Exploratory Intertidal Clam Surveys in British Columbia - 1997

G.E. Gillespie and N.F. Bourne

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
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EXPLORATORY INTERTIDAL CLAM SURVEYS IN BRITISH COLUMBIA - 1997

by

G.E. Gillespie and N.F. Bourne

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

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ABSTRACT

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.

Results of the 1997 exploratory intertidal clam surveys to assess populations of commercially important clams on selected beaches in Chatham Sound, Masset Inlet and Naden Harbour, British Columbia are presented. These surveys continue a program of exploratory clam surveys in the North Coast district which began in 1990.

The primary focus of these surveys was to document dispersal and population parameters of Manila clams, *Venerupis philippinarum*, as this is the clam species currently most important in commercial fisheries and aquaculture in the South Coast. Surveys in Masset Inlet and Naden Harbour were undertaken to determine if residual populations remained from deliberate introductions of Manila clams in the 1960's. Manila clam populations were absent from all three areas.

Limited abundance and population structure information is also presented for littleneck clams, *Protothaca staminea*, butter clams, *Saxidomus giganteus*, soft-shell clams, *Mya arenaria*, cockles, *Clinocardium nuttallii*, and *Macoma* spp. collected during the surveys.

Factors affecting the dispersal, distribution, establishment of populations and potential for aquaculture of Manila clams in the North Coast are discussed.

RÉSUMÉ

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.

Nous présentons ici les résultats des campagnes exploratoires menées en 1997 pour évaluer les populations de coquillages intertidaux commercialement importants sur certaines plages du détroit de Chatham, du bras Masset et du havre Naden, en Colombie-Britannique. Ces campagnes s'inscrivent dans un programme de campagnes exploratoires lancé en 1990 dans le district de la côte Nord.

Les relevés ont visé principalement la distribution et les paramètres démographiques de la palourde japonaise (*Venerupis philippinarum*), qui est le bivalve le plus important actuellement dans la pêche commerciale et dans l'aquaculture sur la côte Sud. Dans le bras Masset et le havre Naden, nous voulions vérifier s'il restait des populations résiduelles résultant des introductions délibérées de palourdes japonaises dans les années 60. Dans les trois zones couvertes, les palourdes japonaises étaient absentes.

Nous présentons quelques données sur l'abondance et la structure démographique des palourdes du Pacifique (*Protothaca staminea*), des palourdes jaunes (*Saxidomus giganteus*), des myes (*Mya arenaria*), des coques (*Clinocardium nuttallii*) et des *Macoma* spp., données recueillies pendant les campagnes.

Les facteurs qui agissent sur la dispersion, la répartition, l'établissement des populations et le potentiel aquacole de la palourde japonaise sur la côte Nord sont également analysés.

INTRODUCTION

Intertidal clams are 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 socio-economic factors, shifts in market preference and demand, and availability (Figure 1). Since the late 1970's market demand has focused primarily on Manila clams, *Venerupis philippinarum* (= *Tapes philippinarum*), and landings of this species peaked in 1988 at 3,909 tonnes (t) but decreased since, largely due to harvesting of accumulated stocks, management actions and loss of habitat to fecal contamination. Recent increases in Manila clam landings include production from depuration fisheries, and thus reflect production from some beaches which would still be inaccessible to the open commercial fishery.

Prior to the 1980's, the clam fishery was driven by demand for butter clams, *Saxidomus giganteus*, but landings of this species have declined greatly since then because of the high cost of harvesting and processing. The commercial intertidal clam fishery is currently driven by demand for Manila clams, 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*, are also reported. Preliminary figures for 1996 indicate that landings of Manila clams comprised 77% of the landed weight and 87% of the landed value in the fishery (R. Webb, DFO, pers. comm.).

The North Coast of B.C. (Statistical Areas 1-10) has been closed to harvesting intertidal clams since 1963 primarily because of the lack of monitoring programs to detect chronic low level outbreaks of paralytic shellfish poisoning (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 because of the economics of harvesting. 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). Strong market demand for Manila clams resulted in extensive and intensive harvesting of this species on virtually all intertidal beaches where they occurred in the South Coast since the early 1980's. As landings of Manila clams began to decline after the peak in 1988, industry inquired if Manila clam populations in the North Coast were sufficient to harvest commercially. In 1990, a program was initiated to survey intertidal clam stocks in the North Coast, and this program has continued (Bourne and Cawdell 1992; Bourne *et al.* 1994; Bourne and Heritage 1997; Heritage *et al.* 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, distribution and population characteristics in the North Coast. This survey was a continuation of this program.

An additional focus of the present survey was to determine whether populations of Manila clams had become established in the Queen Charlotte Islands after an intentional transplant there in 1962 (Bourne 1982). A cursory survey was made of Masset Inlet and Naden Harbour in the mid 1960's, where the intentional transplants were made in 1962, but no Manila

clams were found there at that time. A more extensive survey of these two areas was required to determine if Manila clams had become established in either location.

SURVEY METHODS

Survey 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). Beaches were selected for survey based on chart surveys, previous experience and local information. As in previous surveys, it was decided to maximize the number of beaches explored during a tide, rather than exhaustively surveying one or two beaches. Results give general estimates of clam distribution and abundance in the surveyed areas, not statistically rigorous stock estimates.

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. Slope of the beach and substrate type were recorded. The high tide line was surveyed for drift shell of intertidal clams, as were large rocks which are used by birds to drop and break clams. In the past, evidence of the presence of Manila clam has been determined with these latter assessment methods.

Clam distribution was assessed by digging experimental plots. When aggregations of clams were found, quadrats of 0.25 or 1.00 m^2 were dug. Samples in the upper portion of the intertidal zone (0.25 m^2 targeting Manila clams, and to a lesser degree, littleneck clams) were dug with a clam scraper to a depth of about 15 cm. Quadrats lower on the beach (1 m^2 targeting butter clams and, to a lesser extent, 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 was measured to the nearest mm with vernier calipers. Ages were determined by counting annuli (Quayle and Bourne 1972). Length and age frequency distributions were determined and graphed. Length at annulus was measured for a representative sample of littlenecks, butter and soft-shell clams. Mean length at annulus and standard errors were calculated and graphed. This provided length and age distribution and growth rate information for these species in each area surveyed.

Surface water temperature at a depth of 1 m was recorded with a standard hand held thermometer in Masset Inlet and Naden Harbour.

RESULTS

A total of 15 beaches were surveyed in three areas: one beach at Lucy Islands in Chatham Sound; ten beaches in Masset Inlet; and four beaches in Naden Harbour (Table 1; Figure 2).

Chatham Sound

1. Lucy Islands

The Lucy Islands are a complex of small islands in Chatham Sound near Prince Rupert, three large islands and several smaller islets (Figure 3). No previous surveys had been undertaken there and no information was available on bivalve populations in this area.

Physical Description of Beaches

There was a large beach on the southeast side of the main island that had a steep slope and a sand substrate. This beach was too exposed to be suitable as clam habitat. Lower parts of this beach were cobble covered with a layer of algae and patches of eelgrass, *Zostera marina.* The area to the east of this beach was bordered by large reefs and had numerous boulders and cobble covered with algae, interspersed with patches of eelgrass. The area at the eastern end of the islands was steep with a sand substrate and too exposed to be suitable for clam habitat.

Beaches on the western part of the Islands were steep with a sand substrate, and again, were poor clam habitat. Dead shell of butter and horse clams occurred on this beach, along with some dead shell of cockles and *Macoma inquinata.* A sheltered plateau with a gravel-rock substrate was present between the three large islands with an area of about 0.5 ha, which was suitable clam habitat. The lower part of this plateau had eelgrass in the flooded area. Three samples were taken in this plateau. The substrate was anoxic and shells of all clams were stained black. There was a slightly higher beach, approximately 100 m^2 in area, eastward of the plateau which was suitable clam habitat and one sample was dug there.

Clam Populations

Butter Clams

There was a difference in butter clam populations between the two areas surveyed; *i.e.,* between samples at Site 1 (quadrats 1, 2 and 3) and Site 2, (quadrat 4).

At the first site, density ranged from 48-132 clams m^{-2} and 48% were 63 mm shell length (minimum legal size in the commercial fishery) or larger (Table 2; Figure 4). Age of these clams ranged from 3-15 years with a peak distribution at 8 years (Figure 5). At Site 2, density was 228 clams m^{-2} and all were sublegal size. The largest clam at Site 2 was 41 mm shell length. Most of these clams were between 5-8 years old. Site 2 was at a higher elevation than Site 1 and perhaps poorer butter clam habitat. Some clams at Site 2 were growing extremely slowly (*i.e.*, were "stunted") which accounted in part for the small size.

A growth curve was constructed for butter clams from Site 1 (quadrats 1, 2, and 3). Growth was slow, about 8.5 years were required to attain a shell length of 63 mm (Figure 8).

Littleneck Clams

Littleneck clams were common on beaches at Lucy Island. As with butter clams, there was a difference in populations between Sites 1 and 2.

At Site 1, density ranged from 20-128 clams m^{-2} and most (68%) were 38 mm shell length (minimum size in the commercial fishery) or larger (Table 2; Figure 6). At Site 2, density was 236 clams m^{-2} but all the clams were smaller than 38 mm shell length.

Littleneck clams at Lucy Island were dominated by older age classes. In both areas, littlenecks were 5 years and older (Figure 7). Littlenecks at Site 2 were very stunted, again reflecting poor habitat. The lack of younger age classes indicated poor recent recruitment for littlenecks at this location. Although a growth curve was not determined for littlenecks at the Lucy Islands, comparison of length and age frequency distributions indicates that growth was slow.

Manila Clams

No live Manila clams or dead shell were found on beaches in the Lucy Islands.

Other Species

Other invertebrates observed at Lucy Islands included: small patches of *Mytilus californianus*; shell of horse mussels, *Modiolus modiolus*; shell of horse clams, *Tresus capax*; shell of cockles, *Clinocardium nuttallii*; shell of *Macoma balthica* and *M. inquinata*; moon snail, *Polinices lewisi*; dire whelk, *Lirabuccinium dirum*; frilled dogwinkle, *Nucella lamellosa*; striped dogwinkle, *Nucella emarginata*; checked periwinkle, *Littorina scutulata*; puppet margarite, *Margarites pupillus*; wrinkled amphissa, *Amphissa columbia*; plate limpet, *Tectura scutum*; ribbed limpet, *Lottia digitalis*; black katy chiton, *Katherina tunicata*; and mossy chiton, *Mopalia muscosa*.

Queen Charlotte Islands

A major goal of this survey was to determine if Manila clams had become established in the Queen Charlotte Islands, in Masset Inlet or Naden Harbour.

In 1962 about 15,000 adult Manila clams from Ladysmith Harbour were planted in Masset Inlet and a similar number were planted in Naden Harbour (Bourne 1982). Maximum monthly mean surface water temperatures of slightly above 14°C have been recorded in Masset Inlet (Hollister and Sandes 1972) and Black and Elsey (1948) found surface water temperatures were generally below 14°C at the head of the Inlet (where the transplant occurred) although they rose to 20°C in August. It was felt that environmental conditions would be suitable to permit successful breeding of Manila clams in Masset Inlet and perhaps in Naden Harbour and hence

allow establishment of a population in both locations which would be a valuable addition to intertidal clam resources.

A brief survey was made of both transplant areas in 1965 (Quayle 1966). There was survival of some Manila clams in both areas, but growth was poor and no apparent reproduction occurred. No further surveys of intertidal clam stocks were made in either location, and it was presumed that Manila clam populations had disappeared in both locations. Occasional minor landings of Manila clams were reported from the Queen Charlotte Islands in annual DFO statistics, but when these were checked they were found to be in error.

A thorough survey was needed of clam beaches in both areas to determine the presence or absence of Manila clams. Three days were spent in Masset Inlet and one day in Naden Harbour (Table 1).

Masset Inlet

Masset Inlet is a large body of water with several intertidal beaches scattered through the area, although some have been used for past logging operations. Landings of butter clams were reported from this area in the past although no recent harvest has occurred there (Quayle and Bourne 1972). Three days were spent sampling eight beaches (Table 1; Figure 9).

2. Makai Point

Two beaches were surveyed in the Makai Point area, one at Makai Point and the second in a small bay about 1 km to the west (Figure 9).

Physical Description of Beaches

Beach 1 was a terrace with a gentle slope and an area of about 0.2 ha. The substrate was mostly cobble covered with *Fucus* sp. with small patches of sand-gravel between the rocks. The lower part was mostly sand with eelgrass.

Beach 2 had an area of about 1.5 ha, and had a small creek with gravel banks flowing down the center of it. Substrate of the beach was gravel with cobble imbedded in the sand. There was a sparse covering of *Fucus* sp. and some wood debris.

Clam Populations

No live clams were found on either beach. There was some old butter and littleneck shell on Beach 1 and some butter, soft-shell, and cockle shell on Beach 2.

No live Manila clams or dead shell were found on either beach.

Other Species

There were a large number of blue mussels, *Mytilus trossulus*, on Beach 1.

3. Fraser Island

Physical Description of Beach

Beach 3 at Fraser Island was similar to Beach 2 and about 0.2 ha in area. It was a steep gravel beach that ended in rocky substrate covered with *Fucus* and some eelgrass at the low tide line. There was a channel on the eastern side of the Island that had a substrate with more sand and small gravel and retained some water at low tide. The southern part was badly scoured, probably by wood debris. Sample 1 was collected there. A 0.5 m^2 quadrat was dug in the channel to the south of the island, which had a sand gravel substrate and eelgrass beds.

Clam Populations

Two exploratory plots dug at Fraser Island failed to locate significant concentrations of butter or littleneck clams to provide a reasonable estimate of density. Additional clams were collected as encountered from exploratory digging, until a reasonable size sample was obtained to estimate population characteristics.

Of 30 butter clams collected, only one was larger than 63 mm shell length (Figure 10). Most were 2-7 years of age (Figure 10). Many were stunted and growth was slow, individuals of 10 years had still not attained a shell length of 63 mm (Figure 12).

Littlenecks were more plentiful than butter clams, but only 112 clams were found in two plots and numerous exploratory scratches. There was a wide size range, 59% were smaller than 38 mm shell length (Figure 11). There was a wide range in ages, most were 4-8 years (Figure 11). Growth was slow and it required about 8 years to attain a shell length of 38 mm (Figure 12).

No live Manila clams or dead shell were found.

Other Species

Some *Macoma inquinata* and *M. balthica* were found. A few *Hiatella arctica* were also present, as were *Nucella lamellosa* and *Margarites pupillus*. The channel had large quantities of green sea urchins, *Strongylocentrotus droebachiensis*.

Other Observations

Water temperature at a depth of 1 m off Fraser Island was 18°C and 22°C in the lagoon on September 3.

4. Yakoun Bay

Physical Description of Beach

Beach 4 was an extensive beach about 10 ha in area in the estuary of the Yakoun River. The substrate was sand with small patches of rock and wood debris partially buried in the substrate. There were sparse clumps of eelgrass scattered over the beach.

