Exploratory Intertidal Clam Surveys in British Columbia - 1998

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Results of a 1998 exploratory intertidal clam survey to assess populations of commercially important clams on selected beaches in the North Coast District of British Columbia (B.C.) are presented. This survey was a continuation of exploratory clam surveys begun in 1990 to assess intertidal clam resources in the North Coast.

Primary focus in this survey was an assessment of Manila clam, *Venerupis philippinarum*, populations and dispersal since they are the most important intertidal clam species at present in the commercial fishery. No commercially exploitable stocks of Manila clams were found in this survey but a population was found at the head of Laredo Inlet 52° 58' N latitude, the farthest north the species is known to occur in B.C. Caamaño Sound appears to limit further northward dispersal of Manila clams in B.C.

Limited abundance and population structure information was also obtained on other potentially important commercial clam species including, butter, *Saxidomus giganteus*, littleneck, *Protothaca staminea*, soft-shell, *Mya arenaria*, cockles, *Clinodardium nuttallii*, and *Macoma* sp.

Factors affecting dispersal, abundance, establishment of populations and culture of Manila clams in the North Coast are discussed. The potential for commercial harvest of butter, littleneck, soft-shell clams and cockles is also discussed.

RÉSUMÉ

Gillespie, G.E. and N.F. Bourne. 2000. Exploratory intertidal clam surveys in British Columbia - 1998. Can. Manuscr. Rep. Fish. Aquat. Sci. 2508: 98 p.

Ce document présente les résultats d'une étude des populations intertidales de palourdes sur certaines plages de la région nord de la côte de la Colombie-Britannique pour déterminer s'il existe des stocks d'intérêt commercial à cet endroit. Il s'agit de la continuation des campagnes de recensement commencées en 1990 pour connaître les effectifs de palourdes dans les zones intertidales de la région nord de la côte.

L'accent a été mis sur les populations de palourdes japonaises, *Venerupis philippinarum*, et sur leurs zones de distribution, puisque c'est cette espèce qui présente actuellement le plus grand intérêt économique. Aucun stock commercialement exploitable n'a été trouvé dans la zone étudiée, mais une population a été découverte à l'embouchure de Laredo Inlet, à 52° 58' de latitude N, soit l'endroit le plus au nord où l'on trouve des palourdes japonaises en Colombie-Britannique. Il semble que la zone de Caamaño Sound est un obstacle à l'extension des populations de palourdes japonaises encore plus au nord.

Quelques renseignements sur l'abondance et la structure démographique ont également été obtenus sur d'autres espèces de palourdes présentant un potentiel économique : palourde jaune *Saxidomus giganteus*, palourde du Pacifique *Protothaca staminea*, palourde *Mya arenaria*, coques *Clinodardium nuttallii*, et *Macoma* sp.

Les auteurs traitent des facteurs qui affectent la répartition, l'abondance et l'établissement des populations de palourdes japonaises et leur culture dans la région nord de la côte. Ils traitent également de l'intérêt économique que présente la pêche aux palourdes jaunes, aux palourdes du Pacifique, aux palourdes *Mya arenaria* et aux coques.

INTRODUCTION

Intertidal clams continue to be an important commercial, recreational and subsistence resource to coastal communities and First Nations in British Columbia (B.C.). Commercial landings since 1951 have fluctuated greatly due to market demand, shifts in market preference, other socio-economic factors and availability (Webb and Hobbs 1997). Prior to 1980, the B.C. intertidal clam fishery was driven by demand for butter clams, *Saxidomus gigantea*, but landings of this species have declined greatly since then because of the high cost of harvesting and processing (Fig. 1). Since the late 1970's, commercial intertidal clam fisheries have been driven by demand for Manila clams, *Venerupis philippinarum* (= *Tapes philippinarum*), with minor landings of littleneck, *Protothaca staminea*, butter and razor clams, *Siliqua patula*. Small quantities of cockles, *Clinocardium nuttallii*, soft-shell clams, *Mya arenaria*, and horse clams, *Tresus capax* and *T. nuttallii*, were occasionally reported.

Landings of Manilas peaked in 1988 at 3,909 tonnes (t) but decreased since, largely due to reduction of accumulated stocks, management actions and loss of habitat to fecal contamination (Fig. 1). Recent increases in Manila clam landings include production from depuration fisheries, in which clams are held live in approved facilities until they purge themselves of fecal contamination, and thus reflect production from some beaches which would be inaccessible in the open commercial fishery. Preliminary Figures for 1998 indicate that landings of Manila clams comprised over 80% of the landed weight from the intertidal clam fishery, and depurated clams represented approximately 1/3 of commercially landed Manila clams (R. Webb, DFO, pers. comm.).

The North Coast area of B.C., Pacific Fishery Management Areas (PFMA) 1-10, has been closed to harvesting of intertidal clams since 1963, primarily because of chronic low levels of paralytic shellfish poisoning (PSP) (Quayle 1969) and the lack of monitoring programs to detect outbreaks of PSP and levels of bacterial contamination. A closely regulated permit system was initiated by DFO to allow harvest of intertidal clams in the North Coast but industry showed little interest in such harvest because of economic concerns. As a result, little assessment activity was directed towards intertidal clam stocks in the North Coast.

Manila clams were first found in the North Coast in 1972 and more extensive populations were found on some beaches in the Bella Bella area in 1980 (Bourne 1982). In 1990, a program was initiated to survey intertidal clam stocks in the North Coast (Bourne and Cawdell 1992), and further surveys were conducted in 1991 (Bourne *et al.* 1994), 1992 and 1993 (Bourne and Heritage 1997), 1994 and 1996 (Heritage *et al.* 1998) and 1997 (Gillespie and Bourne 1998). Information was gathered on stocks of all commercially important clam species, but the focus of most work was on assessment of Manila clam dispersal and the extent of populations in the North Coast.

Strong market demand and a decline in Manila clam landings after the peak in 1988 resulted in renewed industry interest in North Coast clam harvests. Exploratory surveys indicated that Manila clam populations in the North Coast were sufficient to support limited harvest, and presented an economic opportunity for the local community. A pilot fishery agreement was established between DFO and the Heiltsuk First Nation in 1992 to allow commercial harvest of intertidal clams from the Bella Bella area (parts of PFMA 7) (Gillespie *et al.* 1999). No butter clams have been landed, only a few minor landings of littleneck clams were made, and Manila landings have fluctuated considerably (Fig. 2).

The present survey was a continuation of the exploratory survey program, designed to provide information on distribution, general abundance and population characteristics of commercially important intertidal clam species, primarily Manila clams, in the North Coast.

SURVEY METHODS

Methods were similar to those used in previous surveys (Bourne and Cawdell 1992; Bourne *et al.* 1994; Bourne and Heritage 1997; Heritage *et al.* 1998; Gillespie and Bourne 1998). Beaches were selected for survey from charts (using area of the intertidal and substrate information), as well as from previous experience and information from Fisheries Officers and local inhabitants. As in previous surveys, time constraints required that we maximize the number of beaches explored during a tide, rather than exhaustively surveying one or two beaches (as in Gillespie and Kronlund 1999). Results give general estimates of clam distribution and abundance in the surveyed areas, not statistically rigorous stock estimates. It was also decided to intensify work at the head of inlets, since oceanographic conditions in these localities are thought to be suitable to support Manila clam populations.

A brief survey was made of each beach visited to assess the presence or absence of intertidal clams and determine the area of the clam-bearing part of the beach prior to sampling. Clam-bearing area was estimated by making exploratory scratches to delimit clam distribution, and roughly estimating the area encompassed. Subjective categories of slope and substrate type of the beach were recorded. The high tide line was surveyed for drift shell of intertidal clams. In addition, large rocks, which are used by birds to drop and break clams, were examined for shell fragments. In the past, evidence of the presence of Manila clam has been determined with these latter assessment methods.

Clam distribution was assessed by digging test scratches. When aggregations of clams were found, quadrats of 0.25 or 1.00 m^2 were dug. Quadrats in the upper portion of the intertidal zone (0.25 m^2 targeting mainly on Manila clams and to a lesser degree on littleneck clams) were dug with a clam scraper to a depth of about 15 cm. Quadrats lower on the beach (1 m^2 targeting mainly on butter clams and to a lesser extent on littleneck clams) were dug with a potato fork to a depth of about 35 cm. In both cases, the dug substrate was reworked back into the quadrat through the fingers, to detect clams missed when the quadrat was initially dug. All dug clams were washed, bagged and labeled for processing. Additional information was gathered on incidental species of invertebrates found on beaches and some specimens were collected to confirm identification.

Total length of each clam (the longest anterior-posterior length) was measured to the nearest mm with vernier calipers. Shell height, from the umbo to the ventral shell margin, was measured for cockles. Ages were determined by counting annuli (Quayle and Bourne 1972). Length/height and age frequency distributions were determined and graphed. Length/height at annulus was measured for a representative sample of littlenecks, butter, soft-shell clams and cockles. Mean length/height at annulus and confidence intervals were calculated and graphed. This provided size and age distribution and growth rate information for these species in each area surveyed.

Surface water temperature at a depth of ~30 cm was recorded with a standard hand held thermometer in Borrowman Bay, Kitasu Bay, Bolin Bay, Poison Cove, Anger Inlet and Wilson Inlet. Five minute surface plankton tows, using a 40 cm diameter frame and 70 µm mesh net, were made in Laredo Inlet and Surf Inlet to determine the presence or absence of Manila clam larvae.

Samples of Manila clam gonads were collected at three locations, Corney Cove in Meyers Passage, at the head of Laredo Inlet, and in Windy Bay in Sheep Passage, preserved in Davidson's solution, blocked in paraffin, sectioned at 5 µm, stained with haematoxylin-eosin and examined microscopically to determine the stage of gonadal development after the method of Holland and Chew (1974).

RESULTS

Thirty-five beaches were surveyed in six areas: eight beaches at Aristazabal Island; five beaches in the Meyers Passage-Laredo Inlet area; five beaches in Finlayson Channel; six beaches in the Sheep Passage-Mussel Inlet-Mathieson Channel area; seven beaches in the Chapple Inlet-Surf Inlet area; and four beaches in the Anger Island-Cosine Island-Wilson Inlet area (Table 1; Fig. 3).

ARISTAZABAL ISLAND

During the 1994 survey, live Manila clams were found on two beaches in Weeteam Bay and on one beach in Clifford Bay on the southwest side of Aristazabal Island and shell was found on two more beaches in Weeteam Bay, but extensive populations were not found at either location (Heritage *et al.* 1998). In the present survey, sampling was undertaken to determine if Manila clams had dispersed further northward along the eastern side of Hecate Strait and the outer coast of Aristazabal Island. In this survey, sampling was confined to two areas along the northwestern part of Aristazabal Island, Borrowman Bay and Kettle Inlet (Fig. 4).

Borrowman Bay

Borrowman Bay is a large bay on the northwestern shore of Aristazabal Island (Fig. 3). The bay opens directly onto Hecate Strait, but is afforded some protection by Trickey Island and the Wall Islets at its mouth, and by the Anderson Islands across Beauchemin Channel. Turtish Harbour and the southeastern shore of the bay are further protected by Thomson, Tarte and Wilks Islands. Six beaches were examined during this survey (Fig. 4).

Physical Description Of Beaches:

Beach 1: A small beach (total area approximately 400 m^2) on the north side of Borrowman Bay that was moderately to steeply sloped, with rocks and rockweed, *Fucus* sp., in the upper intertidal, and a small area (approximately 50 m^2) of good clam habitat on the lower intertidal, above an eelgrass, *Zostera* sp., bed (Table 2). Substrate in the lower intertidal was sand and gravel.

Beach 2. A small beach (total area approximately 400 m^2) with a moderate slope opposite Wilks Island that was located between two rocky headlands (Table 2). The lower intertidal was sand and eelgrass, and the extreme upper intertidal was rocks and rockweed. The mid-intertidal had approximately 200 m^2 of good clam habitat.

Beach 3. A beach at Turtish Harbour that was the large estuary of Stannard Creek (total area approximately 4-5 ha), divided into two sections by bedrock outcrops (Table 2). The upper section was a gently sloped sand/gravel beach, approximately 2-3 ha in size. The lower section, approximately 2 ha in size, was gently sloped sand/silt/gravel, covered with a thick mat of filamentous green algae.

Beach 4. A small beach (total area approximately 0.5 ha) at Tate Cove with a steeply sloped upper intertidal of broken rock and rockweed, and a gently sloped lower intertidal of mud, sand and gravel (Table 2).

Beach 5. A beach opposite Thompson Island with a moderate slope that was about 1 ha in area, divided into two 0.5 ha portions by a rocky point (Table 2). The lower portion was mud-gravel and the upper portion was firmer substrate.

Beach 6. A more exposed, extensive beach at Switzer Cove that had a moderate slope with soft substrate divided by rocky headlands (Table 2).

Clam Populations: Numerous test scratches were dug on all six beaches to assess the presence or absence of clams. Sample quadrats of either 1 m^2 or 0.25 m^2 were dug at Beaches 2, 4 and 5 (Table 3).

Butter Clams. Dead shell of butter clams was common on all six beaches and live animals were found in test scratches in the lower parts of the beaches (Table 3). In sample quadrats, abundance ranged from 0-48 clams m^{-2} (Table 3). There was a wide distribution of length and age frequencies (Fig. 5). Growth was similar to growth of butter clams in the North Coast, it required about 8 years to attain a size of 63 mm total length (TL), the legal size in the commercial fishery (Fig. 6).

Littleneck Clams. Littleneck clams were the most common bivalve found on beaches in Borrowman Bay. Dead shells were abundant and live littlenecks were common in test scratches. Abundance ranged from 7-124 clams m^{-2} in sample quadrats (Table 3). There was a large number of smaller littlenecks, 16-20 mm TL, age 2, and larger clams, >38 mm, ages 7-9 years (Fig. 7). As observed in previous years, many of the littlenecks were stunted (stunting is an abnormal growth pattern in which clams are shorter and rounder than would be expected, generally due to very slow growth).

Manila Clams. No live Manila clams or dead shells were found on any of the six beaches despite numerous test scratches.

Other Species. Cockles were common in the lower part of the six beaches and a density of 28 m^{-2} was found on Beach 2 (Table 3). They were particularly numerous on Beach 3, many were on the surface under the algal mat and 94 were collected from the surface and when siphon shows were detected on this Beach. Most were 6-8 years old (Fig. 8) and they attained a shell height of 60 mm in about 5 years (Fig. 9).

Live or dead shell of *Macoma* sp., false-jingle, *Pododesmus macrochisma*, bay mussel, *Mytilus* sp., sea mussel, *Mytilus californianus* and horse clams, *T. capax* were found in the area (Table 2). One soft-shell clam was found on Beach 4.

At Beach 2, the seastars *Solaster* sp. were common on soft substrate and *Pisaster* sp. on rock areas. Mud shrimp, *Upogebia pugettensis*, were common at Beach 4.

Other Observations: Water temperature was 13°C off Beach 4.

Kettle Inlet

Kettle Inlet is a long narrow inlet immediately southeast of Borrowman Bay. It is fairly steep-sided, with few extensive beach areas. Two beaches were surveyed, one at the outlet of a small creek on the south side of the inlet near the head, and an extensive estuarine beach at the head of the inlet (Fig. 4). The survey was hampered somewhat because of a flooding tide

Physical Description Of Beaches:

Beach 7. A beach divided into an upper and lower part by a rocky headland, both parts with moderate slopes (Table 2). The lower portion was at least 1.5 ha and the upper portion 1 ha. Substrate of the upper part was sand/silt and the lower part was sand/gravel.

Beach 8. A beach with a low slope and divided by three fish weirs (Table 2). The beach above the highest weir was rocky and had no clams. The beach between the highest and middle weir was about 2 ha in area and had a substrate of sand/gravel/broken rock. The beach between the middle and lower weir was about 2 ha in area and had a substrate of sand/gravel. The lower part of the beach could not be examined because of the flooding tide.

Clam Populations: Numerous test scratches and five sample quadrats were dug on the two beaches (Table 3).

Butter Clams. Dead shell of butter clams was found on both beaches but no live animals were found in sample plots since sampling was only by scrapers and high on the intertidal beach, outside the habitat of butter clams.

Littleneck Clams. Littlenecks were the most common bivalve found and density ranged from 0-156 clams m^{-2} (Table 3). Most were small, <38 mm TL (the legal size in the commercial fishery) and the dominant ages were 6-8 (Fig. 10). As in Borrowman Bay, many of the littlenecks were badly stunted.

Manila Clams. One live Manila clam, 45 mm TL and 5 years in age was found on Beach 2. Kettle Inlet, 52°41' N is the farthest north Manila clams have been found in the Hecate Strait area. The population was very sparse and it is doubtful if a breeding population exists in this area.

Other Species. Soft-shell clams were common on both beaches and abundance ranged from 13-256 clams m^{-2} (Table 3). Most were large, >45 mm TL, and most ranged in age from 3-9 years (Fig. 11). They attained a size of 50 mm TL in about 4 years (Fig. 12).

Cockles were moderately abundant on both beaches. The dire whelk, *Lirabuccinium dirum*, was common on Beach 2.

MEYERS PASSAGE-LAREDO INLET

Assessment of Manila clam dispersal in the Meyers Passage and Laredo Inlet areas was undertaken during this survey to extend observations of earlier surveys. In the 1990 intertidal clam survey, Manila clams were found in Kitasu Bay but not on three beaches in the central part of Meyers Passage (Bourne and Cawdell 1992). Since then, information provided by K. Cripps (Kitasoo First Nation, pers. comm.), indicated Manila clams were present on a beach at the western end of this Passage. In the 1994 survey, Manila clams were present at the Bay of Plenty, about half way up Laredo Inlet, which was the farthest north the species had been found in B.C. (Heritage *et al.* 1998). Time did not permit further sampling of this area to determine if Manila clams had spread farther northward in this inlet.

During the present survey, intensive sampling was undertaken in the Meyers Passage area to determine if extensive Manila clam populations existed there, since this could be a route for dispersal of the species into Tolmie and Finlayson Channels. Sampling was also undertaken at the head of Laredo Inlet to determine if Manila clams had spread that far north. The survey at the head of Laredo Inlet was limited because of a flooding tide.

Meyers Passage

Meyers Passage is a narrow passage that connects Laredo Sound with Tolmie and Finlayson Channels (Fig. 3). Formerly, it was an important butter clam harvest area for the Kitasoo First Nations people. As stated above, three beaches were surveyed there in 1990 but no Manila clams were found at that time (Bourne and Cawdell 1992). Four beaches were explored in the present survey (Fig. 13).

Physical Description of Beaches:

Beach 1. Two small beaches opposite Saunders Point in Meyers Passage. Area of the first beach was about 1,500 m^2 and about 250 m^2 for the second (Table 2). Slope of both beaches was low to moderate. Substrate of the first beach was mainly rock with sand/shell in between; the lower portion of the second beach was mainly sand/silt with eelgrass, the upper portion was sand/gravel.

Beach 2. A small triangular beach east of Saunders Point with a low slope and a substrate of broken rock/sand/shell (Table 2).

Beach 3. A beach about 1.5 ha in area at the narrows in Meyers Passage with a low slope and a substrate of sand/silt/gravel, much of which was covered with an algal mat (Table 2). This beach was sampled during the 1990 survey.

Beach 4. A small beach at the head of Corney Cove at the western end of Meyers Passage with an area about 300 m^2 and a low-moderate slope and a substrate of sand/silt/gravel (Table 2).

Clam Populations: Numerous exploratory scratches were dug on all four beaches to assess the presence of clam populations. Sample quadrats were dug on Beaches 3 and 4 (Table 3).

Butter Clams. Butter clams were found on all four beaches in Meyers Passage and dead shell was abundant. Density at Beaches 3 and 4 ranged from 0-45 clams m^{-2} (Table 3). Most butter clams were large, over 63 mm TL and most were between 10-12 years old (Fig. 14). Growth was similar to that found in other areas in the North Coast, it required about 8 years to attain a size of 63 mm TL (Fig. 15), which was similar to the growth rate for butter clams in Kitasu Bay in the 1990 survey (Bourne and Cawdell 1992).

Littleneck Clams. As observed on many beaches in the North Coast, the most common bivalve in Meyers Passage was littleneck clams. They were common on all four beaches and abundance ranged from 0-204 clams m^{-2} (Table 3). There were no small littlenecks, ages 1-3;

most were large, >38 mm TL and between 7-10 years in age (Fig. 16). As observed elsewhere, many littlenecks were badly stunted.

Manila Clams. Manila clams were found only on Beach 4, the head of Corney Cove, at the western end of Meyers Passage. Density ranged from 0-36 clams m^{-2} (Table 3). There were no small Manilas, ages 1-3; most were large, >38 mm TL and 5 and 6 years of age (Fig. 17), which indicates there has been little if any recent recruitment. Manila clams have been on this beach for some time (at least ten years) as indicated by the amount of old dead shell. Growth was moderate and it required 3.5-4 years to attain a size of 38 mm TL (Fig. 18).

The fact that no Manila clams were found on beaches further to the east of Corney Cove in Meyers Passage indicates dispersal into Tolmie and Finlayson Channels probably has not occurred through this Passage.

Other Observations: Samples of gonads from 15 Manila clams from Corney Cove were examined to determine the state of gonadal development. Gonads of most males were ripe, four showed some initial spawning; most females were ripe but one showed evidence of some spawning (Table 4).

Surface water temperature at Kitasu Bay was 13.5°C.

Laredo Inlet

Laredo Inlet opens into Laredo Channel just northwest of Meyers Passage, and terminates 20 miles north, near Brew Island (Fig. 3). The inlet is steep sided, with few extensive clam beaches. There was an extensive beach at the head of Laredo Inlet, in the Arnoup Creek estuary (Fig. 19). Unfortunately only a cursory survey could be undertaken there because of a flooding tide.

Physical Description Of Beach:

Beach 5. Area of the beach could not be estimated because of the flooding tide. The beach had a low slope and substrate of the part of the beach and a bar in the estuary that was surveyed was sand/mud/gravel (Table 2).

Clam Populations:

Butter Clams. Butter clam shell was observed in the water but no live animals were found because the tide was too high.

Littleneck Clams. Littleneck clam shell was observed in the water but no live animals were found.

Manila Clams. Most sampling was confined to a sand bar in the estuary at the head of the inlet. There was considerable dead Manila clam shell on the sand bar and nine live animals that ranged in size from 13-48 mm TL and in age from 1-6 years were found (Fig. 20). Both dead shell and live animals were used to calculate a growth curve for Manilas in this area. Growth was slow and it required about 4.5 years to attain a size of 38 mm TL (Fig. 21). Since animals of several ages were found, it is obvious that the population has been there for several years and that regular recruitment has occurred, either from local breeding or from settlement of larvae from elsewhere.

This is the farthest north that Manila clams have been found in B.C. (Lat 52°58'N) and perhaps the farthest north they have been found in the world. A more thorough survey should be undertaken of this area during a suitable tide to obtain a better assessment of the extent of Manila clam populations there.

Other Observations: Unfortunately, the temperature of the surface water was not recorded, however, the water felt quite warm to the touch and it was estimated the temperature was 16-18 °C.

A five minute surface plankton two was taken in this area. Few bivalve larvae were present; most were mussels, *Mytilus* sp., but there were a few littleneck and soft-shell clam larvae along with unidentified species.

Gonads of six Manila clams were examined to determine the state of sexual development. Most males were ripe, one showed some initial spawning; one female was ripe and the other showed some initial spawning (Table 4).

Finlayson Channel

Finlayson Channel runs north from Milbanke Sound for 24 miles, where it divides into Sheep Passage, which runs northwest to Mathieson Channel and Mussel Inlet, and Hiekish Narrows, which runs northwest to Princess Royal Channel (Fig. 3).

In previous studies, cursory surveys in the Klemtu area of Finlayson Channel failed to find any live Manila clams or dead shell. Further, there were no reports from other sources of the presence of Manila clams in this area. During the present survey, a thorough assessment was undertaken in the Finlayson Channel area to determine if Manila clams had spread this far north. Five beaches were visited, all on the eastern side of the channel (Fig. 22).

Physical Description Of Beaches:

Beach 1. A beach in Mary Cove about 1 ha in area with a low slope and a substrate of broken rock/sand/silt (Table 2). The upper intertidal margins of the beach were predominantly rocky substrate.

Beach 2. A beach 3-4 ha in area in a long estuary at the southeast corner of Watson Bay that had a low/moderate slope and a substrate of sand/silt/broken rock (Table 2). A small stream ran through the centre of the beach.

Beach 3. A large beach of 12-15 ha in an extensive estuary at the head of Bottleneck Inlet that had a low slope and a substrate of sand/silt/gravel/broken rock (Table 2). The margins were gravel/broken rock.

Beach 4. A large beach 4-5 ha in area on the north side of Wallace Bight that had a low slope and a substrate of sand/broken rock (Table 2).

Beach 5. A large beach about 20 ha in area with a low slope and a substrate of sand/silt in Carter Bay at the northern end of Finlayson Channel or the eastern end of Sheep Passage that was exposed to wind and sea from Finlayson Channel (Table 2). A deep stream, Carter River, divided the beach.

<u>Clam Populations</u>: Clams were modestly abundant on Beaches 1-4 but few were found on Beach 5, probably because of the exposed nature of the beach. Sample plots were dug on Beaches 2 and 3.

Butter Clams. Live butter clams and dead shell were common on Beaches 1-4. In sample plots dug on Beaches 2 and 3, density ranged from 0-44 clams m^{-2} (Table 3). Butter clams at Watson Bay ranged in size from 45-85 mm TL and from 5-14 years in age (Fig. 23). Growth was similar to that found in other areas of the North Coast, requiring about 8 years to attain a size of 63 mm TL (Fig. 24).

Littleneck Clams. Littleneck clams were a common bivalve on Beaches 1-4, density ranged from 0-432 clams m^{-2} on Beaches 2 and 3 (Table 3). Most were large, >38 mm, and most were 6-8 years of age (Fig. 25). Many were badly stunted.

Manila Clams. Only one live Manila clam was found (Beach 3) on the five beaches, but dead shell was found on Beaches 2 and 3 (Table 2). Manila clams have not spread into Finlayson Channel in large numbers. Both the live animal and dead shell were used to calculate a growth rate for Manila clams in the area. Growth was slow, requiring 4.5-5 years to attain a size of 38 mm TL (Fig. 26).

<u>Other Species</u>. Cockles were common on Beaches 2, 3 and 4 (Table 2). At Beach 2, all were 2 and 3 years of age and ranged in shell height from 22-51 mm (Fig. 27).

Soft-shell clams were common at Beaches 2 and 3 (Table 2). In a sample taken at Beach 3, they ranged in age from 5-10 years and from 46-81 mm TL (Fig. 28). Growth was similar to that observed on other beaches in the North Coast, it required about 5.5 years to attain a size of 50 mm TL (Fig. 29).

Macoma nasuta, *Macoma* sp., bay mussels, and horse mussels, *Modiolus* sp., were found on some beaches (Table 2).

SHEEP PASSAGE-MUSSEL INLET-MATHIESON CHANNEL

Sheep Passage is located at the northern end of Finlayson Channel and extends eastward to Mussel Inlet and Poison Cove (Fig. 3). Beaches in this area were surveyed to determine if Manila clams had dispersed this far northward. The southern part of Mathieson Channel was surveyed in 1990 (Bourne and Cawdell 1992); during the present survey work was undertaken to survey the northern part of this Channel to assess northward dispersal of Manila clams in this area.

Sheep Passage

Sheep Passage is a narrow channel at the northern end of Finlayson Channel, that runs eastward and then northeast to Mussel Inlet. Sides of the channel are steep, with only a few pocket beaches. Two beaches were visited (Fig. 30).

Physical Description Of Beaches:

Beach 1. A beach in Bolin Bay in a broad estuary with two stream channels crossing it (Table 2). It was 7-8 ha in area with a low slope and substrate of sand/silt/gravel. There were some bars present that were covered with barnacles, bay mussels and *Fucus* sp.

Beach 2. A large beach in Windy Bay located in a large estuary with a single stream running through it (Table 2). It was about 20 ha in area with a low/moderate slope. Substrate of the upper half was rocks covered with *Fucus* sp., the lower part was good clam habitat.

Clam Populations: Sampling focussed on determining whether Manila clams were present in this area. Three sample quadrats were dug on Beach 1 and four on Beach 2.

Butter Clams. Evidence of butter clams, dead shell and live animals, was found on both beaches. Sample quadrats were dug in the upper intertidal area and hence few butter clams occurred in these samples, maximum 8 clams m^{-2}; all were small (Table 3).

Littleneck Clams. As was observed on many beaches in the North Coast, littlenecks were the most common bivalve on the two beaches and density was as high as 552 clams m^{-2} (Table 3). Most (95%) were <38 mm TL, however, this was not a reflection of young age classes but of badly stunted clams, since most clams were 5-9 years of age (Fig. 31).

Manila Clams. Both dead shell and live Manila clams were found on both beaches but they were more common at Windy Bay; density ranged from 0-24 clams m^{-2} (Table 3). At Windy Bay, all were 3-6 years of age and most were >38 mm TL, indicating no recruitment in the past three years (Fig. 32). Growth was slow and it required 4.5-5 years to attain a size of 38 mm TL (Fig. 33).

Since few Manila clams were found in Finlayson Channel, it is possible that populations on these two beaches have resulted from dispersal northward through Mathieson Channel.

Other Species. Cockles, soft-shell clams and *Macoma inquinata* were found at Beach 2.

Other observations: Water temperature was 14°C off Beach 2, Windy Bay.

A sample of gonads from 22 Manila clams from Windy Bay showed that males were either ripe or showed initial signs of spawning. Most females were ripe but three showed some evidence of spawning (Table 4).

Mussel Inlet

Mussel Inlet runs north from the convergence of Sheep Passage and Mathieson Channel, and then northeast to its terminus at Mussel Bay and Poison Cove. Three beaches were examined in Mussel Inlet (Fig. 30).

Mussel Inlet has particular historic significance when discussing shellfish harvests and paralytic shellfish poisoning (PSP). The first recorded fatality due to PSP in British Columbia occurred June 15, 1793, when a crew member on Capt. George Vancouver's vessel died, and three others became quite ill, after eating mussels from Poison Cove (Vancouver 1798). The names Mussel Inlet and Poison Cove were coined by Vancouver after the incident. The crew member that died, John Carter, was buried in Carter Bay, which was named in his honour.

Physical Description Of Beaches:

Beach 3. A large beach about 15 ha in area in an estuary with two stream channels (Table 2). Low slope and a sand/silt substrate. It is a dynamic beach and the surface is probably greatly altered at times by the two streams. The beach was poor habitat for clams.

Beach 4. A beach that was 7-8 ha in area with a low/moderate slope and a substrate of broken rock/sand/silt covered with bay mussels, barnacles and *Fucus* sp. (Table 2). Most of the beach was broken rock and poor habitat for clams.

Beach 5. A small beach at the head of Oatswish Bay with primarily a rocky substrate covered with *Fucus* sp. (Table 2). No clam habitat was visually apparent, and we did not stop to survey.

Clam Populations: Beaches 3 and 4 were poor habitat for clams mainly due to the dynamic nature of the beaches. Beach 5 had no suitable clam habitat. Two sample quadrats were dug in the softer substrate on Beach 4.

Butter Clams. A few butter clams were found at Beach 4, density 0-12 clams m^{-2} (Table 3). This was not unexpected because of the sample location and poor clam habitat on the beach.

Littleneck Clams. Littleneck clams were the most common bivalve found on both surveyed beaches and density ranged from 2-252 clams m^{-2} (Table 3). Size ranged from 9-53 mm TL but most were old, 7-10 years of age, indicating extensive stunting (Fig. 34).

Manila Clams. No evidence was found of Manila clams on either surveyed beach (Table 3).

Other Species. Soft-shell clams and bay mussels were found on beach 3 and 4, cockles and *Macoma* sp. were found on beach 4.

Other Observations: Water temperature off Beach 4, Poison Cove was 14.5°C.

Mathieson Channel

Mathieson Channel runs 36 miles north from Milbanke Sound to Sheep Passage. Seven beaches were surveyed in southern Mathieson Channel in 1990: four in Rescue Bay, one in Jackson Narrows, one at Hird Point and one at Salmon Bay (Bourne and Cawdell 1992). Manila clams were found at Hird Point, about half way up Mathieson Channel. During the present survey they were found in Sheep Passage at the head of Mathieson Channel, and it was of interest to determine if they occurred on beaches between Sheep Passage and Hird Point. This would indicate that this channel and not Finalyson Channel was the route for northward dispersal of Manila clams. One beach was surveyed in James Bay (Fig. 30).

Physical Description of Beach:

Beach 6. A large beach, >10 ha in area, in a large, long estuary at James Bay with a deep stream channel down the center (Table 2). The slope was low/moderate and most of the substrate was sand/silt. It was a dynamic beach with sand bars and the surface is probably altered frequently by the stream.

Clam Populations: Because of the flooding tide, sampling was confined to exploratory scratches to determine the presence of Manila clams. No sample quadrats were dug.

Butter Clams. Dead shell was found on the beach and butter clams undoubtedly occur in suitable habitat.

Littleneck Clams. The ubiquitous littleneck clam was found on the beach and was probably common.

Manila Clams. One live animal and dead shell were found on the beach. Both were used to estimate growth rate; growth was slow, it required about 5 years to attain a size of

38 mm TL (Fig. 33). Manila clams occur throughout Mathieson Channel although abundance is probably low on most if not all beaches.

CHAPPLE INLET - SURF INLET

Surf Inlet extends northeast from the northern end of Laredo Channel and the southern end of Caamaño Sound (Fig. 3). Chapple Inlet opens into Surf Inlet and runs northwest. In this and other surveys, Manila clams were found in bays on the outer coast of Aristazabal Island and in Trahey Inlet at the southern end of Laredo Channel (this survey, Heritage *et al.* 1998). Caamaño Sound is located at the northern end of Aristazabal Island (Fig. 3) and sampling was undertaken in the Surf Inlet area to determine if the Caamaño Sound area is the limit of northward dispersal of Manila clams. Seven beaches were sampled, the first three in Chapple Inlet, and the last four on the south side of Surf Inlet (Fig. 35). There was a logging operation about the middle of the west side of Chapple Inlet.

Physical Description Of Beaches:

Beach 1. A beach in Kiln Bay was briefly examined but not sampled (Table 2). The upper intertidal was mostly boulders covered with *Fucus* sp.

Beach 2. The beach at the head of Chapple Inlet had an area about 8 ha, but only about 2 ha was exposed at the time of sampling (Table 2). Slope of the part of the beach sampled was low/moderate and the substrate was sand/silt/gravel.

Beach 3. A small saddle beach about 0.5 ha in area between an island and the mainland at McKechnie Point with a moderate slope and a substrate of sand/silt/shell (Table 2). The upper part was covered with dead clam shell.

Beach 4. A narrow beach about 0.5 ha in area at Argyh Cove with a large stream channel on the side (Table 2). Moderate/steep slope with a substrate mostly of sand in the lower part and boulders on bedrock in the upper part.

Beach 5. A beach at Adams Bay with an area about 4 ha but only about 0.5 ha of good clam habitat (Table 2). Low/moderate slope and a substrate of broken rock/sand/silt.

Beach 6. A beach about 4 ha in area at Penn Harbour with a large stream channel on the side (Table 2). Low slope and a substrate of silt/sand/broken rock in the lower part of the beach below a rocky part.

Beach 7. The beach at the head of Surf Inlet was about 2 ha in area but half of it was rocky with several stream channels (Table 2). The other half had a low/moderate slope and a substrate of sand/silt/broken rock.

Clam Populations: The tide was rather high when beaches in Chapple Inlet were sampled, thus only limited information on the clam species present could be collected. Sample quadrats were dug at Beaches 2, 3, 4 and 6 and observations were made on all bivalve species of commercial interest.

Butter Clams: Evidence of the presence of butter clams, either dead shell or live animals, was found on most beaches in the area. Density in sample quadrats ranged from 0-20 clams m^{-2} (Table 3). Density might have been higher if sampling had been undertaken in more suitable habitat during lower tides.

A growth curve calculated for butter clams collected in Chapple Inlet showed that growth was extremely slow; by 7 years they had only attained a size of 45 mm TL (Fig. 36). Slow growth may have been due to sampling in unsuitable habitat, high in the intertidal area. In Surf Inlet, all butter clams collected were older than 7 years and larger than 60 mm TL (Fig. 37). Growth of these butter clams was faster and they attained a size of 63 mm TL in about 8 years (Fig. 36), which is similar to the growth rate in other North Coast areas. Butter clams were probably abundant in suitable habitat on most beaches in this area.

Littleneck Clams. As observed on many beaches in the North Coast, littleneck clams were the most abundant bivalve on most beaches in the Chapple and Surf Inlet areas; density ranged from 0-660 clams m^{-2} (Table 3). In Chapple Inlet they ranged in age from 3-12 years and in size from 18-40 mm (Fig. 38). In Surf Inlet they ranged from 5-8 years in age and from 32-46 mm TL (Fig. 39). As observed on many other beaches in the North Coast, many were stunted.

