (n=14)
AUG 84
M (n=11)
F (n=14)
FREQUENCY (%)
MEAT WEIGHT (G)
0
200
400
600
800

Figure 40. Female and male _B_. _contrarium_ foot weight (g) by month.

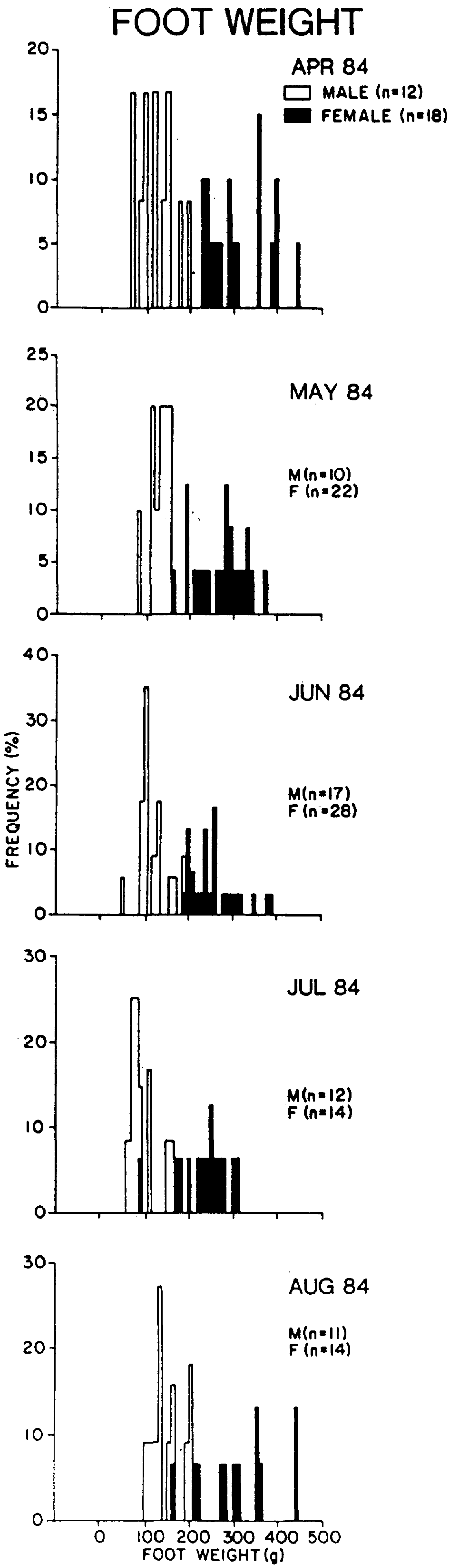
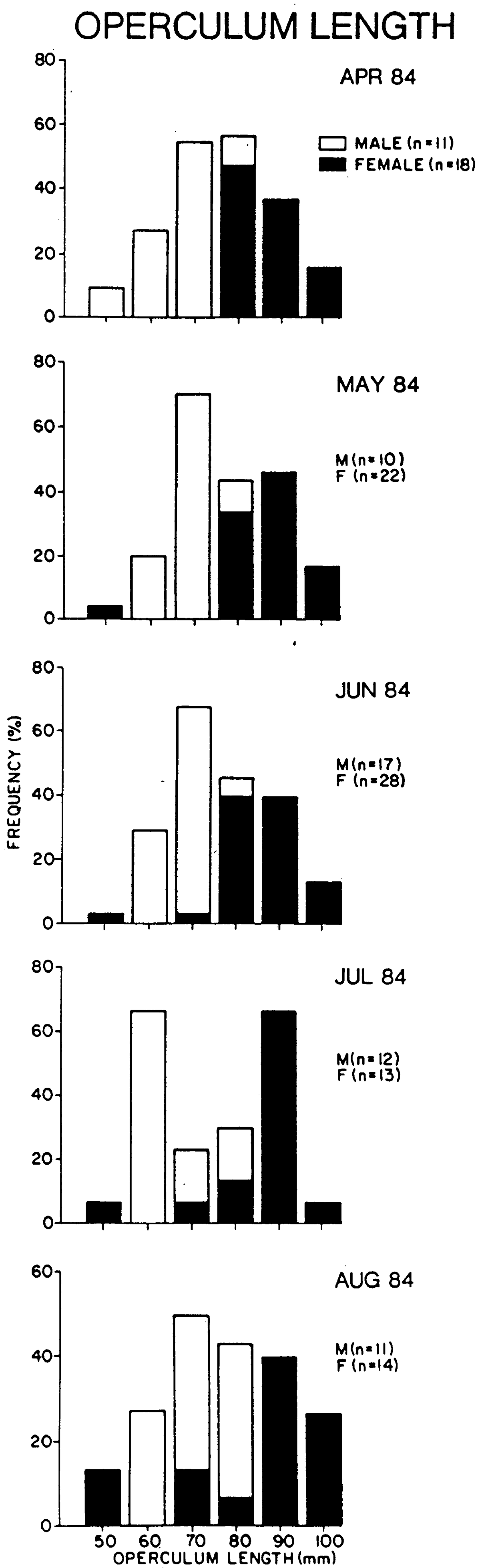

FOOT WEIGHT
APR 84
MALE (n=12)
FEMALE (n=18)
MAY 84
M(n=10)
F (n=22)
JUN 84
M(n=17)
F (n=28)
JUL 84
M(n=12)
F (n=14)
AUG 84
M(n=11)
F (n=14)
FREQUENCY (%)
0 100 200 300 400 500
FOOT WEIGHT (g)

Figure 41. Female and male *B. contrarium* opercula length (mm) by month.



OPERCULUM LENGTH
APR 84
MALE (n=11)
FEMALE (n=18)
MAY 84
M(n=10)
F (n=22)
JUN 84
M(n=17)
F (n=28)
JUL 84
M(n=12)
F (n=13)
AUG 84
M(n=11)
F (n=14)
FREQUENCY (%)
0
20
40
60
80
50 60 70 80 90 100
OPERCULUM LENGTH (mm)

Figure 42. Female and male B. *contrarium* opercula width (mm) by month.