Clam Populations

No evidence of butter, littleneck, or Manila clams was found on this beach.

Other Species

One live soft-shell clam and some cockle shell was found. A local resident, Mr. Chris Mars, stated there were patches of gravel high in the intertidal part of this beach that had small populations of soft-shell clams.

5. Wathus Island

A long bay on the eastern side of Wathus Island was visited but the shore was steep and rocky to the head of the bay. The beach sampled was on the southern tip of the island.

Physical Description of Beach

Beach 5 was about 0.25 ha in area with rock at the low tide line and small tidal pools above. Suitable clam habitat was limited to some small patches of sand-gravel substrate between the rocks. *Fucus* sp. covered some of the rocks and there was eelgrass in the lowest intertidal area.

Clam Populations

Two 0.25 m^2 plots were dug.

No live or dead shell of butter, littleneck or Manila clams were found in either plot.

Other Species

Soft-shell clams were found in both plots, 11 in one and 9 in the other (Table 2). They ranged in shell length from 19-62 mm and in age from 1-7 years (Figure 13). Twenty-five *M. balthica* were found in the first plot.

6. Shannon Bay

Physical Description of Beach

Beach 6 had an area of about 4 ha and was located across the head of the lagoon. The substrate was unsuitable as clam habitat, mostly silt covered with wood debris.

Clam Populations

No live or dead shell of butter, littleneck or Manila clams were found. The only bivalves found were two small soft-shell clams.

7. Dinan Bay

A major focus of this project was to survey the beach at Dinan Bay since this was believed to be the beach where Manila clams were planted in the 1962 transplant (D.B. Quayle, pers. comm.).

Physical Description of Beach

Beach 7 at Dinan Bay had an area of 3-4 ha and a gentle slope. The substrate was mostly sand-gravel and imbedded cobble. There was a greater amount of silt and wood debris near the mouth of the creek that flowed through the beach. Eelgrass occurred in a narrow band at the low tide line. *Fucus* sp. was common on the lower beach and *Salicornia* on the upper beach.

Clam Populations

Few live clams were found on the beach after a careful study. Some littleneck and cockle shells were found and two 0.25 m^2 plots had soft-shell clams. These clams ranged from 20-51 mm TL, and 1-5 years in age, with a strong age mode a 3 years (Figure 14).

No live Manila clams or dead shell were found.

8. Martin Point

Beach 8 at the southern end of Kumdis Slough at Martin Point was extensive with an area about 10 ha and a gentle slope. Substrate varied with beach location. On the eastern side of Kumdis Island it was packed sand with some scattered rock. On the southeastern shore of Martin Point there was an extensive beach, about 3-4 ha in area, of gravel and rock imbedded in the sand, with a long gravel bank extending to the southeast.

Clam Populations

There were numerous dead shells of butter and littleneck clams in the gravel beach at the southeastern end of Martin Point, however, no live animals were found. No live butter or littlenecks clams nor dead shell were found in areas with softer substrate.

No live Manila clams or dead shell were found.

Soft-shell clams were found in low densities, <1 m^{-2}, in areas with softer substrate. Two 1 m^2 quadrats dug in the gravel area in the southeastern part of Martin Point had 37 clams. Shell length ranged from 27-64 mm and age distribution from 1-8 years with peaks of 2, 3 and 6 years (Figure 15). Growth rate showed that it required about 5 years to attain a shell length of 50 mm (Figure 16).

Dead *M. balthica* shell was common on the beach. One small area was dug to a depth of about 50 cm and a layer of very old shells was unearthed. This layer contained white sand clams, *Macoma secta*, bent nose clams, *M. nasuta*, and ringed lucines, *Lucinoma annulata*. No live individuals of these species were found on this or any other beach in Masset Inlet.

Naden Harbour

Naden Harbour is an extensive bay off southern Dixon Entrance on the north shore of Graham Island (Figure 17). As pointed out previously, about 15,000 Manila clams were transplanted to this area in 1962, and a goal of the present survey was to determine if a population of Manila clams had become established in Naden Harbour. There are extensive intertidal beaches in Naden Harbour which extend more or less continuously around the Harbour. Four beaches were visited on September 6, 1997 (Table 1; Figure 17). Extensive observations were made of the beach surfaces to determine the presence or absence of dead Manila clam shell and numerous exploratory plots were dug to determine the presence or absence of live Manila clams. Few sample quadrats were dug.

9. Germania Creek

Physical Description of Beach

Beach 1 at the mouth of Germania Creek had an area of about 2 ha. The beach had a gentle slope and the substrate was mostly sand-gravel. Germania Creek divided the beach more or less in half. The lower part of the beach had more silt and some eelgrass.

Clam Populations

The upper part of the beach had low densities of butter and littleneck clams. One plot had 86 littleneck clams m^{-2} (Table 2); 88% were smaller than 38 mm shell length. Shell length ranged from 16-40 mm with a peak at 30-32 mm (Figure 18). Age distribution was from 2-7 years with most 5 and 6 years old. Growth was slow and it required over 7 years to attain a shell length of 38 mm (Figure 19). Many of the littlenecks were stunted.

No live Manila clams or dead shell were found.

10. Stanley Creek and Naden River Estuaries

Estuaries of Stanley Creek and Naden River form a broad, flat beach that is several ha in area (Figure 17; Beach 2). The substrate was sand-silt with eelgrass at the lower margin, poor habitat for butter or littleneck clams but suitable for cockles. Some cockle shell was found. There were numerous burrows in the substrate, probably dug by mud shrimp or polychaete worms. Large Dungeness crabs, *Cancer magister*, were found in the water immediately below the low tide line.

No live Manila clams or dead shell were found.

No samples were dug since the habitat was unsuitable for hard-shell clams.

11. Tee Island

The beach at Tee Island on the eastern side of Naden Harbour is large and extensive. Sampling was undertaken on this beach to determine the presence or absence of live Manila clams or dead shell since it was believed this is the beach where the transplant was made in 1962.

Physical Description of Beach

Beach 3 surrounded Tee Island and had an area about 20 ha and a gentle slope. The substrate was consistent sand-gravel with varying amounts of rock present, good habitat for butter, littleneck and Manila clams. There were numerous dead shells of butter, littleneck and horse clams on the beach.

Clam Populations

Two 1 m^2 plots were dug, both near the low water line.

Butter clam density was 11 and 12 clams m^{-2} and half were larger than 63 mm shell length (Table 2). Shell length ranged from 42-72 mm and ages ranged from 6-12 years, most were 8-10 years old (Figure 20). Growth was slow and it required about 10 years to attain a shell length of 63 mm (Figure 23).

Littleneck clams were not common and the density was 3 and 24 clams m^{-2}; most (70%) were smaller than 38 mm shell length (Table 2). Shell length ranged from 14-44 mm and age from 2-7 years, most were 5 and 6 years old (Figure 21). Growth was slow and it required over six years to attain a shell length of 38 mm (Figure 23).

No live Manila clams or dead shell were found.

Other Species

A few cockles were found that ranged in shell height from 29-55 mm and were 2-5 years in age (Figure 22). At five years they were almost 50 mm in shell height (Figure 24).

12. Mary Point

Only a brief survey was made of the beach at Mary Point because of tide levels and time constraints.

Physical Description of Beach

Beach 4 at Mary Point, near the village site of Kung, was fairly extensive; area could not be determined because the tide was too high. There was a sand ridge at the high tide line and a pile of boulders lower down the beach. A superficial examination was made of the upper part of Haswell Reef. The upper portion of the reef was rock and boulder interspersed with patches of sand-gravel.

Clam Populations

No live clams were found in the sand-gravel patches but the reef was littered with large, recent butter and horse clam shell indicating populations of these species existed at lower intertidal levels. Moon snail, *Polinices lewisi*, shell was also present.

No samples were collected.

No live Manila clams or dead shell were found.

Other Observations

A sand cliff on the northeastern side of Mary Point had a layer of bivalve shells buried deep in the sediment. The layer was about 1 m thick and about 3 m above the present high tide line and about 6 m down from the top of the cliff. The shells were well preserved and species identified included; butter clam, littleneck clam, cockles, *Macoma* sp., and horse clams, *T. capax*. This layer with bivalve shells was obviously below the high tide line sometime during the past.

Clague (1989) and Fladmark (1989) proposed that sea levels in the Queen Charlotte Islands were lower than present levels during deglaciation, approximately 16,000 years before present (B.P.). Sea levels increased as continental ice sheets decayed and land levels decreased due to isostatic sinking of the islands, and sea levels similar to present were reached approximately 10,000 years B.P. Maximum sea levels in the islands were reached approximately 8,000 years B.P., and sea levels may have been as much as 15 m above present levels in some areas. These higher sea levels may have persisted until approximately 4,500 years B.P., after which sea levels decreased, possibly due to tectonic uplift of the islands (Clague, *op. cit.*).

The stratum bears further investigation, possibly including carbon dating, as the fauna appears to be similar to the present day intertidal fauna in the area.

Naden Harbour Dredge Sample

As part of another investigation, a naturalist dredge was towed for ten minutes at a depth of 7-9 m off the Naden River estuary. The dredge was filled with dead shell of butter, littleneck and horse clams, as well as some dead shell of stout cardita, *Cardita ventricosa*, milky venus, *Compsomyax subdiaphana*, and truncated soft-shell clam, *Mya truncata*. The only living molluscs were wrinkled slipper snails, *Crepipatella dorsata*, which were found on the dead clam shell.

The dead butter and littleneck clam shell was considerably larger and older than those found in the intertidal areas. Whether this shell was from accumulation of animals low in the

intertidal zone or from a subtidal population is not known. Maximum shell length of littlenecks was 76 mm and of butters 105 mm. Maximum ages of littlenecks was 13 years and 27 for butters. Length at annuli measurements were taken to provide a general growth rate for these animals. These showed that littlenecks attained a shell length of 38 mm in 4-5 years and butters attained a shell length of 63 mm in 7-8 years (Figure 25).

DISCUSSION

Results of this survey provided further information on the dispersal of Manila clams in B.C.

Manila clams have not spread northward as far as the Chatham Sound area which agrees with results of the 1990 survey in which no Manila clams were found in the Kitkatla Inlet area of Porcher Island or in the Campania Islands at the mouth of Douglas Channel (Bourne and Cawdell 1992). The farthest north population of Manila clams known in B.C. occurs at the southern end of Laredo Channel (Heritage *et al.* 1998). Further survey work is required to determine if Manila clams occur farther north in Laredo Channel or in other areas north of this Channel.

Manila clam populations have not become established in the Queen Charlotte Islands in either Masset Inlet or Naden Harbour. Both areas were thoroughly surveyed and neither live animals nor dead shell were found in either location. Annual reports of the Fisheries Research Board of Canada (Anon. 1963) did not provide exact transplant locations. Unfortunately, documentation uncovered after the survey revealed that the Masset Inlet transplant site was McClinton Bay, not Dinan Bay, as was previously believed (Quayle 1963). However, had successful reproduction occurred, larvae would not have been entrained exclusively in McClinton Bay, and Manila clams would have settled in nearby Shannon and Dinan Bays. McClinton Bay should be surveyed at the next possible opportunity, to completely and thoroughly prove the failure of the attempted introduction.

Neither report (Anon. 1963; Quayle 1963) provided exact locations for the Naden Harbour transplant. An independent survey was undertaken of intertidal beaches in Naden Harbour earlier in 1997, which included extensive sampling of the beaches there. No live Manila clams nor dead shell were found during this survey (B. Kingzett, pers. comm.).

Masset Inlet had surprisingly few significant clam populations for the number of beaches there. Intertidal populations of butter and littleneck clams were virtually absent, except at Fraser Island, and only sparse populations of soft-shell clams were found. Large amounts of butter and littleneck clam shell found at Martin Point may indicate that subtidal populations exist there. The shell layer found deep in the beach at Martin Point indicate that a significantly different clam fauna existed here in the past, but the age of these shells is unknown.

One can only speculate on reasons why Manila clam populations did not become established in either Masset Inlet or Naden Harbour.

The introduction in 1962 was large, about 15,000 animals were planted in each locality (Quayle 1963). There were adequate numbers of animals to permit establishment of a population if suitable environmental conditions had existed.

Water temperatures of 14°C and 15°C are required to permit gonadal development and spawning in Manila clams (Obah 1959; Mann 1979). Temperatures higher than this have been recorded in Masset Inlet (Black and Ellsey 1948; Hollister and Sandes 1972) and during this survey a temperature of 18° was recorded off Fraser Island and 22°C inside the lagoon there on September 3. Whether such elevated water temperatures occur over a sufficient period of time to permit a time-temperature period for gametogenesis, as described for *Crassostrea gigas* and *Ostrea edulis* (Mann 1979), is not known. A continuous record of surface water temperatures in both locations is required to determine if a sufficient time-temperature period exists to permit gonadal development and spawning in Manila clams.

If spawning occurred, it is possible that environmental conditions (*e.g.*, temperature or salinity) might not have been favourable to permit larval development. Another possible explanation for the failure to establish Manila clam populations in either location is that oceanographic conditions might not have allowed retention of larvae in Masset Inlet or Naden Harbour, and they were lost to Dixon Entrance.

Successful spawning and larval development may have occurred in either or both locations but environmental conditions did not permit survival of spat or juveniles. Both areas are considerably farther north than the farthest known occurrence of Manila clams in B.C. (Heritage *et al.* 1998) and it is possible that winter kill would occur regularly and not permit survival of juveniles (Bower *et al.* 1986; Bower 1992). Successful breeding of Manila clams might have been possible in either or both areas in years with above average surface water temperatures; *i.e.*, in years of El Nino. However, even if successful breeding had occurred, larval or post-settlement mortality were high enough to prevent establishment of a viable population.

One further explanation for failure to establish a Manila clam population in either location would be worth investigating. It is possible that a genetic strain of Manila clams has developed in northern B.C. waters that allows successful breeding and survival at lower temperatures than strains of Manila clams in southern B.C. (Heritage *et al.* 1998). If this is the case it would be worth investigating whether brood stock from the Bella Bella area would permit establishment of a Manila clam population in either Masset Inlet or Naden Harbour.

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Table 1. Survey dates for beaches examined in the North Coast, September, 1997.

Beach	Date(s) Surveyed
Lucy Islands	Sept. 1
Makai Point	Sept. 3
Fraser Island	Sept. 3, 5
Yakoun Bay	Sept. 3
E of Makai Point	Sept. 4
Wathus Island	Sept. 4
Shannon Bay	Sept. 4
Dinan Bay	Sept. 4
Martin Point	Sept. 5
Germania Creek	Sept. 6
Stanley Creek Estuary	Sept. 6
Tee Island	Sept. 6
Mary Point	Sept. 6

Table 2. Clam densities (clams m^{-2}) on beaches surveyed in the North Coast of British Columbia, September 1-6, 1997.