Manila Clams. No live Manila clams or dead shell were found on any beaches in this area.

Other Species. Soft-shell clams were found on most of the beaches and a sample was collected at Beach 2, where density was as high as 106 clams m^{-2} (Table 3). They ranged in size from 34-90 mm TL, in age from 2-9 years (Fig. 40) and attained a size of 50 mm TL in about 4 years (Fig. 41).

Live animals or dead shell of bay mussels, horse clams, *T. capax*, cockles and *Macoma* sp. were found on several of the beaches.

Other observations: A five minute surface plankton tow was taken near the head of Surf Inlet. Few bivalve larvae were found. Most were *Mytilus* sp., but some clam larvae were present. No Manila clam larvae were found.

ANGER ISLAND – COSINE ISLAND – WILSON INLET

Anger Island is on the southwest side of Pitt Island, where Petrel Channel joins Principe Channel (Fig. 3). Two beaches were explored in Anger Inlet, one on Cosine Island and one in Wilson Inlet (Fig. 42).

Beaches in the Anger Anchorage area of Principe Channel have been surveyed on previous occasions (Bourne 1982). The area was important for harvesting butter clams until it was closed because of high levels of PSP (Quayle 1969). An outbreak of PSP in Prince Rupert in August, 1964, was traced to butter clams dug at Cosine Island (Quayle 1969). Fortunately, no fatalities resulted.

In 1969 about 100 Manila clams from the Baynes Sound area were planted on the beach at Cosine Island. Although some survived for a year, apparently no breeding occurred, probably because of low water temperatures, and no evidence of the population was found during a survey in the mid 1970's (Bourne 1982). During the present survey, extensive sampling was undertaken to determine if a vestigial population of Manila clams had survived somewhere in the general area. Four beaches were visited in this area and sample quadrats were dug on three (Table 2; Fig. 42).

Physical Description of Beaches:

Beach 1. A small beach with a low slope in Anger Inlet that was about 1.5 ha in area and had a substrate of sand/silt/broken rock around the border and silt/sand in the centre (Table 2).

Beach 2. A beach about 0.5 ha in area above a rock berm at the mouth of Anger Inlet that had a small lagoon in it (Table 2). Low slope and a substrate of silt/sand/mud/broken rock along the sides and silt/sand/mud in the centre.

Beach 3. A beach on the east side of Cosine Island about 0.8 ha in area with a low/moderate slope and a substrate of broken rock/sand/silt around the edge and sand/silt in the centre (Table 2). The Manila clam transplant was made at this beach in 1969.

Beach 4. A beach at the head of Wilson Inlet about 1.0 ha in area with a low/moderate slope (Table 2). Substrate of the upper half of the beach was broken rock/sand. There was a long bar that extended from the mouth of the stream that had a sand/silt substrate.

Clam Populations: Most sampling focussed on determining whether Manila clams existed in this area but sampling was undertaken to assess populations of other bivalve species. Sample quadrats were dug on Beaches 1, 3 and 4.

Butter Clams. Butter clams were common on all four beaches and density ranged from 0-72 clams m^{-2} (Table 3). There was a difference in the populations between the beaches. At Anger Island (Beach 1) butter clams were 41-66 mm TL and 4-12 years in age (Fig. 43). At Cosine island (Beach 3) they were 40-93 mm TL and 4-15 years in age (Fig. 44). Growth at Anger Island was slower than at Cosine Island; it required about 10 years for butter clams to attain a size of 63 mm TL at the first beach compared to about 7 years at the latter beach (Fig. 45).

Littleneck Clams. Littleneck clams were the most abundant bivalve species in this area; density ranged from 32-156 clams m^{-2} (Table 3). As observed elsewhere, many of the littlenecks were badly stunted. There was a difference in populations at Beaches 1, 3 and 4. At Beach 1 (Anger Island), most littlenecks were badly stunted and ranged in size from 29-45 mm TL and 6-8 years in age (Fig. 46). At Beach 3 (Cosine Island), there was wider range in size and age distribution, 18-63 mm TL and 2-10 years in age (Fig. 47). At Beach 4 (Wilson Inlet), there was also a wide distribution of size and age classes, 12-51 mm TL and 2-9 years in age (Fig. 48). Growth rate was calculated for littlenecks at Cosine Island; it required about 5 years to attain a size of 38 mm TL (Fig. 49).

Manila Clams. No evidence of Manila clams, dead shell or live animals, was found on any of the four beaches. It is obvious that a population of Manila clams did not become established in this area as a result of the 1969 transplant, probably because low water temperatures did not permit successful breeding.

Other Species. Cockles were common at Beaches 3 and 4. At Beach 4 they ranged in shell height from 45-79 mm and in age from 2-7 years (Fig. 50). Growth of this population is shown in Fig. 51.

Horse clams, *T. capax*, *Macoma nasuta*, *M. inquinata*, *M. balthica*, soft-shell clams and *Pododesmus cepio*, were found on the beaches.

Burrowing sea cucumbers, *Cucumaria* sp., were found at Beach 2.

Other Observations: Water temperature was 14° C in both Anger Inlet and Wilson Inlet.

DISCUSSION

The 1998 exploratory clam survey provided considerable new information on intertidal clam resources in the North Coast, particularly on the northward dispersal of Manila clams. This information should be valuable in developing management policies for commercially important species.

BUTTER CLAMS

Butter clams were a common bivalve in suitable habitat in the lower third of many beaches sampled during this survey. Although only limited sampling was specifically devoted to assessing the extent of butter clam populations, densities as high as 72 clams m^{-2} were found (Table 3). Generally there was a wide range in sizes and ages in the populations, indicating that recruitment has been consistent at some level in past years (Figs. 5, 14, 23, 37, 43 and 44). Growth was similar for most beaches, it required about 8 years to attain a size of 63 mm TL (Figs. 6, 15, 24, 36 and 45). Some stunting was observed, particularly when sampling occurred high in the intertidal zone.

Results of this survey corroborate those in other surveys (Bourne and Cawdell 1992; Bourne *et al.* 1994; Bourne and Heritage 1997; Heritage *et al.* 1998; Gillespie and Bourne 1998). Butter clam populations on many beaches in the North Coast are sufficient to support commercial harvesting, however, with the current economic situation for harvesting and processing butter clams and with the additional cost of surveys to assess PSP and bacterial levels, it is doubtful if there is any interest on the part of industry to harvest butter clams in this area.

If PSP and bacterial monitoring concerns were alleviated, butter clams, along with littleneck clams, would likely support a significant recreational fishery, as well as supporting First Nations food, social and ceremonial needs.

LITTLENECK CLAMS

As observed in previous surveys, littleneck clams were the most common bivalves on most beaches sampled during this survey. They were found from the low intertidal to well above mid intertidal levels in a variety of habitats in densities as high as 660 clams m^{-2} (Table 3). There was a wide range in size and age distribution indicating that recruitment has been consistent over past years (Figs. 7, 10, 16, 25, 31, 34, 38, 39, 46, 47 and 48). Growth varied with location and position on a beach but under optimum conditions it required 4-5 years to attain a size of 38 mm TL (Fig. 49).

As with butter clams, populations of littleneck clams in the North Coast could support commercial harvest, however, the current market for steamer clams shows little interest in this species. This is unfortunate since harvest of littlenecks could contribute to the economies of North Coast communities. A potential project might be to encourage acceptance of this species in the market, which could lead to establishment of a commercial fishery for littlenecks in the North Coast.

Many littlenecks were badly stunted, indeed some were so badly stunted that it was difficult to identify them. In severe instances, littlenecks that were 10 years in age had not attained a size of 38 mm TL. They had an appearance of a small round nut and would be difficult to identify for the novice. The splotched colour pattern that is common on shells of littlenecks in the South Coast area was rarely found on littlenecks in the North Coast, and never found on stunted clams.

It would be of interest to determine the cause of this stunting. High densities (causing crowding) and poor habitat (too high in the intertidal zone) may contribute to the condition but it is not the entire explanation since stunted clams often occurred with normal growing clams in area of high densities or in areas high on the beach.

Stunted clams affect growth estimates. If only normal growing clams are included in growth assessments, then the stunted part of the population is not represented in the growth estimate of the population. If stunted clams are included in growth estimates, then it can lead to a much slower estimate of growth of normal clams in the population. Because one objective of this survey was to collect data for comparison of optimal growth rates in other areas, only normal growing clams were used in growth rate estimates. The high incidence of stunted littlenecks on most beaches surveyed discouraged us from measuring growth rates, as these would likely not represent optimal growth. Only one estimate of growth was made for littleneck clams at Cosine Island (Fig. 49) and these took approximately 5 years to reach 38 mm TL. This is somewhat slower growth than in Georgia Strait (3.5-4 years to 38 mm TL) (Quayle and Bourne 1972), similar to growth rates (4-5 years to 38 mm TL) recorded for other North Coast locations by Bourne and Cawdell (1992), and more rapid than growth rates of intertidal littlenecks recorded from Masset Inlet and Naden Harbour, Queen Charlotte Islands (Gillespie and Bourne 1998).

MANILA CLAMS

Results of this survey provided further information on the northward dispersal of Manila clams in B.C. and the state of these populations.

Dispersal

A major focus of this survey was to study the northward dispersal of Manila clams in B.C. and if possible determine dispersal pathways. Work was concentrated in six areas: Hecate Strait, Caamaño Sound, Laredo Inlet, Meyers Passage, Finlayson and Mathieson Channels and Sheep Passsage (Fig. 3).

A single Manila clam was found in Kettle Inlet on the northwest coast of Aristazabal Island, but none was found in Borrowman Bay slightly farther north (Fig. 4). In a previous survey a few live Manila clams and some dead shell were found in two bays on the southwest coast of Aristazabal Island (Heritage *et al.* 1998). Aristazabal Island appears to be the northern limit of Manila clam dispersal along the east side of Hecate Strait, and it is doubtful if these populations are sufficient to support extensive breeding. The residual tidal current is northward along the east side of Hecate Strait (Thomson 1981) but it appears that few Manila clam larvae have survived in these waters in the vicinity of Aristazabal Island, at least too few to permit establishment of large populations on the outer coast of this island. This current does not appear to be important to the northward dispersal of Manila clams.

In a previous survey an extensive population of Manila clams was found in Trahey Inlet at the southern end of Laredo Channel (Heritage *et al.* 1998). In the present survey extensive sampling was undertaken in Surf Inlet at the northern end of Laredo Channel and the southern end of Caamaño Sound (Figs. 3 and 35). No Manila clams were found in the Surf Inlet area and it would appear that Caamaño Sound is a barrier to further northward dispersal of Manila clams. In future it would be worth examining beaches in Laredo Channel to determine if Manila clams occur throughout this Channel or only in the southern part.

The occurrence of Manila clams at the head of Laredo Inlet is of interest since it is the farthest north the species has been found in B.C. and is probably the farthest north that a natural population occurs in the world. Successful establishment of Manila clam populations at the head of some inlets in the North Coast may be due to unique environmental conditions that are conducive to the establishment of Manila clam populations. Most have large rivers that provide nutrients. Circulation is probably restricted in these areas permitting surface waters to become warm which would be favourable to gonadal development and spawning. The restricted circulation and warm waters would lead to rapid larval growth and retention of the larvae in the immediate area thus leading to successful breeding and establishment of populations. Biological and oceanographic investigations are needed to explain why these areas support Manila clam populations.

The occurrence of a small Manila clam population at the western end of Meyers Passage, but not on beaches to the eastward, indicates that Manila clam dispersal into Finlayson and Mathieson Channels probably resulted from spawnings in the Bella Bella area that spread northward through Milbanke Sound rather than through Meyers Passage (Figs. 3 and 13). Populations in Finlayson Channel and the northern part of Mathieson Channel were sparse, but a reasonable population of Manila clams was found at Windy Bay in Sheep Passage at the northern end of Finlayson and Mathieson Channels (Fig. 30). This is probably near the northern limit of Manila clam distribution in this area. Although there are few beaches in Tolmie Channel and the Graham Reach area of Princess Royal Channel, it would be worth surveying these beaches in future to determine if Manila clams occur father north than Sheep Passage (*i.e.*, north of latitude 53°N).

When reasonable numbers of Manila clams were found at the northern limits of dispersal, more than one year class was present indicating successful recruitment in more than one and sometimes several years (Figs. 17, 20 and 32). Whether this recruitment results from local successful breeding or from transport of larvae from other areas farther south is unknown, but warrants further investigation. One would suspect that in some places, such as the head of Laredo Inlet and Windy Bay, that successful local breeding is occurring.

Populations

No commercially exploitable Manila clam populations were found during this survey. This is understandable since the survey was undertaken in areas at the northern extremity of the range of Manila clams and sparse populations would be expected. Modest populations were only found in two locations, Corney Cove and Windy Bay (Figs. 13 and 30), and both populations could be easily harvested in less than a tide. Maximum density at Corney Cove was 36 clams m^{-2} and 24 clams m^{-2} at Windy Bay (Table 3). At both locations most of the Manila clams were 4-6 years of age, indicating little recent recruitment (Figs. 17 and 32). There was considerable dead Manila clam shell on the beach at Corney Cove, indicating the population had been there for several years, likely ten or more. On beaches where only a few live animals occurred, little or no dead shell was found indicating the population on those beaches was never large.

Another reason no commercially exploitable Manila clam populations were found during this survey was the lack of suitable habitat. Most of the shoreline was steep sloped with few beaches that were often small and steep sloped (Table 2). The central part of many of these beaches was soft mud and suitable habitat for Manila clams was present only around the perimeter of the beaches and then there was often considerable rock and cobble in this area. Areas of suitable Manila clam habitat were limited.

A possible exception to the lack of extensive habitat for Manila clams was the beach at the head of Laredo Inlet, which appeared to be large and had a low slope and a substrate of sand/shell/gravel. Warm surface waters and a restricted circulation would be favourable for Manila clams and a large population may exist in this area. Although based on very few individuals (n=9), the growth rate estimated for this beach was slower than for other beaches examined, requiring between 5-6 years to reach 38 mm TL. The area warrants a much more thorough investigation to determine if a significant Manila clam population exists there, and if it does, what environmental factors have permitted establishment of the population.

Growth

Growth of Manila clams was similar in most surveyed areas, it required 3.5-4.5 years to attain a size of 38 mm TL (Figs. 18, 21, 26 and 33). This growth rate is only slightly slower than growth rates found in optimum growing areas farther south around Bella Bella (Bourne and Cawdell 1992; Bourne *et al.* 1994; Heritage *et al.* 1998). In spite of different environmental conditions at the various locations, growth was similar indicating that Manila clams can grow under a variety of environmental conditions. Only at the extremities of their range was growth slightly slower than recorded optimum conditions (Figs. 21, 26 and 33).

Breeding

It is obvious from this and other surveys (Bourne *et al.* 1994; Heritage *et al.* 1998; Gillespie *et al.* 1999) that successful Manila clam breeding is occurring in the North Coast of B.C. Evidence for this is seen from examining year class distribution and from histological studies.

Where modest populations of Manila clams were found, more than one year class was present, indicating repeated although perhaps low recruitment. At the extremities of distribution, this recruitment may result from settlement of larvae from spawnings elsewhere, but nevertheless spawnings are occurring regularly in some localities in the North Coast.

Histological studies show that gonadal development occurs, even in animals at the extremity of distribution (*e.g.*, Corney Cove, head of Laredo Inlet and Windy Bay). Gonads of all animals were either ripe or showed some initial signs of spawning. Mann (1979) and Obah (1959) stated that a temperature of 12-13°C was required for gonadal development in Manila clams and spawning occurred when a temperature of 15°C was attained. Surface water temperatures of 14°C or higher were found at several locations during this and previous surveys and hence gonadal development can probably occur there. Whether water temperatures are sufficient to permit spawning and larval development and to retain larvae within the area is not known but warrants further study.

It should be pointed out that 1998 was an El Nino year and surface water temperatures were probably higher than in normal years. This survey was in early August 1998, so surface water temperatures would be at maxima, and might be higher than in normal years. Although gonadal development and limited spawning occurred in 1998 in these Manila clam populations at the extremity of distribution, it might not occur in normal years with cooler surface water temperatures.

Another point is that gonads of most males and females examined in this survey were in the ripe stage and only limited initial spawning had occurred. The period of spawning is unknown for Manila clams in the North Coast, but in the Strait of Georgia it is from mid June to the end of August (Bourne 1982). Since sampling occurred in August during this survey, one would expect that much greater spawning would have occurred if successful breeding was to occur. It is possible that extensive spawning does not occur in these Manila clam populations at the extremity of their distribution. Although gonadal development may occur and the gonads attain the ripe stage, massive spawning does not occur and the gonads remain in a ripe condition.

It would be worth studying the gonadal cycle of Manila clams from selected sites in the North Coast to determine if a complete cycle occurs annually throughout the area, or if the gonads of clams in some areas only become ripe without significant spawning. If such is the case, successful recruitment from local spawning in some places would be erratic or rare.

Mortalities

Winter kill is probably a factor limiting northern dispersal of Manila clams in B.C. Since Manila clams are buried at shallow depths and occur in the mid intertidal zone, they are susceptible to freezing during cold periods in winter, particularly if strong winds occur at the same time (Bower *et al.* 1986; Bower 1992). This can lead to mass mortalities that result in large quantities of dead and dying clams on the surface of a beach and subsequent large quantities of dead shell. This situation occurs frequently in the Strait of Georgia, and probably more frequently in the North Coast, where winter temperatures are colder. Large quantities of dead Manila clam shell have been observed in previous surveys, which probably were the result of winter kill (Bourne and Cawdell 1992; Bourne *et al.* 1994; Bourne and Heritage 1997; Heritage *et al.* 1998).

In the present survey, quantities of dead shell were found only at Corney Cove. Maximum age of the dead shell was 6 years, and it had been on the beach for several years, indicating the population had been there for at least ten years. Some dead shell was found at the head of Laredo Inlet, and large amounts may exist there. A more thorough survey of the area is required. The lack of quantities of dead shell on the other beaches was probably due to the fact that the populations there were small and little dead shell has accumulated over the years.

Stunting

On most beaches, many littlenecks and some butter clams were badly stunted, which was due in part to adverse environmental conditions.

It is interesting that stunting was rare in Manila clams, even in areas at the northern extremity of their distribution. All shells had a normal shape, although some may have been somewhat thicker than found in Manila clams from southern areas. The slight difference in growth rates between all areas is another indication that little if any stunting is occuring.

Aquaculture

About 40% of Manila clam production in the South Coast District is from some type of culture operation (R. Webb, DFO Parksville, pers. comm.). Market demand for Manila clams remains strong and the question arises as to whether production from the North Coast could be increased through culture. There are some problems that would have to be investigated before an accurate assessment could be made of the economic viability of Manila clam culture in the North Coast.

The number of beaches with extensive suitable habitat for Manila clam culture is limited in the North Coast. Other than in the Bella Bella area, many of the beaches are "pocket beaches" which may only have an area of 0.25 ha that is suitable for Manila clams. These beaches are widely distributed and this along with the long distances that must be travelled to get to them makes culture economically difficult.

A major consideration is the supply of seed (juveniles). In the South Coast area, much of the production from culture operations might be termed "pseudo culture". Production results in part or in total not from planted seed but from good husbandry of natural sets. In some operations, no seed is actually planted, the grower relies entirely on good husbandry of natural sets. This is possible only because annual recruitment is relatively consistent in the Strait of Georgia.

In the North Coast, such culture from natural sets may or may not be possible. Annual recruitment appears to be regular on some beaches in the immediate Bella Bella area, but it is probably erratic in areas towards the extremity of distribution. As shown by histological studies, gonadal development and spawning occurs even in Manila clams at the extremity of distribution, but whether it is sufficient or consistent enough to permit culture by good husbandry of juveniles is unknown. As pointed out previously, 1998 was an El Nino year with above normal water temperatures that probably allowed more widespread and successful Manila clam breeding than in more normal, cooler years, when successful breeding could be more erratic.

If recruitment were too low or too erratic to allow culture through good husbandry of natural sets, then culture operations would have to rely on planted seed, which adds greatly to costs. This, along with the possibility of heavier mortalities due to winter kill, may make Manila clam culture in the North Coast uneconomic.

Experimental Manila clam culture should be undertaken in the North Coast to determine if such operations would be based on good husbandry of natural sets or on planted seed, so that people can make an accurate assessment of the economic feasibility of Manila clam culture in this area. If such an experiment is undertaken, it should include planting some seed from brood stock from the South Coast and North Coast areas to determine if a genetic strain of Manila clam has developed in the North Coast that is more suited to environmental conditions there.

OTHER SPECIES

Virtually all landings in the B.C. intertidal commercial clam fishery are comprised of four species, butter, littleneck, Manila and razor clams (Fig. 1). Occasionally minor landings of cockles and soft-shell clams occur. With strong continuing markets for shellfish, enquiries are received about the possibility of utilizing these two species to a greater extent in commercial or recreational fisheries. During past surveys in the North Coast, information has been gathered on these two species that could assist in formation of management policies should they be utilized.

Cockles

Cockles occur throughout coastal B.C. and are a common bivalve on many intertidal beaches (Quayle 1960). Many beaches in the North Coast have good habitat for cockles, the central part of these beaches has a substrate of sand/mud and the lower portion is covered with eel grass. Densities as high as 140 cockles m^{-2} were found on a beach in Finlayson Channel during this survey (Table 3). Sampling targeting on cockles has not been undertaken to accurately assess populations and age and size frequency distribution but general observations indicate that a wide size and age range is present on most beaches indicating consistent recruitment. In the present survey, cockles found ranged in shell height from 15-88 mm and in age from 1-10 years (Figs. 8, 27 and 53). Cockle larvae have been identified in five minute surface plankton tows during surveys to the North Coast.

Growth was calculated by measuring shell height at annual rings. Mottet (1983) showed differences can occur in estimates of age of cockles when age is determined by measuring annuli and taking peels. It is believed that measuring annuli during these surveys provided an accurate estimate of growth rate of cockles in the North Coast since annuli on most cockles were well defined.

Growth was determined at two locations during the present survey, Borrowman Bay on the northwest side of Aristazabal Island and Wilson Inlet in Principe Channel (Figs. 9 and 51). At Borrowman Bay a shell height of 60 mm was attained in about 6 years, at Wilson Inlet this size was attained in about 4 years. In a previous survey (Gillespie and Bourne 1998), cockles in Naden Harbour had not attained a shell height of 50 mm in 5 years.

Mottet (1983) showed that longevity of cockles was increased when age was determined by peels rather than by reading annuli; he reported a maximum longevity of 11-12 years from San Juan Island, Washington. Weymouth and Thompson (1930) indicated the life span of cockles was 7 years in Oregon and Washington. Fraser (1931) found no cockles older than 7 years in southern B.C. and Quayle and Bourne (1972) stated they rarely lived beyond 7 years in southern B.C. In the present survey, cockles aged 10 were found at Borrowman Bay (Fig. 8) indicating that longevity is probably a result of location rather than method used to determine age.

Cockles have been harvested in commercial fishery in California, Oregon, Washington and Alaska (Schink *et al.* 1983). In California the extent of landings was probably small and is difficult to determine since early statistics that reported cockles included littleneck and three species of *Chione* as well as cockles. Commercial fisheries for intertidal clams in California are now negligible but the resource is used in the recreational fishery (Shaw 1997).

In Oregon, cockles were harvested for bait in the local Dungeness crab, *Cancer magister*, fishery, for recreational use and also for the restaurant and fresh market trade (Marriage 1954). Landings were never large but they comprised 20-58% of total clam landings while they were harvested and peaked at about 35 t in 1943 but declined to 5 t in 1970 (Marriage 1954). A small commercial clam fishery continues in Oregon and cockles usually account for half of the landings, however, total clam landings in 1990 were only 33 t (Robinson 1997). Cockles are used in the recreational fishery.

In Washington, landings of cockles in the commercial fishery were incidental to other species (Schink *et al.* 1983).

A commercial fishery for cockles occurred in Alaska from 1943-1962 (Schink *et al.* 1983). Landings fluctuated greatly but peaked at about 600 t in 1960 and then declined sharply. High labour costs, relatively low meat recovery and PSP problems led to a decline in the fishery and no landings have been recorded since 1962. The present fishery for cockles, commercial or recreational, is small and no data on landings are available (Foster 1997).

In B.C. landings of cockles in the commercial fishery have been incidental to landings of the other four major species. No actual landings have been recorded in DFO statistics and it is estimated that annual landings have been much less than 1 t. Cockles are used in the recreational fishery and in the native food fishery and some people occasionally make trips to "get a feed of cockles".

<u>Soft-shell Clams</u>

Soft-shell clams are an exotic to the west coast of North America and their dispersal in B.C. is well documented (Quayle 1964). They are now ubiquitous throughout coastal B.C. and a common bivalve on many intertidal beaches. They can be found throughout the lower two thirds of the intertidal zone but are most prevalent in soft sand/mud substrate well up in the intertidal area. As with cockles, no sampling has been undertaken to specifically assess soft-shell clam populations but considerable information has been accumulated on this species during surveys to the North Coast. Densities as high as 256 soft-shell clams m^{-2} were found in Kettle Inlet during the present survey (Table 3). Although no directed sampling has been undertaken to assess soft-shell clam populations, a wide range of size and age distribution has been found on many beaches indicating consistent recruitment. In the present survey, soft-shell clams found ranged in length from 34-102 mm and in age from 2-11 years (Figs. 11, 28 and 42). Soft-shell clam larvae have been found in five minute surface plankton tows.

Age and growth rate was determined by counting and measuring shell length at annuli. Various authors have discussed the reliability of ageing soft-shell clams by counting annuli as opposed to making peels (Newcombe 1936; Feder and Paul 1974; MacDonald 1980; MacDonald and Thomas 1982). MacDonald (1980) showed differences occurred in age estimates by the two methods. It is believed that age and growth determinations made during surveys to the North Coast are accurate since annuli were distinct. In the present survey, ages ranged from 2-11 years (Figs. 11, 28 and 42) and they attained a shell length of 50 mm in 4-6 years (Figs. 12, 29 and 43). Feder and Paul (1974) found that soft-shell clams attained a shell length of 50 mm in about 6 years in Prince William Sound, Alaska.

Soft-shell clams are a highly prized bivalve on the Atlantic coast of North America and populations support valuable commercial and recreational fisheries. There have been commercial fisheries for soft-shell clams in California, Oregon and Washington (Schink *et al.* 1983). In California, soft-shell clams were an important species in the intertidal clam fishery and annual landings of about 155 t were reported from 1917-1926. Production began to decline and no landings have been reported since 1949 (Schink *et al.* 1983). They continue to be used in the recreational fishery (Shaw 1997).

In Oregon, production was never large but soft-shell clams comprised 10-39% of clam landings and peaked at about 40 t in 1979 (Marriage 1954; Schink *et al.* 1983). Landings declined sharply since then and are minor at present although they are utilized in the recreational fishery (Robinson 1997).

There was a sizeable commercial fishery for soft-shell clams in the state of Washington (Schink *et al.* 1983). Harvest began with the Hank's harvester in 1969 on privately owned and leased intertidal ground. A profitable specialty market for shucked and steamer clams developed in California and production expanded significantly in 1973 when about 50 t was landed. The industry was virtually halted for the next several years by lawsuits prohibiting use of mechanical dredges. However, a record 162 t was harvested in 1977 mostly by hand digging. Almost all the clams were shipped to the east coast where local clam supplies were severely limited. Since then harvest of soft-shell clams has virtually disappeared.

Soft-shell clams never found favour in B.C. and have never been a target species in the commercial fishery. Some incidental landings occurred along with butter, littleneck or Manila clams but total landings in any year have been well under 1 t. To our knowledge, soft-shell clams have never been important in the native food fishery, probably because they are an exotic and native people were not accustomed to harvesting this species. Soft-shell clams are used to some extent in the recreational fishery, particularly by people who have moved to B.C. from the Canadian Maritimes and who recognize the fine eating qualities of this species

Assessment

It is unlikely that populations of cockles or soft-shell clams in the North Coast will support targeted commercial fisheries, at least not under present economic conditions. The same constraints that prevent commercial exploitation of butter and littleneck clams in the North Coast would apply to these two species. If butter and littleneck clams cannot be harvested economically then it is highly unlikely that cockles and soft-shell clams can support fisheries. Markets for cockles do not exist at present and would have to be established. Meat yield is low and the price paid for cockles would probably be low and these factors would detract from the economics of a fishery. There are strong, established markets for soft-shell clams but the present economic situation may deter development of a commercial fishery in B.C. It would be beneficial to obtain information on the extent and economics of soft-shell clam markets to provide a basis for determination of whether a commercial fishery for this species could develop in B.C. If a commercial fishery for butter and littleneck clams developed in the North Coast, then additional economic value could be realized by developing markets for cockles and soft-shell clams, and harvesting these species at the same time.

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REFERENCES

Bourne, N. 1982. Distribution, reproduction and growth of Manila clams, *Tapes philippinarum* (Adams and Reeve), in British Columbia. J. Shellfish Res. 2(1): 47-54.

Bourne, N. and G. Cawdell. 1992. Intertidal clam survey of the North Coast area of British Columbia - 1990. Can. Tech. Rep. Fish. Aquat. Sci. 1864: 151 p.

Bourne, N.F. and G.D. Heritage. 1997. Intertidal clam surveys in British Columbia - 1992 and 1993. Can. Tech. Rep. Fish. Aquat. Sci. 2168: 95 p.

Bourne, N.F., G.D. Heritage, and G. Cawdell. 1994. Intertidal clam surveys of British Columbia - 1991. Can. Tech. Rep. Fish Aquat. Sci. 1972: 155 p.

Bower, S.M., R. Harbo, B. Adkins, and N. Bourne. 1986. Investigation of Manila clam (*Tapes philippinarum*) mortalities during the spring of 1985 in the Strait of Georgia, with a detailed study of the problem on Savary Island, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 1444: 25 p.

Bower, S.M. 1992. Winter mortalities and histopathology in Japanese littleneck *Tapes philippinarum* (A. Adams and Reeve, 1850) in British Columbia due to freezing temperatures. J. Shellfish Res. 11(2): 255-264.

Feder, H.M. and A.J. Paul. 1974. Age, growth and size-weight relationships of the soft-shell clam, *Mya arenaria*, in Prince William Sound, Alaska. Proc. Nation. Shellfisheries Assoc. 64: 45-52.

Foster, N.R. 1997. The molluscan fisheries of Alaska. NOAA Tech. Rep. NMFS 128: 131-134.

Fraser, C.M. 1931. Notes on the ecology of the cockle, *Cardium corbis* Martyn. Royal Soc. Can. Trans. Section V. Biol. Sci. Series 3. Vol. 25: 59-72.

Gillespie, G.E. and N.F. Bourne. 1998. Exploratory intertidal clam surveys in British Columbia - 1997. Can. Manuscr. Rep. Fish. Aquat. Sci. 2465: 43 p.

Gillespie, G.E. and A.R. Kronlund. 1999. A manual for intertidal clam surveys. Can. Tech. Rep. Fish. Aquat. Sci. 2270: 144 p.

Gillespie, G.E., T.C. Norgard, and F.E. Scurrah. 1999. Review of the Area 7 Manila clam fishery. Can. Stock Assess. Secret. Res. Doc. 99/197: 66 p.

Heritage, G.D., G.E. Gillespie, and N.F. Bourne. 1998. Exploratory intertidal clam surveys in British Columbia - 1994 and 1996. Can. Manuscr. Rep. Fish. Aquat. Sci. 2464: 114 p.

Holland, D.A. and K.K. Chew. 1974. Reproductive cycle of the Manila clam *Venerupis japonica* from Hood Canal, Washington. Proc. Natl. Shellfish. Assoc. 64: 53-58.

MacDonald, B.A. 1980. Age determination of the soft-shell clam, *Mya arenaria*, using shell internal growth lines. Mar. Biol. 58: 105-109.

MacDonald, B.A. and M.L.H. Thomas 1982. Growth reduction in the soft-shell clam *Mya arenaria* from a heavily oiled lagoon in Chedabucto Bay, NS. Mar. Environ. Res. 6: 145-156.

Mann, R. 1979. The effect of temperature on growth, physiology and gametogenesis in the Manila clam, *Tapes philippinarum*, (Adams and Reeve, 1850). J. Exper. Mar. Biol. Ecol. 38: 121-133.

Marriage, L.D. 1954. The bay clams of Oregon. Fish Comm. Oregon. Contr. 20: 47 p.

Mottet, L.C. 1983. Aging from microlines in the shells of intertidal cockles *Clinocardium nuttalli* from San Juan Island, Washington, U.S.A. M.Sc. Thesis, Univ. of Washington, Seattle, WA. 102 p.

Newcombe, C.L. 1936. Validity of concentric rings of *Mya arenaria* for determining age. Nature (London) 137: 191-192.

Obah, S. 1959. Ecological studies in the natural population of a clam, *Tapes japonica*, with special reference to seasonal variations in the size and structure of the population and to individual growth. Biol. J. Okiyama Univ. 5(1-2): 13-42.

Quayle, D.B. 1960. The intertidal bivalves of British Columbia. B.C. Prov. Mus. Hanb. 17: 104 p.

Quayle, D.B. 1964. Distribution of introduced marine molluscs in British Columbia waters. J. Fish. Res. Board Can. 21(5): 1155-1181.

Quayle, D.B. 1969. Paralytic shellfish poisoning in British Columbia. Fish. Res. Board Can. Bull. 168: 68 p.

Quayle, D.B. and N. Bourne. 1972. The clam fisheries of British Columbia. Fish. Res. Board Can. Bull. 179: 70 p.

Robinson, A.M. 1997. Molluscan fisheries in Oregon, past, present and future. NOAA Tech. Rep. NMFS 128: 75-87.

Schink, T.D., K.A. McGraw, and K.K. Chew. 1983. Pacific coast clam fisheries. Tech. Rep. Washington Sea Grant, Univ. of Washington, Seattle, Washington WSG 83-1: 72 p.

Shaw, W.N. 1997. The shellfish industry of California - past, present and future. NOAA Tech. Rep. NMFS 128: 57-74.

Thomson, R.E. 1981. Oceanography of the British Columbia coast. Can. Spec. Publ. Fish. Aquat. Sci. 56: 291 p.

Vancouver, G. 1798. George Vancouver, A Voyage of Discovery to the North Pacific Ocean, and Round the World. 3 Vols. and Atlas. Edited by W.K. Lamb and reprinted as Works Issued by the Hakluyt Society, Second Series, No. 164. London, 1984.

Webb, R. and K. Hobbs. 1997. Intertidal clams. P. 44-63. *In*: R. Harbo and K. Hobbs [eds.]. Pacific Commercial Fishery Updates for Invertebrate Resources (1994). Can. Manuscr. Rep. Fish. Aquat. Sci. 2369.

Weymouth, F.W. and S.H. Thompson. 1930. The age and growth of the Pacific cockle, *Cardium corbis*, Martyn. Bull. Bur. Fish. 46: 633-641.

Table 1. Location of beaches sampled during an exploratory intertidal clam survey in the North Coast District of British Columbia, 6-11 August, 1998.

Location	# Beaches	Date
Borrowman Bay – Kettle Inlet	8	August 6, 1998
Meyers Passage – Laredo Inlet	5	August 7, 1998
Finlayson Channel	5	August 8, 1998
Sheep Passage - Mussel Inlet - Mathieson Channel	6	August 9, 1998
Chapple Inlet – Surf Inlet	7	August 10, 1998
Anger Island – Cosine Island – Wilson Inlet	4	August 11, 1998

Table 2. Physical description of beaches, number of quadrats dug and remarks on the fauna and flora of beaches visited during an exploratory intertidal clam survey, 6-11 August, 1998.