OPERCULUM WIDTH

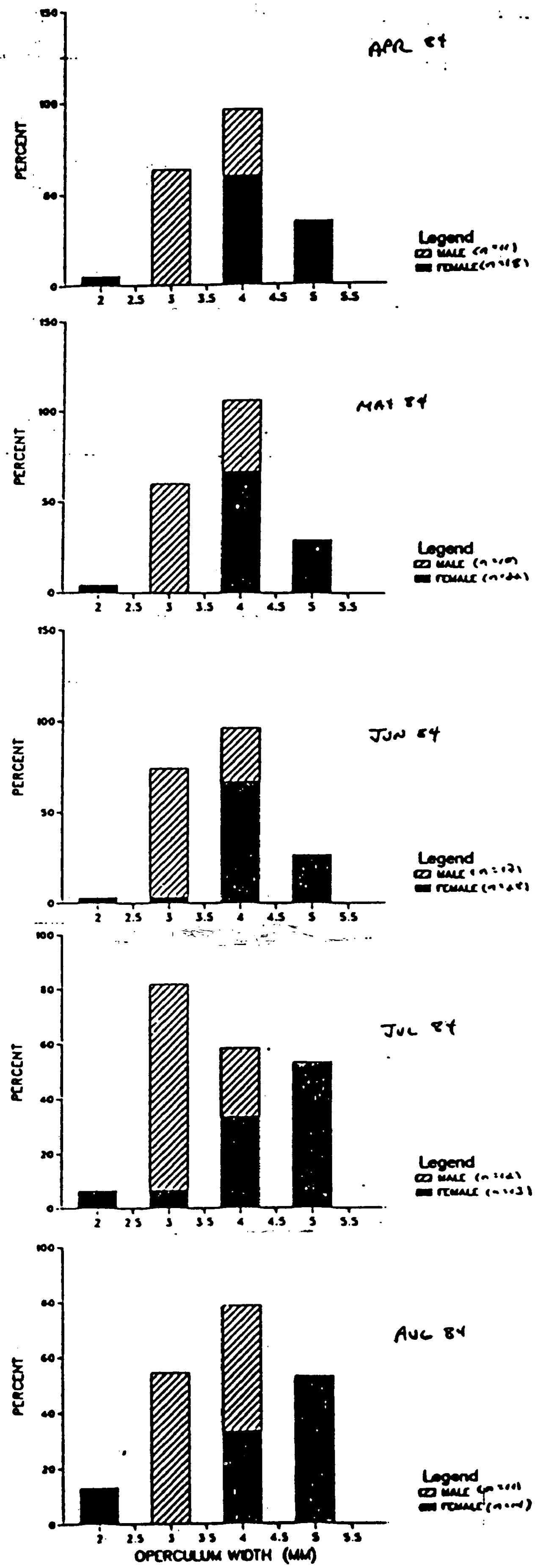


Figure 43. Female and male *B. contrarium* opercula weight (g) by month.