	Butter		Littleneck		Manila				
Quadrat	Legal	Sublegal	Legal	Sublegal	Legal	Sublegal	Macoma	Soft-shell	Cockle
Lucy Islands, Chatham Sound									
1	48	84	44	44	0	0	0	0	0
2	32	16	96	32	0	0	0	0	0
3	45	52	20	0	0	0	0	0	0
4	0	228	0	348	0	0	0	0	0
Wathus Island, Masset Inlet									
1	0	0	0	0	0	0	100	44	0
2	0	0	0	0	0	0	0	36	0
Germania Creek, Naden Harbour									
1	0	0	10	76	0	0	0	0	0
Tee Island, Naden Harbour									
1	5	7	1	2	0	0	0	0	3
2	7	4	7	17	0	0	0	0	9

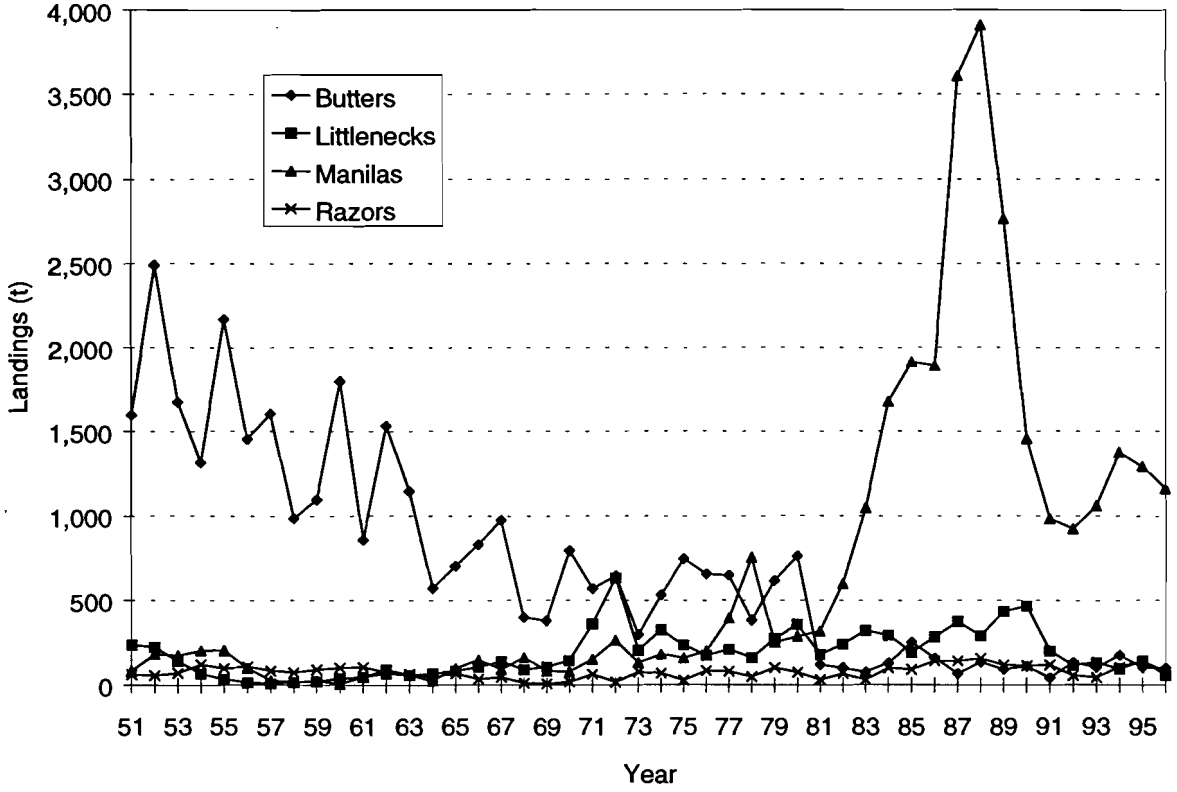

Figure 1. Commercial landings of intertidal clams by species, 1951-1996. 1995 and 1996 landings preliminary.

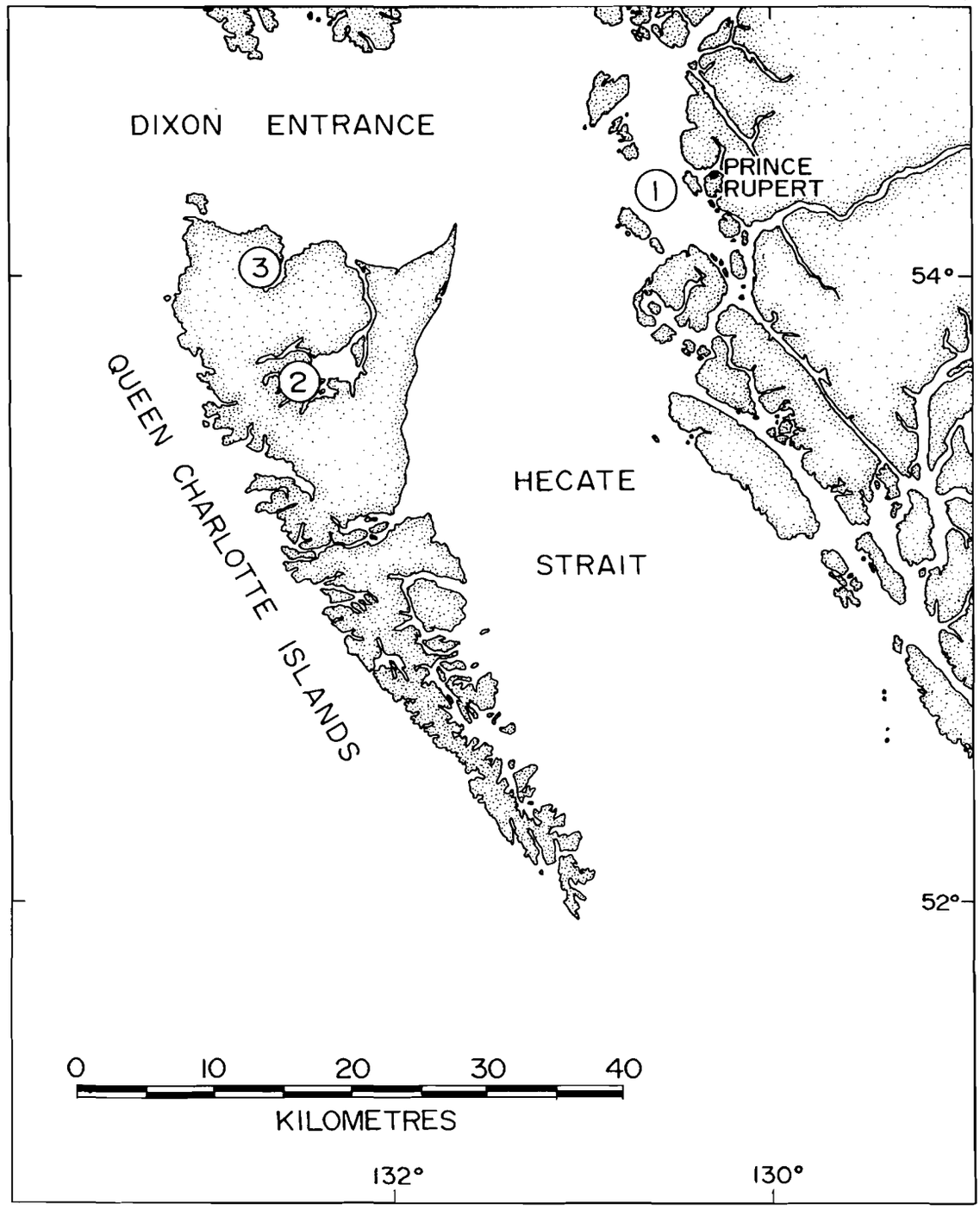

Figure 2. General locations of clam surveys in the North Coast of British Columbia, September 1997.

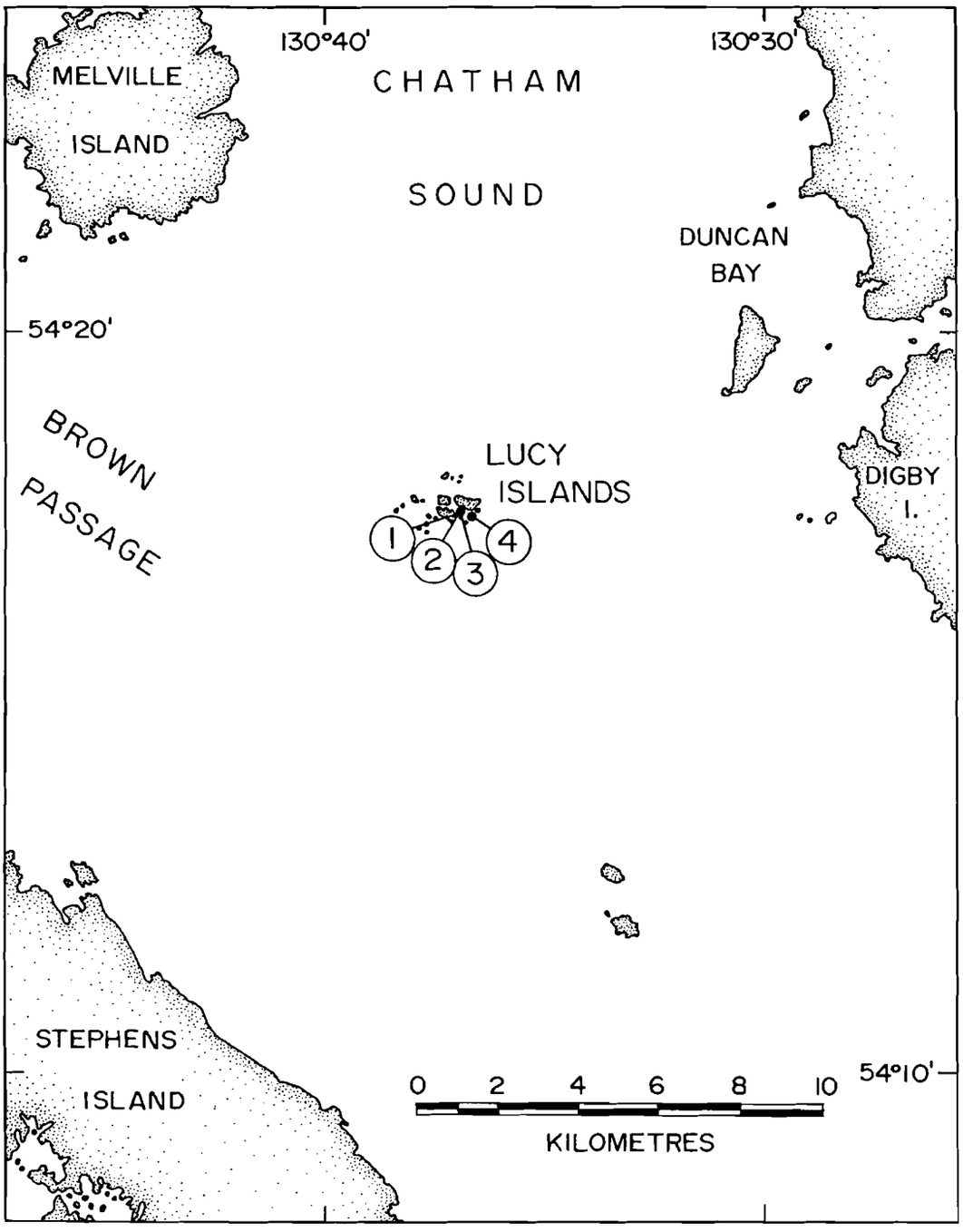

Figure 3. Location of beaches surveyed in the Lucy Islands, September 1, 1997.

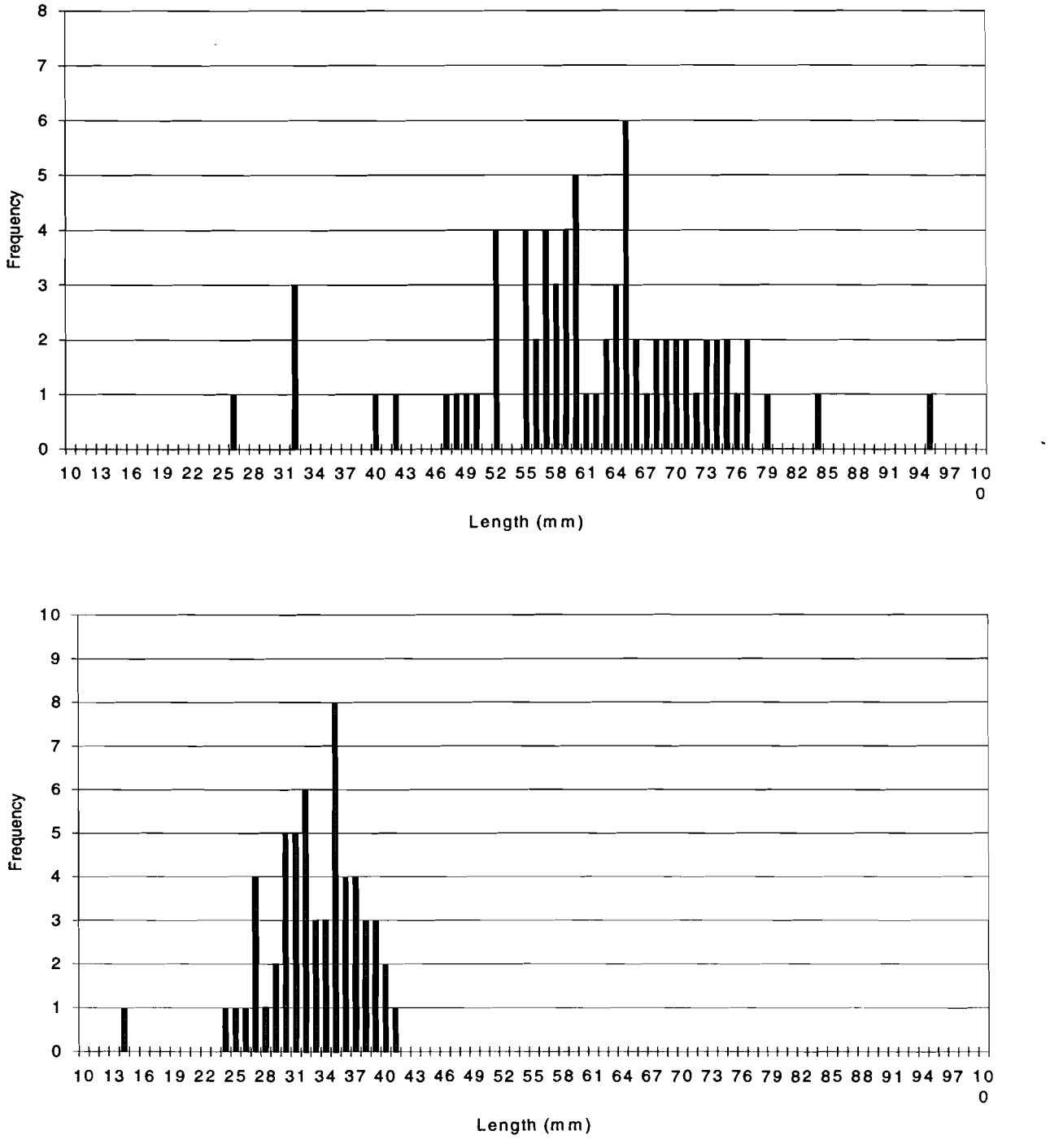

Figure 4. Length frequencies of butter clams from quadrats 1-3 (upper panel) and quadrat 4 (lower panel) from the Lucy Islands, Chatham Sound, September 1997.