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Borrowman Bay - Kettle Inlet		
1	0.04	0	mod./ steep	sand/gravel in lower intertidal, rock in upper intertidal	Borrowman Bay. Small beach with good substrate in lower intertidal below rocky slope. Eelgrass bed below low tide mark, *Fucus* on rocky slope. Only about 50 m^2 of good clam habitat. Shells of butter, littleneck, cockle, macoma, and jingle shell. 1 live littleneck found in several test scratches. Two moon snail egg collars found. No evidence of Manilas found.
2	0.04	1	mod.	sand/gravel	Beach opposite Wilks Island. Small beach between rocky headlands. Eelgrass below low tide mark. Numerous shells of butter, littleneck, cockle, bay mussel (*Mytilus* sp.). Small patches of sea mussel (*Mytilus californianus*) on rocky areas. Only 200 m^2 of good clam habitat. *Solaster* common on soft substrate, *Pisaster* on rocky areas. No evidence of Manilas found.
3	4-5	0	low	sand/silt, sand/gravel	Turtish Harbour. Lower portion approx. 2 ha, sand/silt/gravel. Some shell of cockle, littleneck, butter, horse (*T. capax*) and macoma. Numerous cockles on surface under algal mat. 94 collected for growth sample. Upper estuary approx. 2-3 ha, sand/gravel, few small littlenecks, little shell. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
		Borrowman Bay - Kettle Inlet (cont'd)			
4	0.5	1	low/ mod.	mud/sand/gravel/ broken rock	Tate Cove. Steep upper intertidal of broken rock and *Fucus*. Gently sloped lower intertidal. Shell of butter, littleneck and macoma. One live soft-shell found in test scratch. Mud shrimp (*Upogebia pugettensis*) numerous. Few seastars on soft bottom, 2 *Solaster* and 1 *Dermasterias*. *Dermasterias* numerous in channel to the south. Surface temperature 13°C. No evidence of Manilas found.
5	1	2	low/ mod.	rock, sand/gravel/ broken rock	Beach opposite Thomson Island. Two 0.5 ha portion of beach split by rocky point. Lower portion had shells of butter, littleneck, cockle, macoma, and horse (*T. capax*). Upper portion had no shells other than bay mussels. Mud shrimp and graceful crab (*Cancer gracilis*) numerous on lower portion. Small Pacific herring (*Clupea harengus pallasii*) and Pacific sandlance (*Ammodytes hexapterus*) trapped in filamentous algal mat. No evidence of Manilas found.
6	n/a	0	mod.	sand/gravel/mud	Switzer Cove. Extensive beach of moderately sloped soft substrates divided by rocky headlands. More exposed than other beaches, just visited.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Borrowman Bay - Kettle Inlet (cont'd)		
7	>2.5	3	low	sand/silt, sand/gravel	S side of Kettle Inlet. Upper and lower portions of beach divided by rocky headland. Lower portion at least 1.5 ha of sand/gravel, unable to estimate total area due to incoming tide. Upper portion 1 ha of sand/silt, with creek channel. Bar of upper beach with numerous soft-shell clams, lower beach with numerous littlenecks and cockles. No evidence of Manilas found.
8	>4	2	low	sand/gravel/broken rock	Estuary at the head of Kettle Inlet. Beach divided by three fish weirs. Rocky substrate above highest weir, no clams. Area between highest and middle weir approx. 2 ha, sand/gravel/broken rock. Numerous small soft-shell clams, some butter, littleneck and cockle shell. Portion between middle and lower weir approx. 2 ha, sand/gravel. Numerous large soft-shells, stunted littlenecks and one live Manila. Large portion of beach below lower weir could not be surveyed due to incoming tide. Numerous dire whelks (*Lirabuccinium dirum*).

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Meyers Passage - Laredo Inlet		
1	0.2	0	low/ mod.	rock/sand/shell, sand/silt/gravel	Beaches opposite Saunders Point. Two small beaches separated by rocky headland. First beach approx. 1,500 m^2, substrate mainly rock with sand/shell between. Numerous bay mussels, fair numbers of stunted littlenecks and small butters. Lots of old shells, primarily butter, littleneck, horsemussel (*Modiolus* sp.), bay mussel and horse clam (*T. capax*). Second beach small, approx. 250 m^2, lower portion mostly eelgrass over sand/silt, upper portion sand/gravel. Seastars (*Pisaster*, *Henericia*, and *Solaster*) common on both beaches. No evidence of Manilas found.
2	0.2	0	low	broken rock/sand/ shell	Beach E of Saunders Point. Small triangular beach. Numerous dead shells of butter, littleneck, horse clam (*T. capax*) and horsemussel. Some stunted littlenecks and small butter clams in test scratches. No evidence of Manilas found.
3	2	2	low	sand/silt/gravel	Meyers Narrows. 1.5 ha sand/silt, some algal mat. Few clams, mostly cockles, some littlenecks, butters and soft-shells near margins. Remaining 0.5 ha sand/gravel, good concentration of butter clams. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
		Meyers Passage - Laredo Inlet (cont'd)			
4	0.03	5	low/ mod.	sand/silt/gravel	Small beach at the head of Corney Cove. Approx. 300 m^2 of sand/silt, containing stunted littlenecks and small butters. One live Manila found in first quadrat, none in second, ten test scratches did not yield any more. A small area (approx. 30 m^2) of sand/gravel had numerous dead Manila shells, many live Manilas found in three quadrats.
5	n/a	0	low	sand/mud, sand/gravel	Extensive estuary and beach at the head of Laredo Inlet. Most of beach covered by rising tide. Collected numerous dead Manila shells from flooded beach, and 9 live Manilas from intensive digging on exposed sand bar.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Finlayson Channel		
1	1	0	low	broken rock/sand/silt	Mary Cove. Numerous old shells of butter, littleneck, bay mussel and horsemussel. Reasonable concentrations of butter clams near the rocky fringes of the beach, some stunted littlenecks. No live Manilas or Manila shell found.
2	3-4	2	low/ mod.	sand/silt/broken rock	Watson Bay. A long estuary with a small stream channel in the center. The lower 1 ha of beach was very productive butter, littleneck and cockle habitat. Numerous very old shells of butter, littleneck, macoma, and soft-shell. A sand bar high in the estuary had old, large soft-shell shells which were exposed where the stream channel had eroded the bar. Some old Manila shell collected, no live Manilas found.
3	12-15	1	low	sand/silt/gravel/ broken rock	Bottleneck Inlet. Extensive estuary, mostly silt/sand with gravel/broken rock at margins. Numerous cockles, macomas and stunted littlenecks; some butter clams at low tide mark on outer margins. Soft-shells at margins higher on the tide. Some old Manila shell found on the beach margin, and on a large rock, where they had been dropped by birds. One live Manila dug on beach margin. Time constraints prevented further exploration.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Finlayson Channel - (cont'd)		
4	4-5	0	low	sand/broken rock	Wallace Bight. Lower portion of beach very productive butter/littleneck/cockle habitat. Upper beach harboured stunted littlenecks and *Macoma nasuta*. No evidence of Manilas found.
5	20	0	low	sand/silt	Carter Bay. An extensive sand beach, somewhat exposed to wind and sea from Finlayson Channel. Beach divided by very deep stream channel. Large quantities of very old, large butter and horse clam shell. Lower beach with littleneck and macoma shell. Very few live clams found. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Sheep Passage - Mussel Inlet - Mathieson Channel		
1	7-8	3	low	sand/silt/gravel	Bolin Bay. A broad estuary with two stream channels crossing it. Largest area of beach was sand/silt with some eelgrass cover. Some bars of broken rock/sand/silt, covered in barnacles, bay mussels and *Fucus*. Some littleneck, butter and Manila shell on surface. Stunted littlenecks prevalent, with some small butters. 2 live Manilas found. Water temperature 14°C.
2	20	4	low/ mod.	sand/shell/silt, broken rock/sand/silt	Windy Bay. Large estuary with a single, large stream channel. Upper half of the beach was rocks with *Fucus* cover, lower half good clam habitat. Stunted littlenecks prevalent; small butters, Manilas, soft-shells, cockles and *Macoma inquinata* common. 16 Manilas collected from 4 quadrats, 30 more collected from test scratches.
3	15	0	low	sand/silt	Mussel Bay. Large estuary with two stream channels. Very dynamic beach, channels probably change regularly. Very little shell on surface; only a few soft-shells and one cockle shell found. One live soft-shell dug in test scratches. Rocks and wood debris on beach covered in small bay mussels and barnacles. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
		Sheep Passage - Mussel Inlet - Mathieson Channel (cont'd)			
4	7-8	2	low/ mod.	broken rock/sand/silt	Poison Cove. Beach was almost entirely broken rock with *Fucus* cover, bay mussels and barnacles; only a few small areas of sand/silt. Collected littlenecks and cockles from two quadrats in soft substrate. No evidence of Manilas found. Water temperature 14.5°C.
5	<0.5	0	mod./ steep	broken rock/sand/silt	Oatswish Bay. Narrow steep beach, looked to be mostly rock with *Fucus* cover, small area of silt and sand at river mouth. Visit only, did not survey.
6	>10	0	low/ mod.	sand/silt/broken rock	James Bay. Large, long estuary with a wide, deep stream channel down center. Most of the beach was sand/silt with some rocks, more silt closer to the stream channel. Very dynamic beach with newly formed sand bars and active erosion by wandering stream channels. One stream channel collapsing side of sand bar, carrying clams downstream. Littlenecks, soft-shells and cockles common; some dead butter shell on surface. Several dead Manila shells found, one live Manila found on the surface.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Chapple Inlet - Surf Inlet		
1	n/a	n/a	n/a	n/a	Kiln Bay. Arrived early on falling tide, most of beach not exposed. Upper intertidal boulders and *Fucus*. Did not survey.
2	>2	1	low/ mod.	sand/silt/gravel	Head of Chapple Inlet. Approx. 2 ha of beach exposed, lower intertidal extensive, possibly 8 ha total area. Two old fish weirs at extreme upper intertidal, both heavily silted. Soft-shell clams collected from a quadrat on the moderate slope below the fish weirs. Low slope in mid-intertidal had some littleneck, soft-shell and cockle shells; shells of *Macoma balthica* very numerous over much of the beach. Lower intertidal covered with bay mussel and barnacles in small clumps. No evidence of Manilas found.
3	0.5	2	mod.	sand/silt/shell	McKechnie Point. Small saddle beach between main shore and small island. Lower intertidal sand/silt/shell, upper intertidal with heavy cover of dead shell, barnacles and bay mussels. Stunted littlenecks prevalent on lower intertidal, some *Macoma inquinata* and small butters. Some large butter shell on lower beach. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Chapple Inlet - Surf Inlet (cont'd)		
4	0.5	1	mod./ steep	sand	Argyh Cove. Narrow beach with large stream channel on side. Upper intertidal boulders on bedrock, lower intertidal steep sand. Small amounts of butter, littleneck, cockle and *Macoma nasuta* shell, one shell and egg cases of moon snail (*Polinices lewisii*). Butter clams dug from one quadrat in mid-intertidal. No evidence of Manilas found.
5	4	0	low/ mod.	broken rock/sand/silt	Adams Bay. Only approx. 0.5 ha of good clam habitat. Small butters and stunted littlenecks in rocky areas, larger clams in small areas of sand/silt with eelgrass cover. Butter, littleneck, cockle and horse clam (*T. capax*) shell common over most of the beach. Egg cases of moon snail on lower beach. No evidence of Manilas found.
6	4	1	low	silt/sand/broken rock	Penn Harbour. Large sand/silt bar below rocky beach. Large stream channel on side. Deep silt over middle of bar and near edges of stream. Shells of butter, littleneck, cockles, soft-shell and horse clam (*T. capax*) on bar. Live butters, soft-shells and littlenecks in quadrat dug on shoreward end of bar. Live cockles scattered on the surface. Clam densities low on end of bar. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Chapple Inlet - Surf Inlet (cont'd)		
7	2	0	low/ mod.	sand/silt/broken rock	Head of Surf Inlet. Half of beach rocky, with several stream channels; half firm sand/silt. Bay mussels, barnacles and *Fucus* on rocky portion, littlenecks, butters and bay mussels on sandy portion. Lots of shell on beach: bay mussel, butter, littleneck, cockle and horse clam. No evidence of Manilas found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
			Anger Island – Cosine Island – Wilson Inlet		
1	>0.5	1	low	sand/silt/broken rock	A small beach in Anger Inlet. Approx. 0.5 ha exposed, total area perhaps 1.5 ha. Borders of beach rock/sand/silt, center portion silt/sand. Large butter and horse clam shell on lower beach. Quadrat dug in upper beach had littlenecks, butters, *Macoma nasuta* and moderately large horse clams (*T. capax*). Surface temperature 14°C.
2	0.5	0	low	silt/sand/mud, broken rock	Small lagoon above rock berm between two unnamed islands at the mouth of Anger Inlet. Sides of lagoon broken rock, center silt/sand/mud. Burrowing sea cucumbers (*Cucumaria* sp.) in rocky portions, stunted littlenecks, *Macoma nasuta*, *M. inquinata* and *M. balthica* in soft substrates. Some butter clams near rocky berm at mouth of the lagoon. One live jingle shell (*Pododesmus cepio*) seen on rocks. Old butter, horse clam and littleneck shell in the rocks near the mouth. No evidence of Manila clams found.

Table 2. (cont'd)

Beach No.	Area (ha)	No. of Quadrats	Slope	Substrate	Remarks
		Anger Island – Cosine Island – Wilson Inlet (cont'd)			
3	0.8	2	low/ mod.	sand/silt/broken rock	Bay on E side of Cosine Island. Margins of beach broken rock/sand/silt, center sand/silt. Shells of littleneck, butter, cockle and *Macoma nasuta.* Stunted littlenecks, cockles, soft-shells on upper beach, lower beach had butters and larger littlenecks. No evidence of Manilas found.
4	1	2	low/ mod.	sand/silt/broken rock	Head of Wilson Inlet. Upper half of beach broken rock/sand, long bar from stream mouth silt/sand. Upper beach had stunted littlenecks, bar had numerous large cockles on the surface, cockles, littlenecks and some butters in quadrat. Surface temperature 14°C.

Table 3. Densities of butter, littleneck and Manila clams, as well as densities of soft-shell clams, cockles and *Macoma* sp. (clams m^{-2}) found during an exploratory intertidal clam survey, 6-11 August, 1998. Legal size for Manila and littleneck clams is 38 mm, for butter clams is 63 mm.

		Butters		Littlenecks		Manilas				
Beach	Quadrat	Legal	Sublegal	Legal	Sublegal	Legal	Sublegal	Macoma	Softshell	Cockle
					Borrowman Bay - Kettle Inlet					
2	1	4	44	28	96	0	0	0	0	28
4	1	28	8	24	20	0	0	4	0	0
5	1	4	1	7	0	0	0	0	0	1
5	2	0	0	44	12	0	0	8	0	0
7	1	0	0	0	0	0	0	0	19.5	0
7	2	0	0	32	124	0	0	0	0	4
7	3	0	0	108	20	0	0	0	0	0
8	1	0	0	1	64	1	0	0	13	0
8	2	0	0	0	0	0	0	0	256	0
					Meyers Passage - Laredo Inlet					
3	1	40	5	2	0	0	0	2	0	0
3	2	0	0	60	16	0	0	0	24	0
4	1	0	8	160	44	4	0	0	0	4
4	2	0	16	76	84	0	0	4	0	4
4	3	0	0	4	8	32	4	0	8	0
4	4	0	0	8	0	20	0	0	4	0
4	5	0	0	0	0	8	4	0	4	0
					Finlayson Channel					
2	1	32	4	44	4	0	0	8	0	148
2	2	24	20	352	80	0	0	16	0	16
3	1	0	0	0	0	0	0	0	88	0
					Sheep Passage - Mussel Inlet - Mathieson Channel					
1	1	0	0	0	12	0	4	0	0	0
1	2	0	8	8	56	0	0	0	0	0
1	3	0	0	0	264	0	4	0	4	0
2	1	0	0	48	140	0	0	16	16	24
2	2	0	4	0	552	24	0	0	4	0
2	3	0	0	0	16	12	12	0	0	0
2	4	0	0	0	104	16	0	0	8	0
4	1	0	0	0	2	0	0	2	0	18
4	2	0	12	208	44	0	0	56	0	28
					Chapple Inlet - Surf Inlet					
2	1	0	8	0	0	0	0	0	106	0
3	1	0	0	16	644	0	0	20	0	0
3	2	0	0	4	248	0	0	0	12	0
4	1	20	0	0	0	0	0	0	0	0
6	1	0	4	32	60	0	0	0	8	4

Table 3. (cont'd)

Beach	Quadrat	Butters Legal	Butters Sublegal	Littlenecks Legal	Littlenecks Sublegal	Manilas Legal	Manilas Sublegal	Macoma	Softshell	Cockle
Anger Island – Cosine Island – Wilson Inlet										
1	1	4	68	24	36	0	0	32	4	0
3	1	4	16	68	88	0	0	0	0	0
3	2	30	7	31	3	0	0	0	0	2
4	1	1	2	30	2	0	0	0	0	9
4	2	0	0	0	124	0	0	0	0	0

Table 4. Stage of gonadal development in Manila clams collected from Meyers Passage and Laredo Inlet, August 7, 1998, and Windy Bay, Sheep Passage, August 9, 1998. M = male, F = female.

	Stage of Development				
Date	Early Active	Late Active	Ripe	Partially Spent	Spent
			Meyers Passage		
August 7	0M 0F	0M 0F	7M 3F	4M 1F	0M 0F
			Laredo Inlet		
August 7	0M 0F	0M 0F	3M 1F	1M 1F	0M 0F
			Windy Bay, Sheep Passage		
August 9	0M 0F	0M 0F	5M 10F	4M 3F	0M 0F

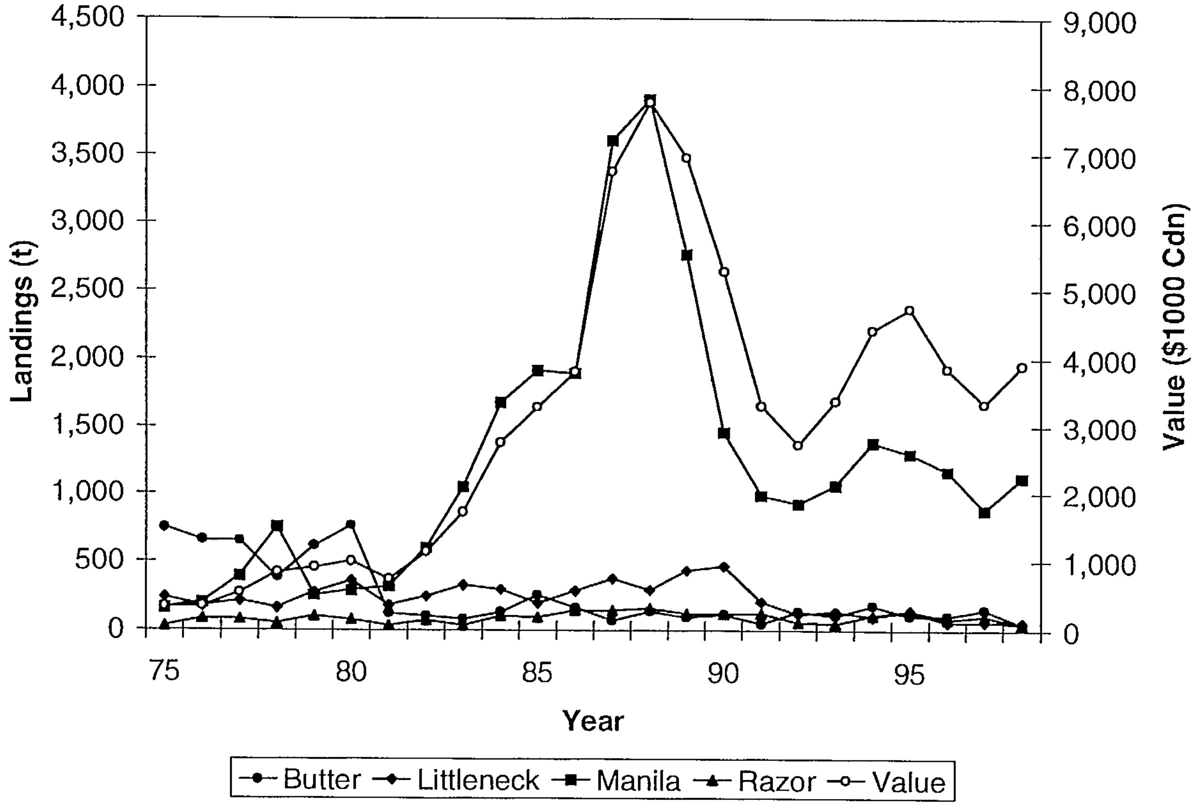


Fig. 1. Landings of intertidal clams (t) and value ($Cdn) in British Columbia commercial fisheries, 1975-98.

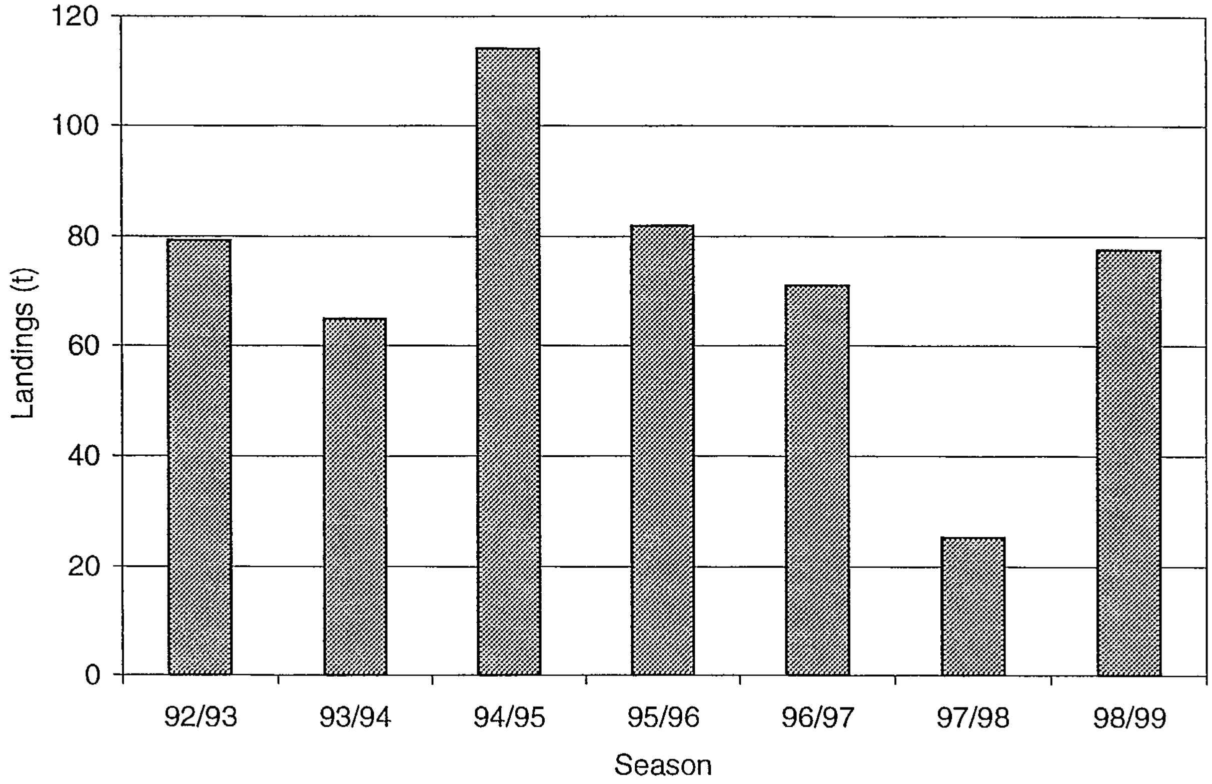


Fig. 2. Landings of Manila clams (t) from Pacific Fisheries Management Area 7, 1992/93 to 1998/99 seasons.

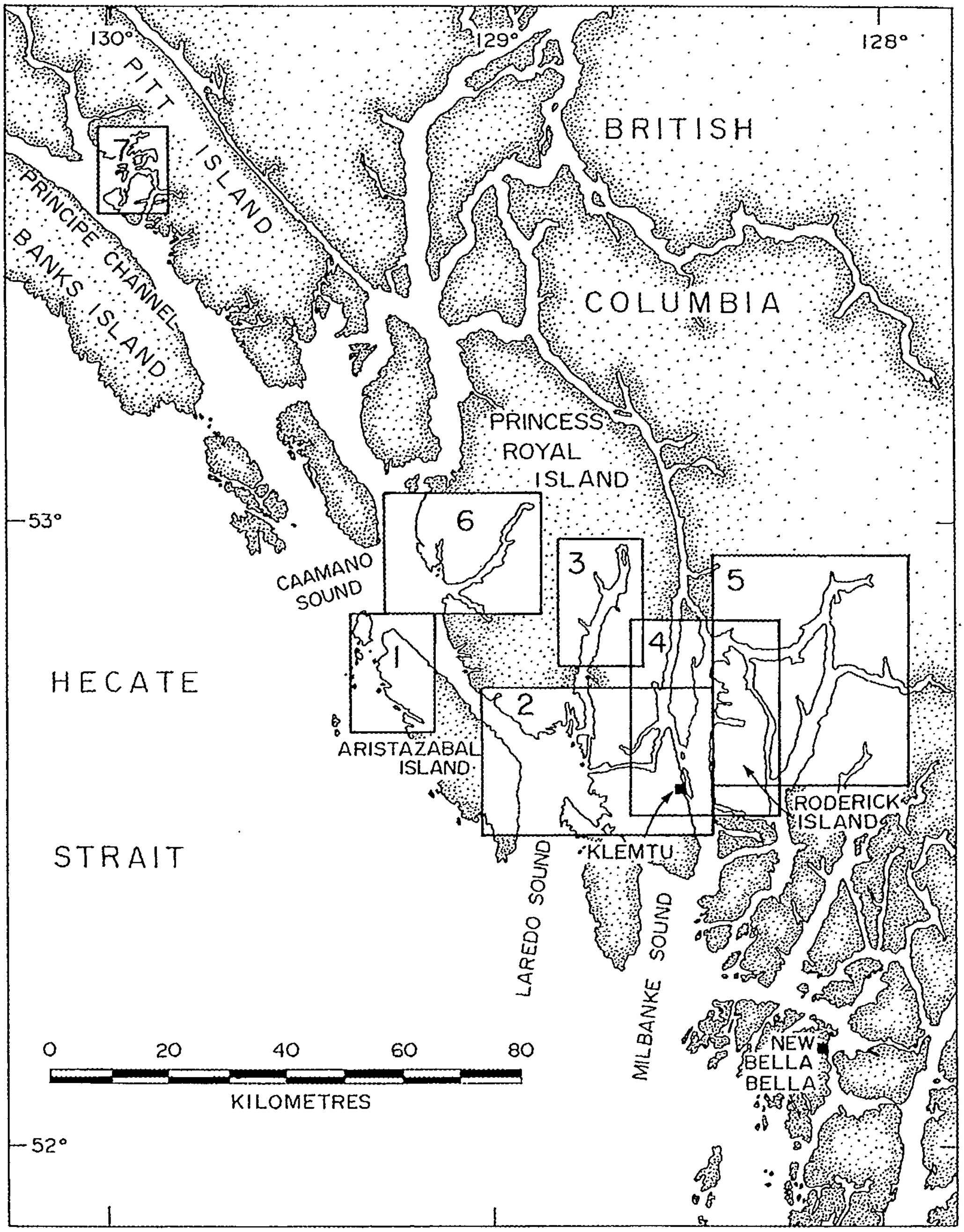


Fig. 3. Location of beaches surveyed during exploratory clam surveys in 1998.

Legend: 1 – Borrowman Bay/Kettle Inlet; 2 – Meyers Passage; 3 – Laredo Inlet; 4 – Finlayson Channel; 5 – Sheep Passage/Mussel Inlet/Mathieson Channel; 6 – Chapple Inlet/Surf Inlet; 7 – Anger Island/Cosine Island/Wilson Inlet.

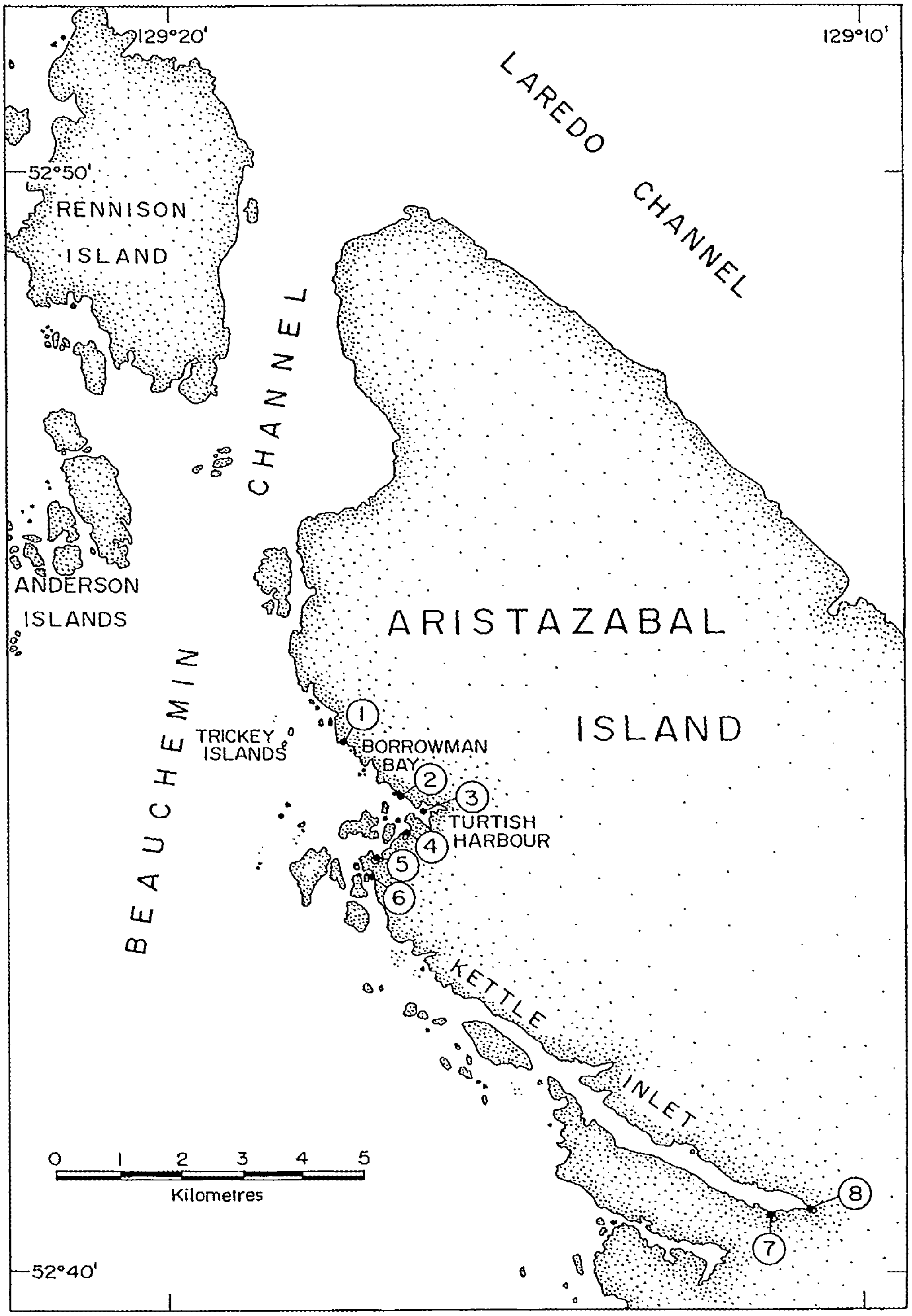


Fig. 4. Location of beaches surveyed in Borrowman Bay and Kettle Inlet, August 6, 1998.

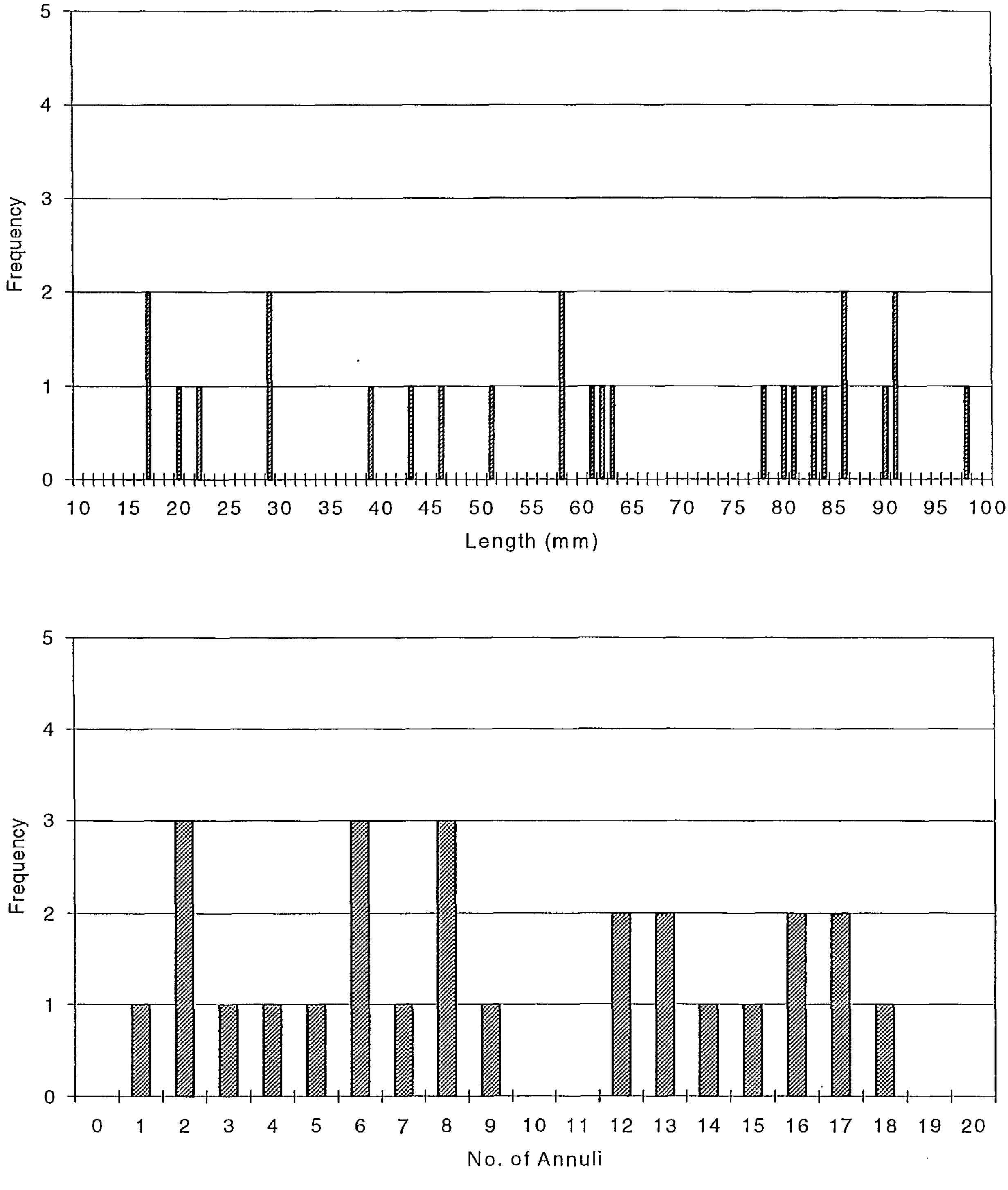


Fig. 5. Length and age frequency distributions of butter clams from Borrowman Bay, August 6, 1998.

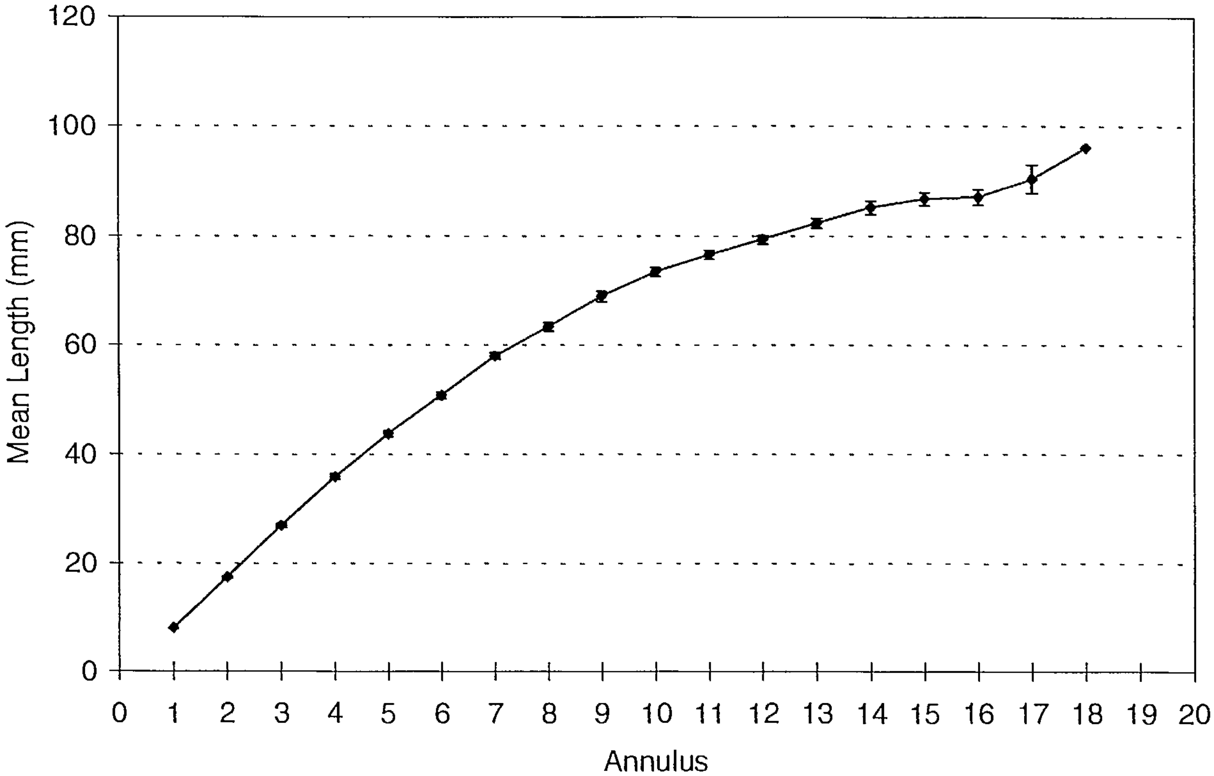


Fig. 6. Growth curve for butter clams (n=26) from Borrowman Bay, August 6, 1998. Error bars are 95% confidence limits of mean length at annulus.