OPERCULUM WEIGHT

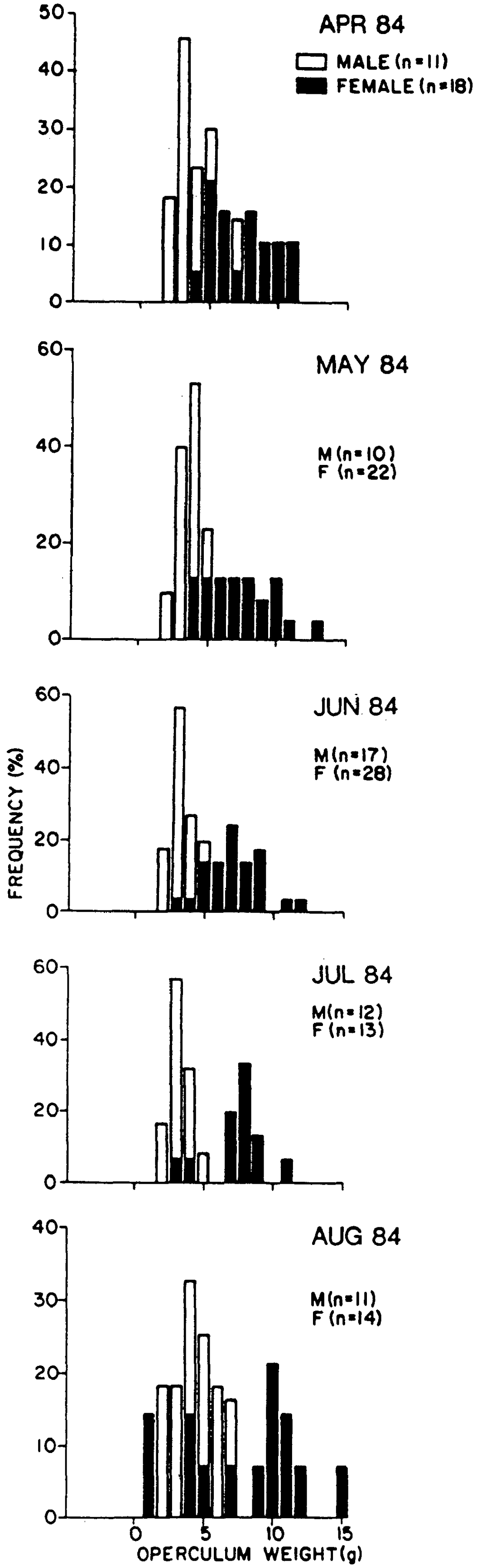
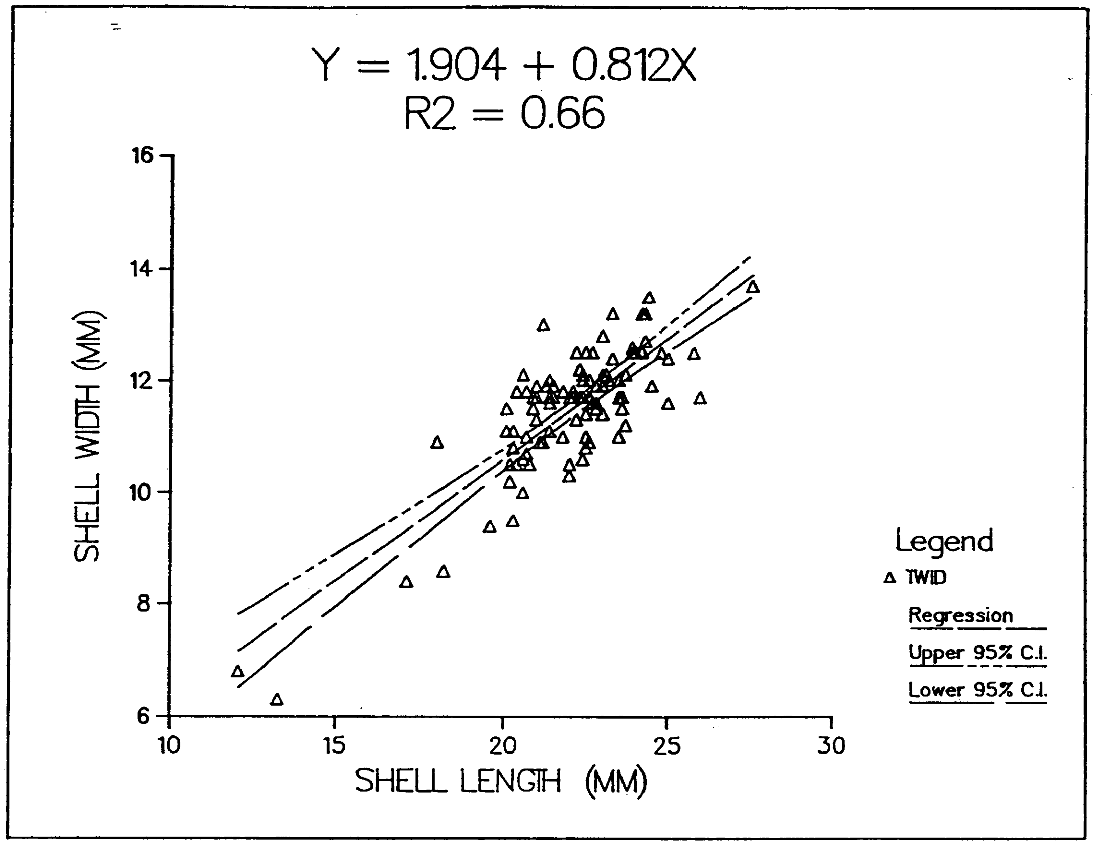
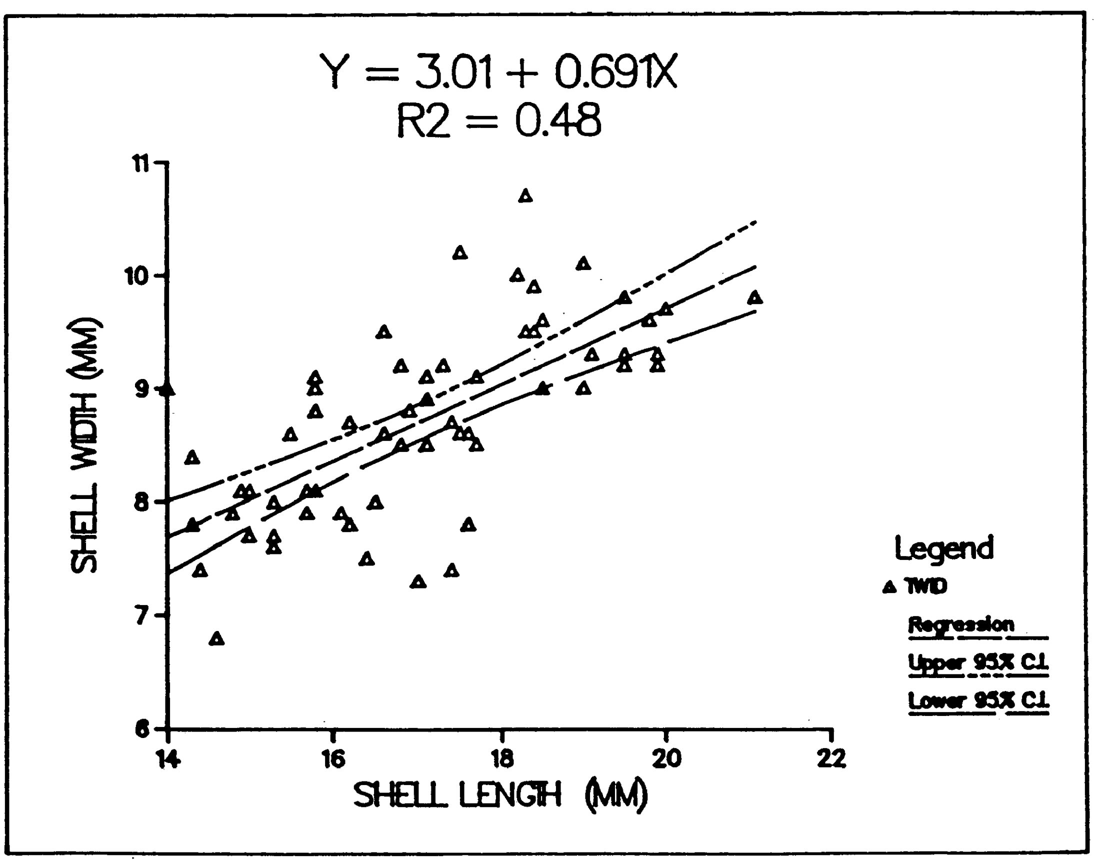


Figure 44. Female (above) and male (below) B. contrarium regression of shell width (mm) on shell length (mm).