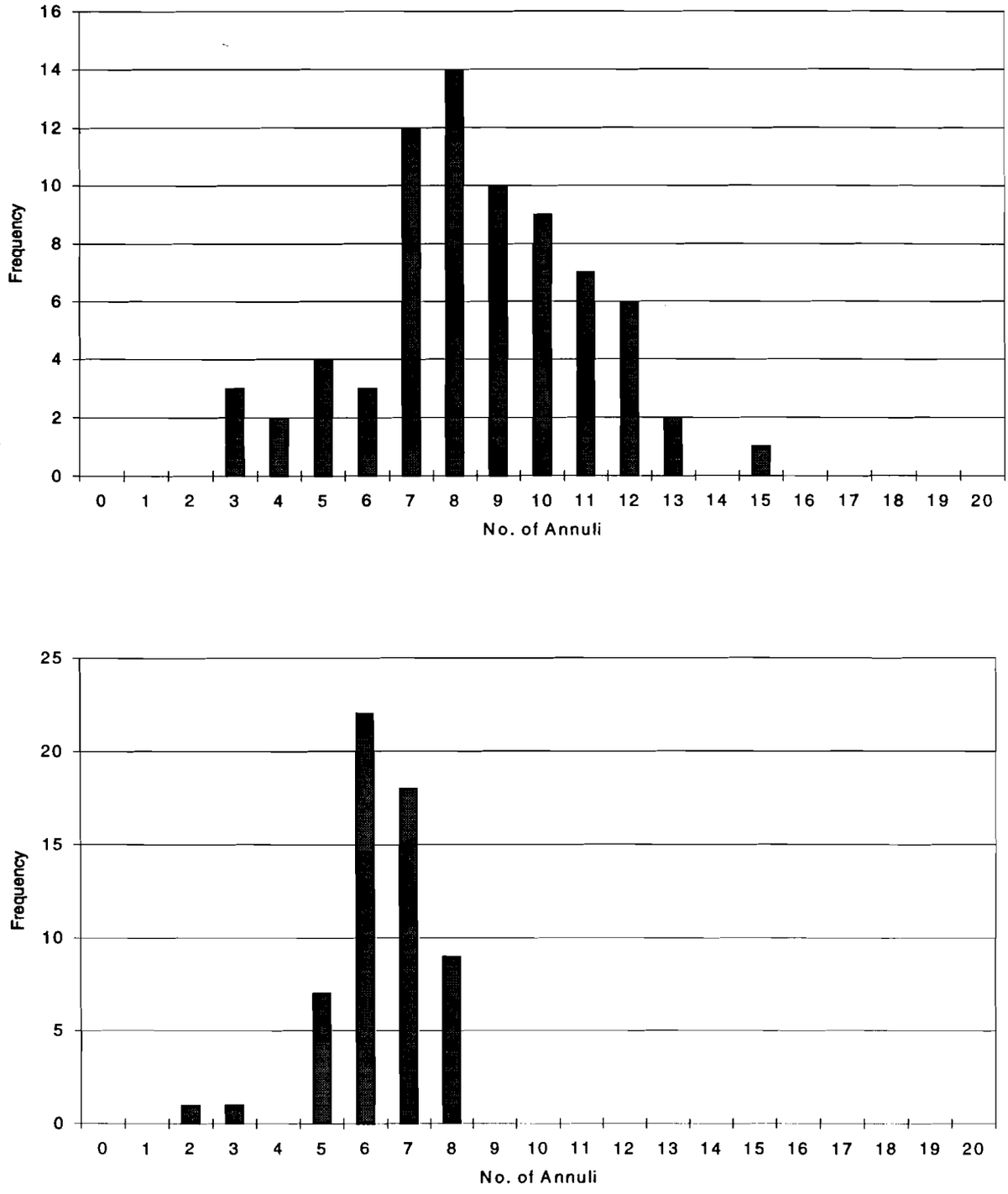

Figure 5. Age frequencies of butter clams from quadrats 1-3 (upper panel) and quadrat 4 (lower panel) from the Lucy Islands, Chatham Sound, September 1997.

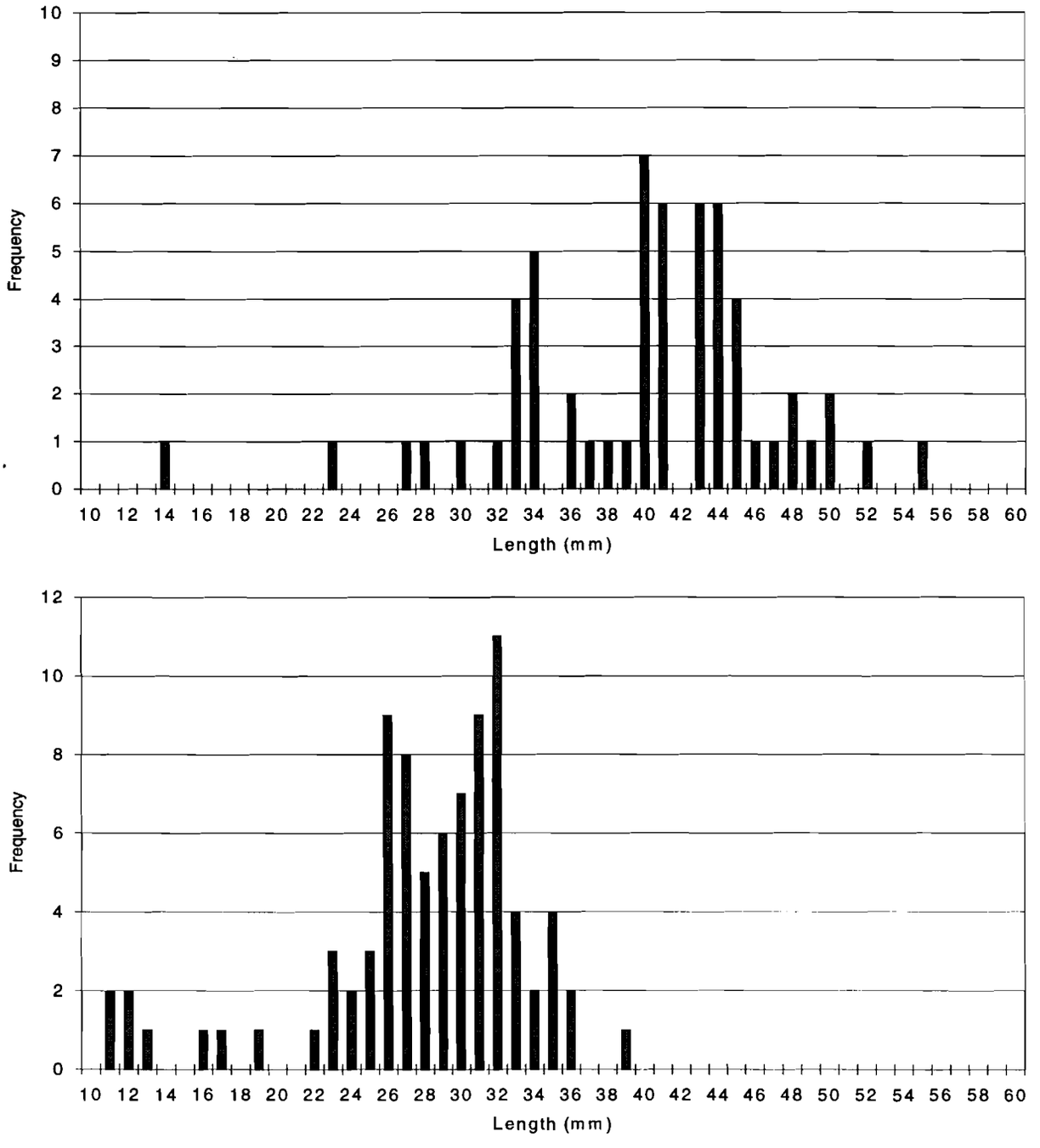

Figure 6. Length frequencies of littleneck clams from quadrats 1-3 (upper panel) and quadrat 4 (lower panel) from the Lucy Islands, Chatham Sound, September 1997.

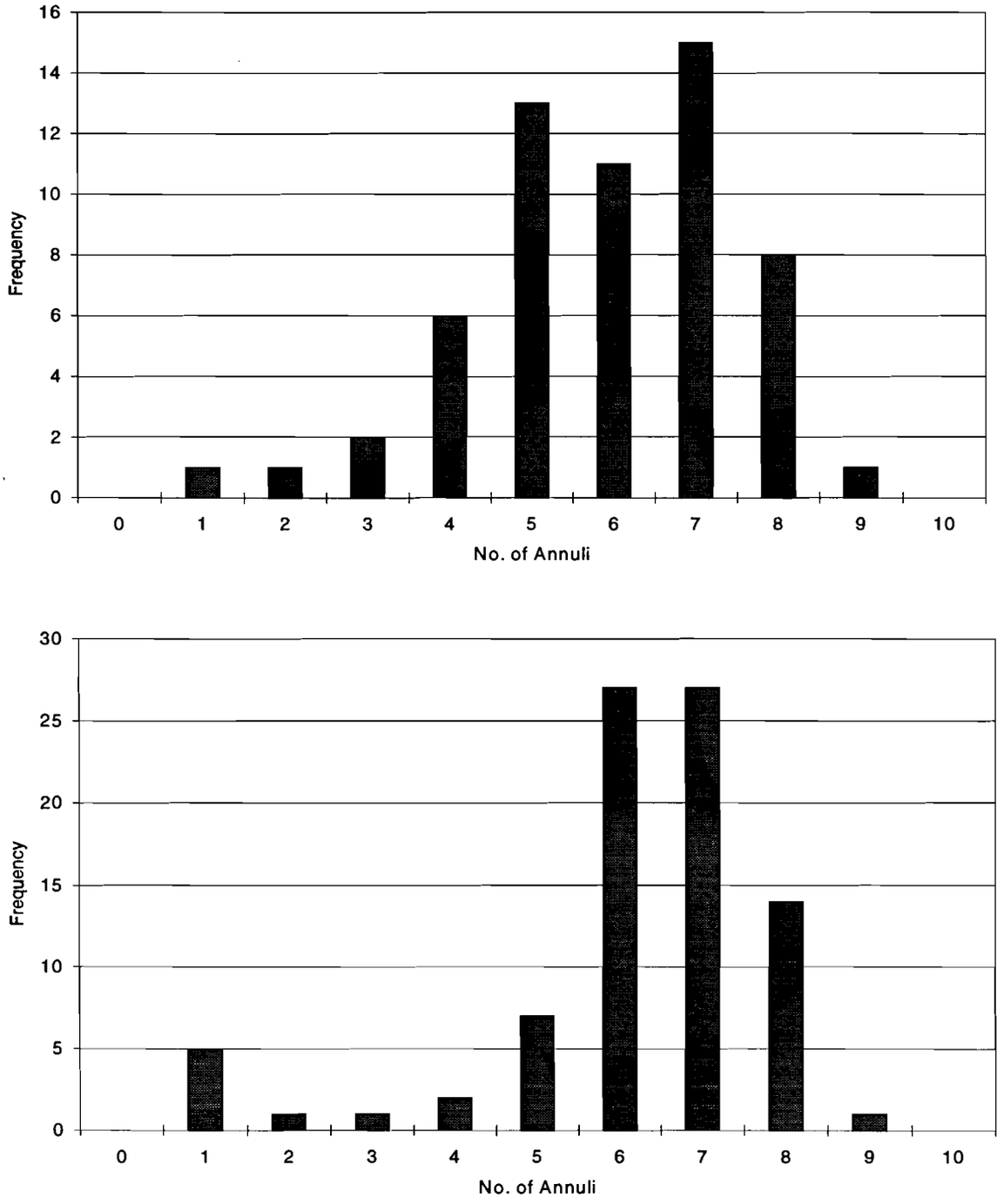

Figure 7. Age frequencies of littleneck clams from quadrats 1-3 (upper panel) and quadrat 4 (lower panel) from the Lucy Islands, Chatham Sound, September 1997.

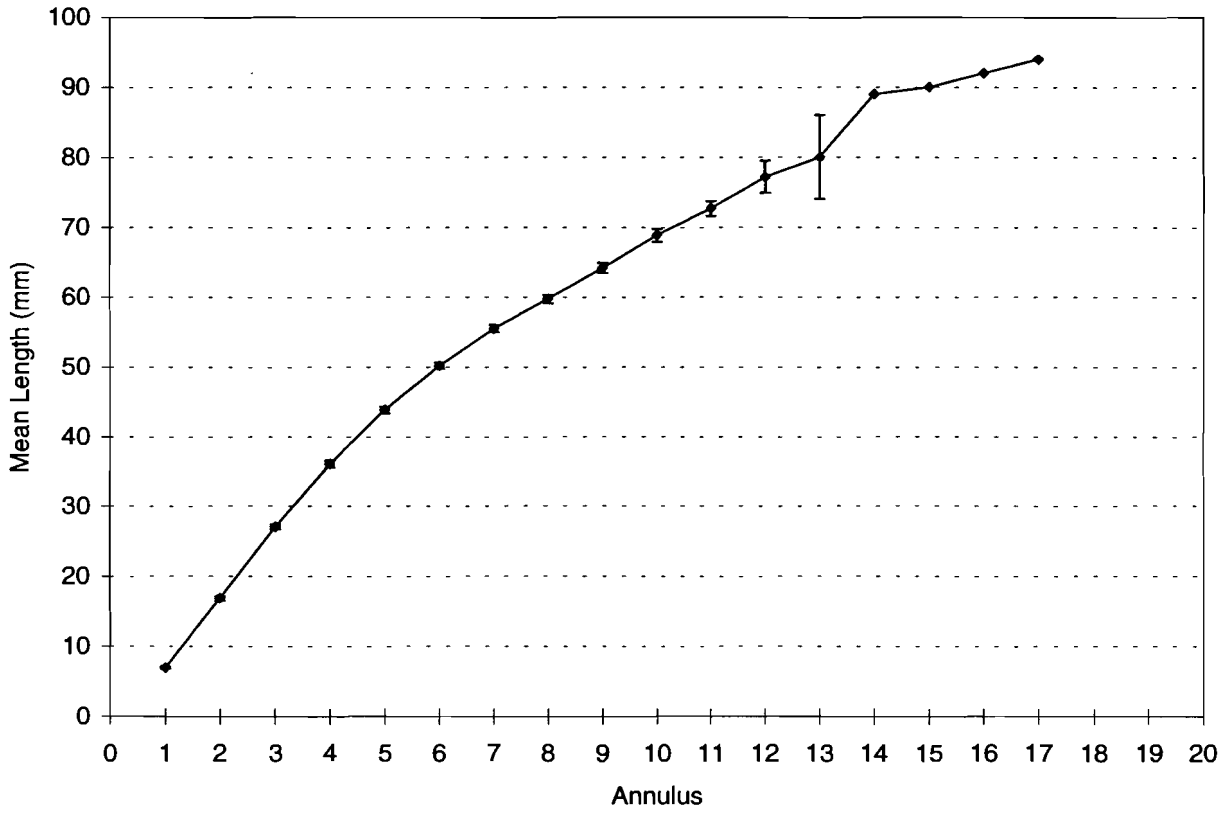

Figure 8. Growth curve for butter clams from quadrats 1-3 from the Lucy Islands, Chatham Sound, September 1997. Error bars are +/- one standard error.