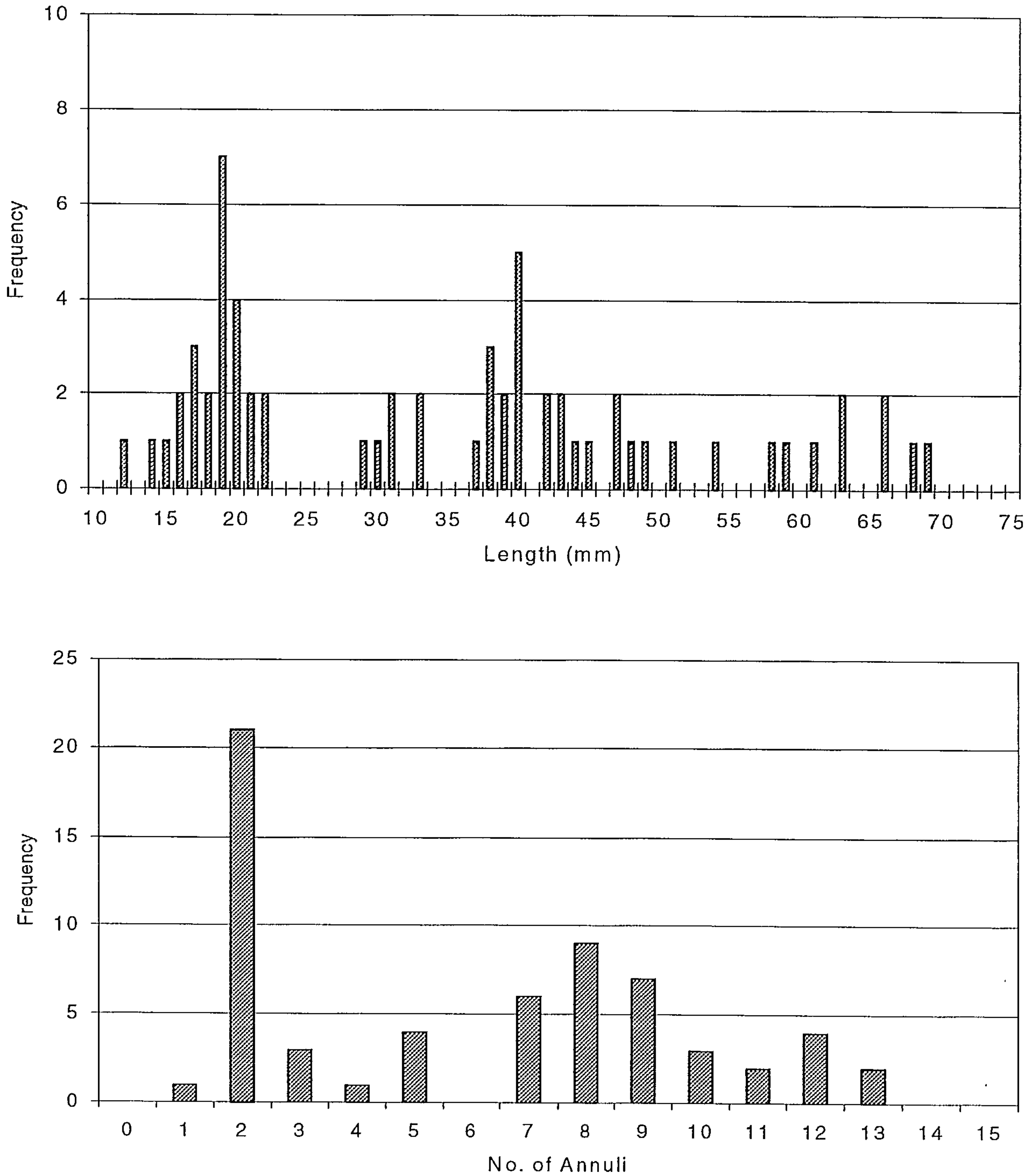


Fig. 7. Length and age frequency distributions of littleneck clams from Borrowman Bay, August 6, 1998.

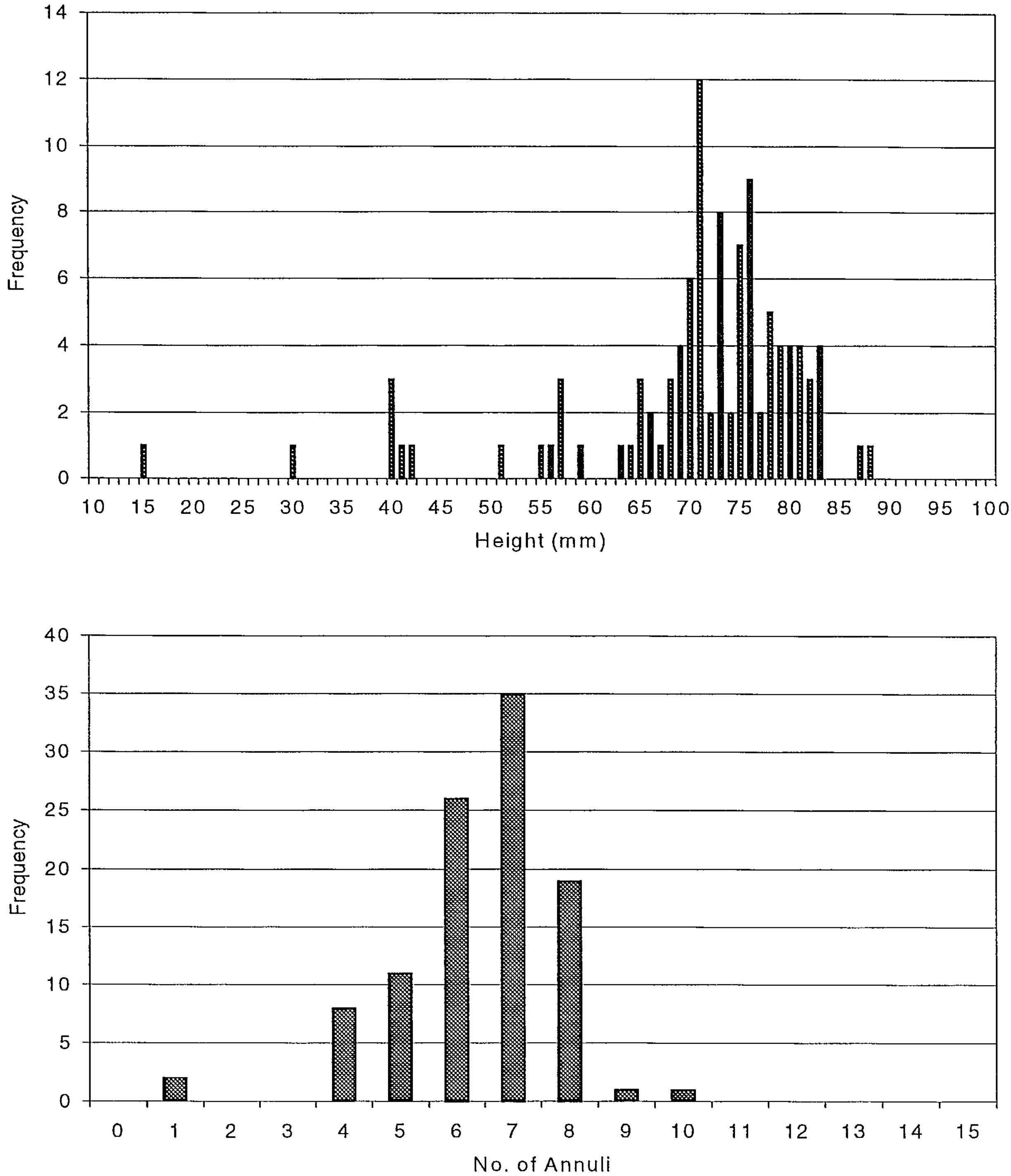


Fig. 8. Height and age frequency distributions of cockles from Borrowman Bay, August 6, 1998.

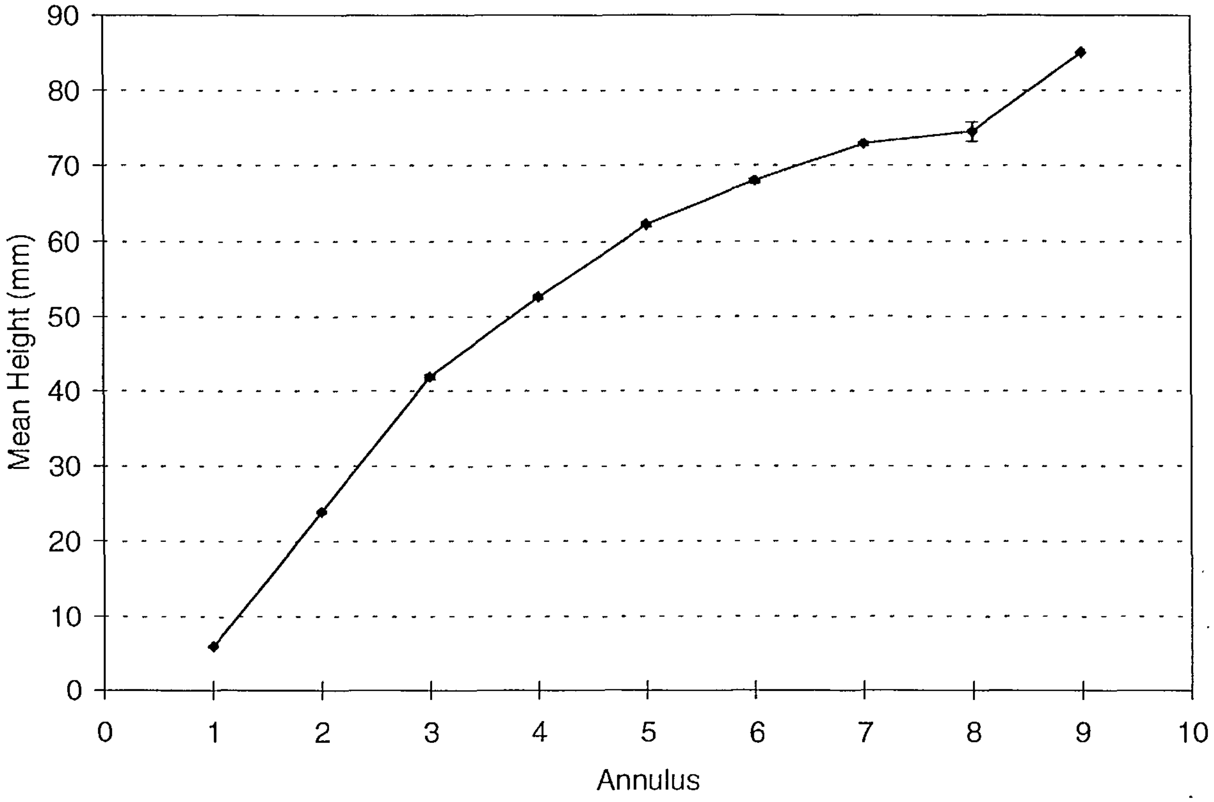
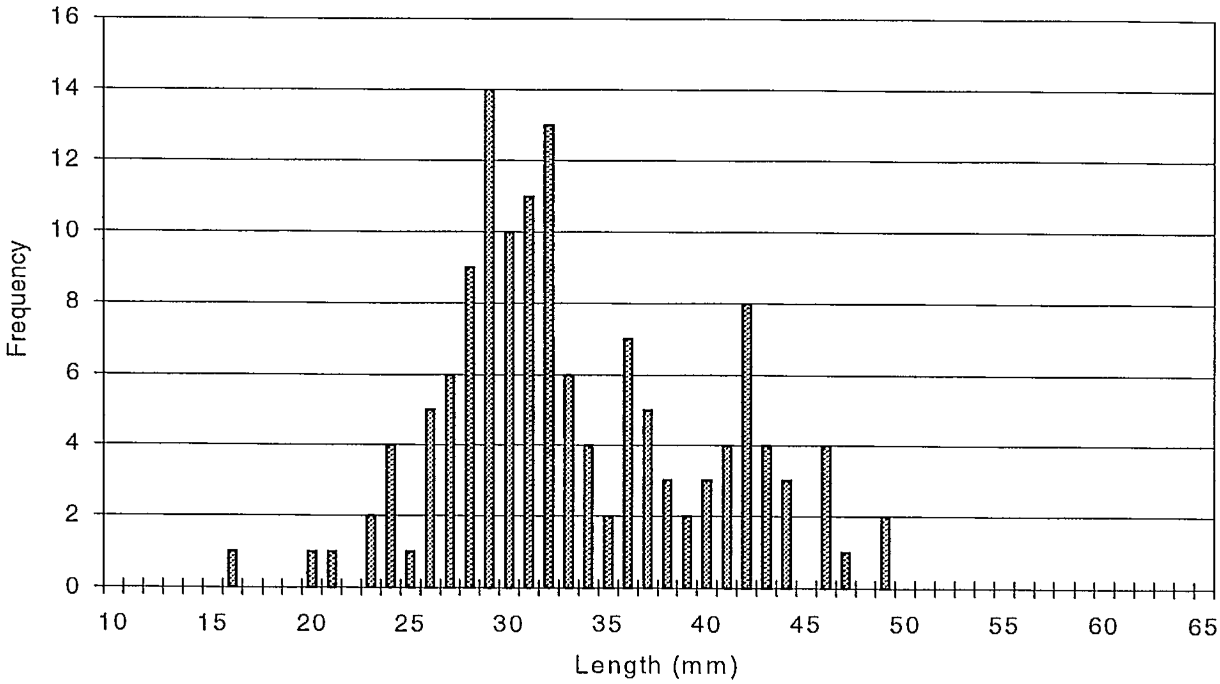


Fig. 9. Growth curve for cockles (n=52) from Borrowman Bay, August 6, 1998. Error bars are 95% confidence limits of mean height at annulus.



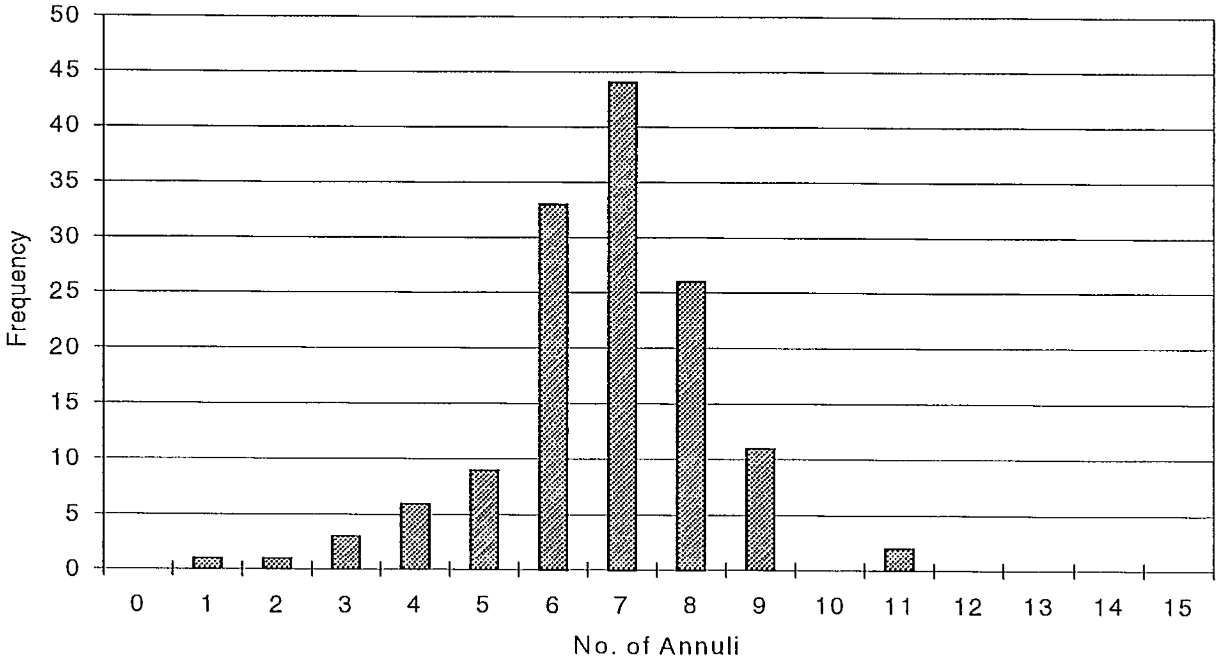
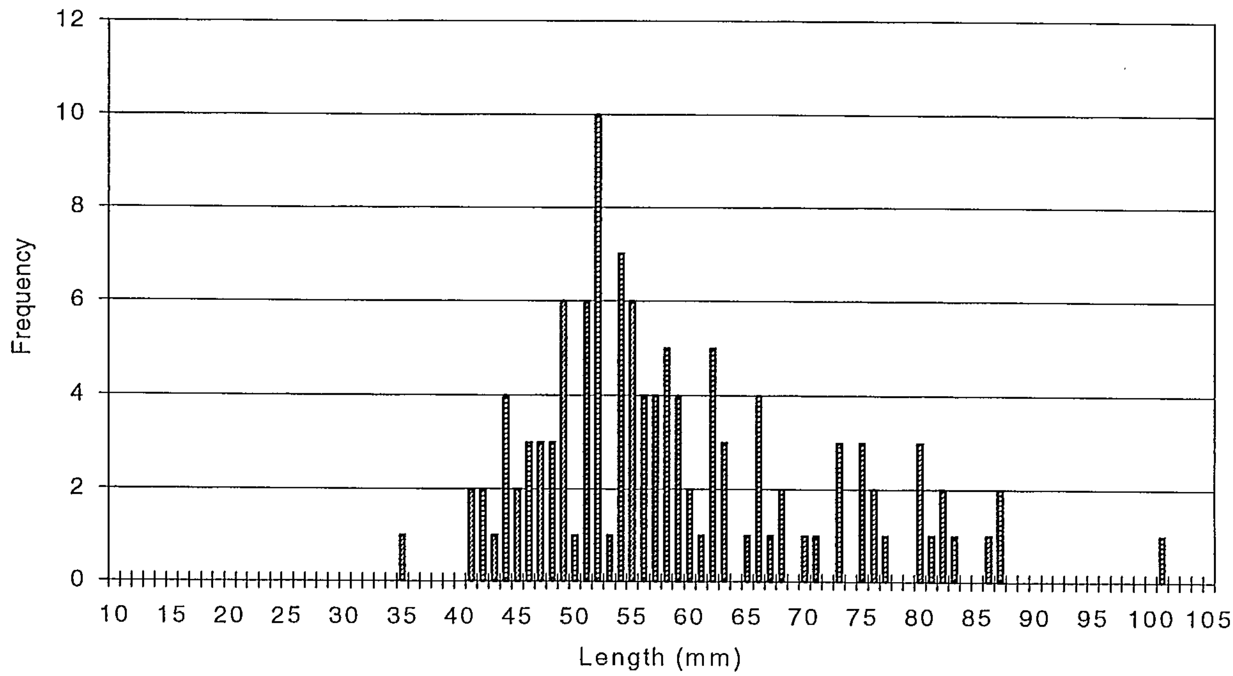


Fig. 10. Length and age frequency distributions of littleneck clams from Kettle Inlet, August 6, 1998.



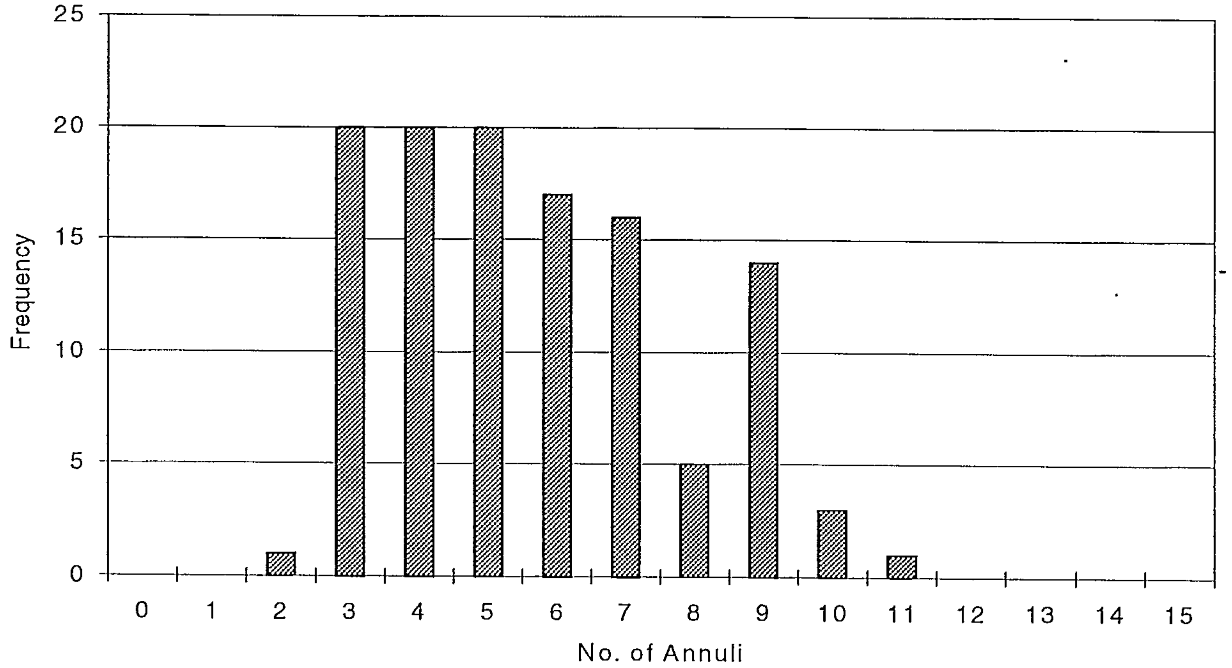


Fig. 11. Length and age frequency distributions of soft-shell clams from Kettle Inlet, August 6, 1998.

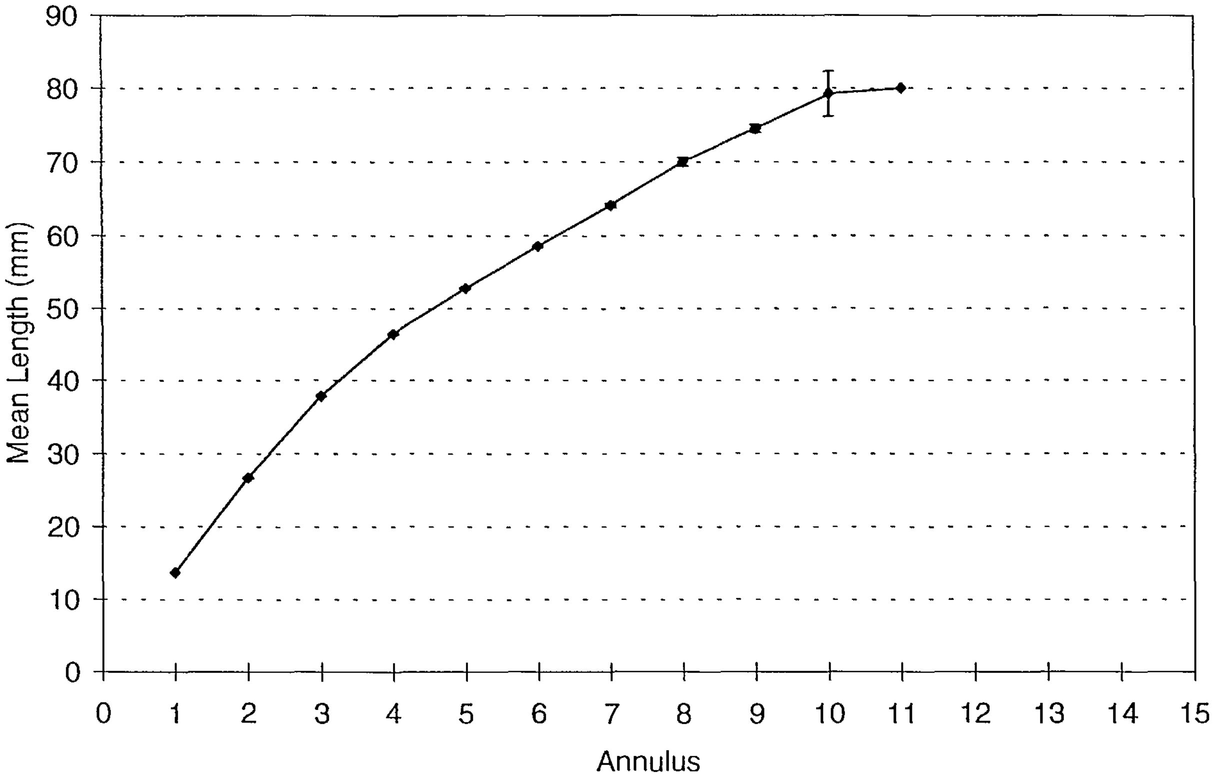


Fig. 12. Growth curve for soft-shell clams (n=116) from Kettle Inlet, August 6, 1998. Error bars are 95% confidence limits of mean length at annulus.

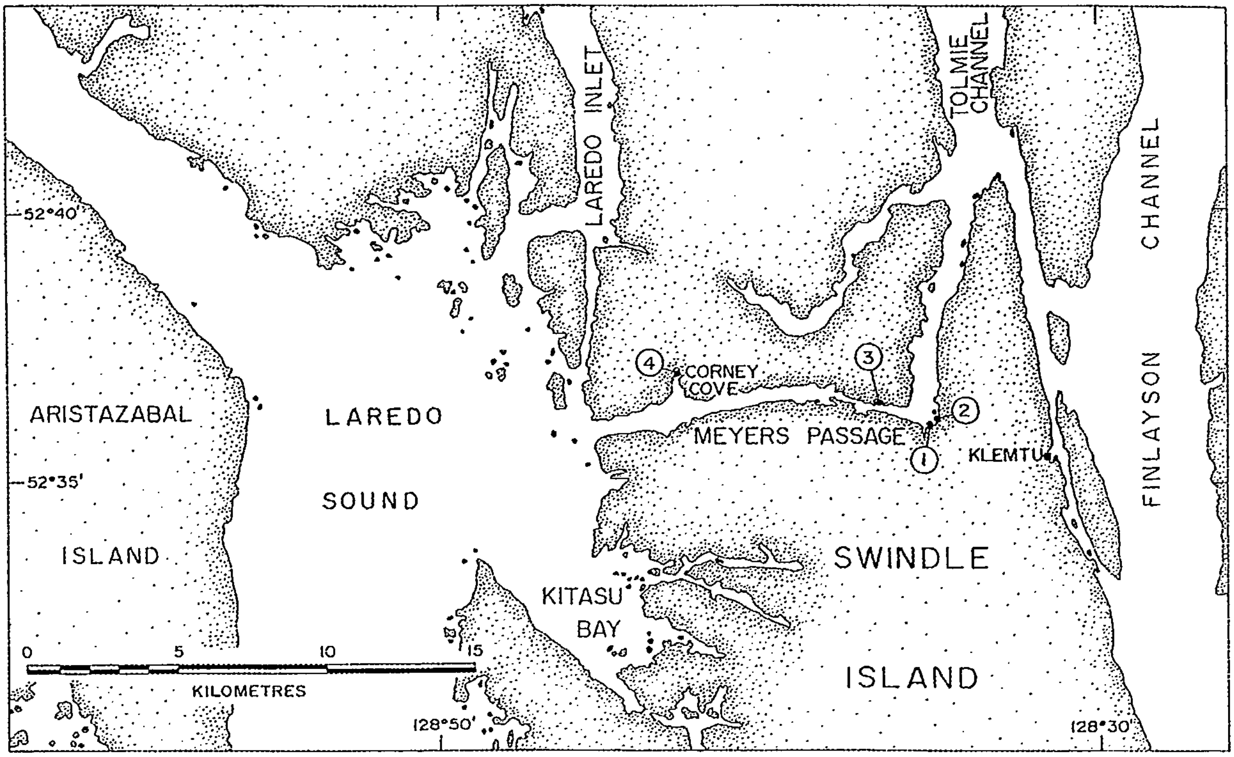


Fig. 13. Location of beaches surveyed in Meyers Passage, August 7, 1998.

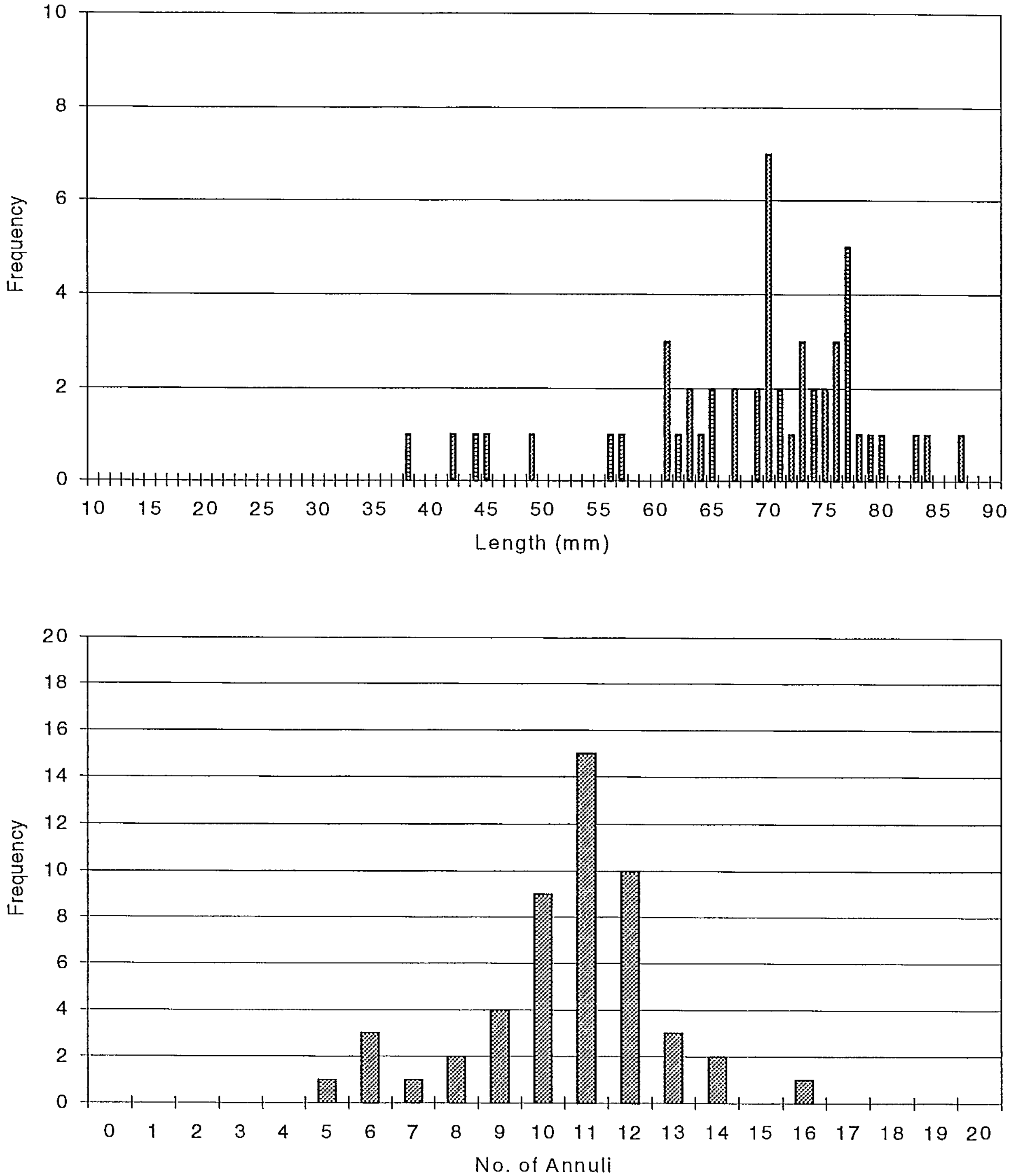


Fig. 14. Length and age frequency distributions of butter clams from Meyers Passage, August 7, 1998.

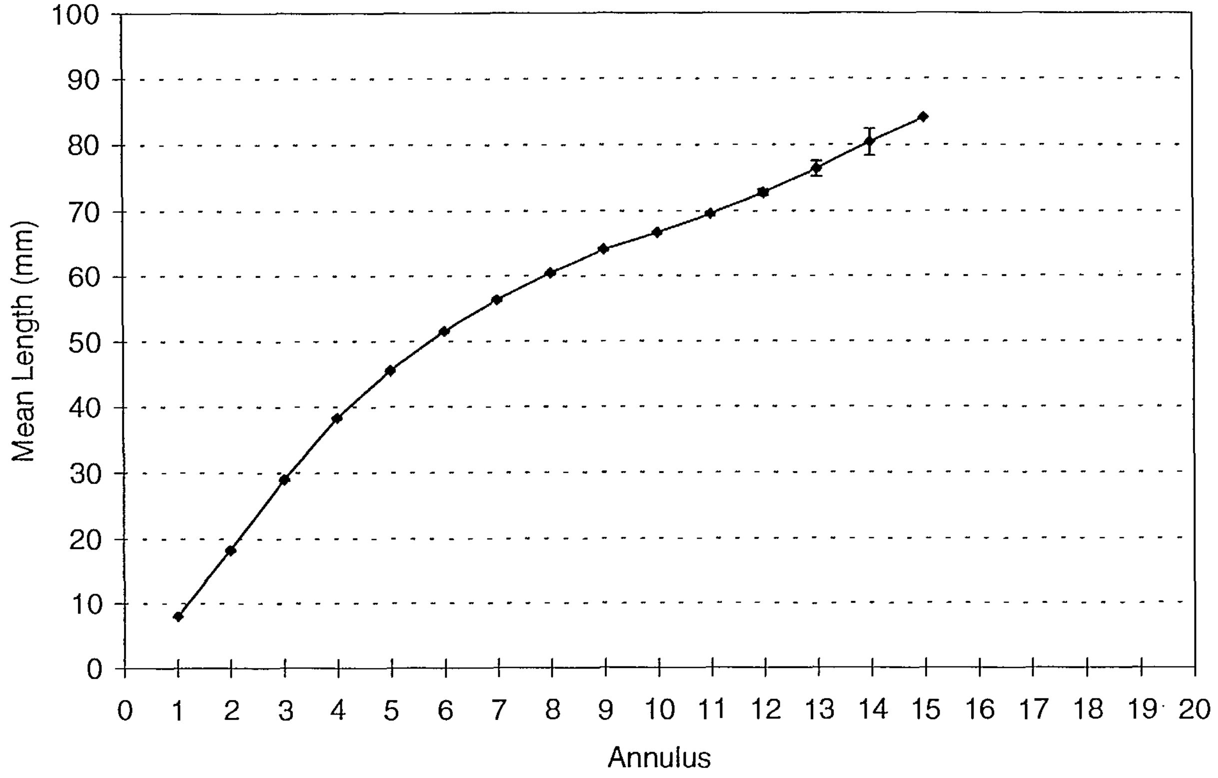


Fig. 15. Growth curve for butter clams (n=45) from Meyers Passage, August 7, 1998. Error bars are 95% confidence limits of mean length at annulus.