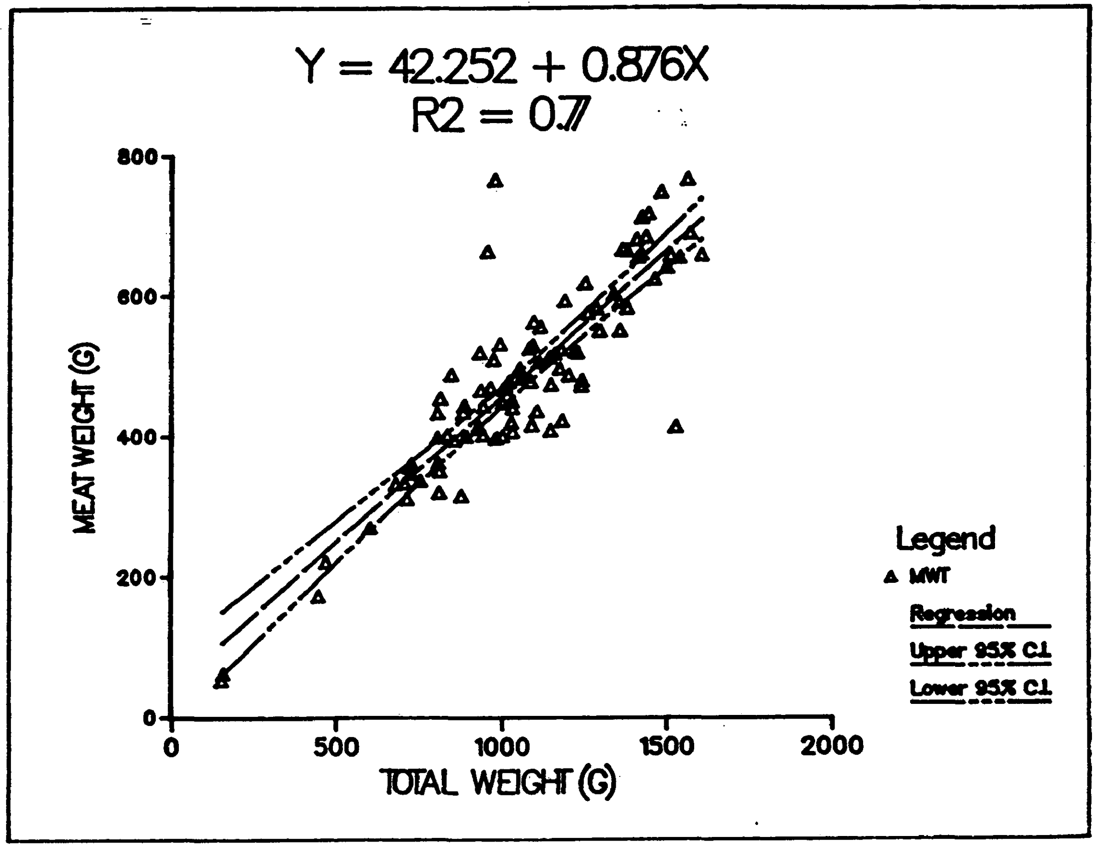


Y = 1.904 + 0.812X
R2 = 0.66
SHELL WIDTH (MM)
SHELL LENGTH (MM)
16
14
12
10
8
6
10
15
20
25
30
Legend
TWID
Regression
Upper 95% C.I.
Lower 95% C.I.



Y = 3.01 + 0.691X
R2 = 0.48
SHELL WIDTH (MM)
SHELL LENGTH (MM)
11
10
9
8
7
6
14
16
18
20
22
Legend
TWID
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 45. Female (above) and male (below) *B. contrarium* regression of meat weight (g) on total weight (g).


Y = 42.252 + 0.876X
R2 = 0.77
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
800
600
400
200
0
0
500
1000
1500
2000
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