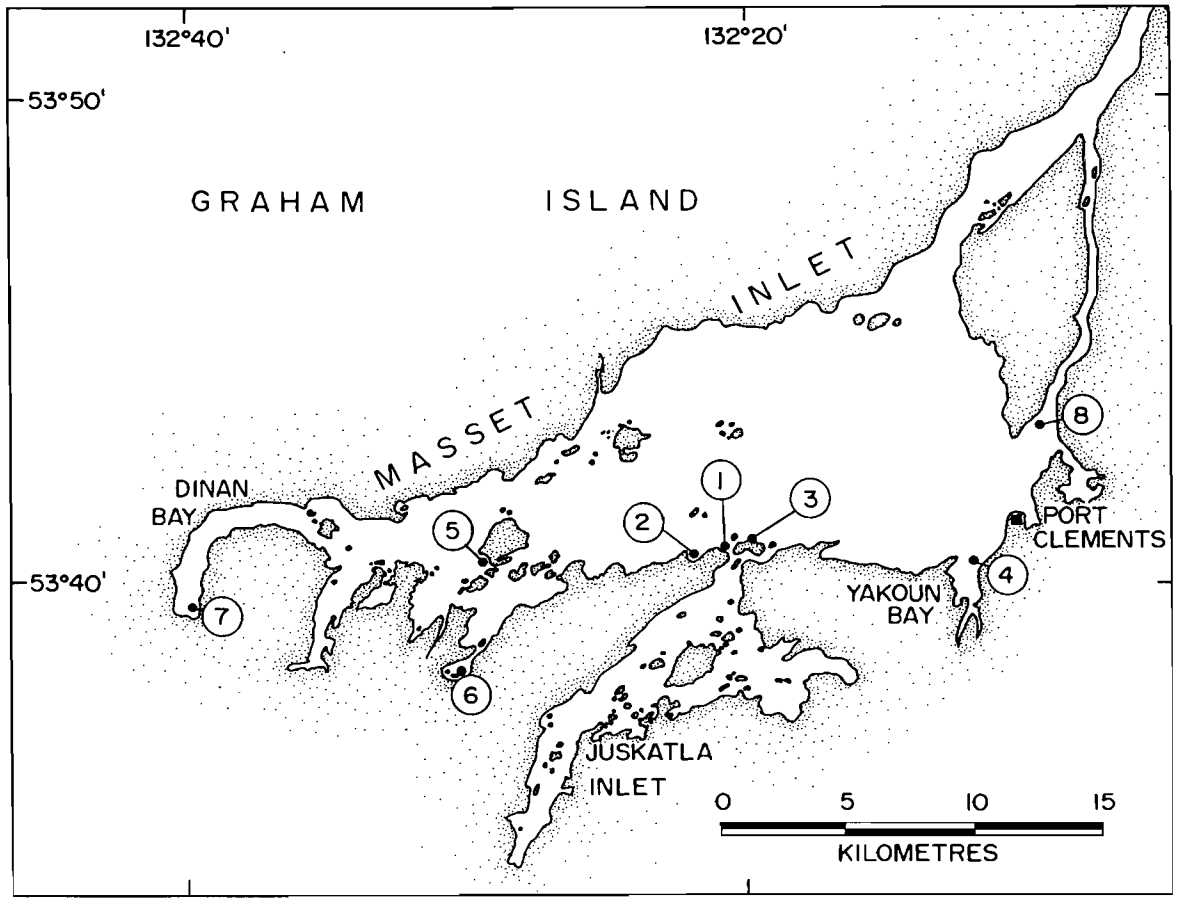

Figure 9. Location of beaches surveyed in Masset Inlet, September 3-5, 1997.

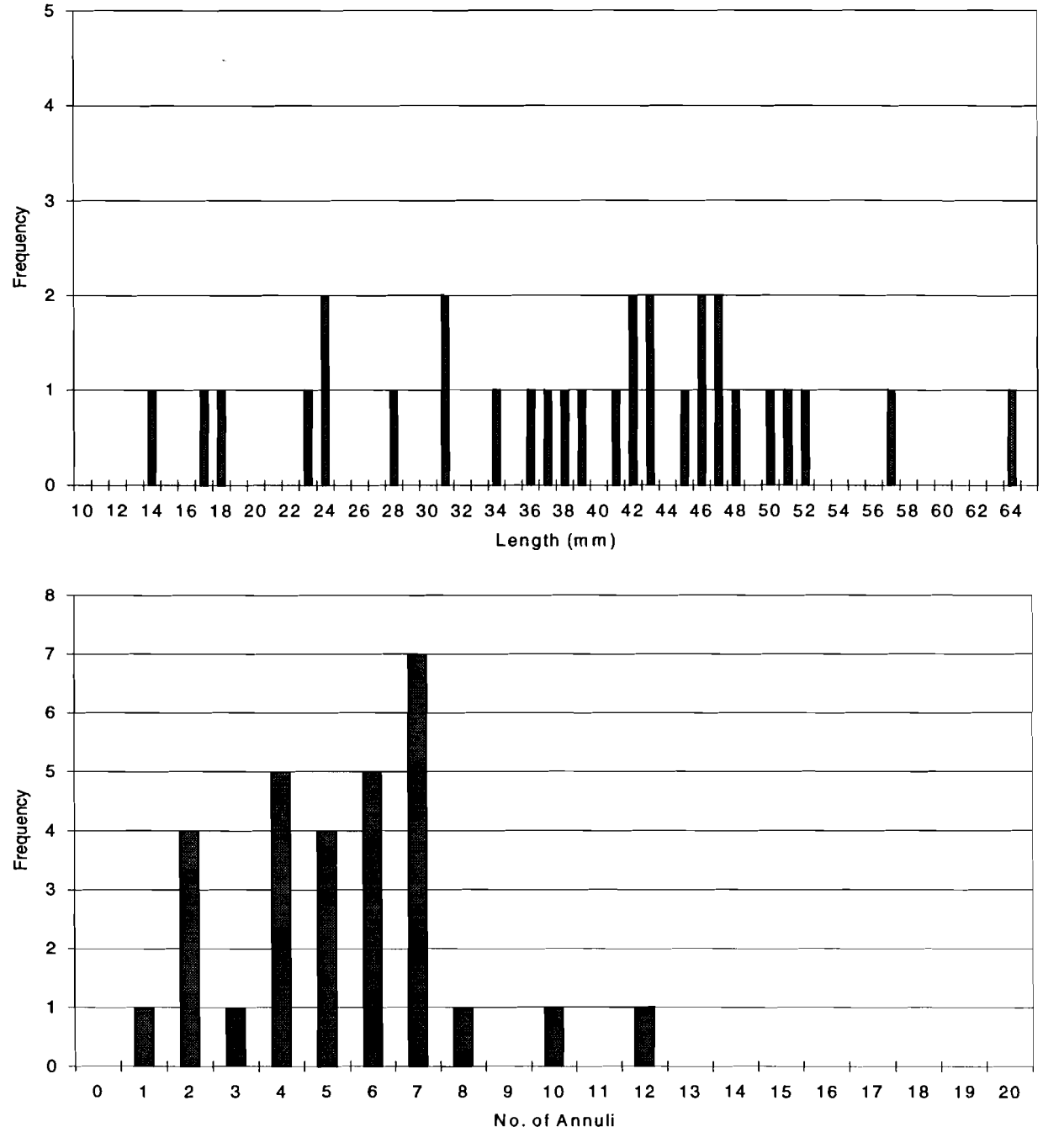

Figure 10. Length and age frequencies of butter clams from Fraser Island, Masset Inlet, September 1997.

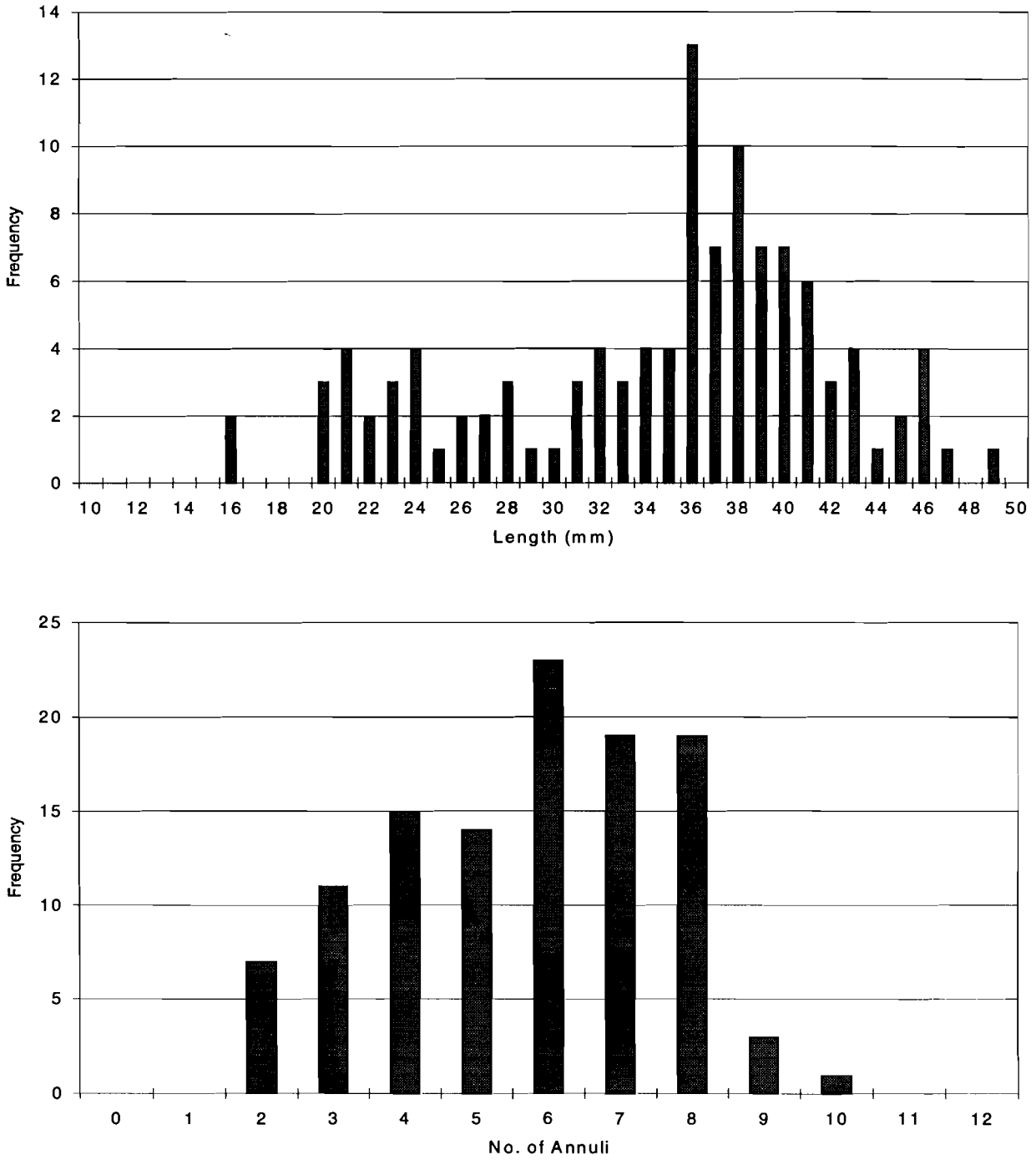

Figure 11. Length and age frequencies of littleneck clams from Fraser Island, Masset Inlet, September 1997.

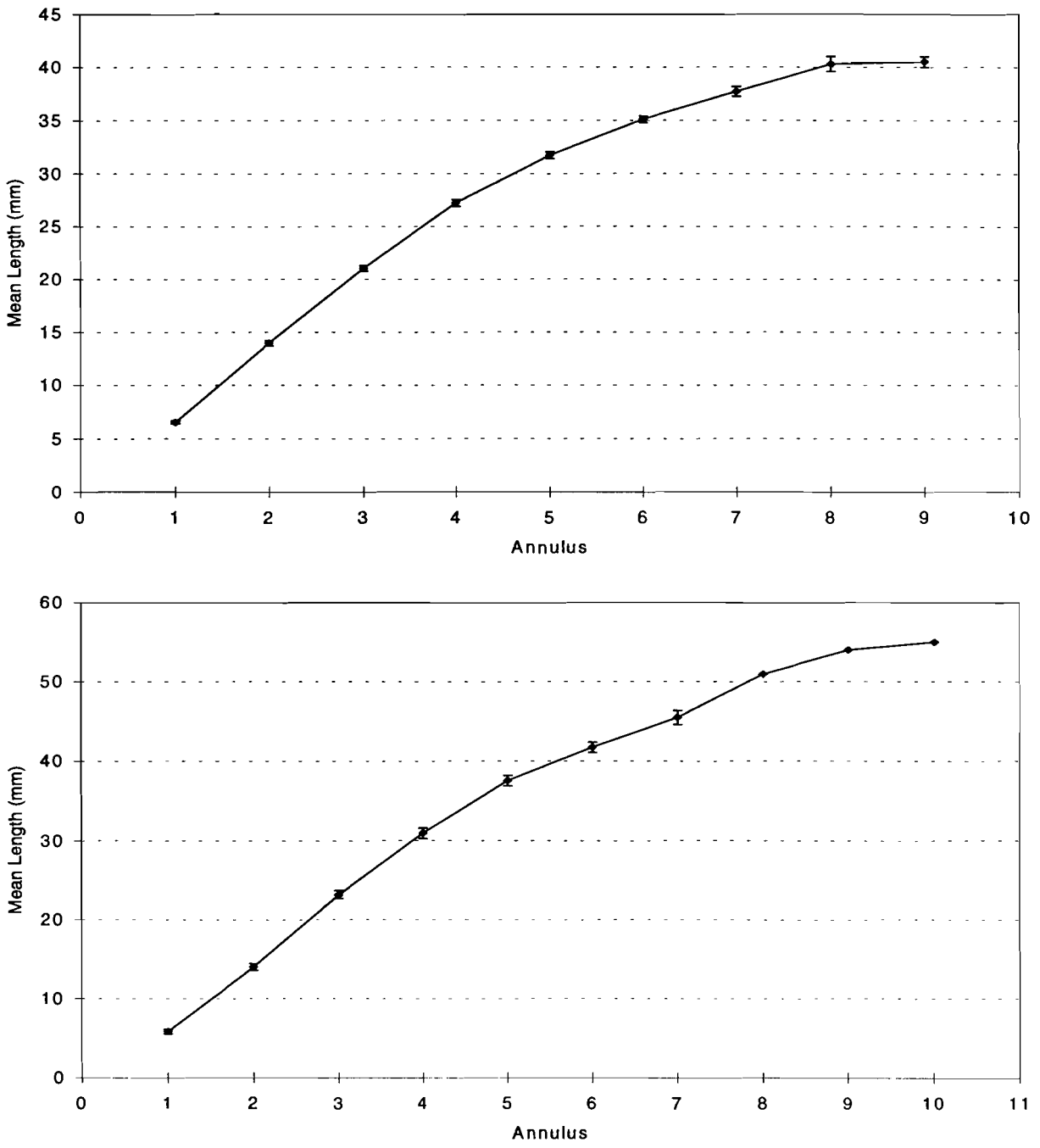

Figure 12. Growth curves for littleneck (upper panel) and butter (lower panel) clams from Fraser Island, Masset Inlet, September 1997. Error bars are +/- one standard error.