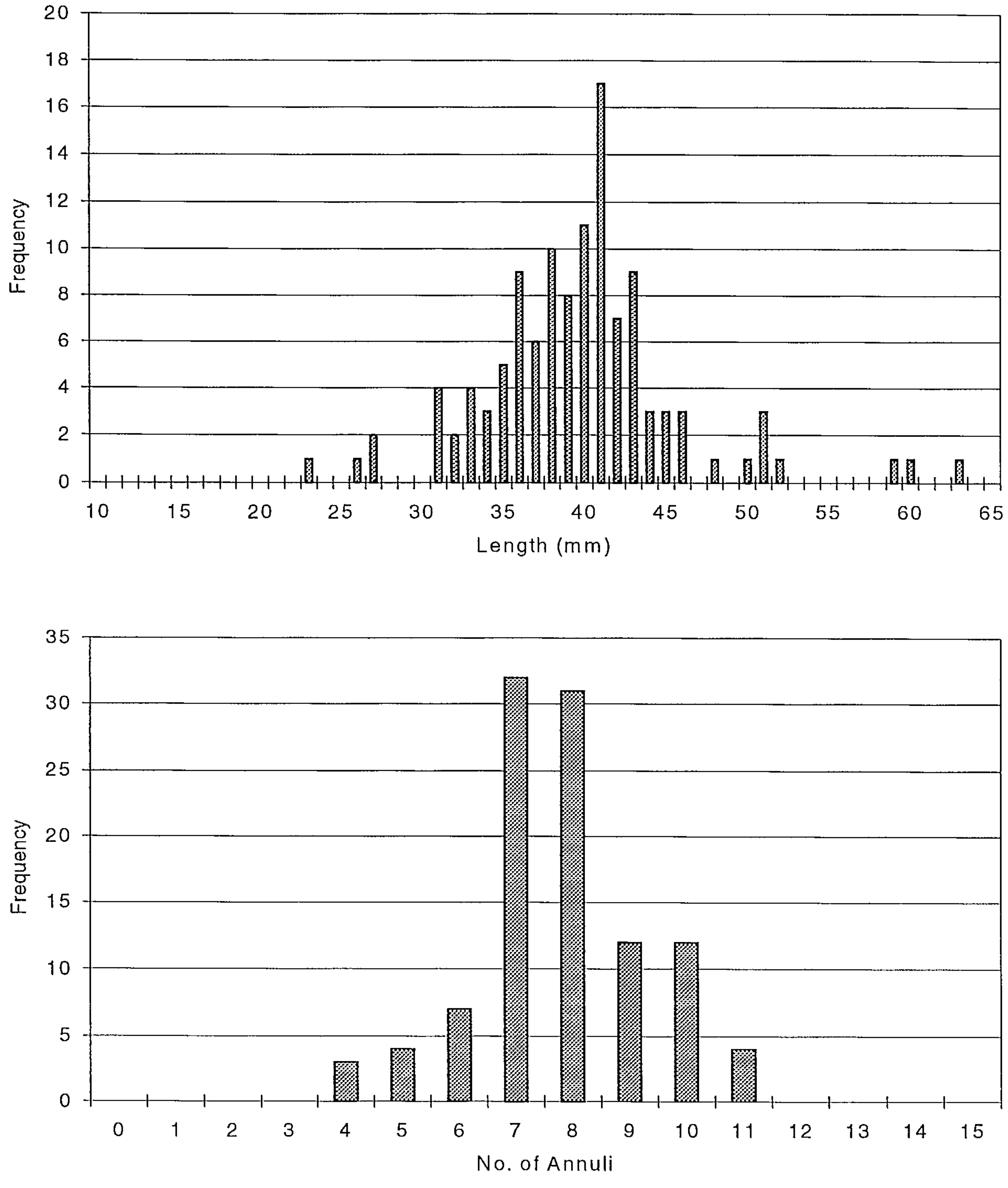


Fig. 16. Length and age frequency distributions of littleneck clams from Meyers Passage, August 7, 1998.

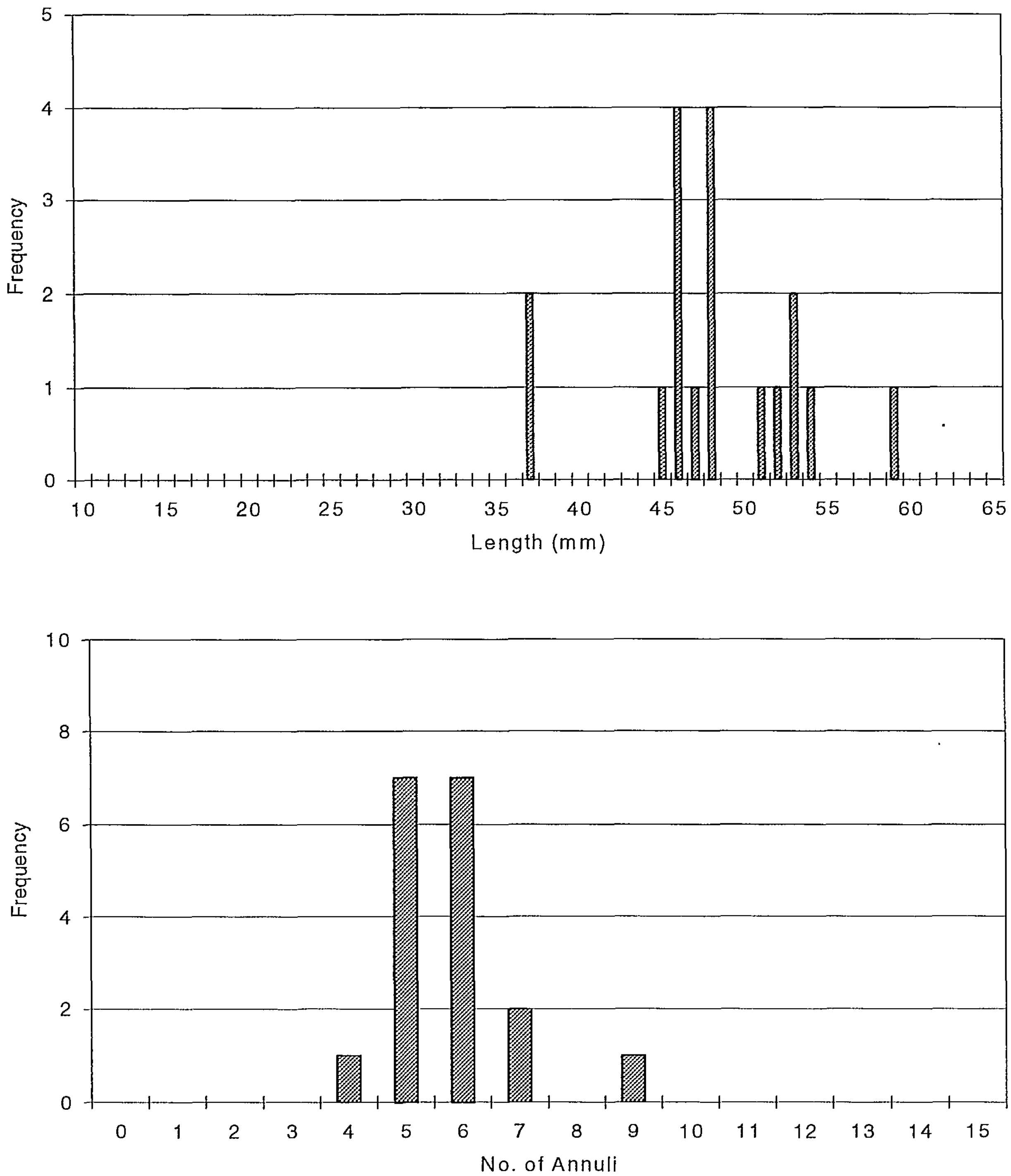


Fig. 17. Length and age frequency distributions of Manila clams from Corney Cove, Meyers Passage, August 7, 1998.

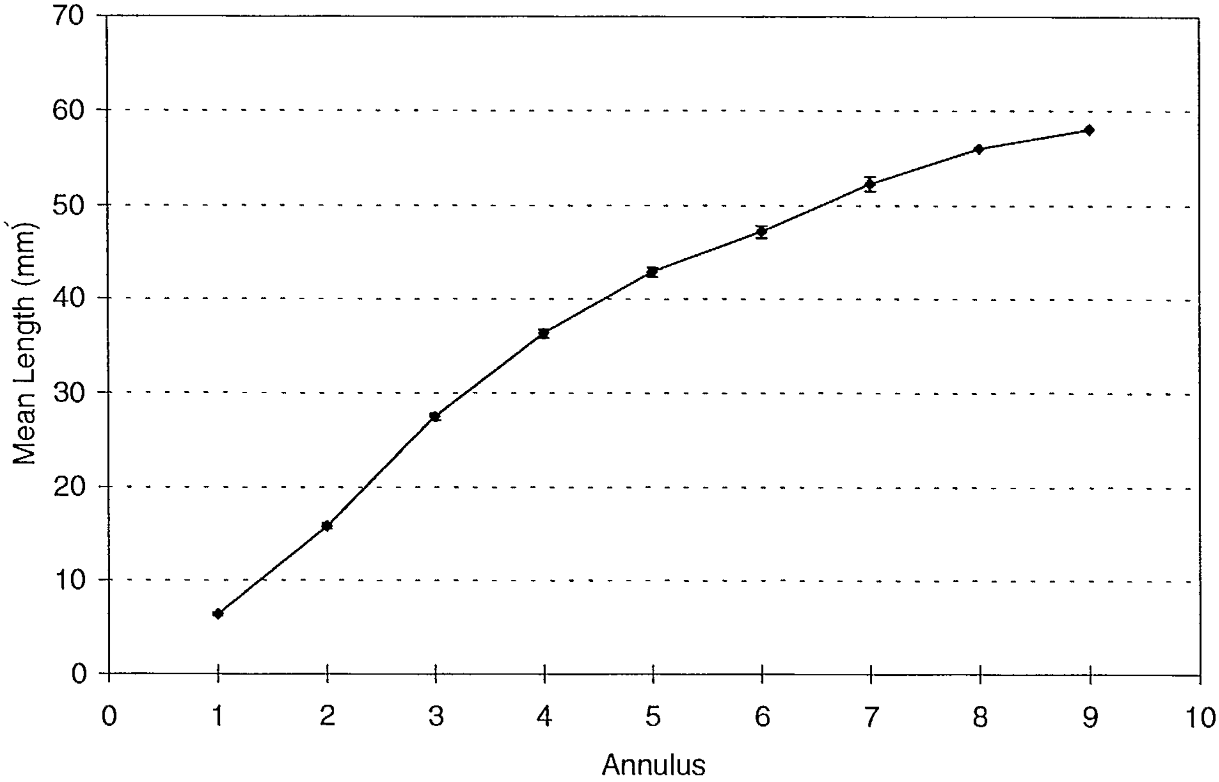


Fig. 18. Growth curve for Manila clams (n=18) from Corney Cove, Meyers Passage, August 7, 1998. Error bars are 95% confidence limits of mean length at annulus.

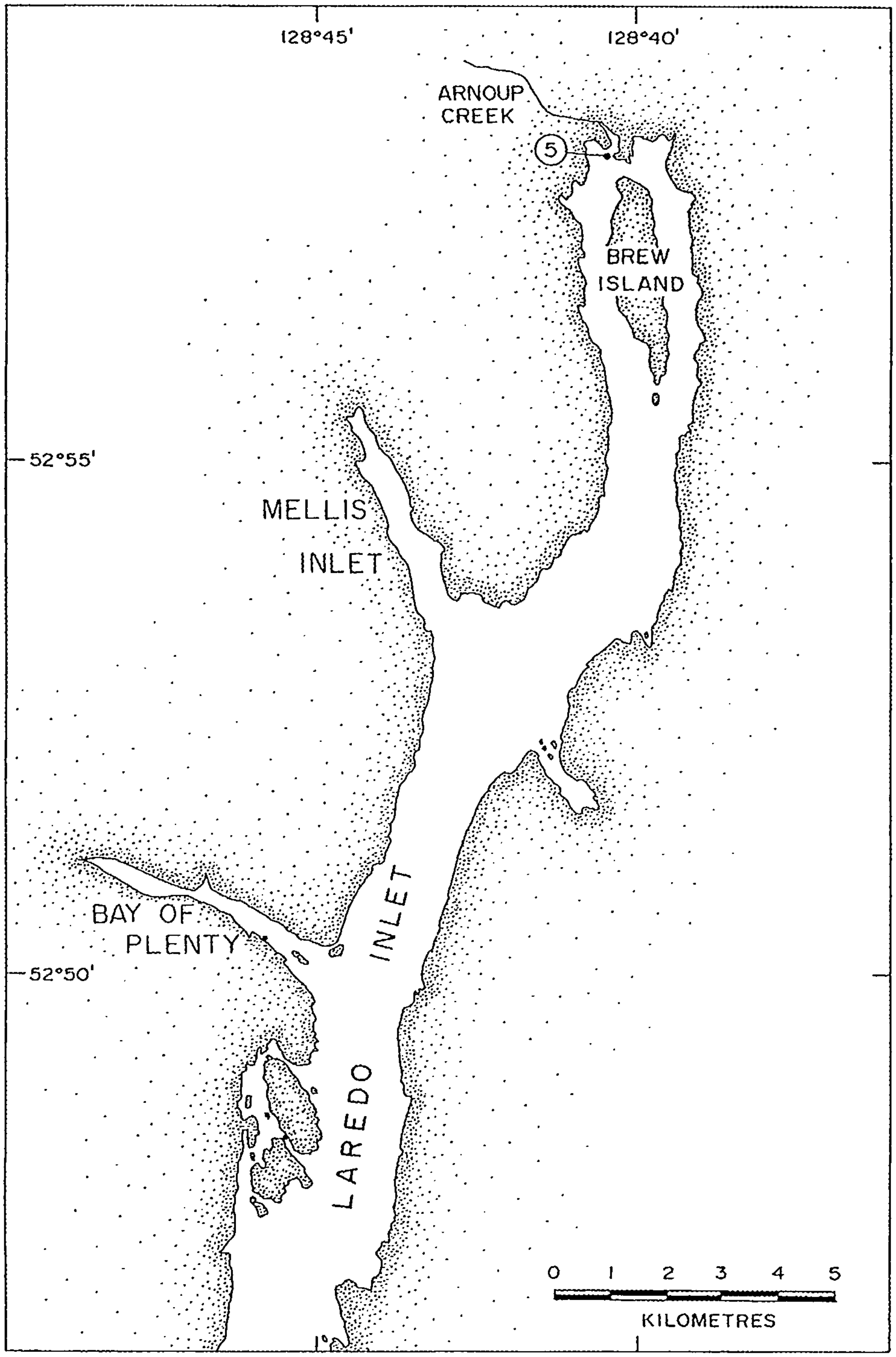
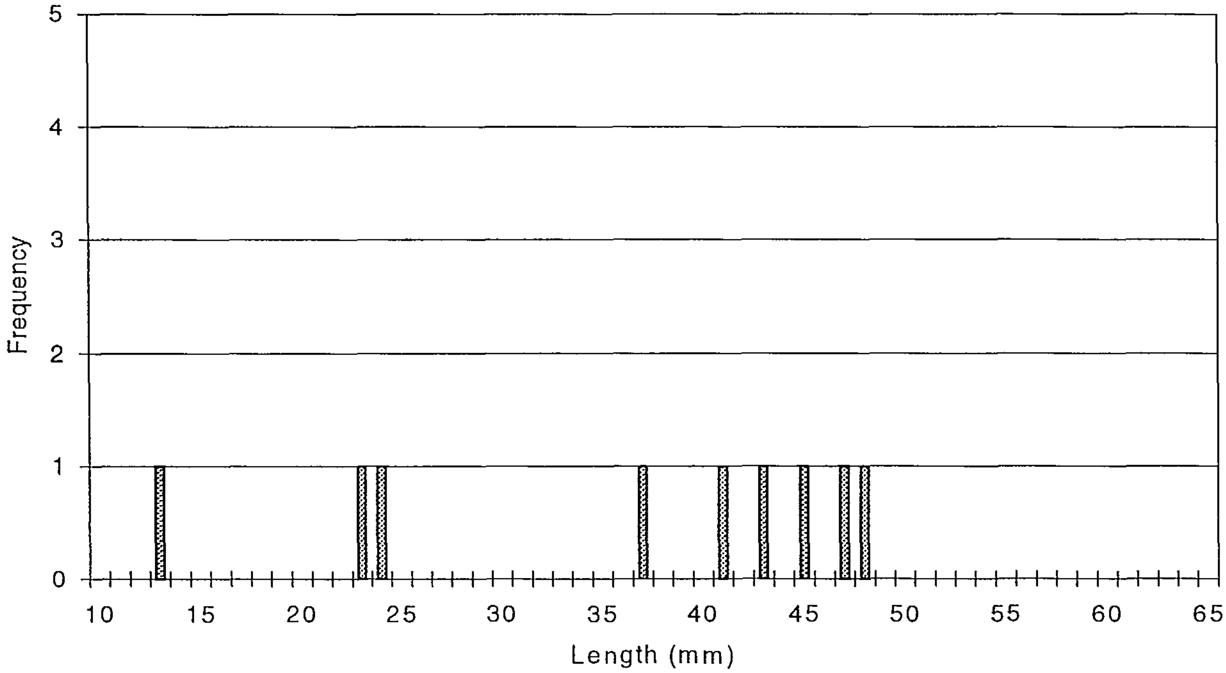


Fig. 19. Location of beach surveyed in Laredo Inlet, August 7, 1998.



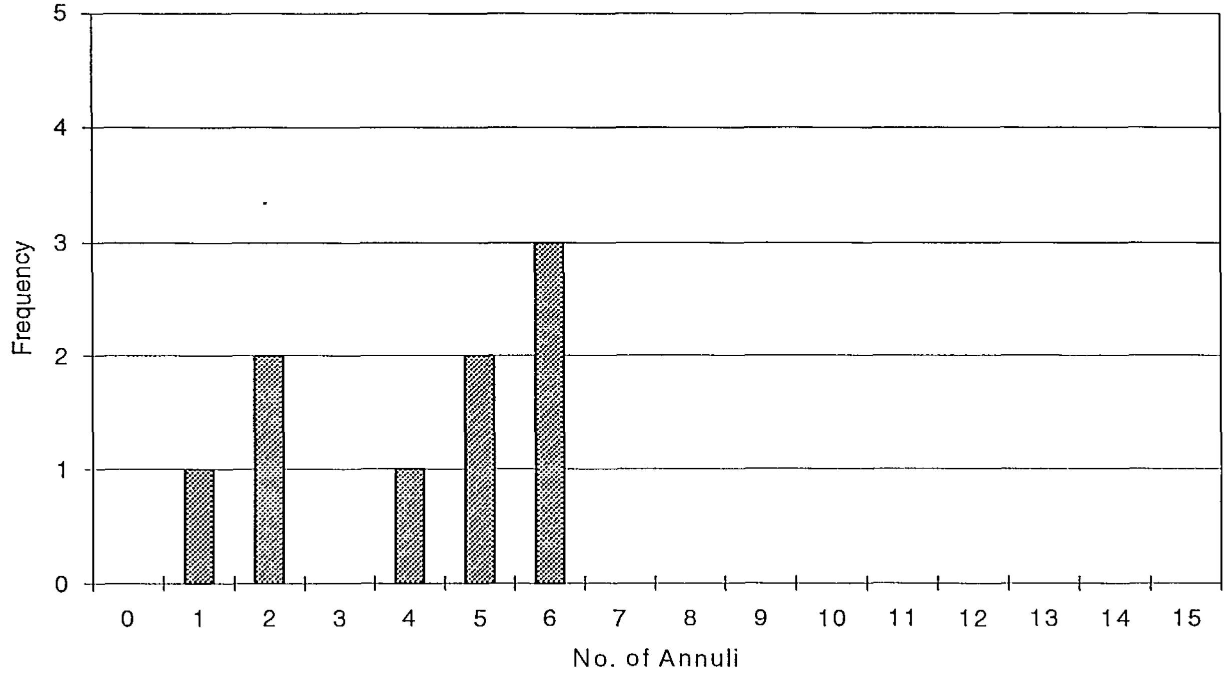


Fig. 20. Length and age frequency distributions of Manila clams from Laredo Inlet, August 7, 1998.

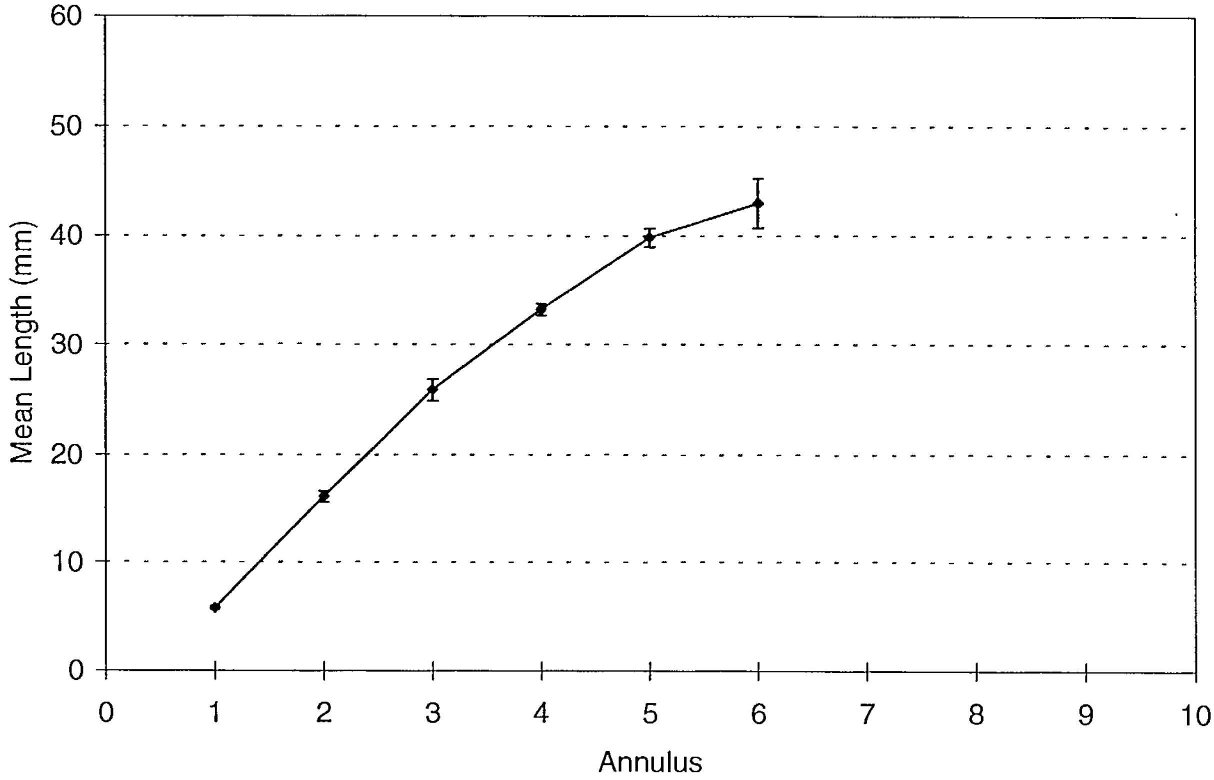


Fig. 21. Growth curve for Manila clams (n=9) from Laredo Inlet, August 7, 1998. Error bars are 95% confidence limits of mean length at annulus.

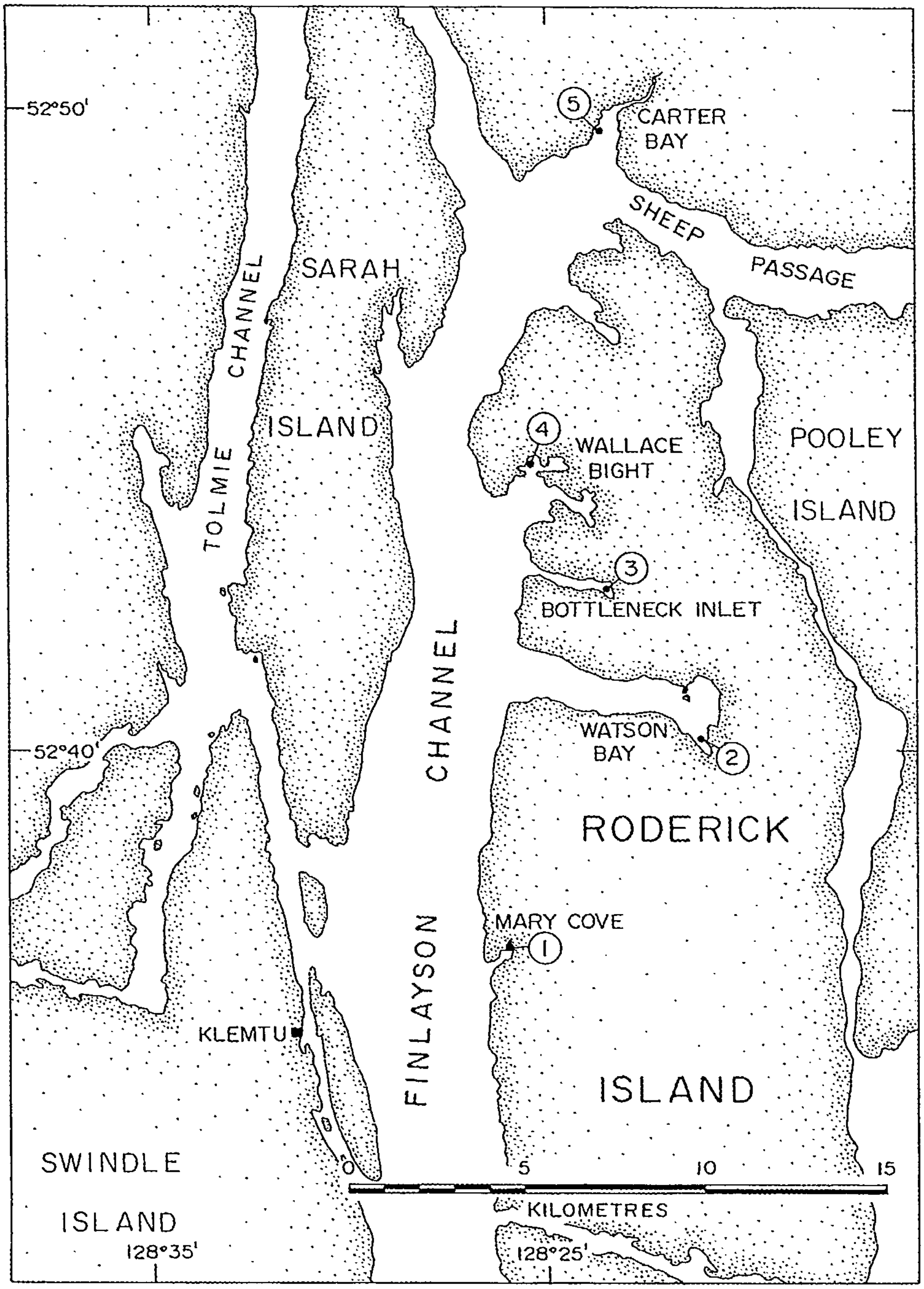


Fig. 22. Location of beaches surveyed in Finlayson Channel, August 8, 1998.

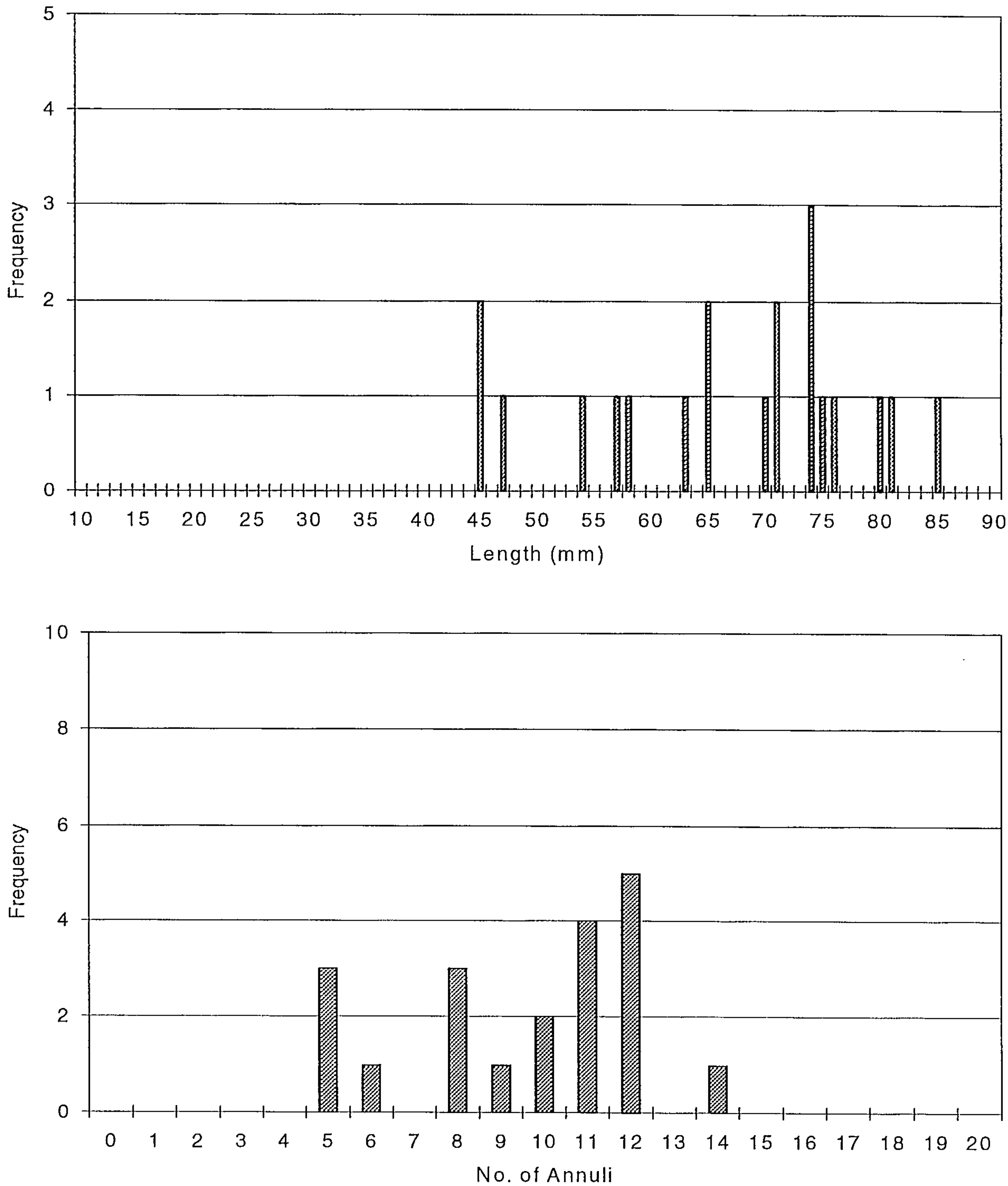


Fig. 23. Length and age frequency distributions of butter clams from Watson Bay, Finlayson Channel, August 8, 1998.

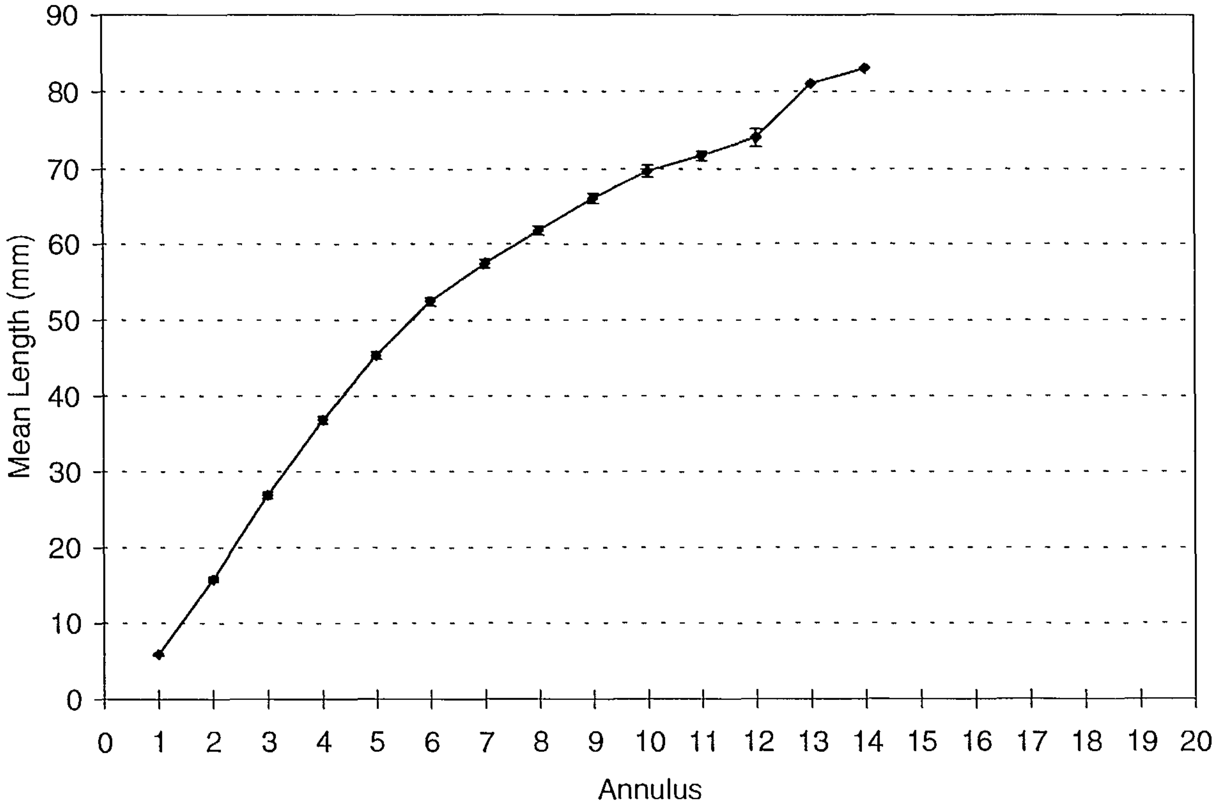
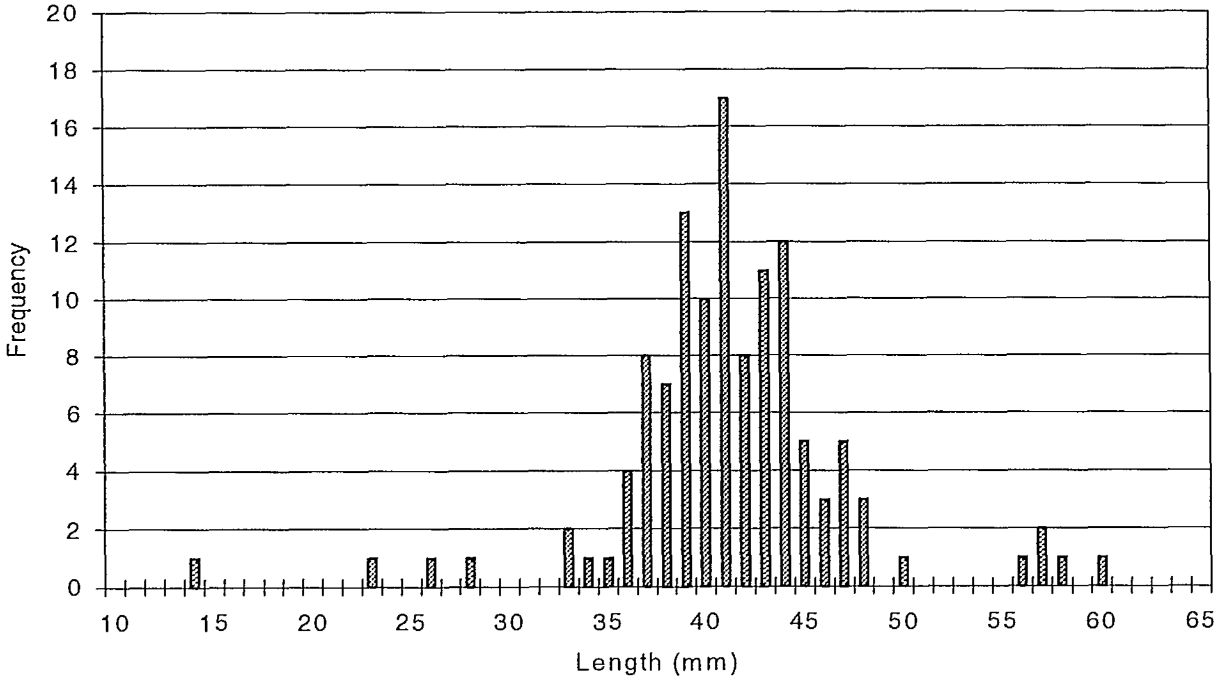


Fig. 24. Growth curve for butter clams (n=11) from Watson Bay, Finlayson Channel, August 8, 1998. Error bars are 95% confidence limits of mean length at annulus.