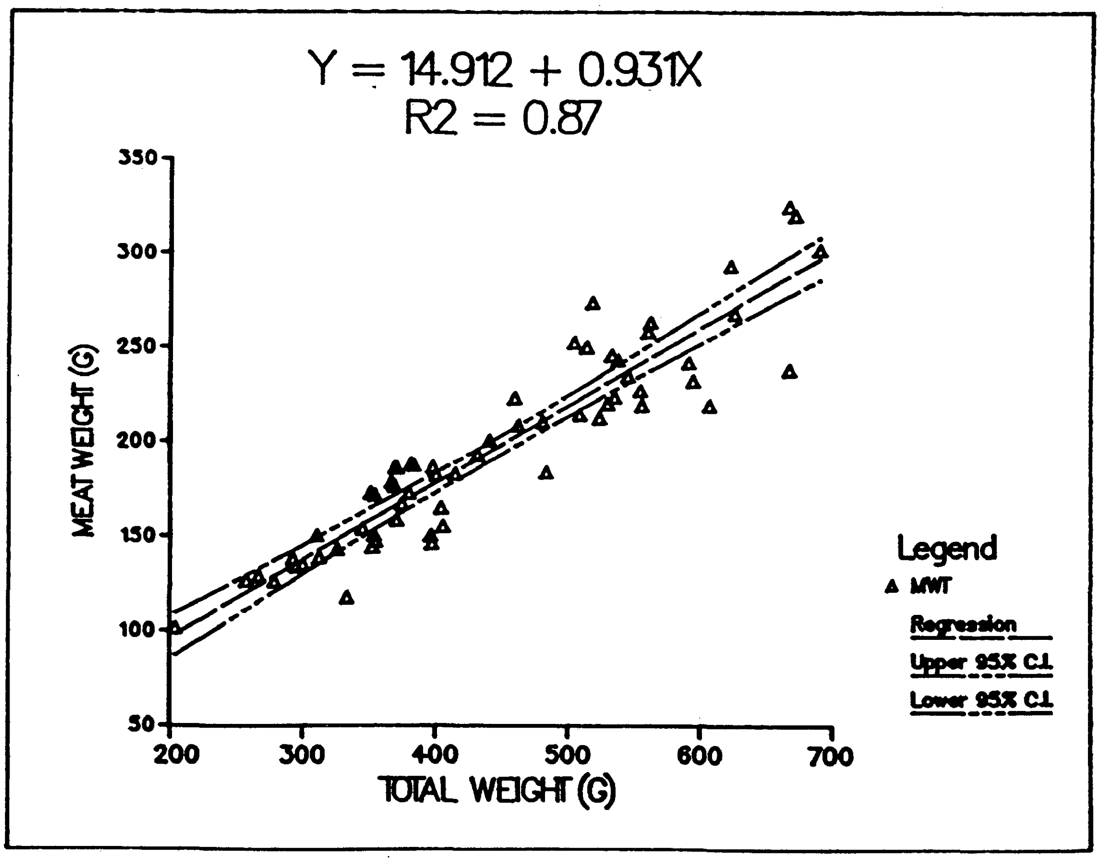
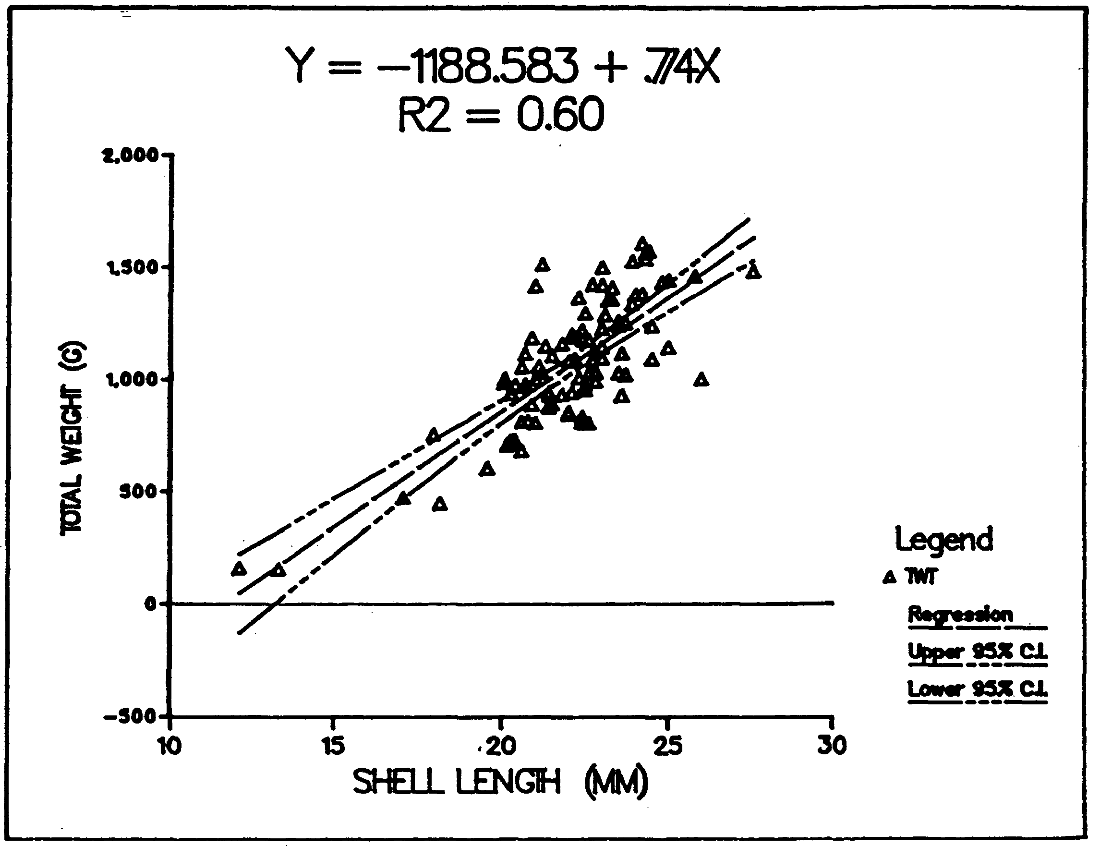
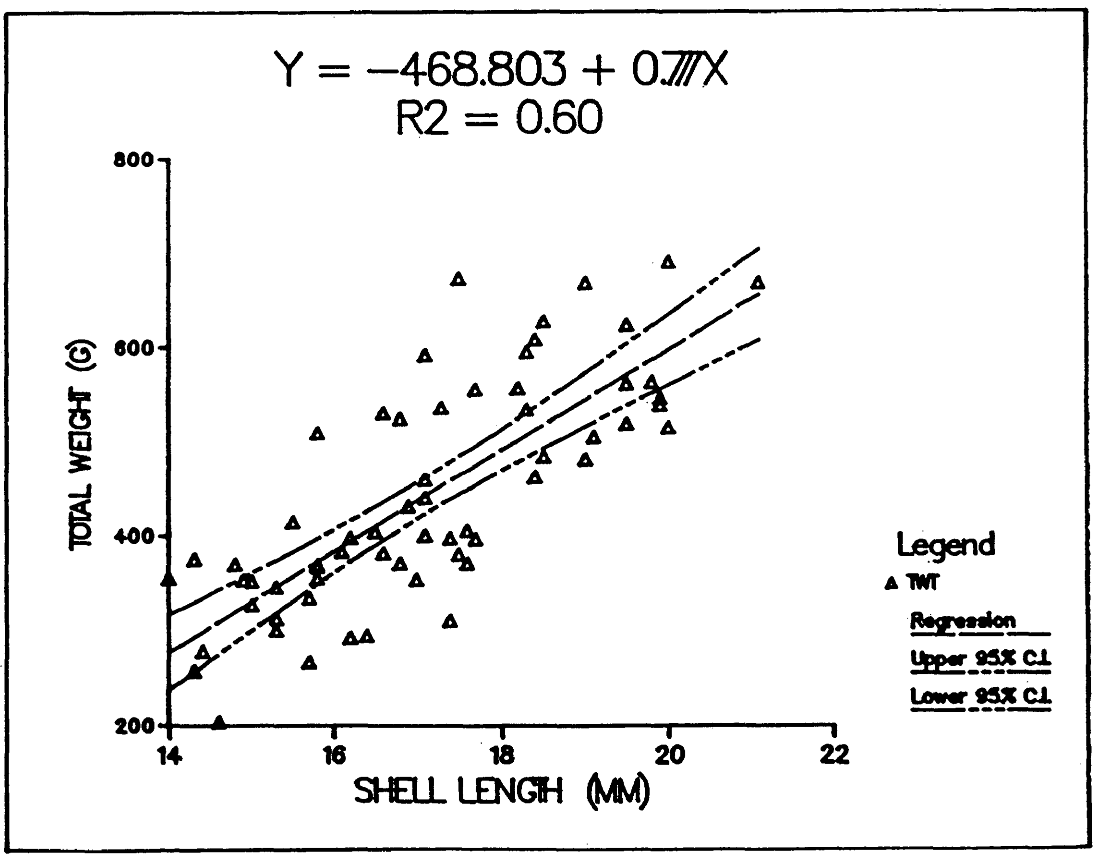

Y = 14.912 + 0.931X
R2 = 0.87
MEAT WEIGHT (G)
TOTAL WEIGHT (G)
350
300
250
200
150
100
50
200
300
400
500
600
700
Legend
MWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 46. Female (above) and male (below) B. *contrarium* regression of total weight (g) on shell length (mm).