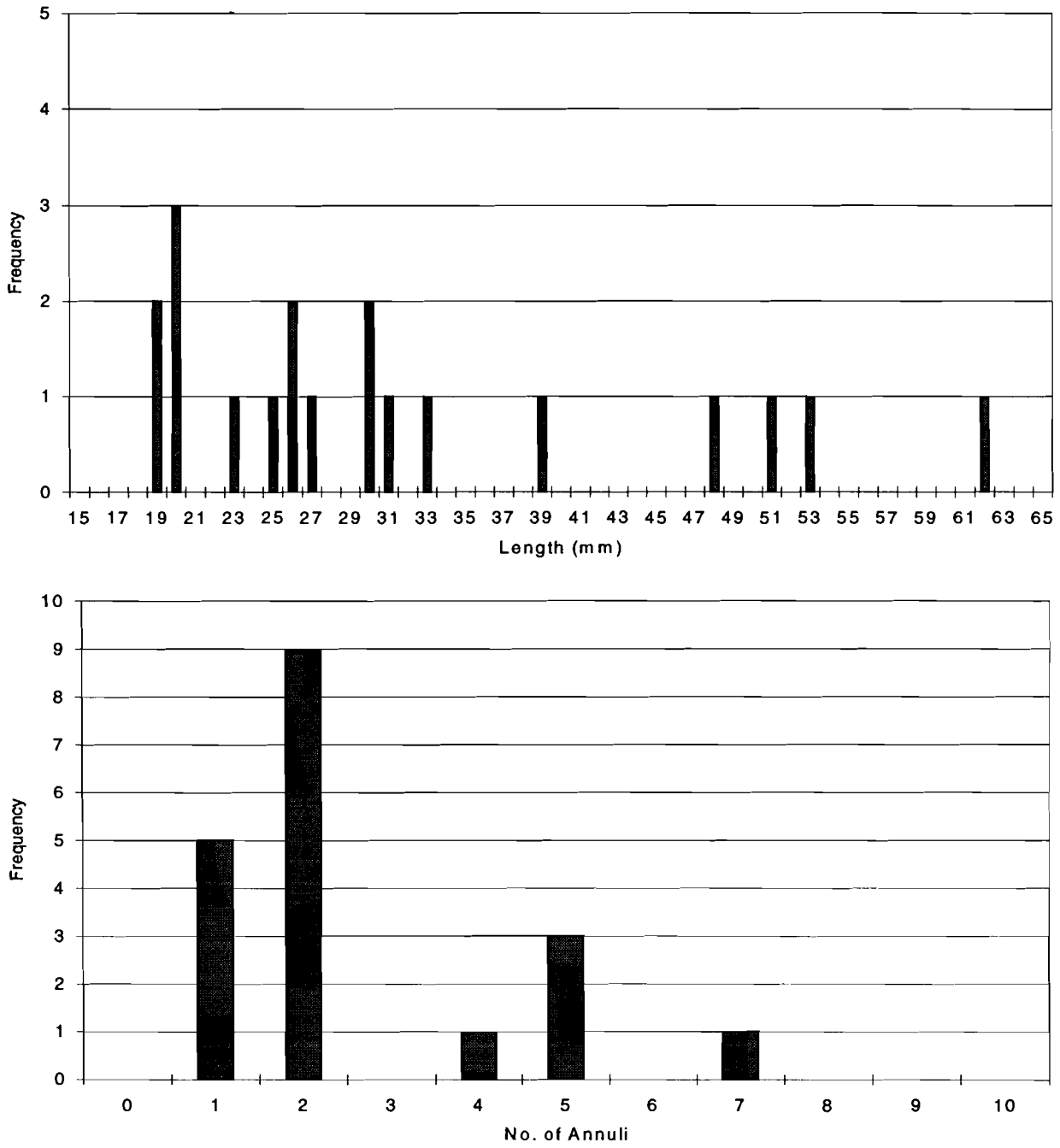

Figure 13. Length and age frequencies of soft-shell clams from Wathus Island, Masset Inlet, September 1997.

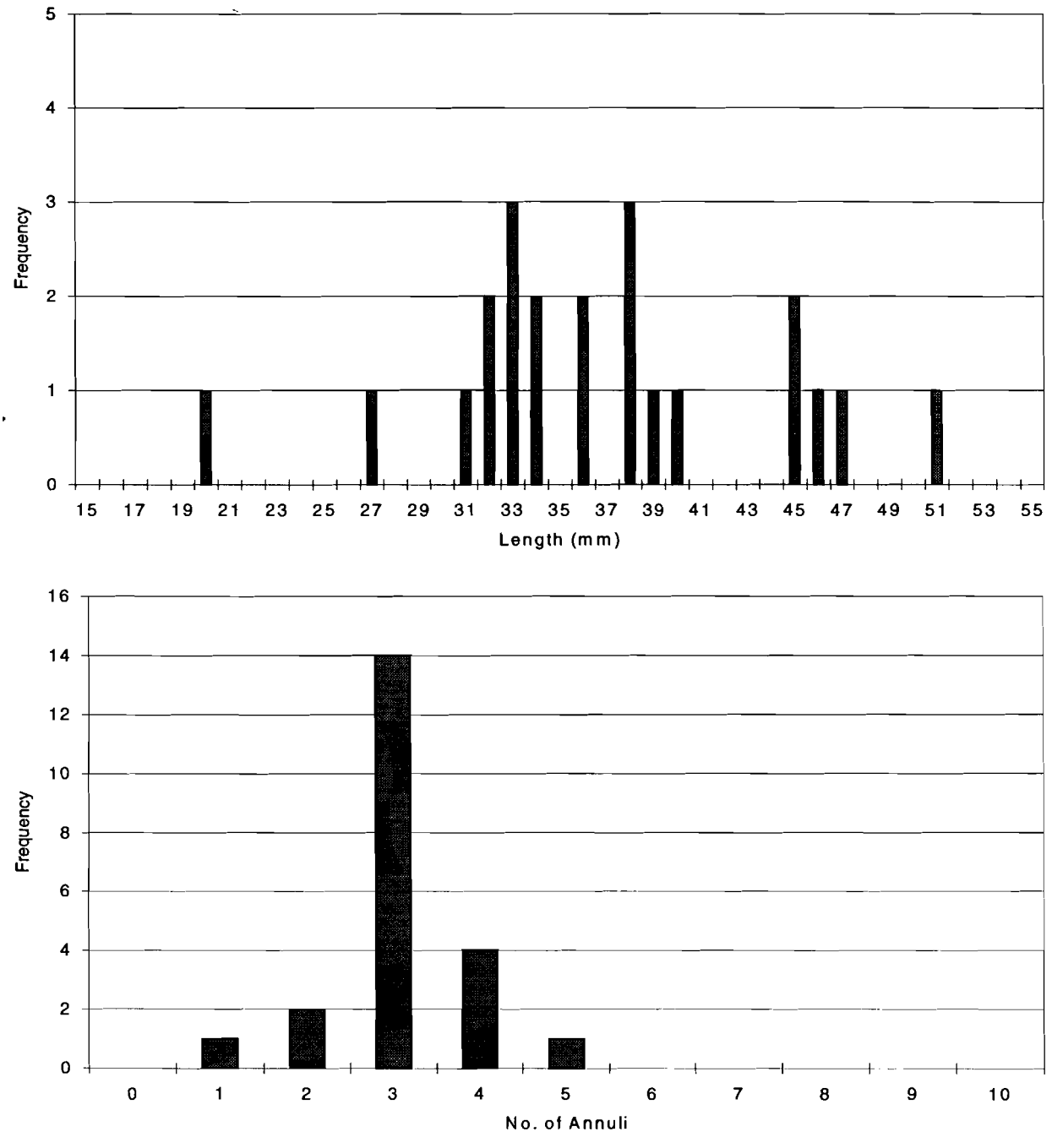

Figure 14. Length and age frequencies of soft-shell clams from Dinan Bay, Masset Inlet, September 1997.

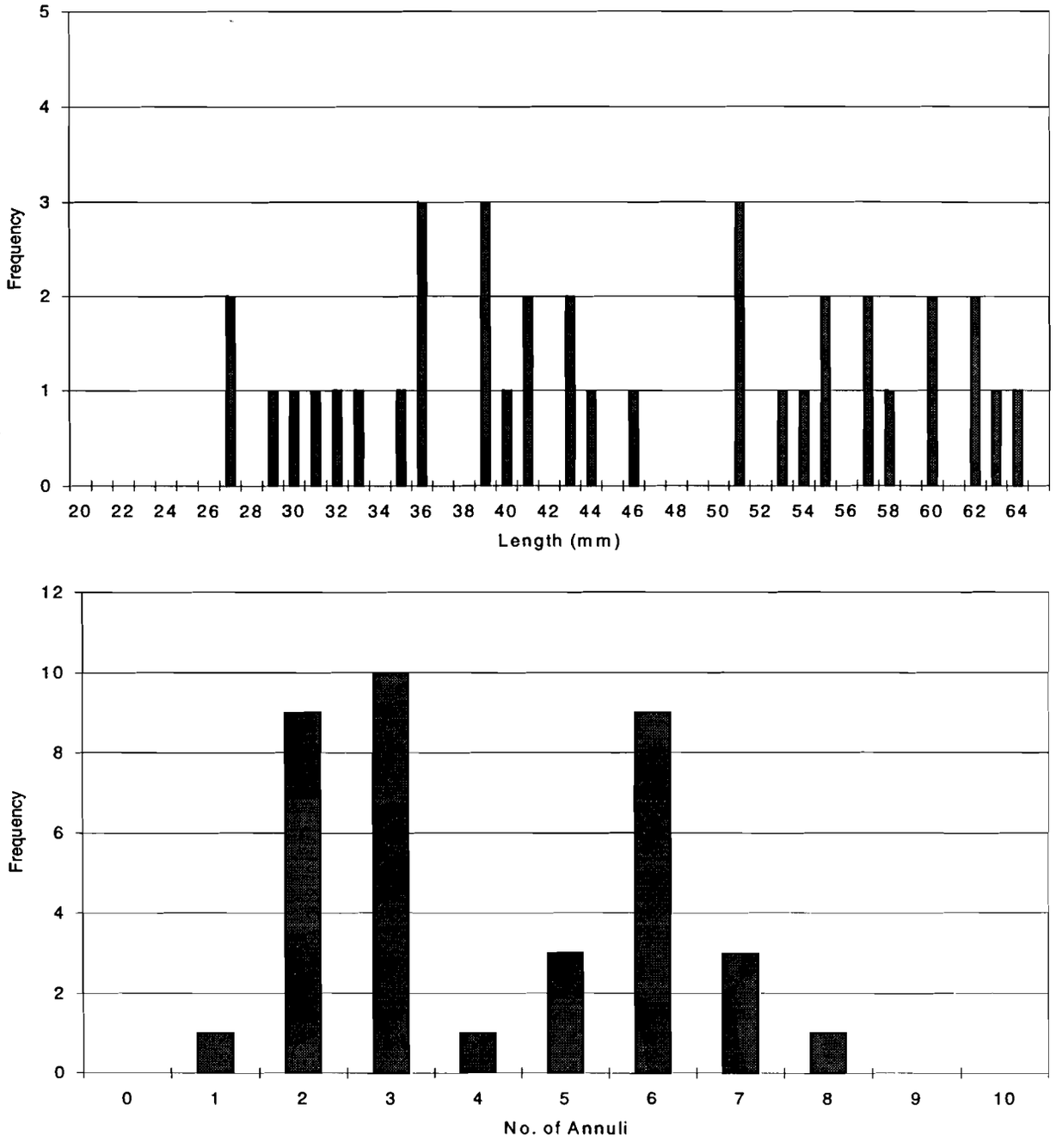

Figure 15. Length and age frequencies of soft-shell clams from Martin Point, Masset Inlet, September 1997.

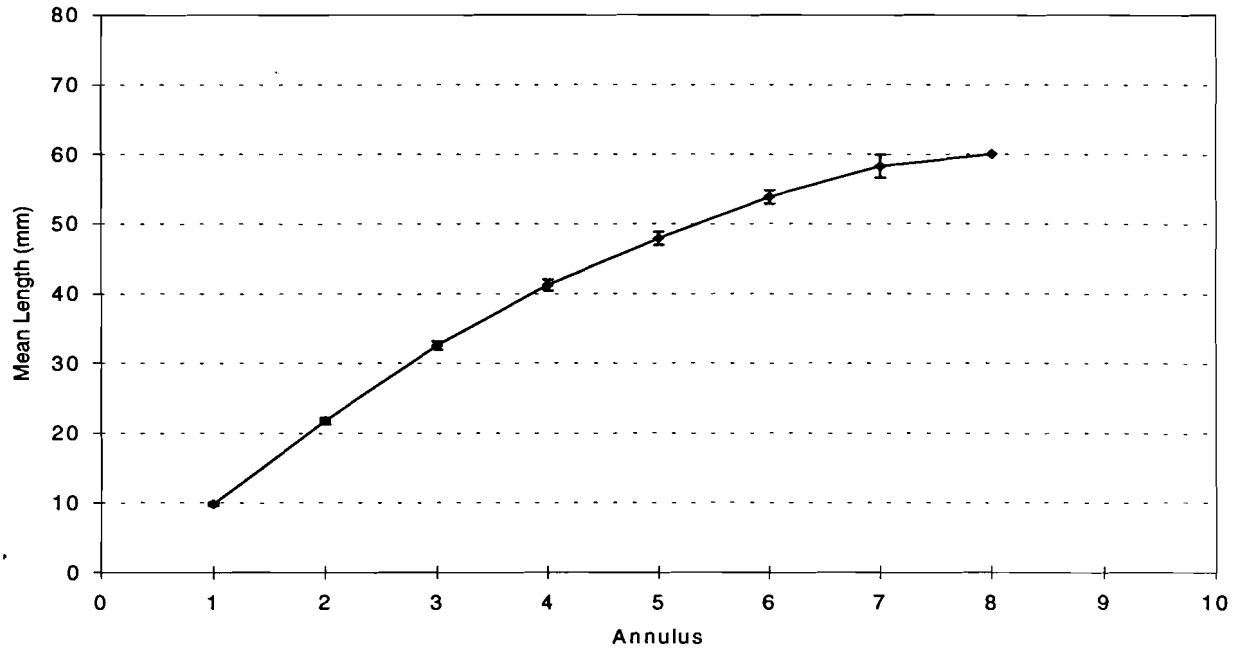

Figure 16. Growth curve for soft-shell clams from Martin Point, Masset Inlet, September 1997. Error bars are +/- one standard error.