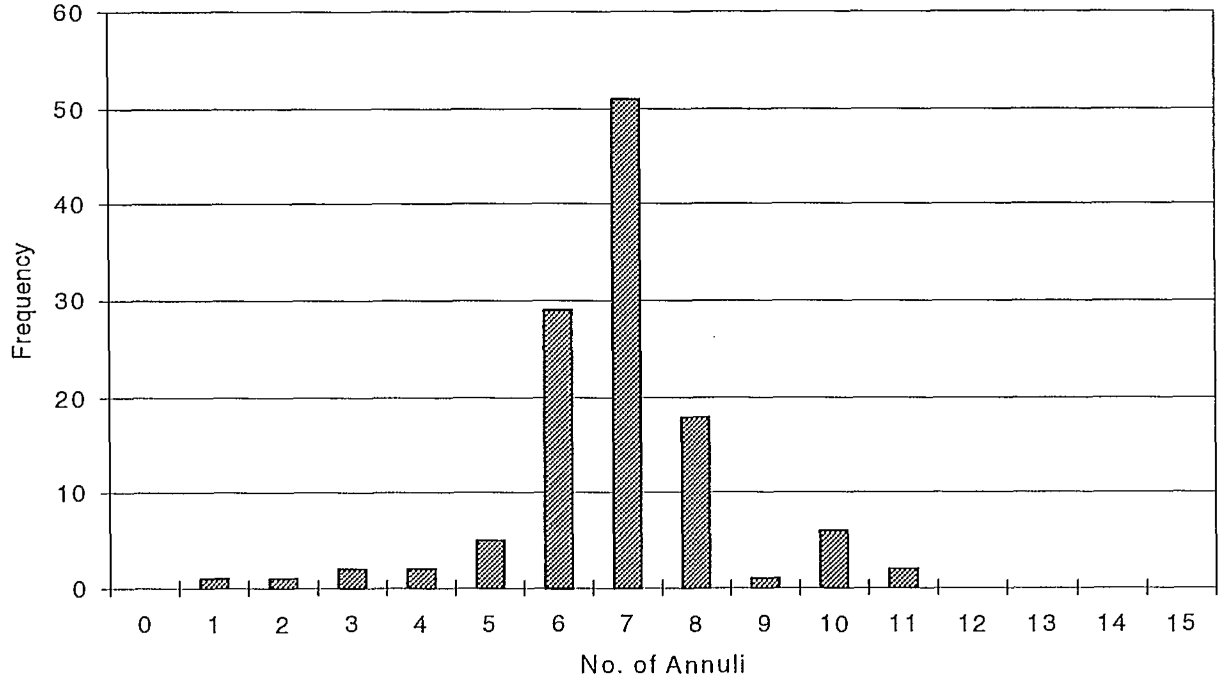


Fig. 25. Length and age frequency distributions of littleneck clams from Watson Bay, Finlayson Channel, August 8, 1998.

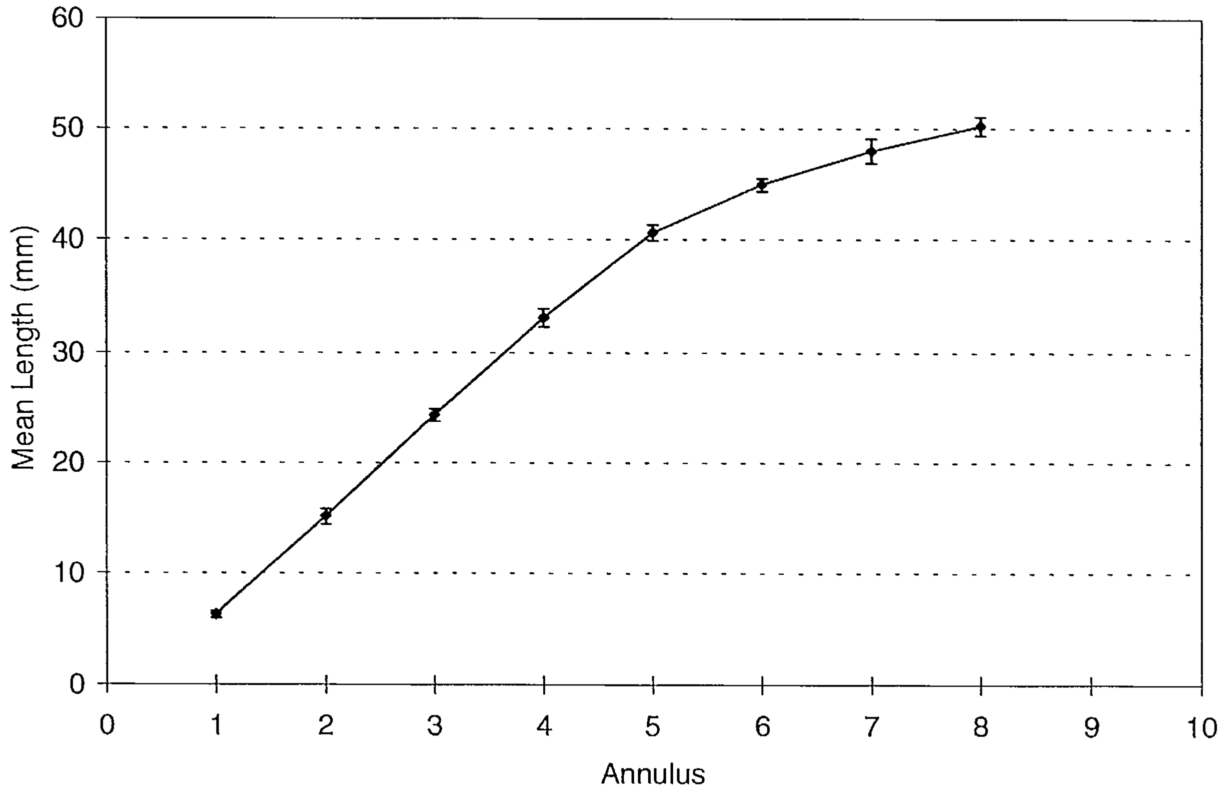
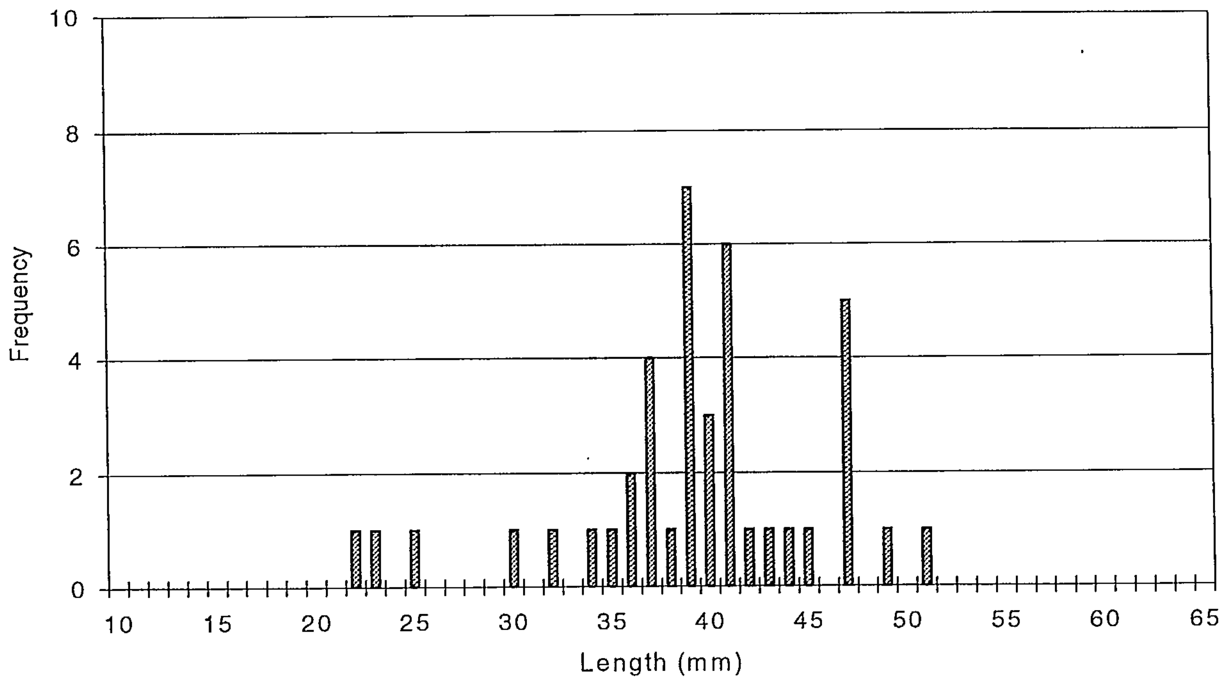


Fig. 26. Growth curve for Manila clams (n=13) from Watson Bay, Finlayson Channel, August 8, 1998. Error bars are 95% confidence limits of mean length at annulus.



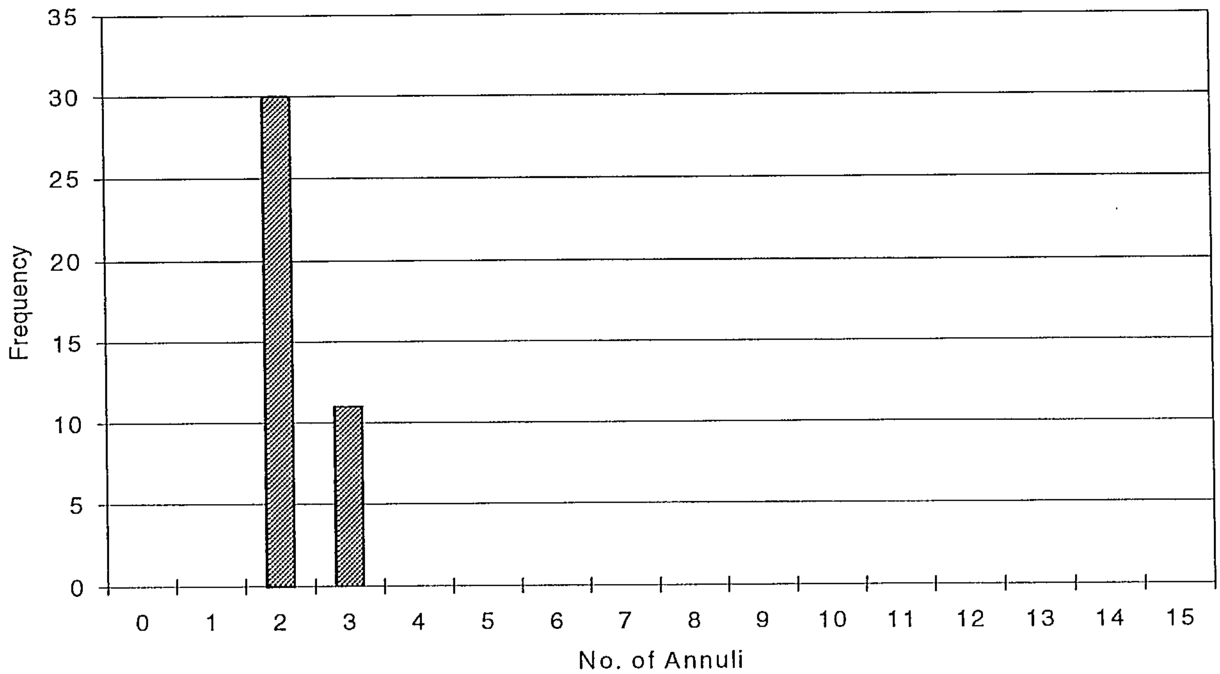
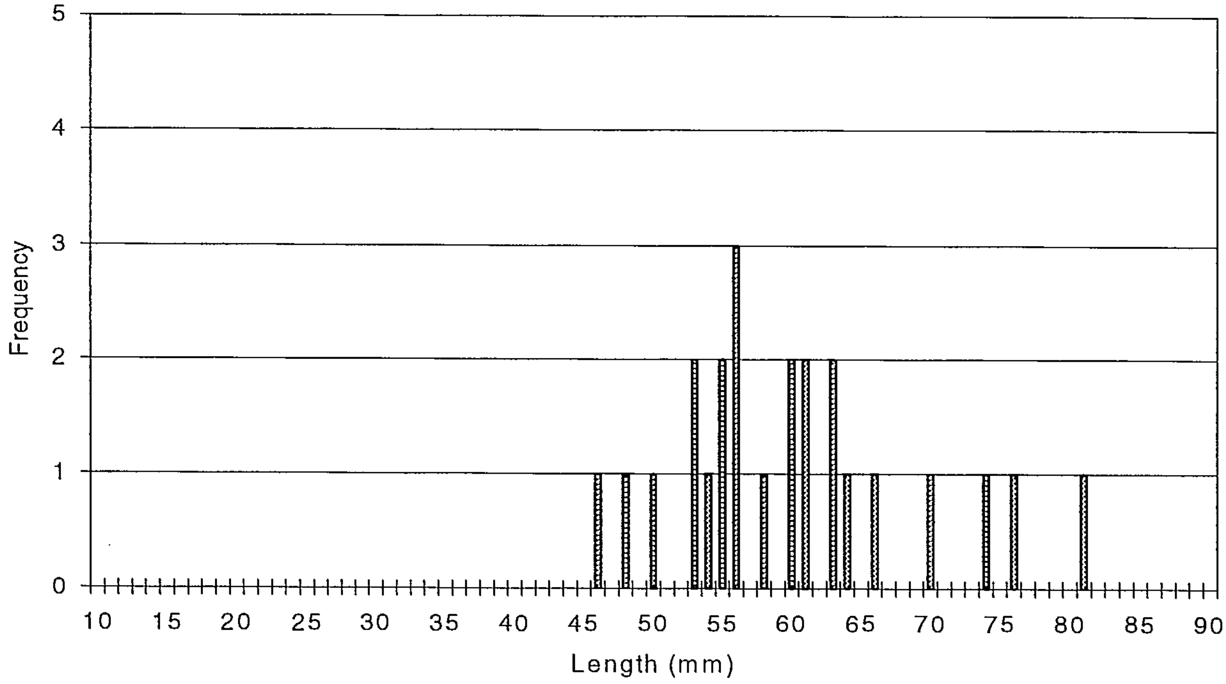


Fig. 27. Height and age frequency distributions of cockles from Watson Bay, Finlayson Channel, August 8, 1998.



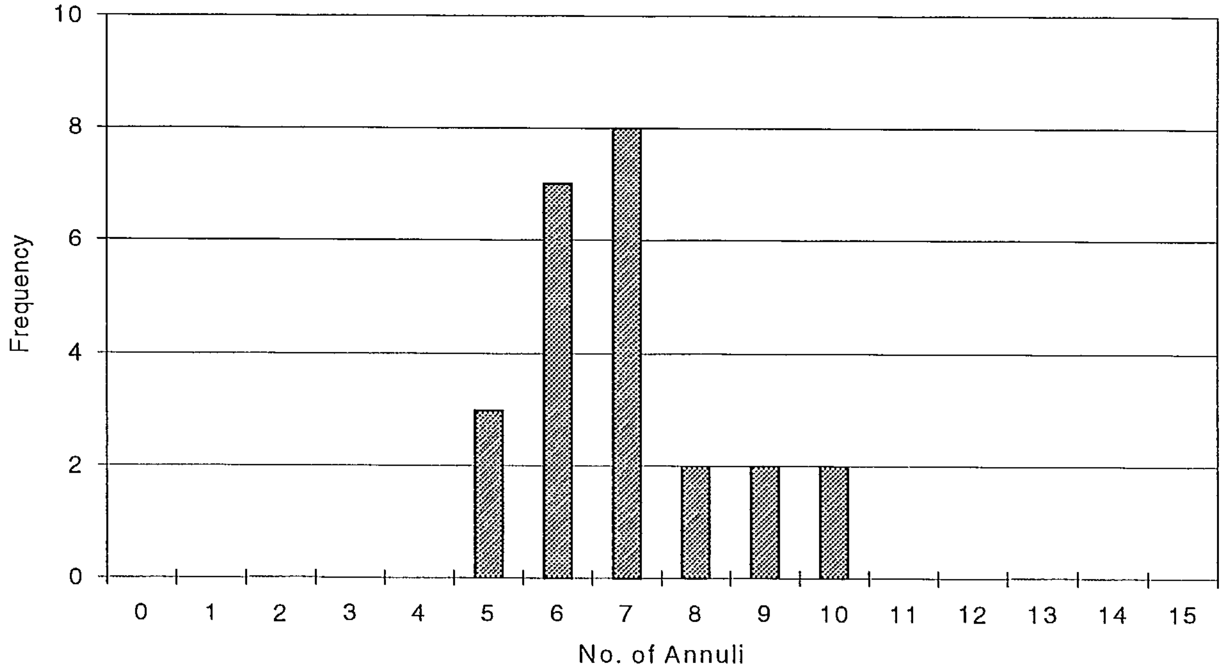


Fig. 28. Length and age frequency distributions of soft-shell clams from Bottleneck Inlet, Finlayson Channel, August 8, 1998.

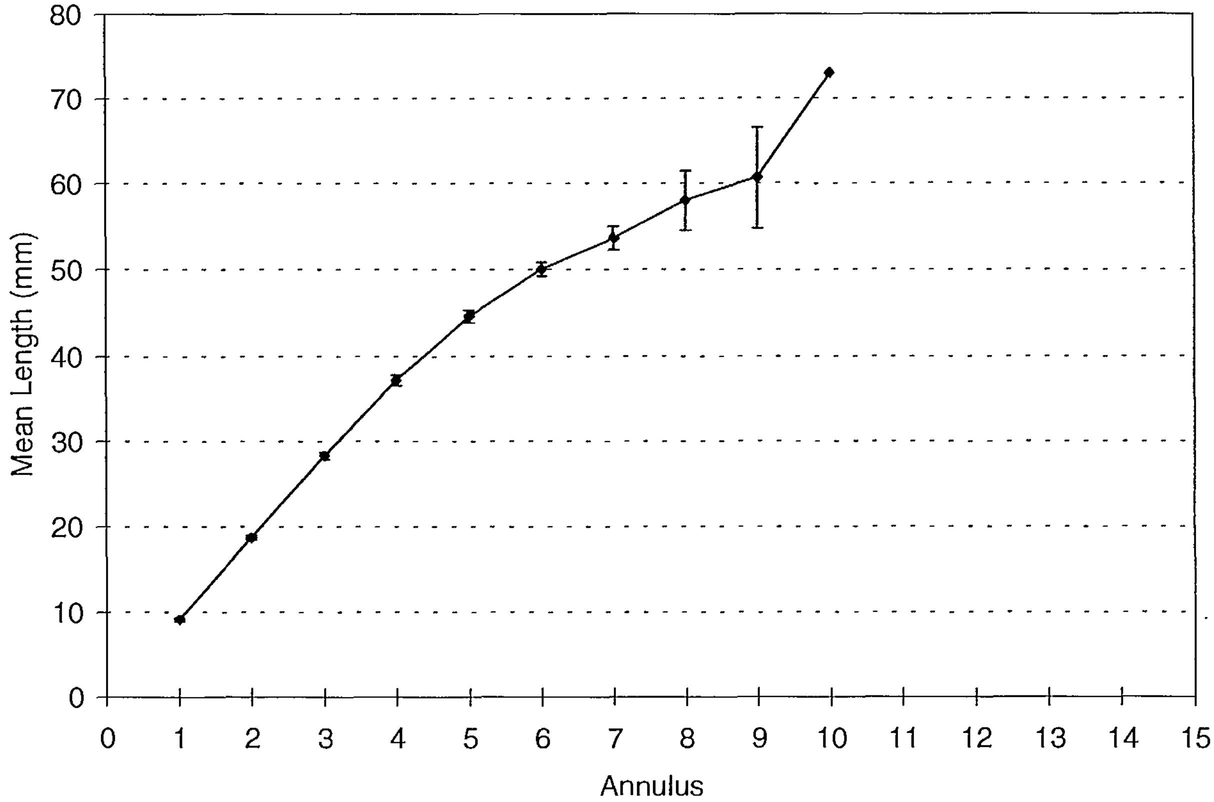


Fig. 29. Growth curve for soft-shell clams (n=22) from Bottleneck Inlet, Finlayson Channel, August 8, 1998. Error bars are 95% confidence limits of mean length at annulus.

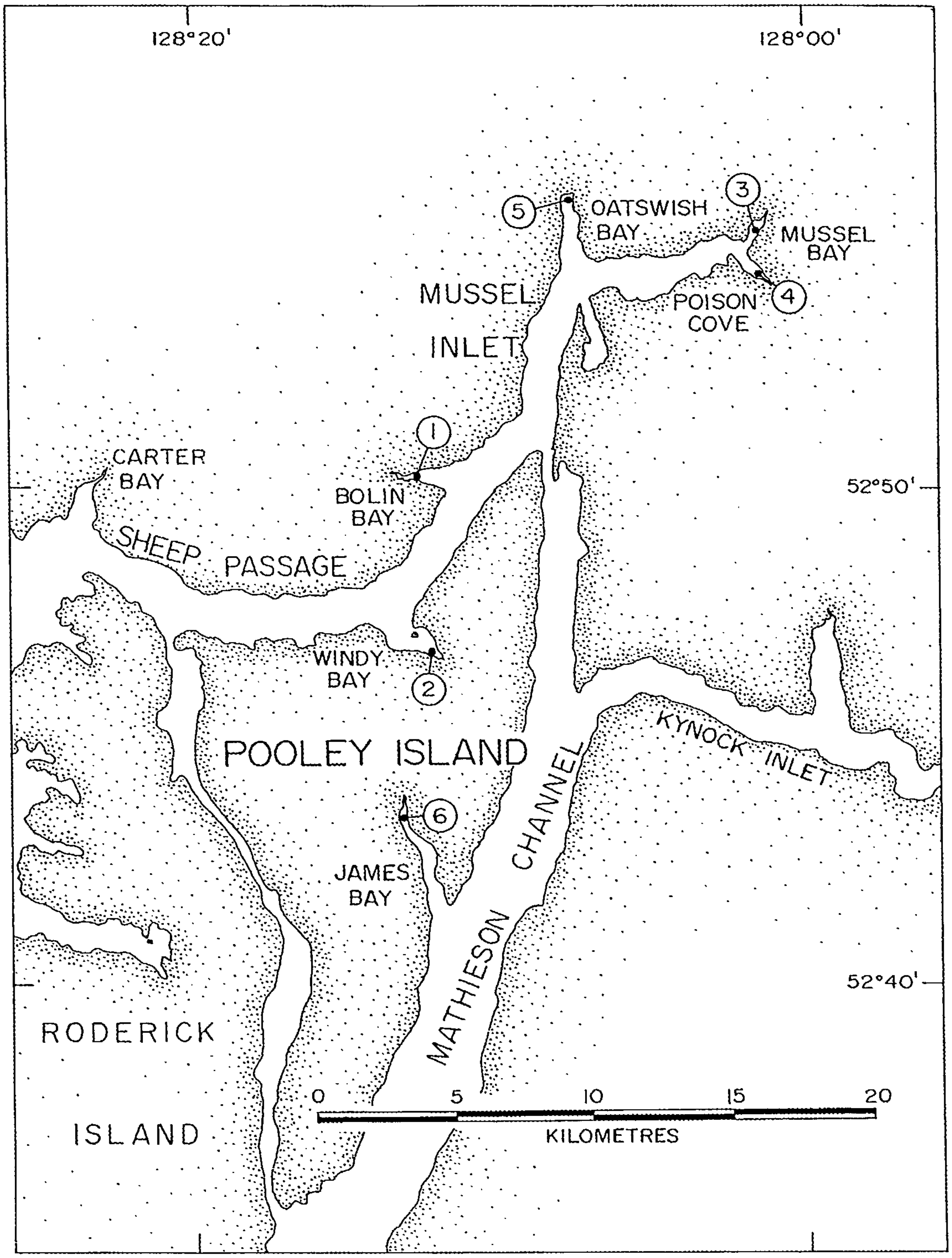


Fig. 30. Location of beaches surveyed in Sheep Passage, Mussel Inlet and Mathieson Channel, August 9, 1998.

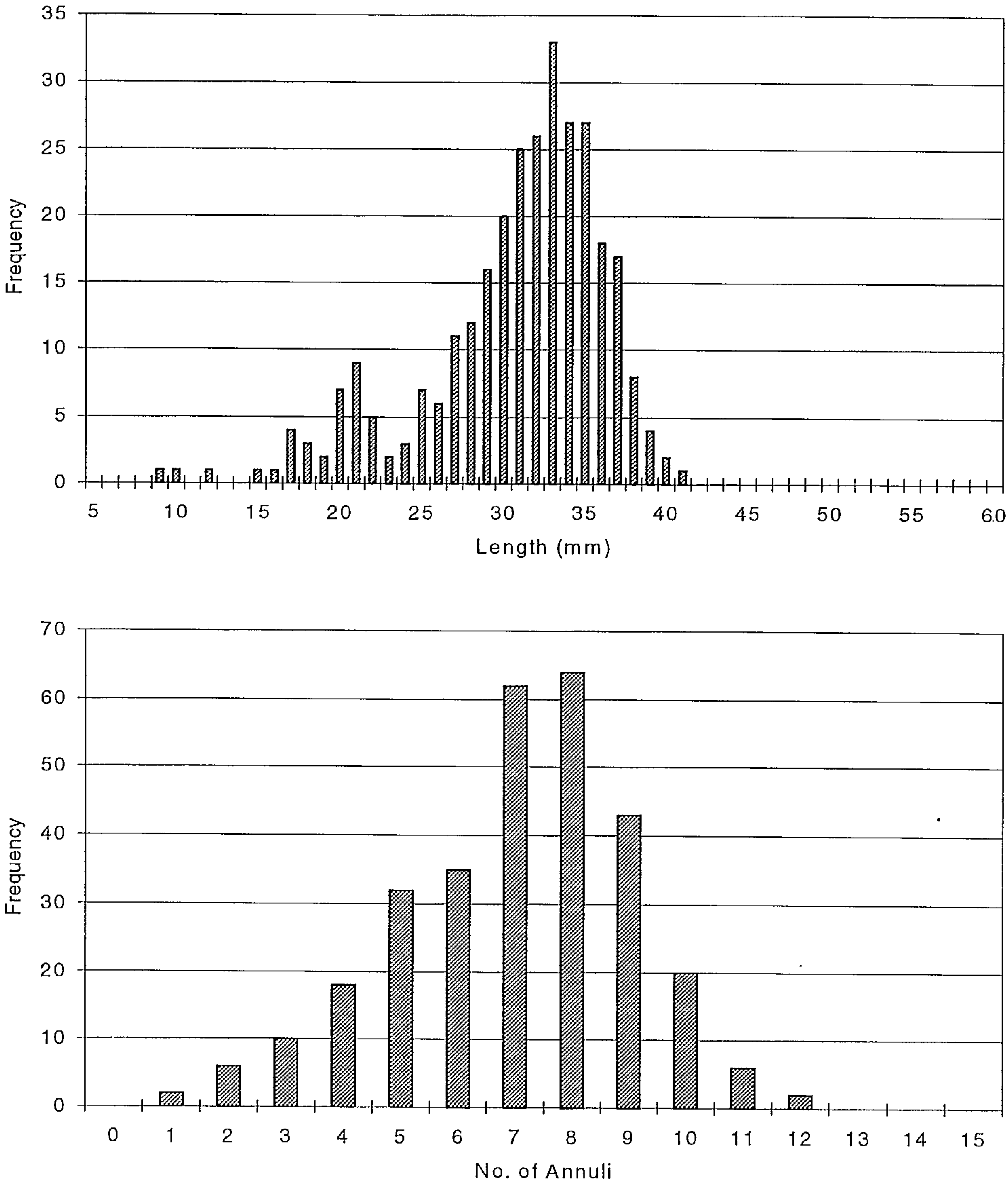
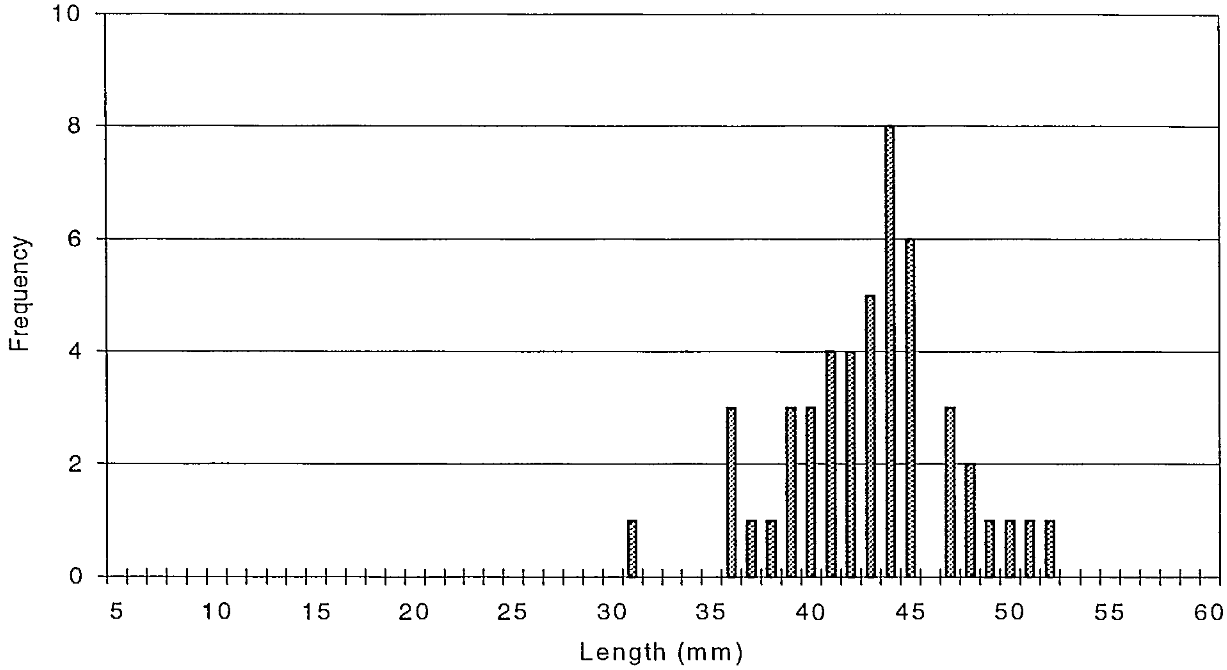


Fig. 31. Length and age frequency distributions of littleneck clams from Sheep Passage, August 9, 1998.



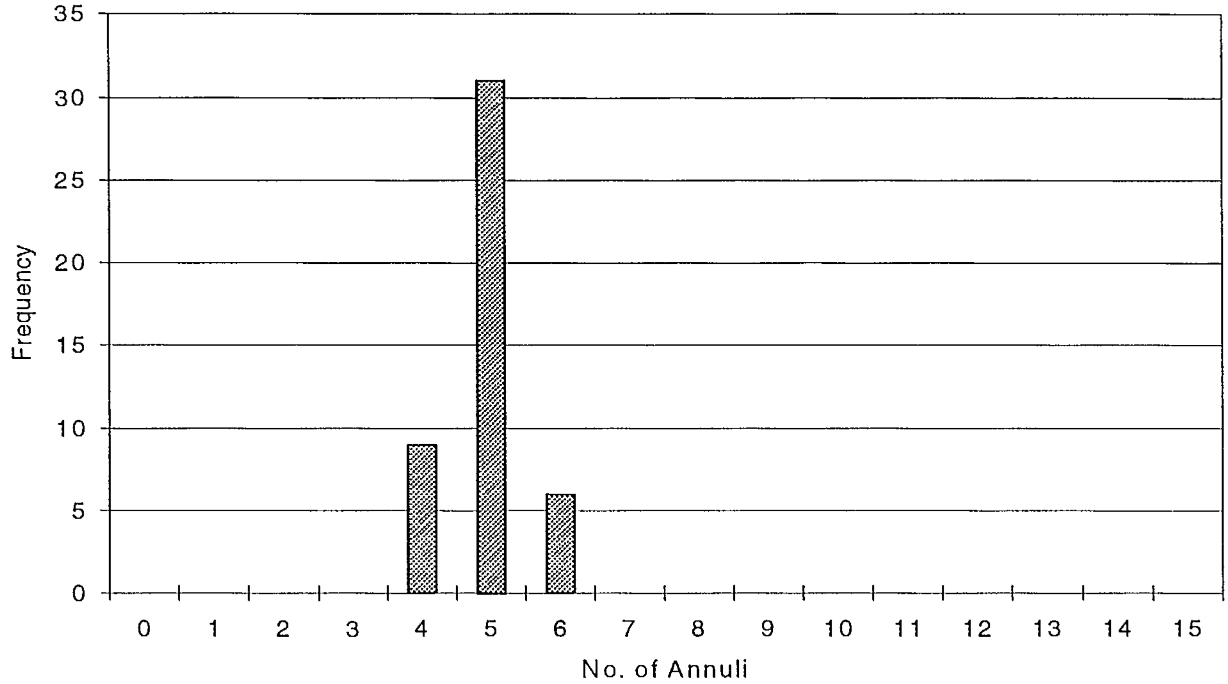


Fig. 32. Length and age frequency distributions of Manila clams from Windy Bay, Sheep Passage, August 9, 1998.

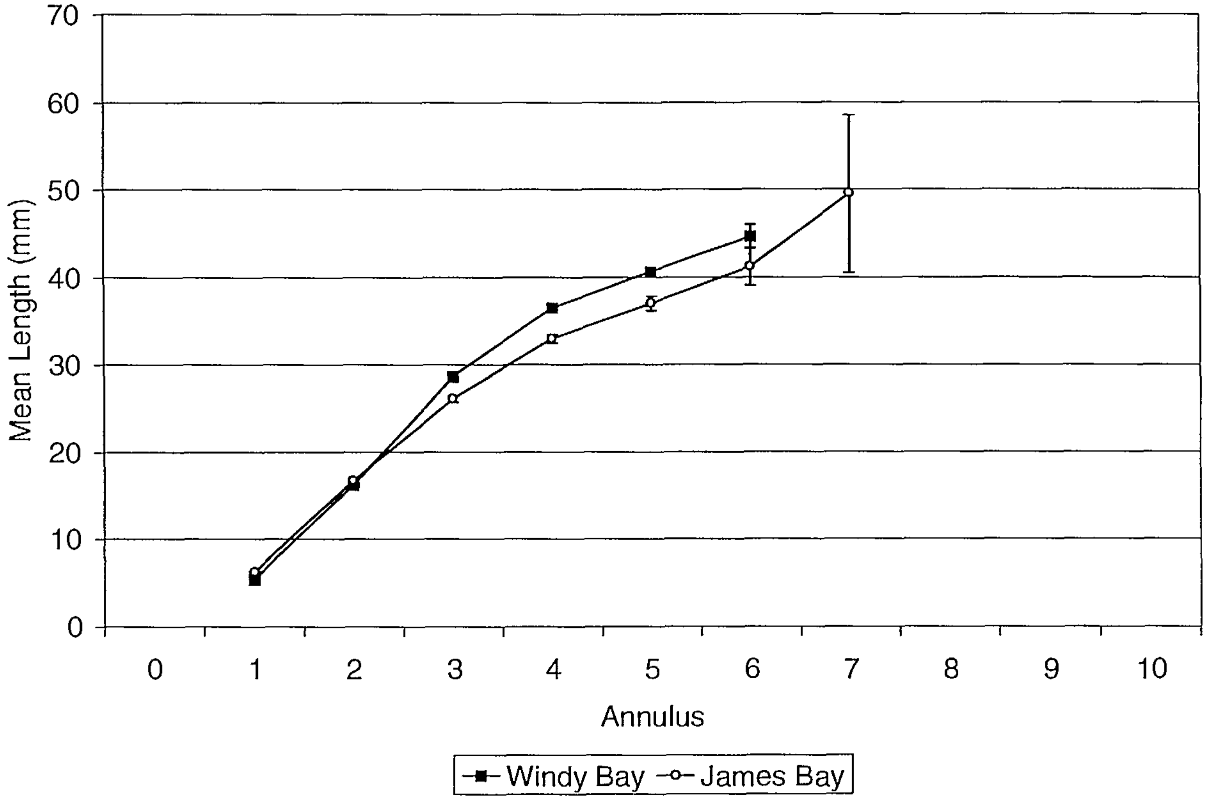


Fig. 33. Growth curve for Manila clams from Windy Bay, Sheep Passage (n=46), and James Bay, Mathieson Channel (n=16), August 9, 1998. Error bars are 95% confidence limits of mean length at annulus.