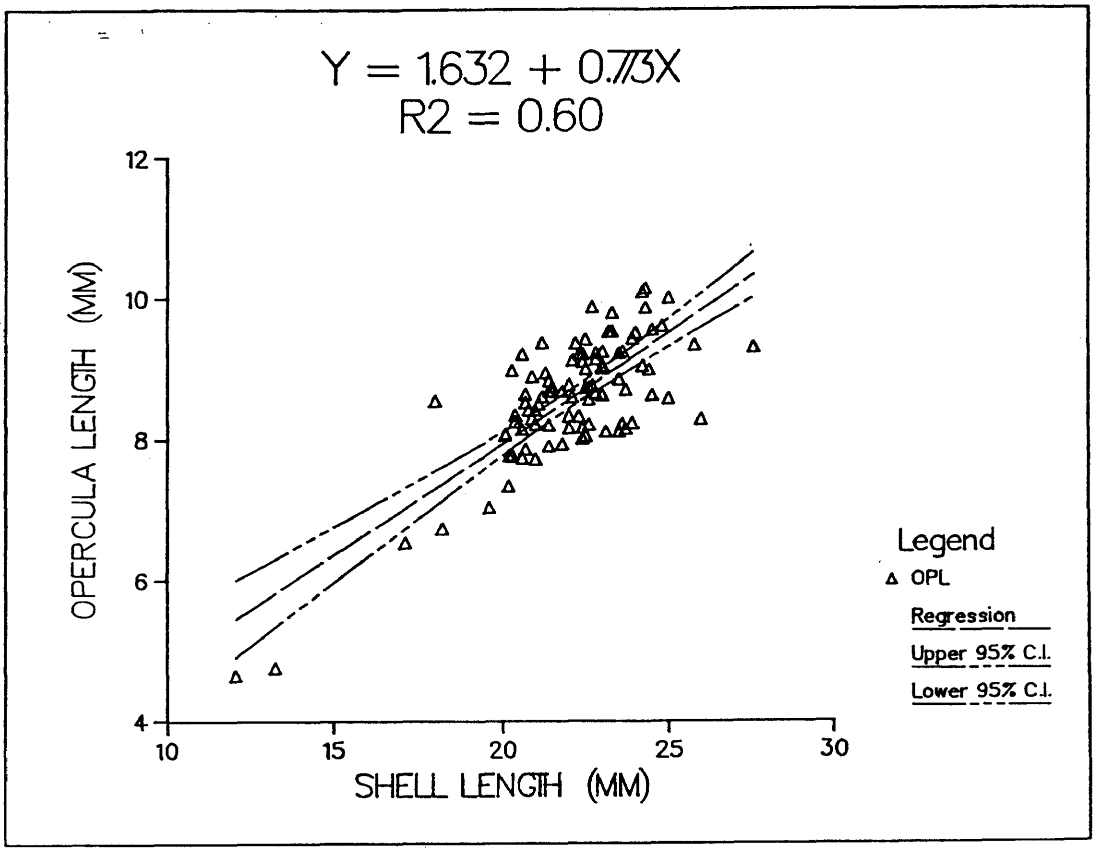


Y = −1188.583 + 74X
R2 = 0.60
2,000
1,500
1,000
500
0
−500
TOTAL WEIGHT (G)
10
15
20
25
30
SHELL LENGTH (MM)
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.

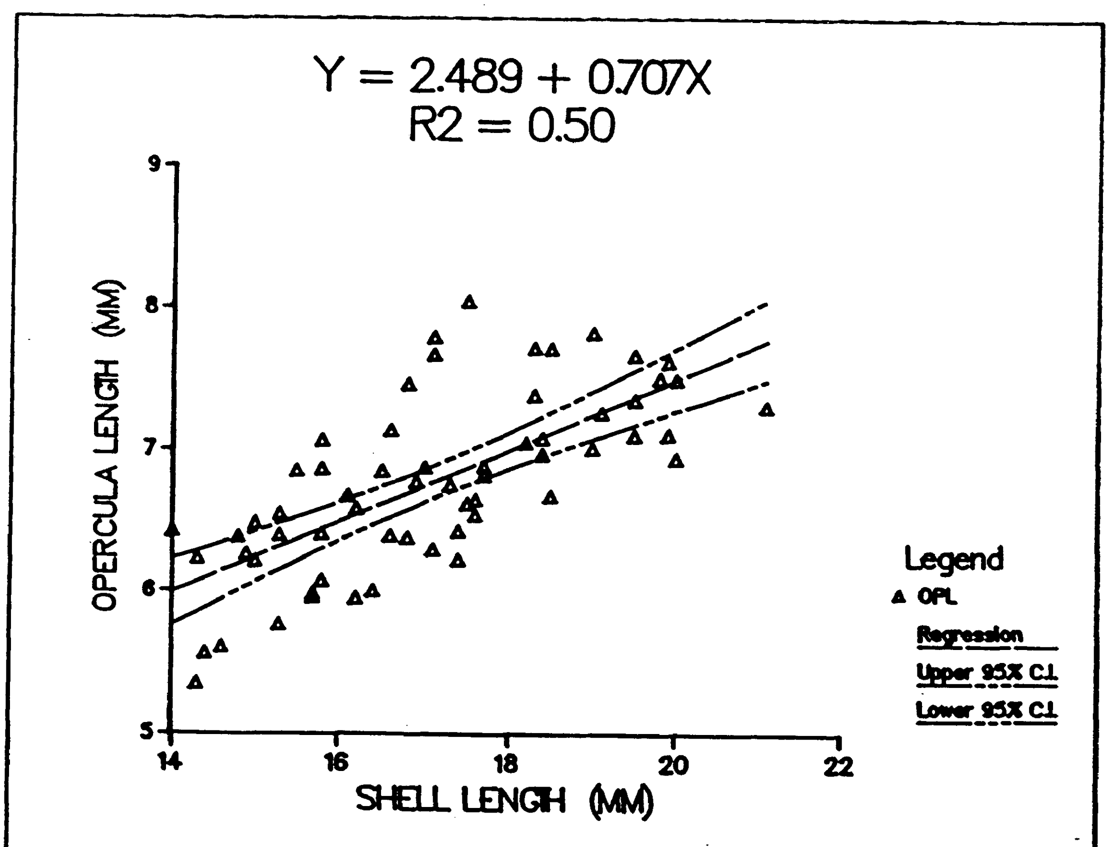


Y = −468.803 + 0.77X
R2 = 0.60
800
600
400
200
TOTAL WEIGHT (G)
14
16
18
20
22
SHELL LENGTH (MM)
Legend
TWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 47. Female (above) and male (below) *B. contrarium* regression of opercula length (mm) on shell length (mm).