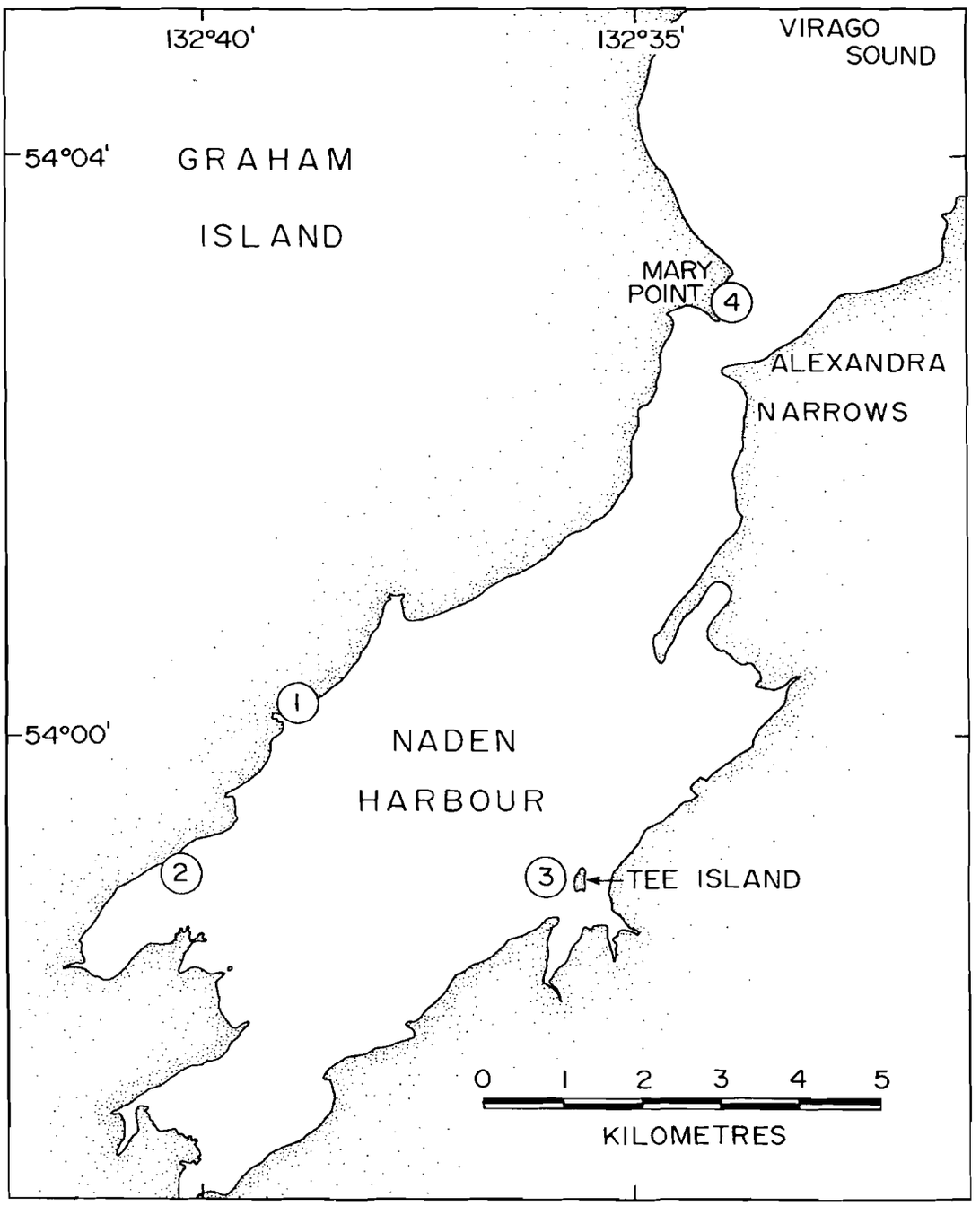

Figure 17. Locations of beaches surveyed in Naden Harbour, September 6, 1997.

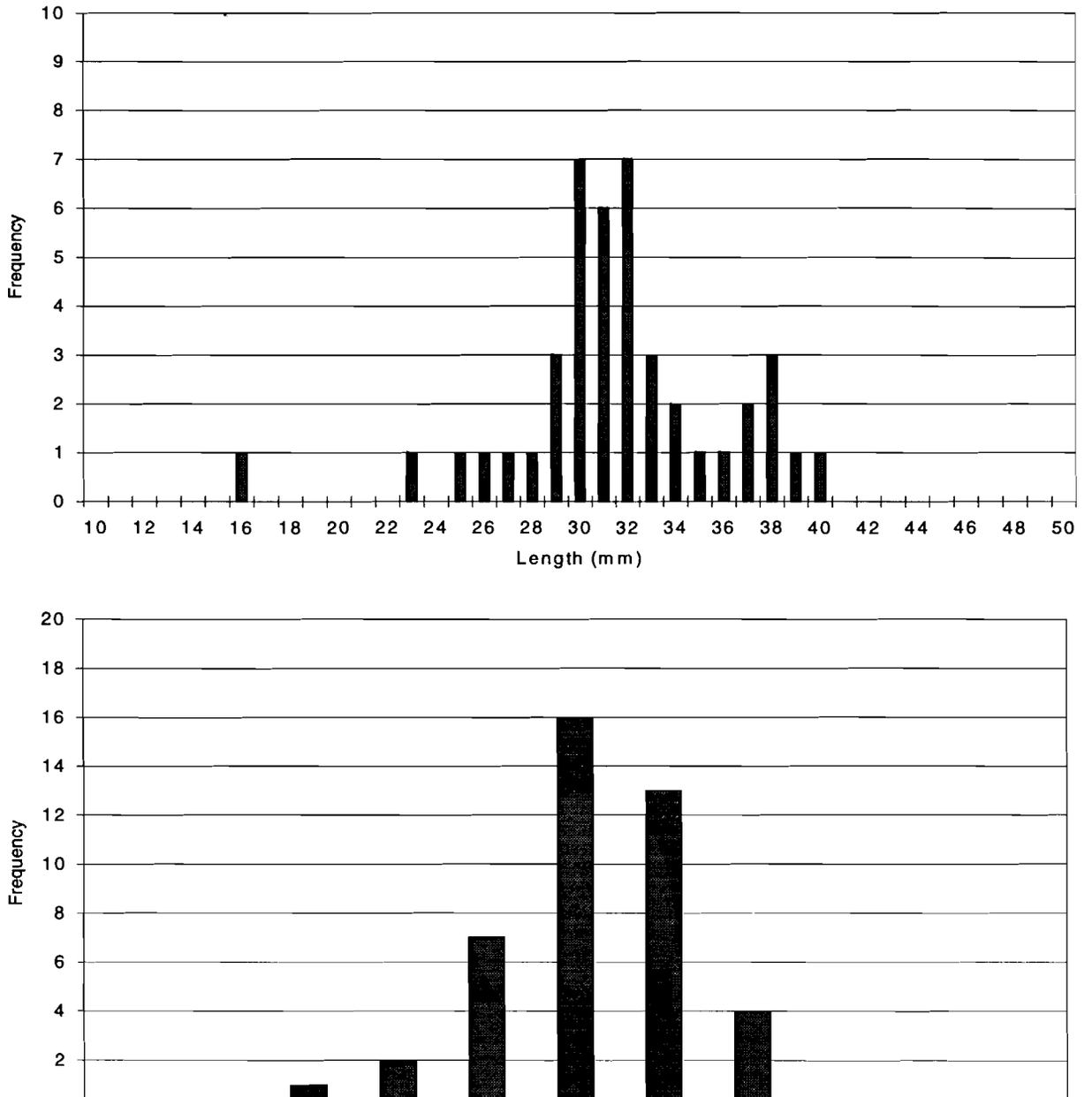

Figure 18. Length and age frequencies of littleneck clams from Germania Creek, Naden Harbour, September 1997.

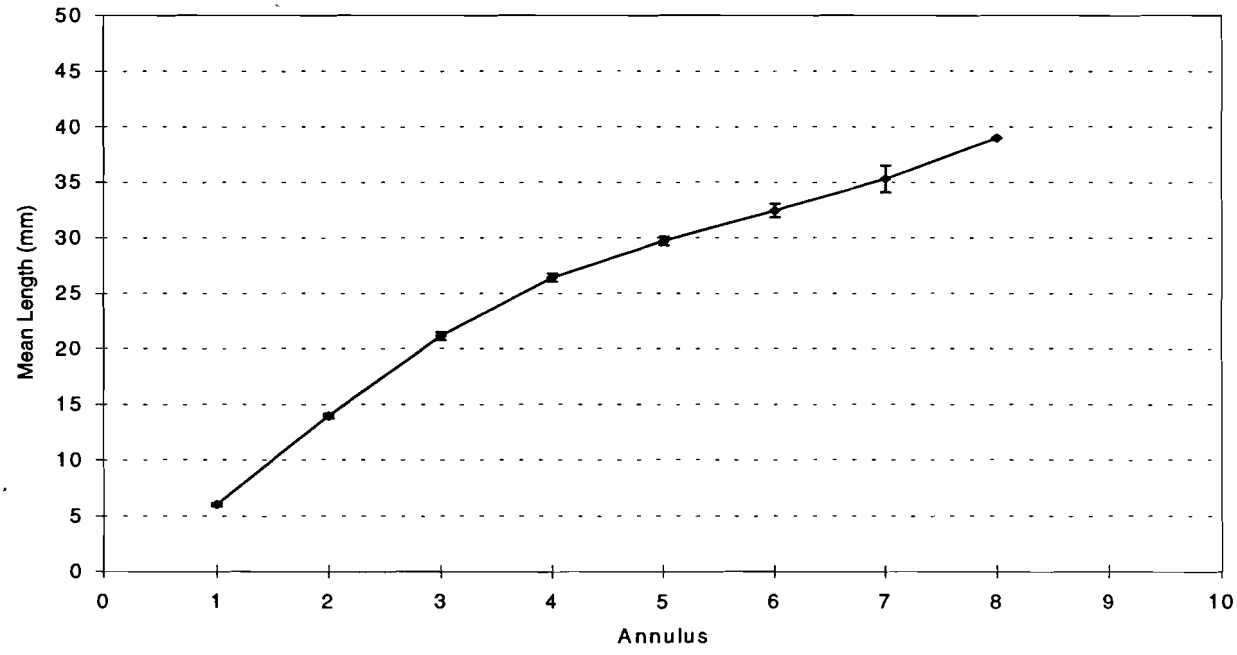

Figure 19. Growth curve for littleneck clams from Germania Creek, Naden Harbour, September 1997. Error bars are +/- one standard error.

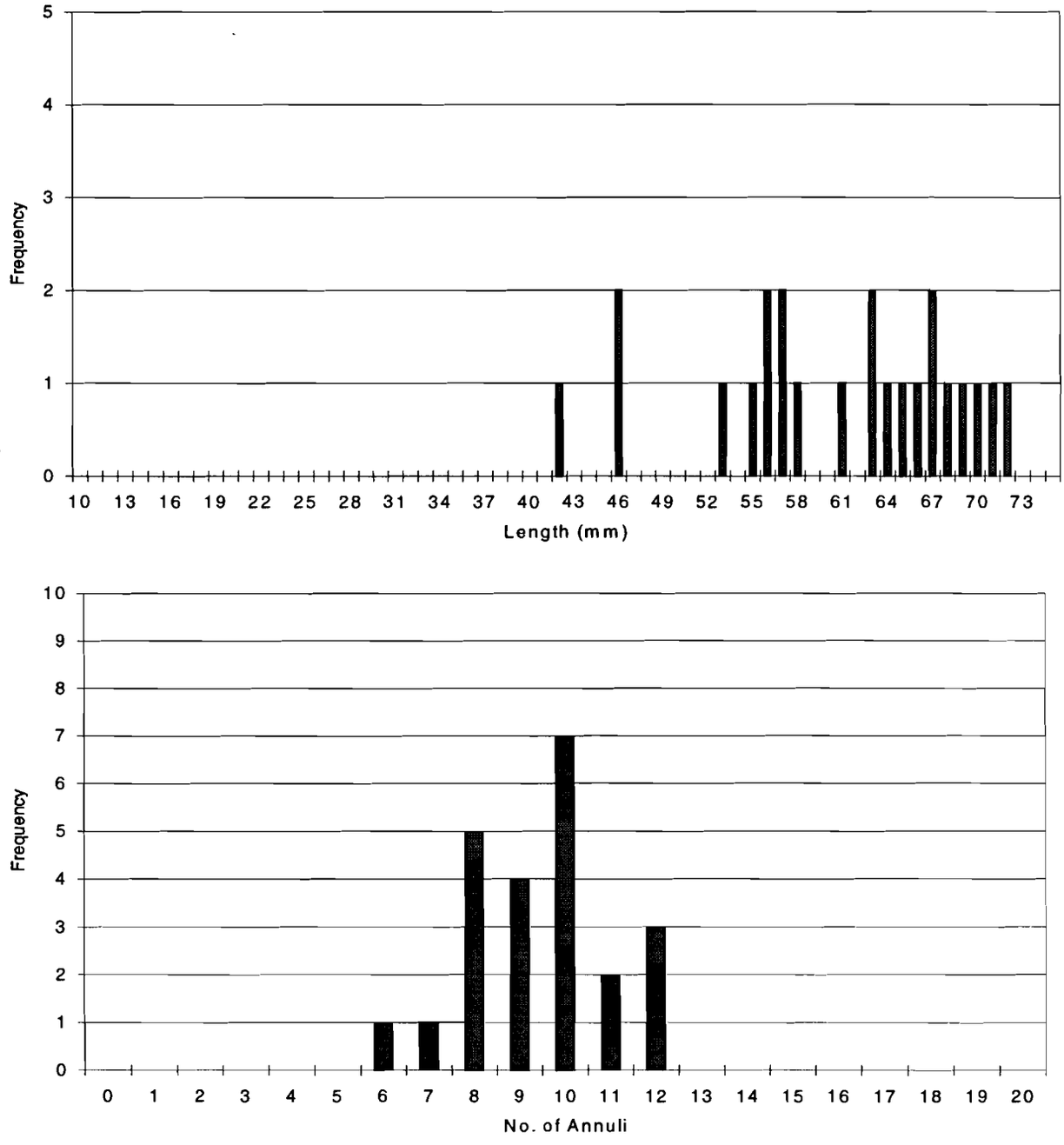

Figure 20. Length and age frequencies of butter clams from Tee Island, Naden Harbour, September 1997.