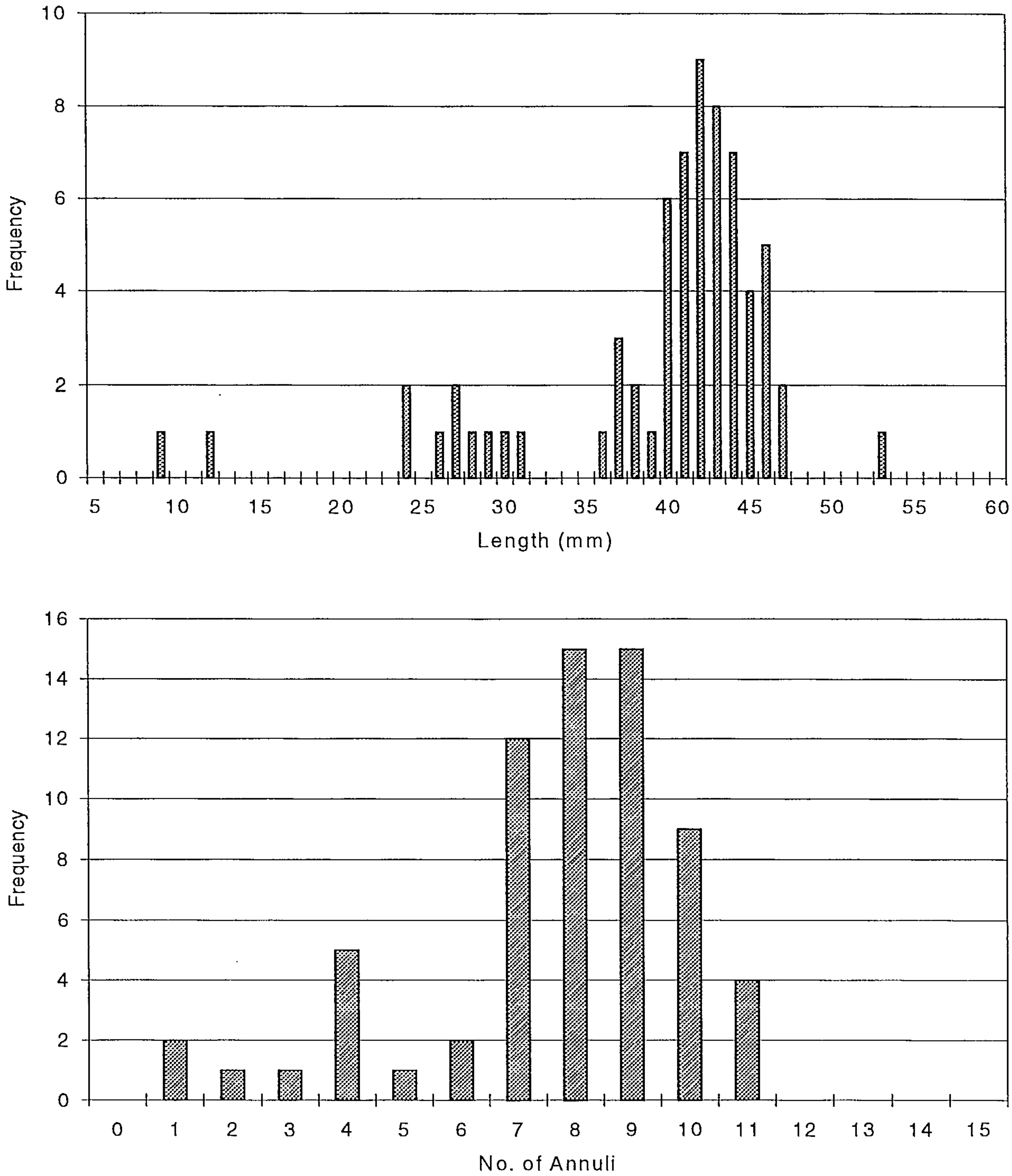


Fig. 34. Length and age frequency distributions of littleneck clams from Poison Cove, Mussel Inlet, August 9, 1998.

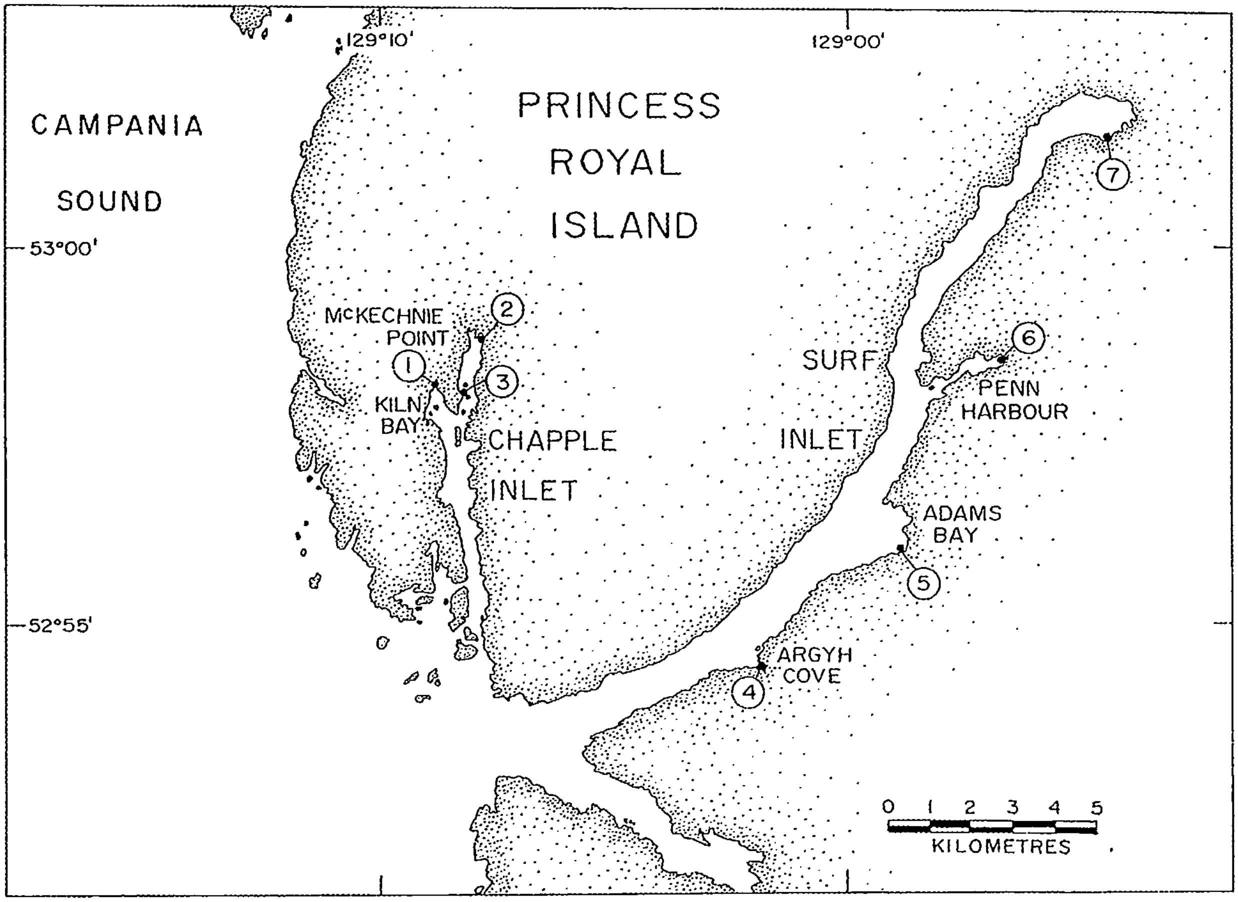


Fig. 35. Location of beaches surveyed in Chapple and Surf Inlets, August 10, 1998.

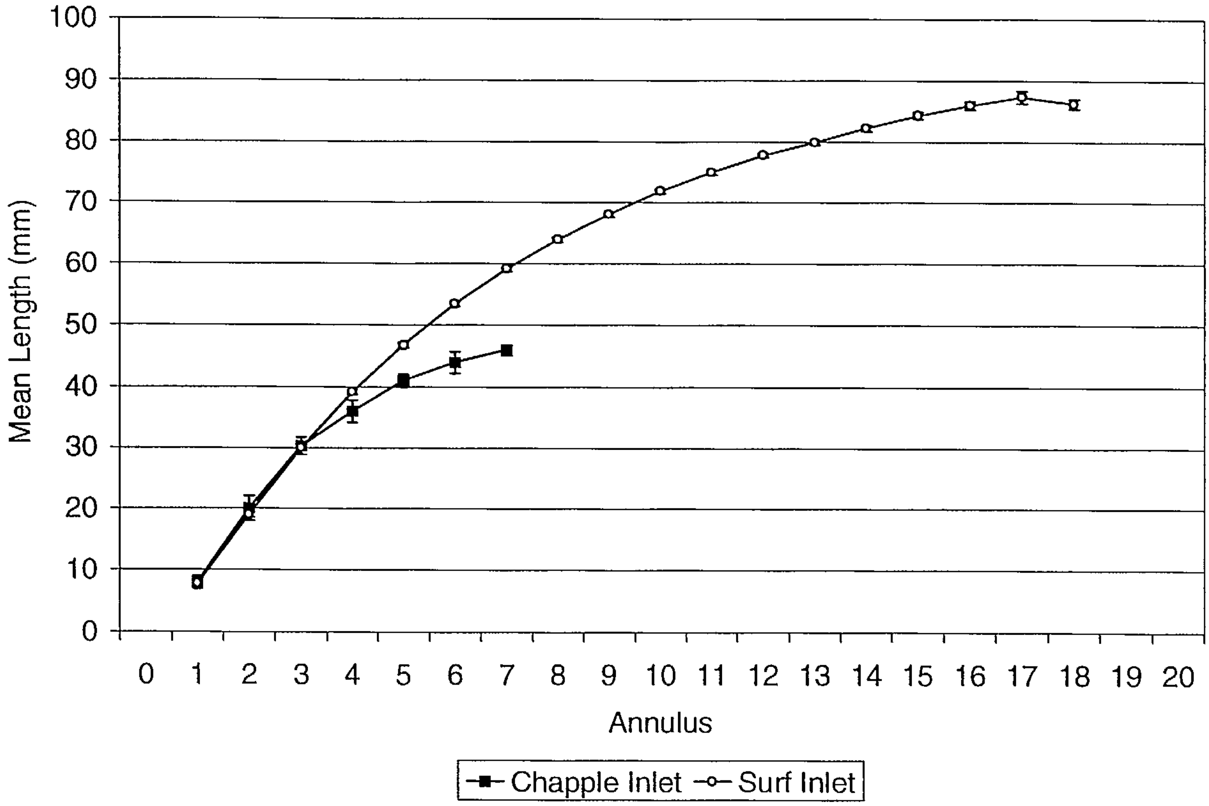


Fig. 36. Growth curve for butter clams from McKechnie Point, Chapple Inlet (n=4), and Surf Inlet (n=21), August 10, 1998. Error bars are 95% confidence limits of mean length at annulus.

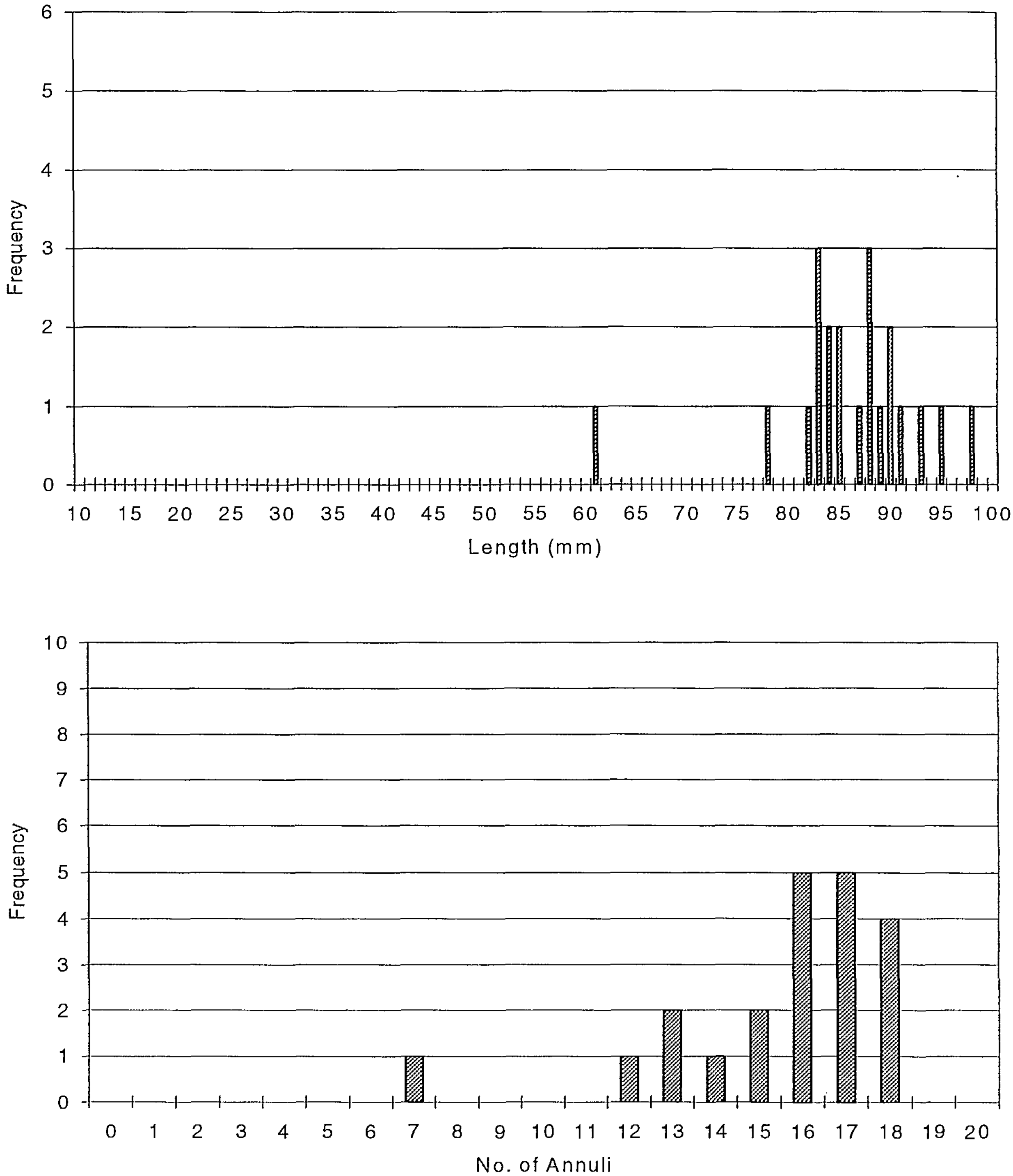
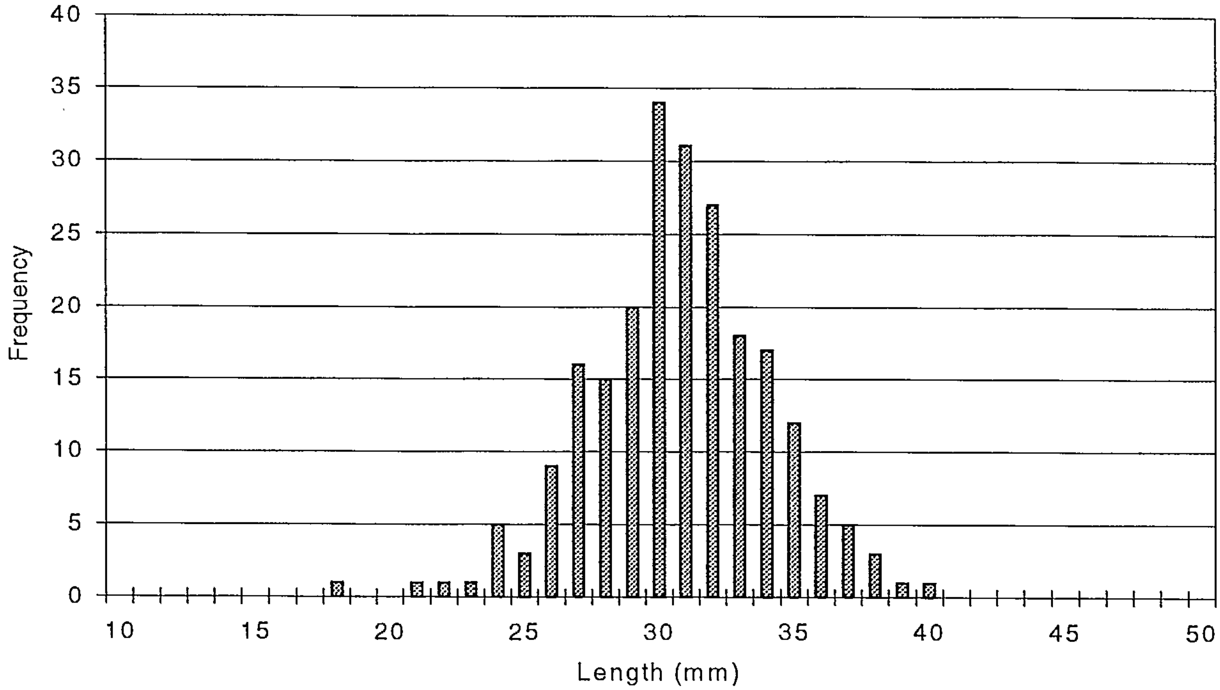


Fig. 37. Length and age frequency distributions of butter clams from Surf Inlet, August 10, 1998.



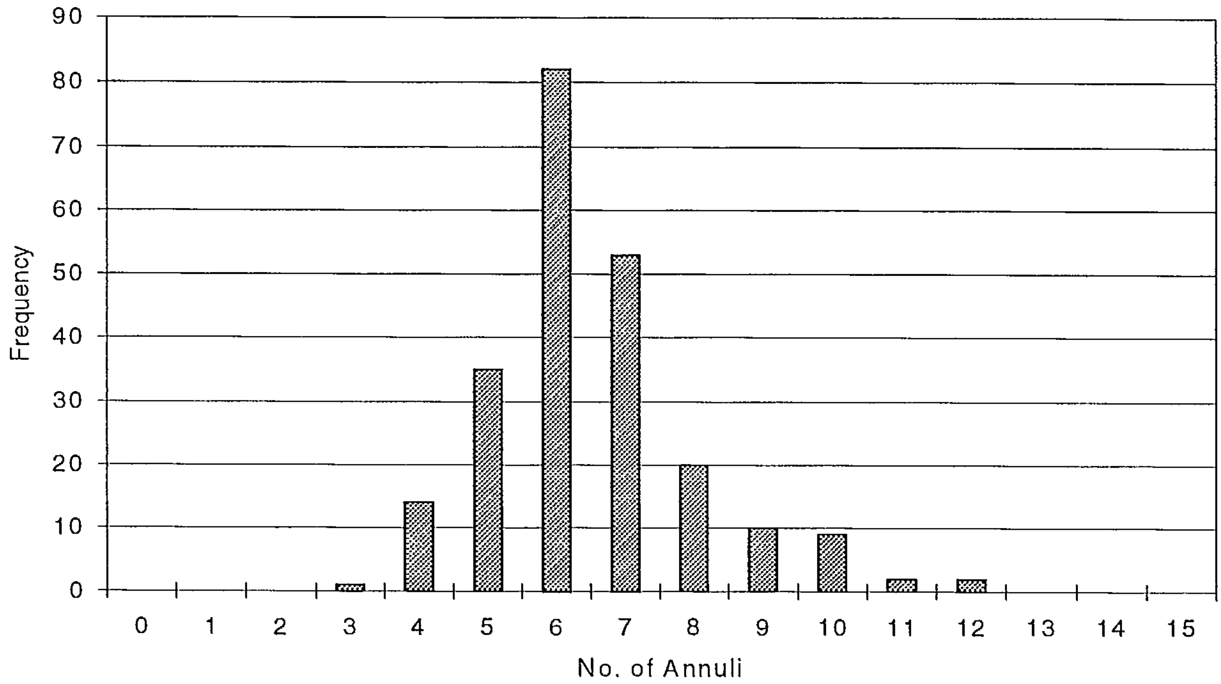
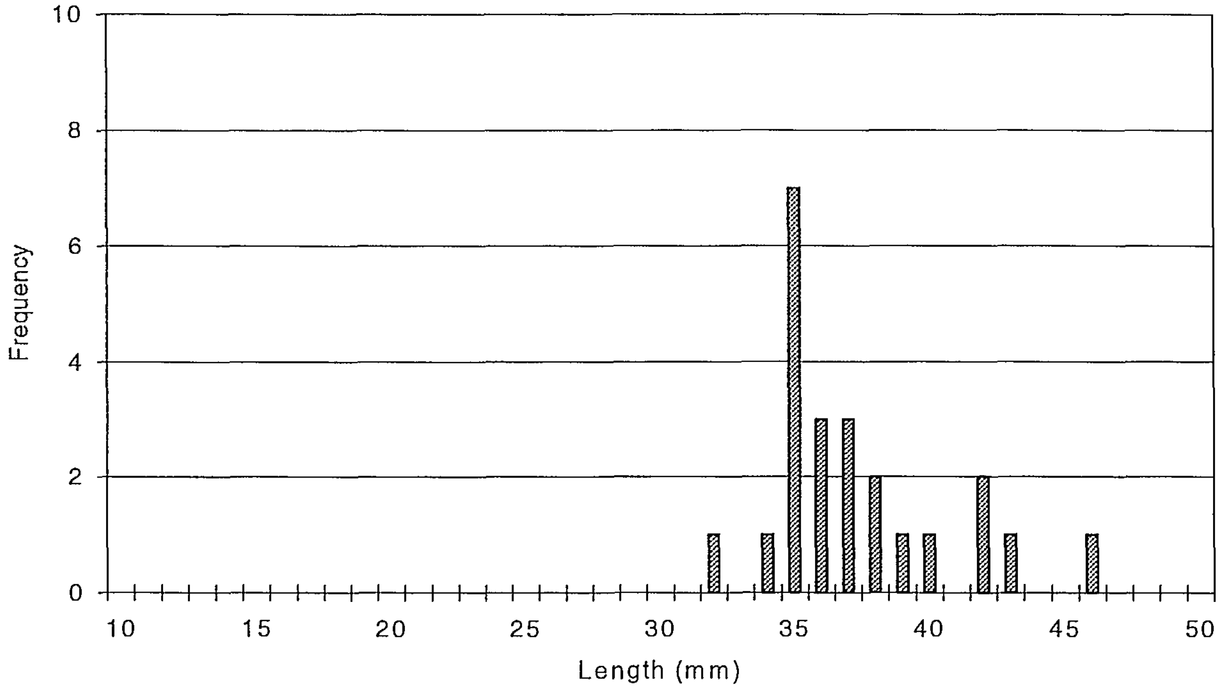


Fig. 38. Length and age frequency distributions of littleneck clams from McKechnie Point, Chapple Inlet, August 10, 1998.



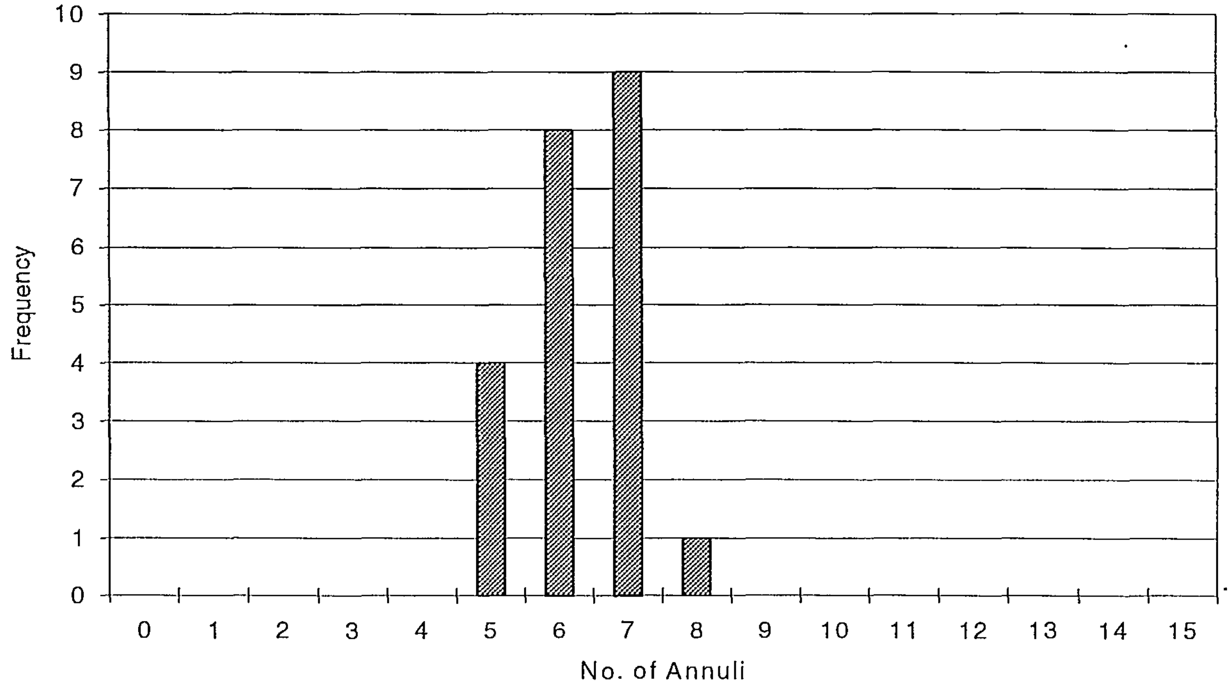


Fig. 39. Length and age frequency distributions of littleneck clams from Penn Harbour, Surf Inlet, August 10, 1998.

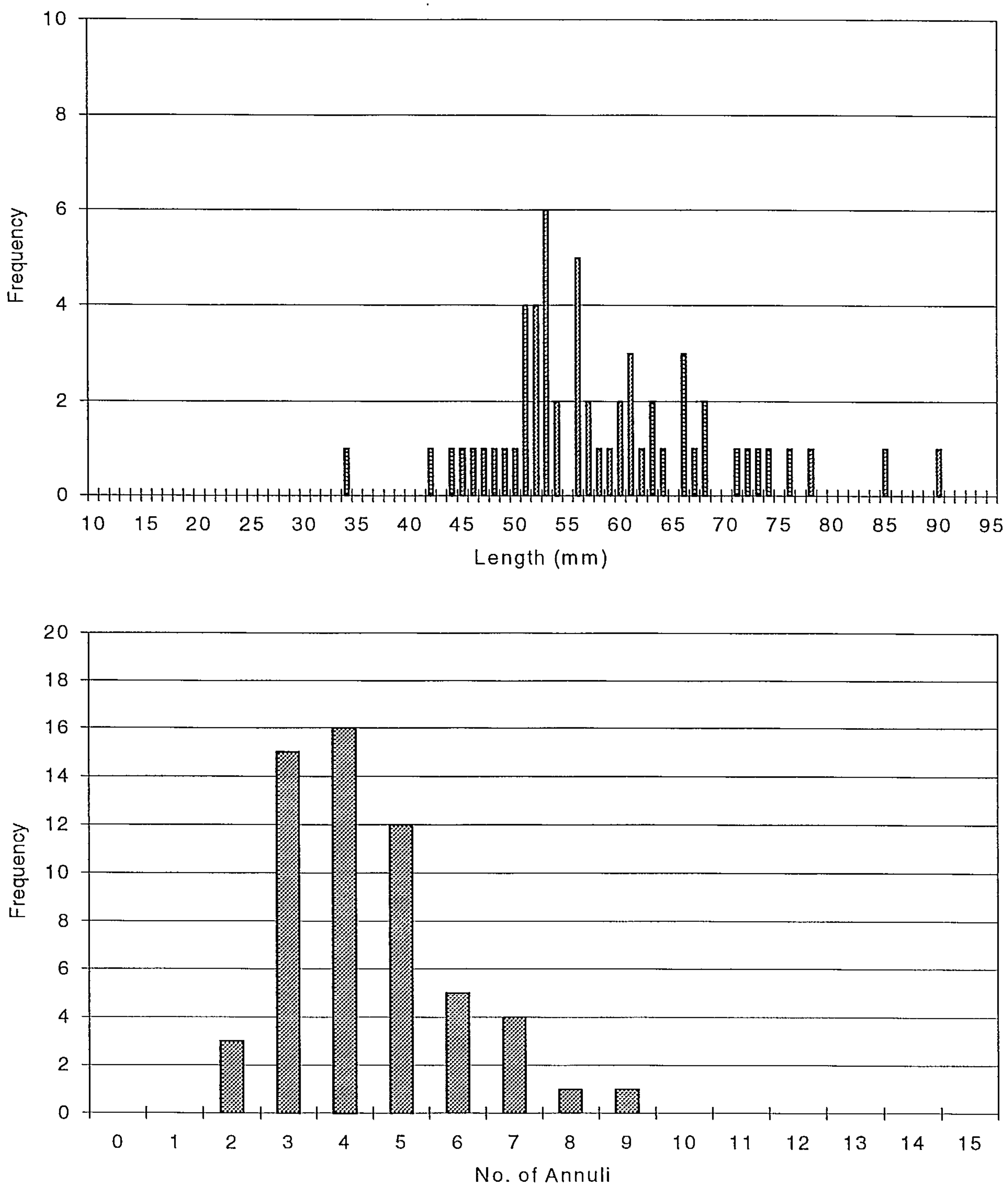


Fig. 40. Length and age frequency distributions of soft-shell clams from Chapple Inlet, August 10, 1998.

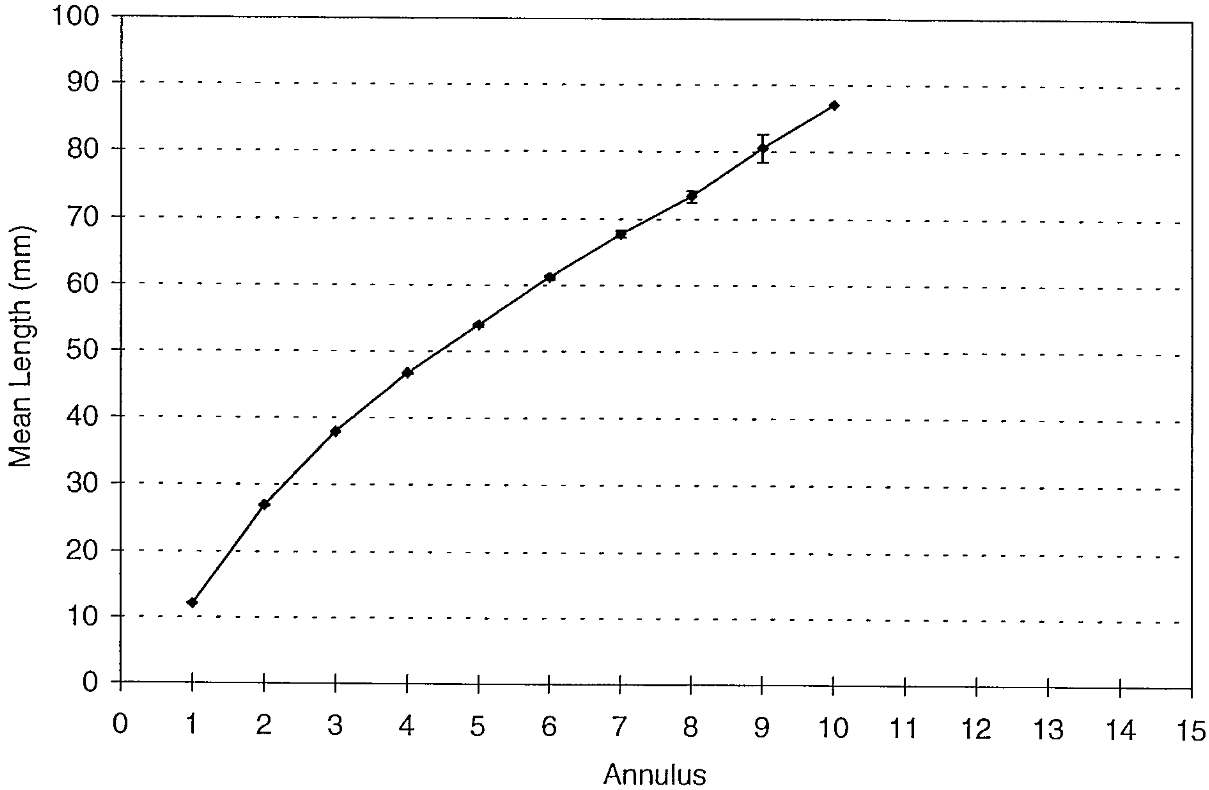


Fig. 41. Growth curve for soft-shell clams (n=59) from Chapple Inlet, August 10, 1998. Error bars are 95% confidence limits of mean length at annulus.

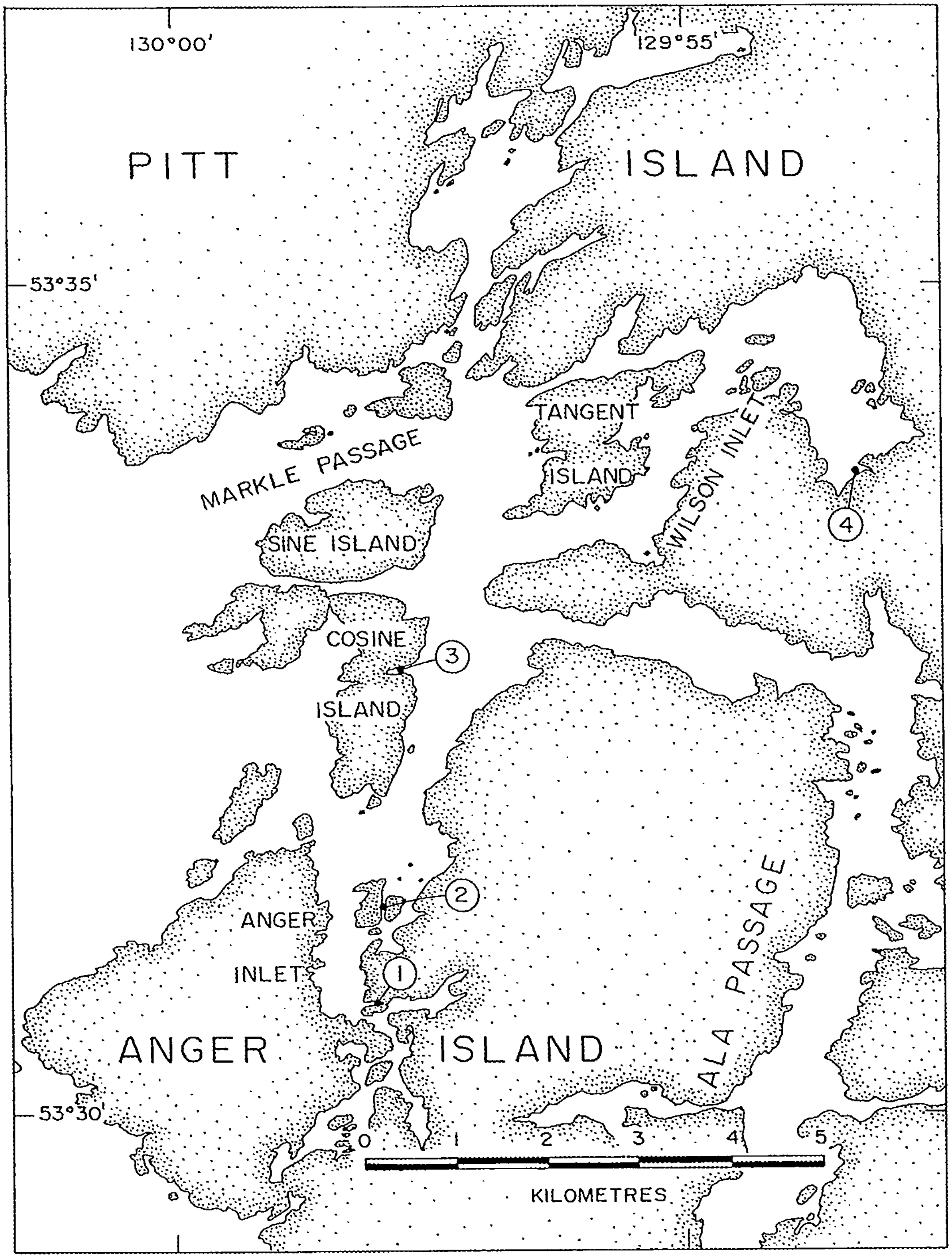


Fig. 42. Location of beaches surveyed at Anger Island, Cosine Island and Wilson Inlet, August 11, 1998.