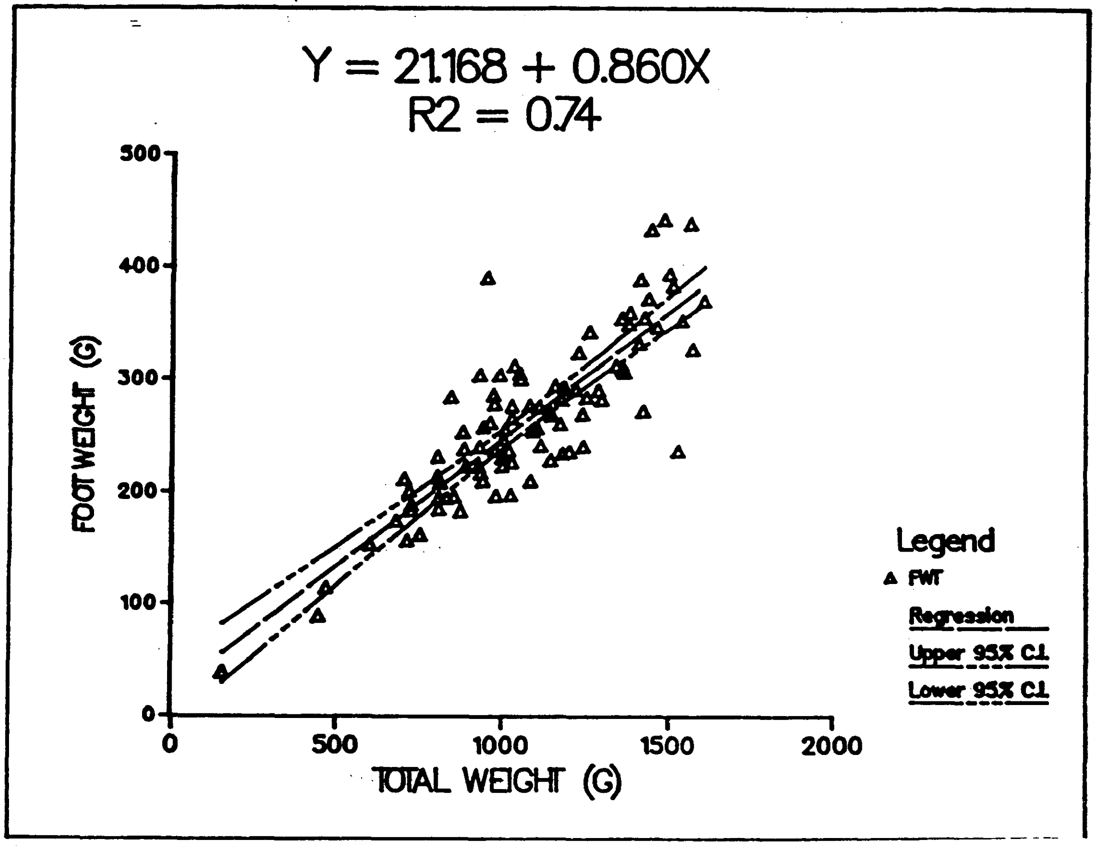


Y = 1.632 + 0.773X
R2 = 0.60
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
12
10
8
6
4
10
15
20
25
30
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

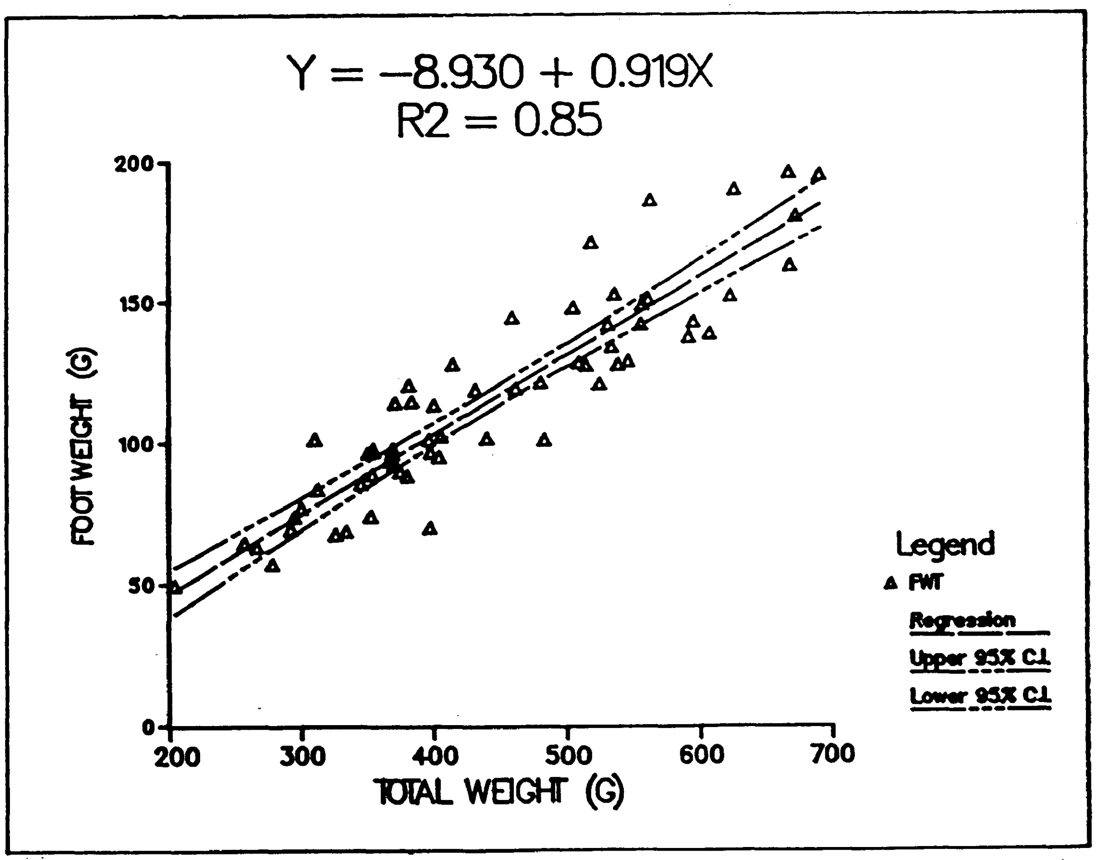


Y = 2.489 + 0.707X
R2 = 0.50
OPERCULA LENGTH (MM)
SHELL LENGTH (MM)
9
8
7
6
5
14
16
18
20
22
Legend
OPL
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 48. Female (above) and male (below) *B. contrarium* regression of foot weight (g) on total weight (g).