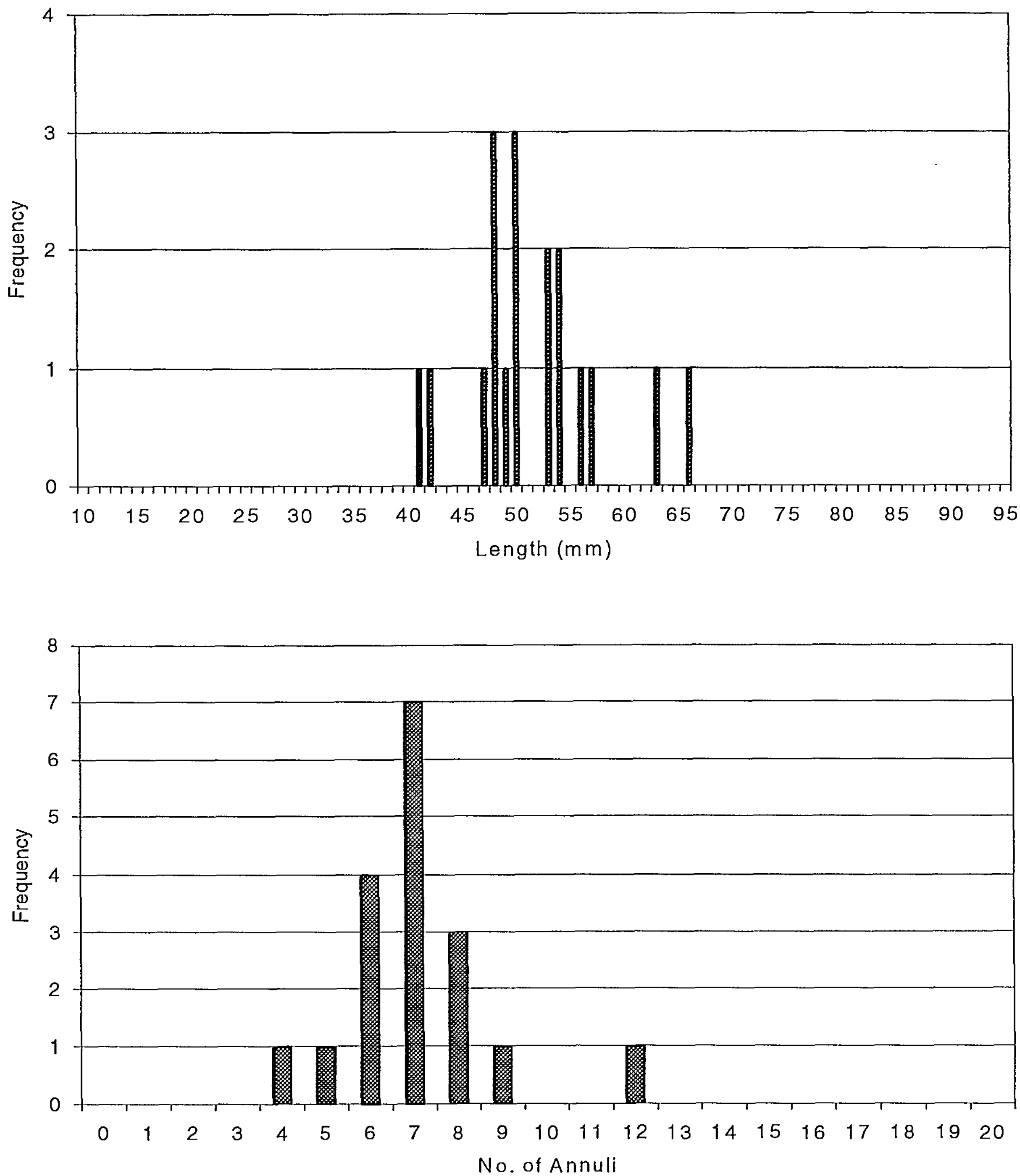
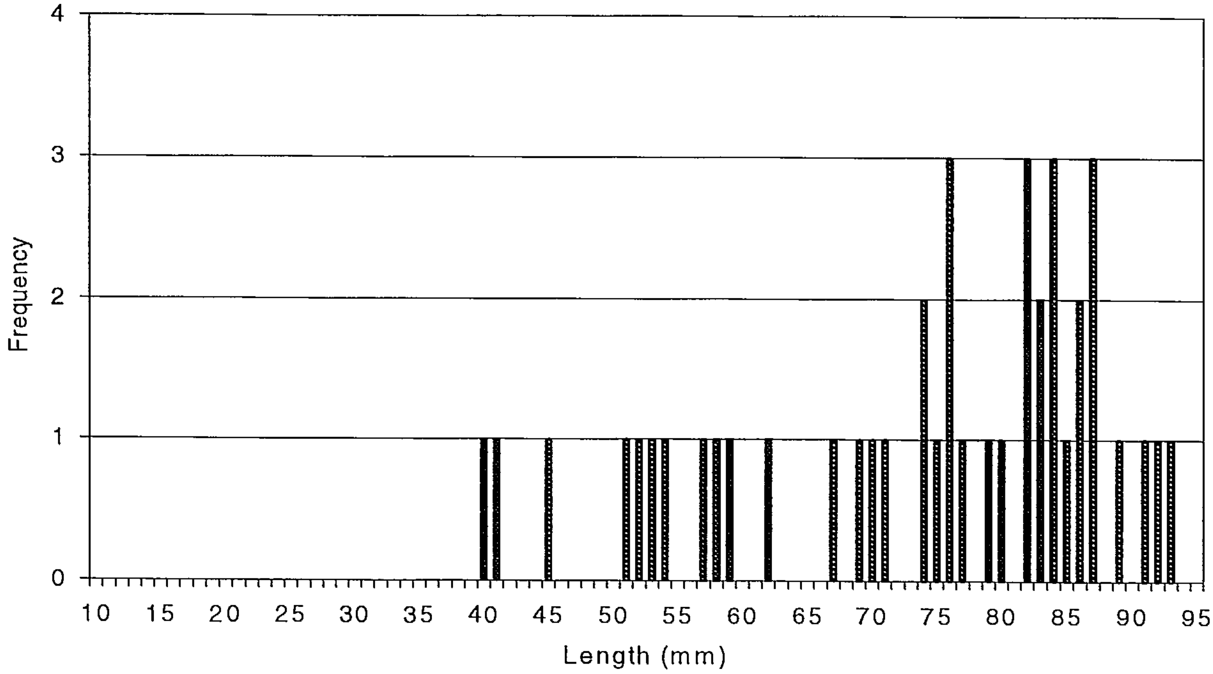


Fig. 43. Length and age frequency distributions of butter clams from Anger Inlet, August 11, 1998.



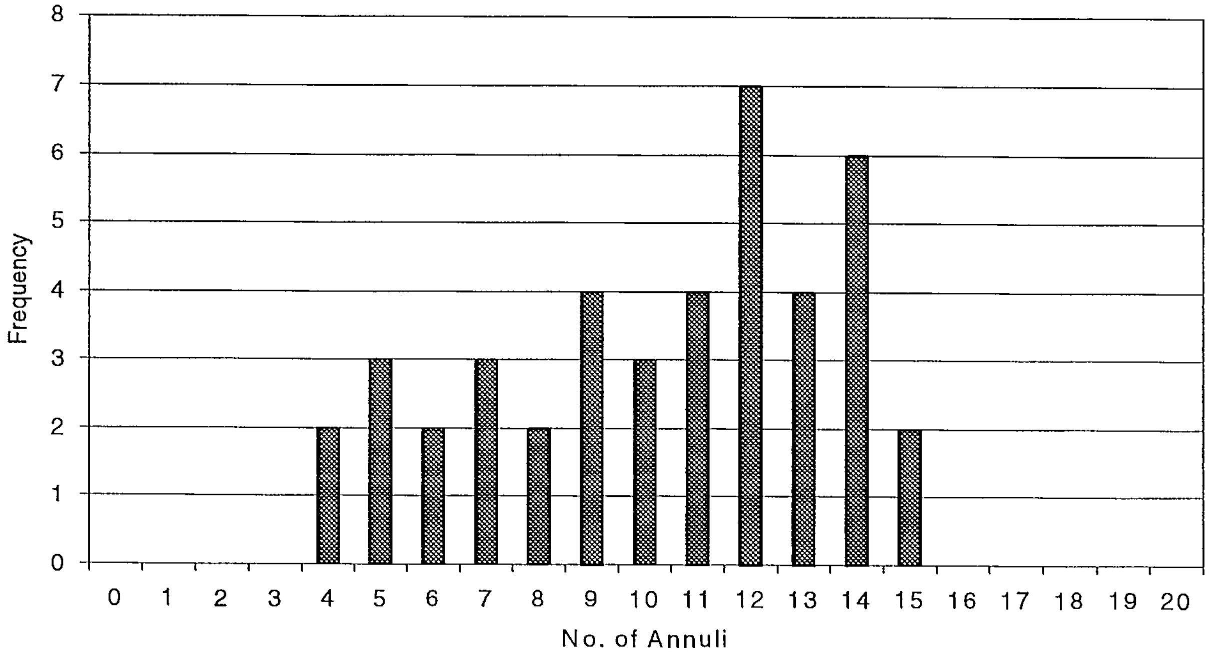


Fig. 44. Length and age frequency distributions of butter clams from Cosine Island, August 11, 1998.

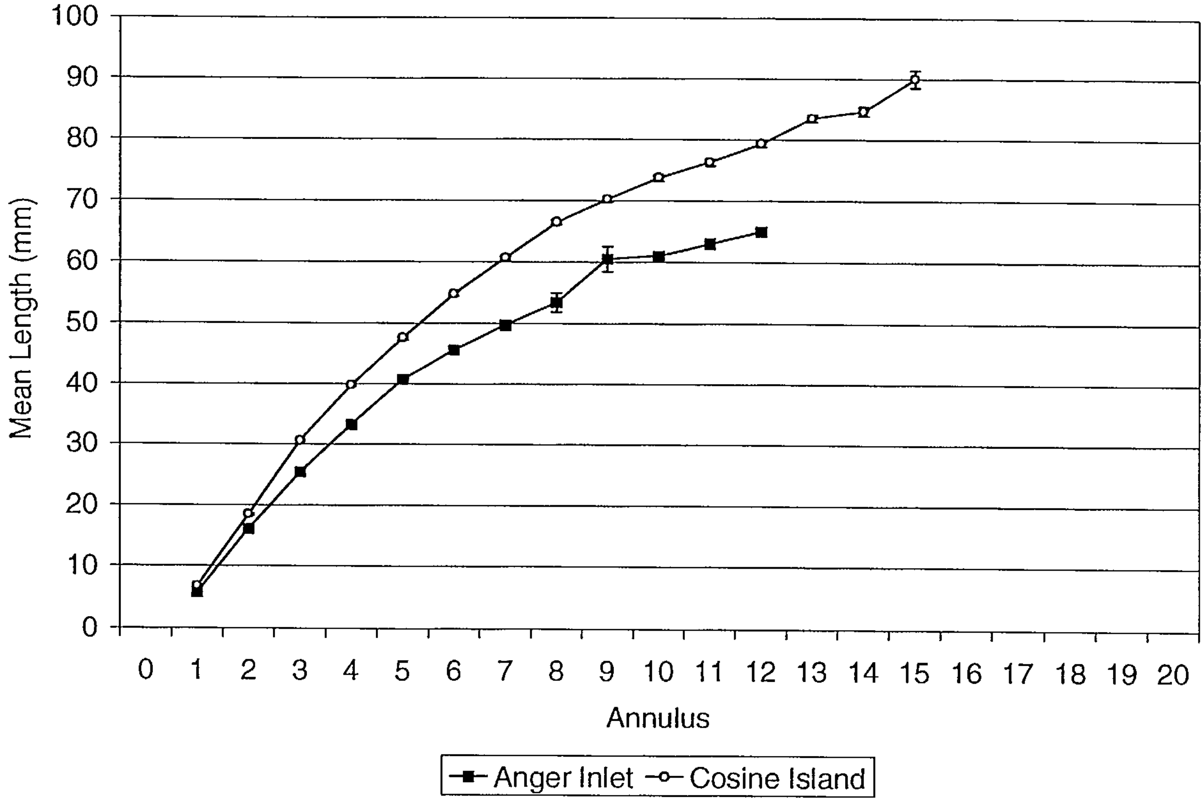
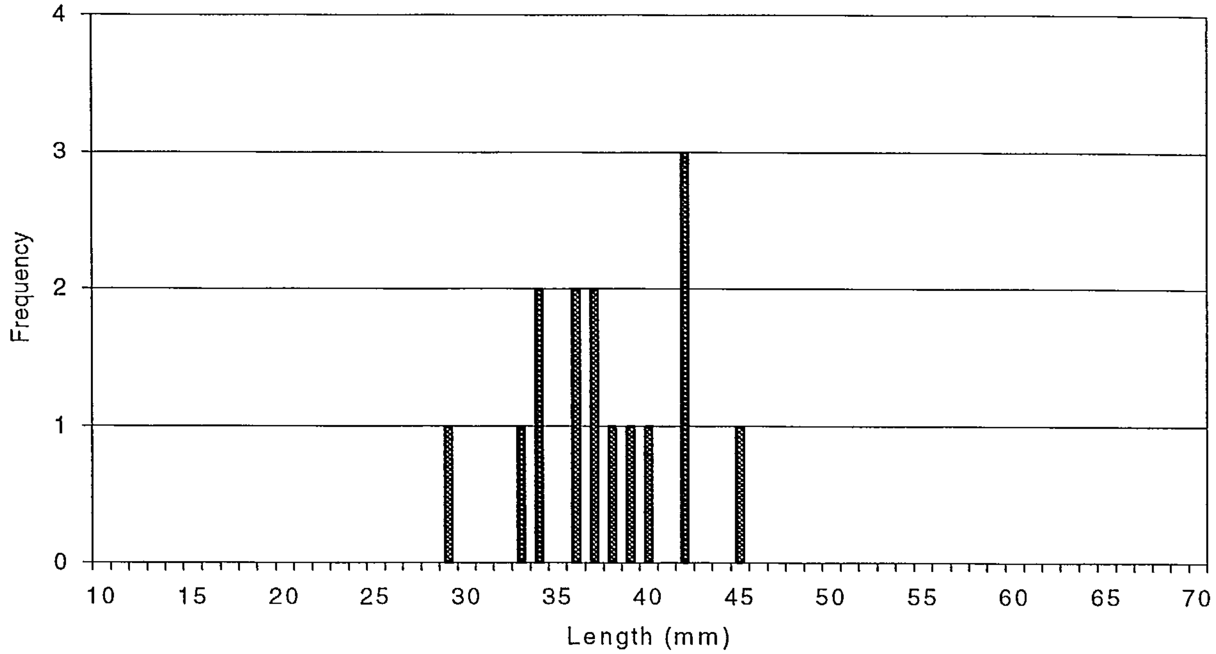


Fig. 45. Growth curve for butter clams from Anger Inlet (n=18), and Cosine Island (n=42), August 11, 1998. Error bars are 95% confidence limits of mean length at annulus.



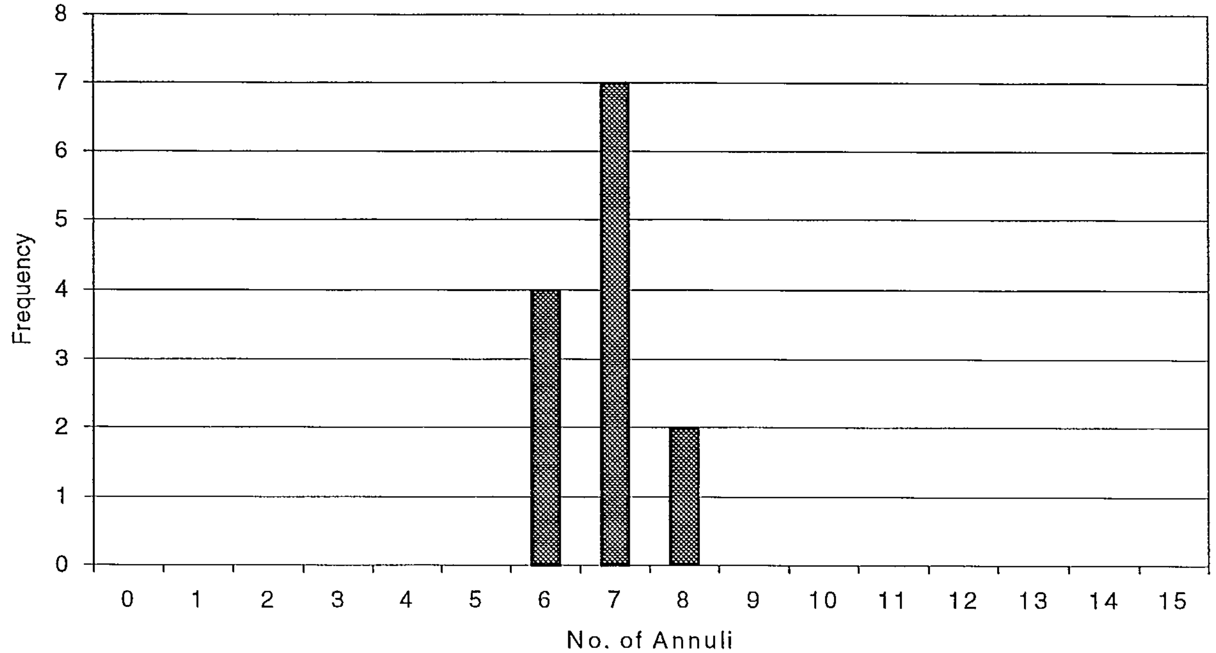
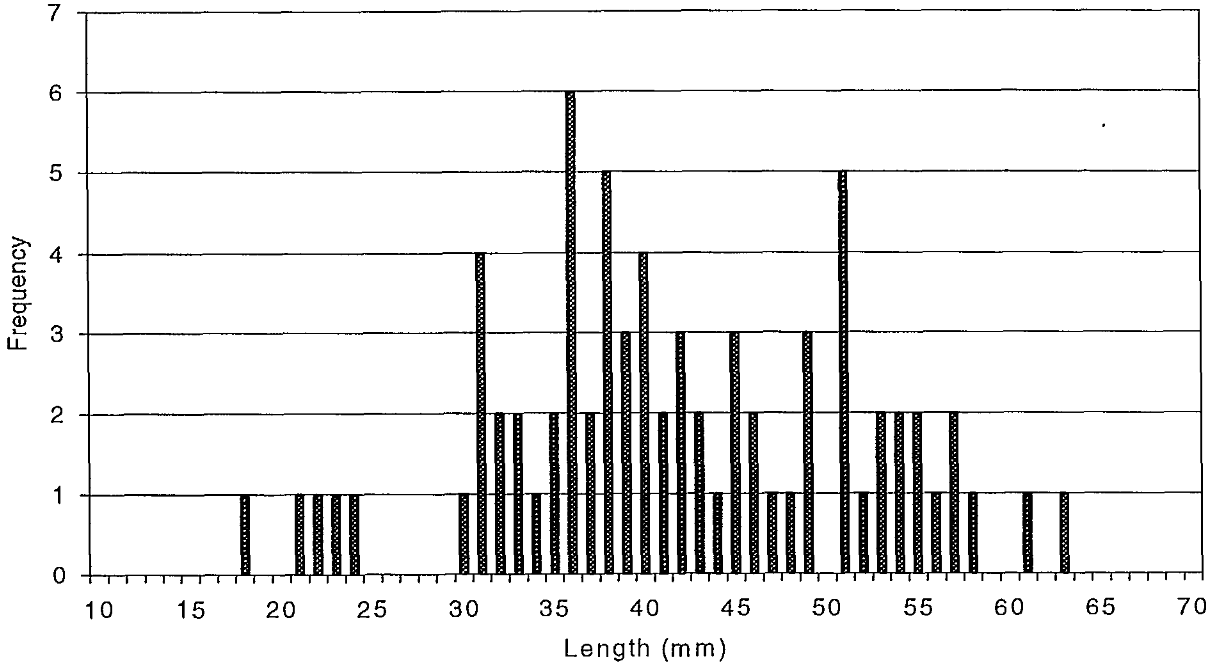


Fig. 46. Length and age frequency distributions of littleneck clams from Anger Inlet, August 11, 1998.



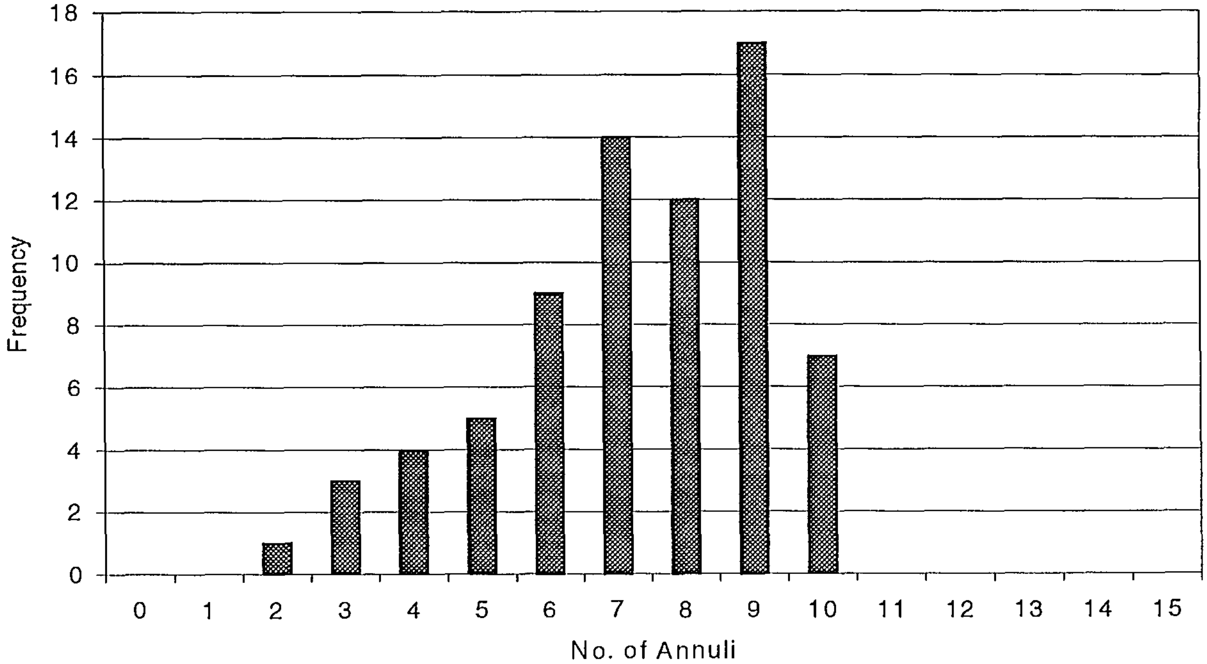
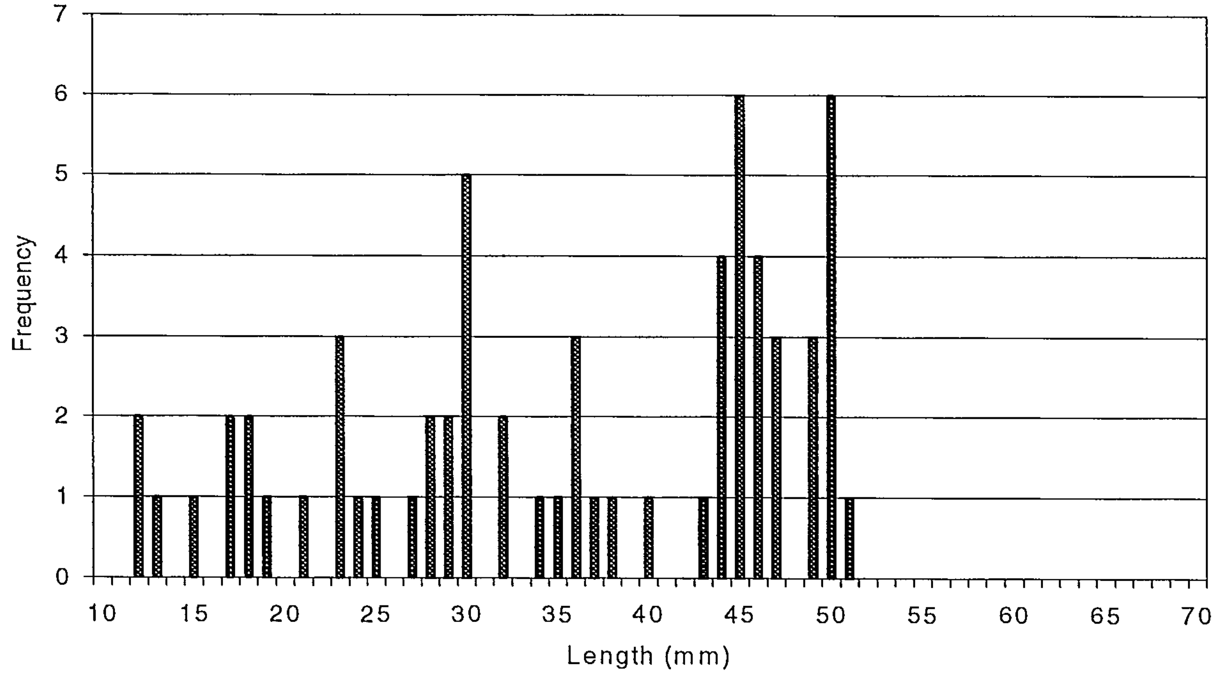


Fig. 47. Length and age frequency distributions of littleneck clams from Cosine Island, August 11, 1998.



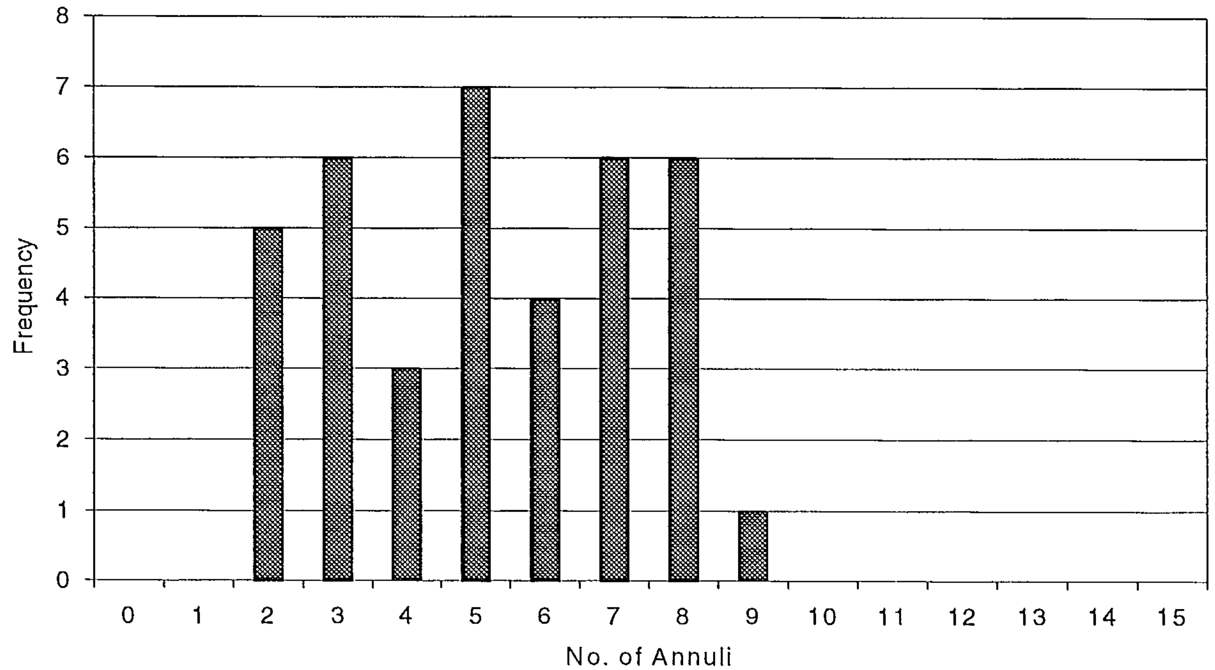


Fig. 48. Length and age frequency distributions of littleneck clams from Wilson Inlet, August 11, 1998.

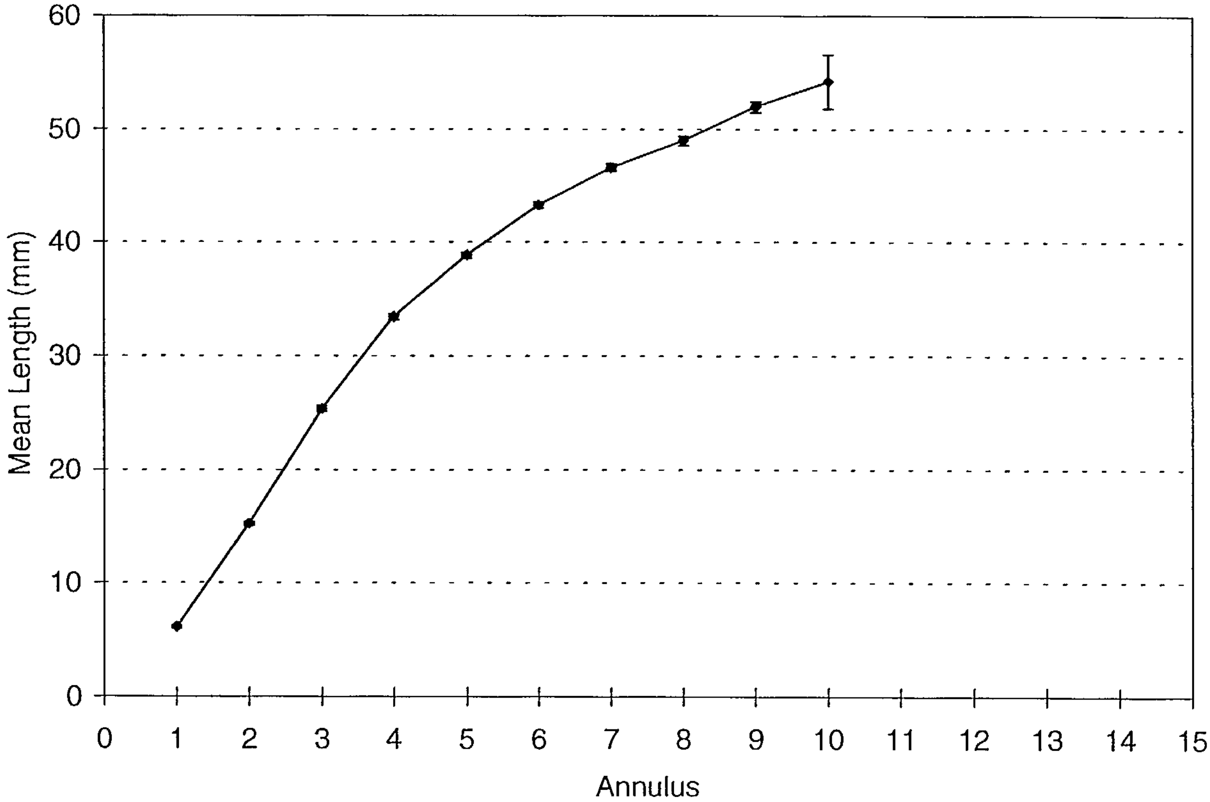


Fig. 49. Growth curve for littleneck clams (n=34) from Cosine Island, August 11, 1998. Error bars are 95% confidence limits of mean length at annulus.

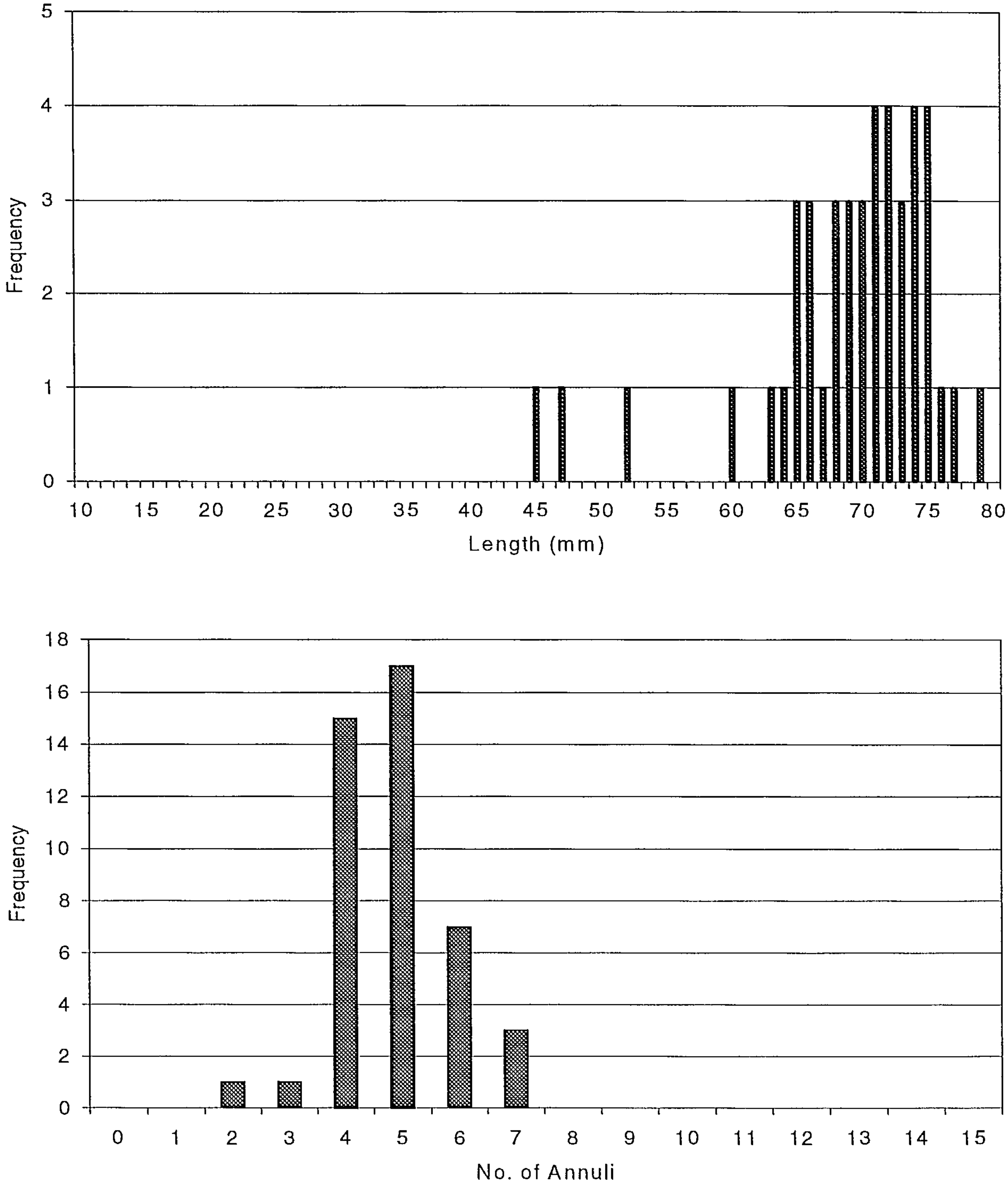


Fig. 50. Height and age frequency distributions of cockles from Wilson Inlet, August 11, 1998,

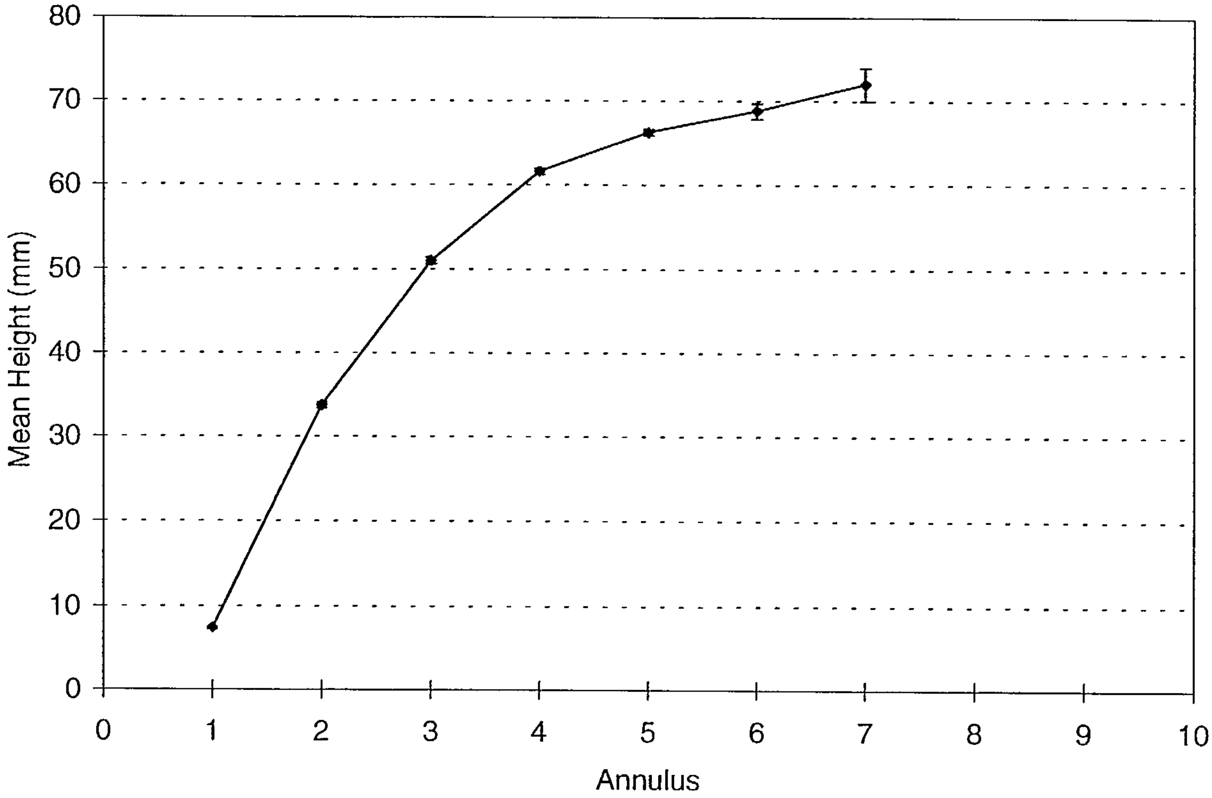


Fig. 51. Growth curve for cockles (n=46) from Wilson Inlet, August 11, 1998. Error bars are 95% confidence limits of mean height at annulus.