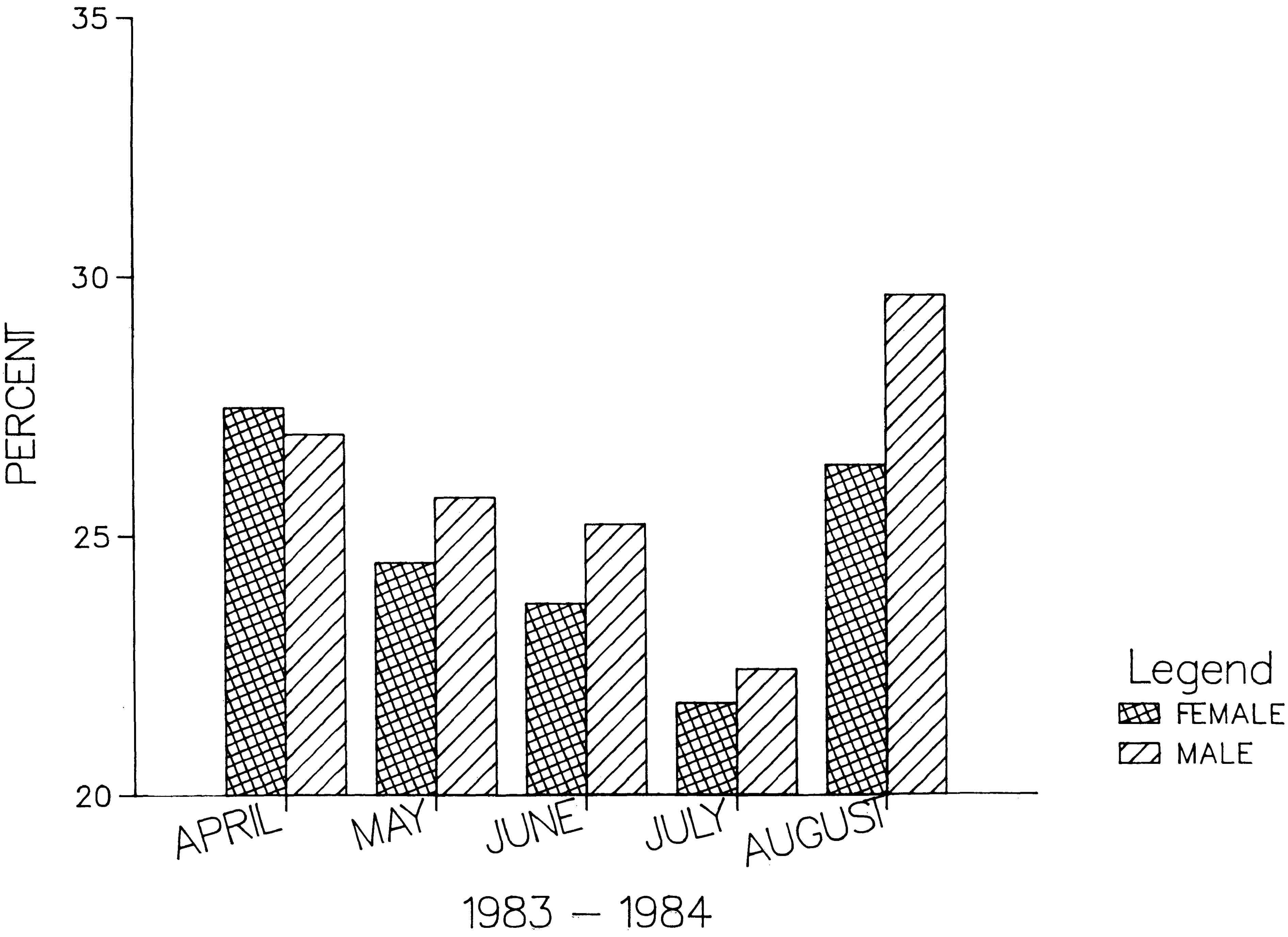
Y = 21.168 + 0.860X
R2 = 0.74
FOOT WEIGHT (G)
TOTAL WEIGHT (G)
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.



Y = −8.930 + 0.919X
R2 = 0.85
FOOT WEIGHT (G)
TOTAL WEIGHT (G)
Legend
FWT
Regression
Upper 95% C.I.
Lower 95% C.I.

Figure 49. Edible meat yield (foot weight/total weight) for

B. contrarium.


35
30
25
20
PERCENT
APRIL
MAY
JUNE
JULY
AUGUST
1983 — 1984
Legend
FEMALE
MALE

VITA

Born in Perth Amboy, New Jersey on May 28, 1959. Graduated from St. Mary's High School in South Amboy, NJ in 1977. Awarded summer student fellowhip at the University of Maryland Horn Point Environmental Laboratory to investigate barnacle distribution in the northern Chesapeake Bay. Received B.A. in Zoology with a minor in Psychology from Rutgers College in 1981.

Enrolled at the Virginia Institute of Marine Science Fall of 1982.Awarded research assistantship sponsored by Virginia Sea Grant in the Department of Advisory Services from 1982 through 1984.

Began four month internship in January 1985 with the Department of Commerce/Office of Ocean and Coastal Resource Management in Washington, D.C. to prepare sections of a study commissioned by Congress on the "consistency" clause of the Coastal Zone Management Act.

Employed by The Virginia Marine Resources Commission in April 1985 as a fisheries management specialist. First duty was to prepare a draft fishery management plan for the American oyster.