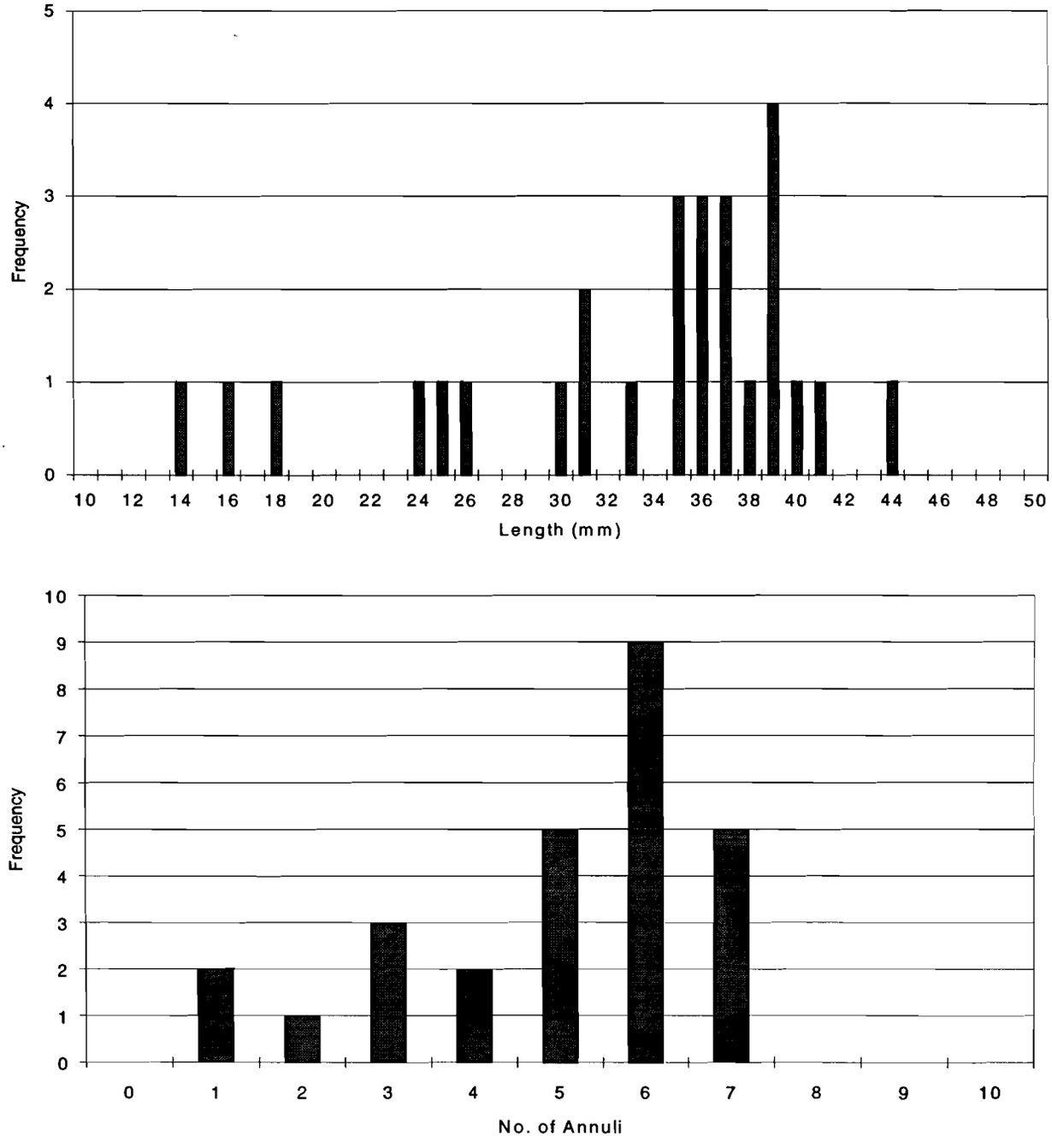

Figure 21. Length and age frequencies for littleneck clams from Tee Island, Naden Harbour, September 1997.

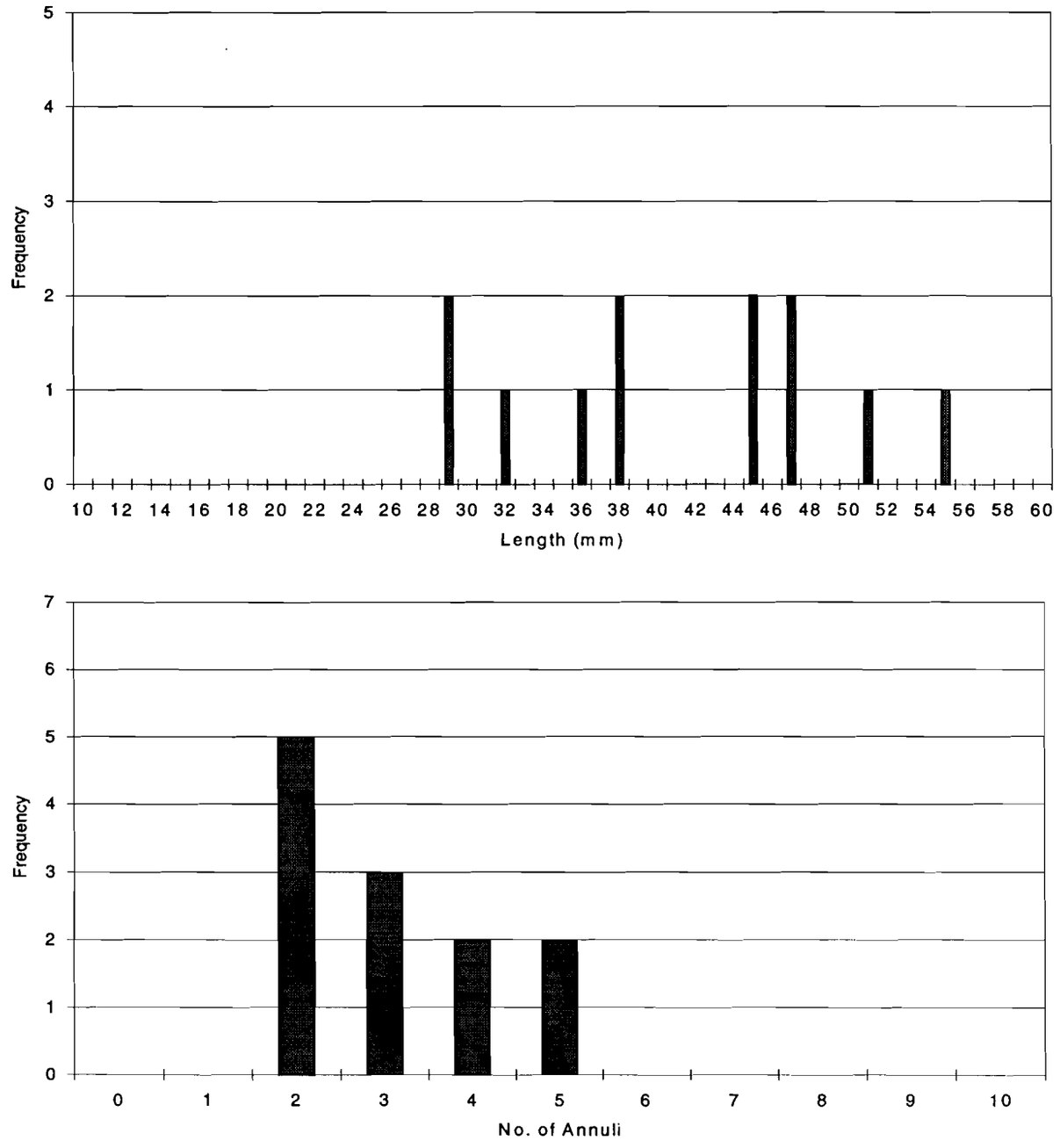

Figure 22. Length and age frequencies of cockles from Tee Island, Naden Harbour, September 1997.

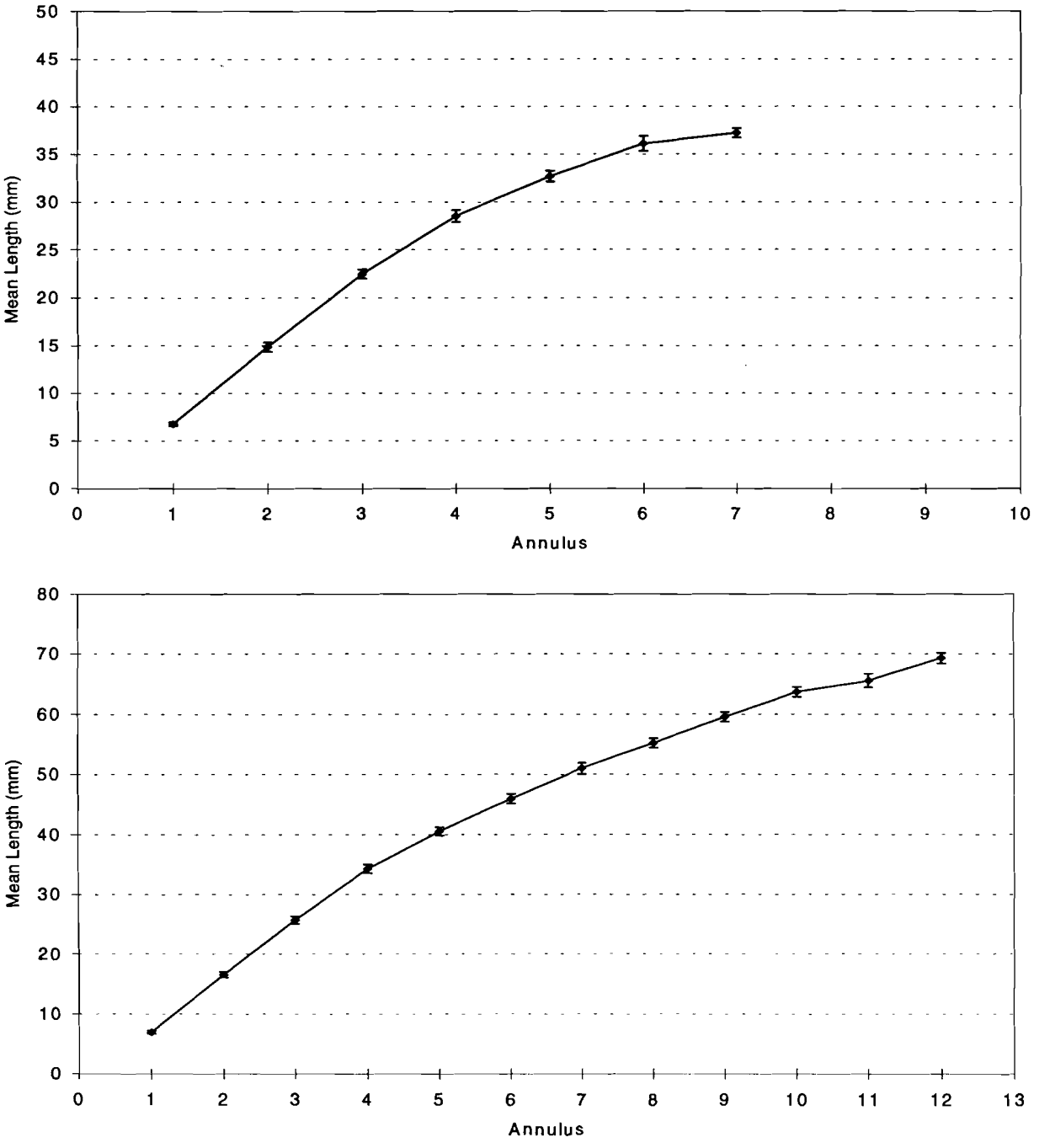

Figure 23. Growth curves for littleneck (upper panel) and butter (lower panel) clams from Tee Island, Naden Harbour, September 1997. Error bars are +/- one standard error.

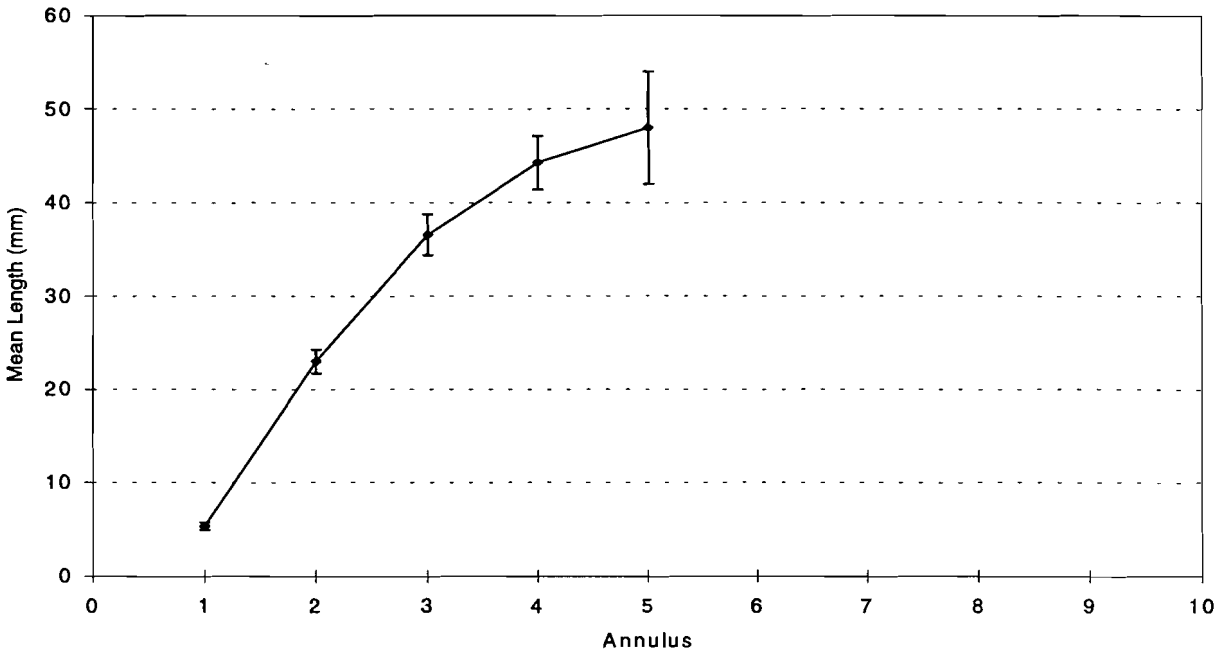

Figure 24. Growth curve for cockles from Tee Island, Naden Harbour, September 1997. Error bars are +/- one standard error.

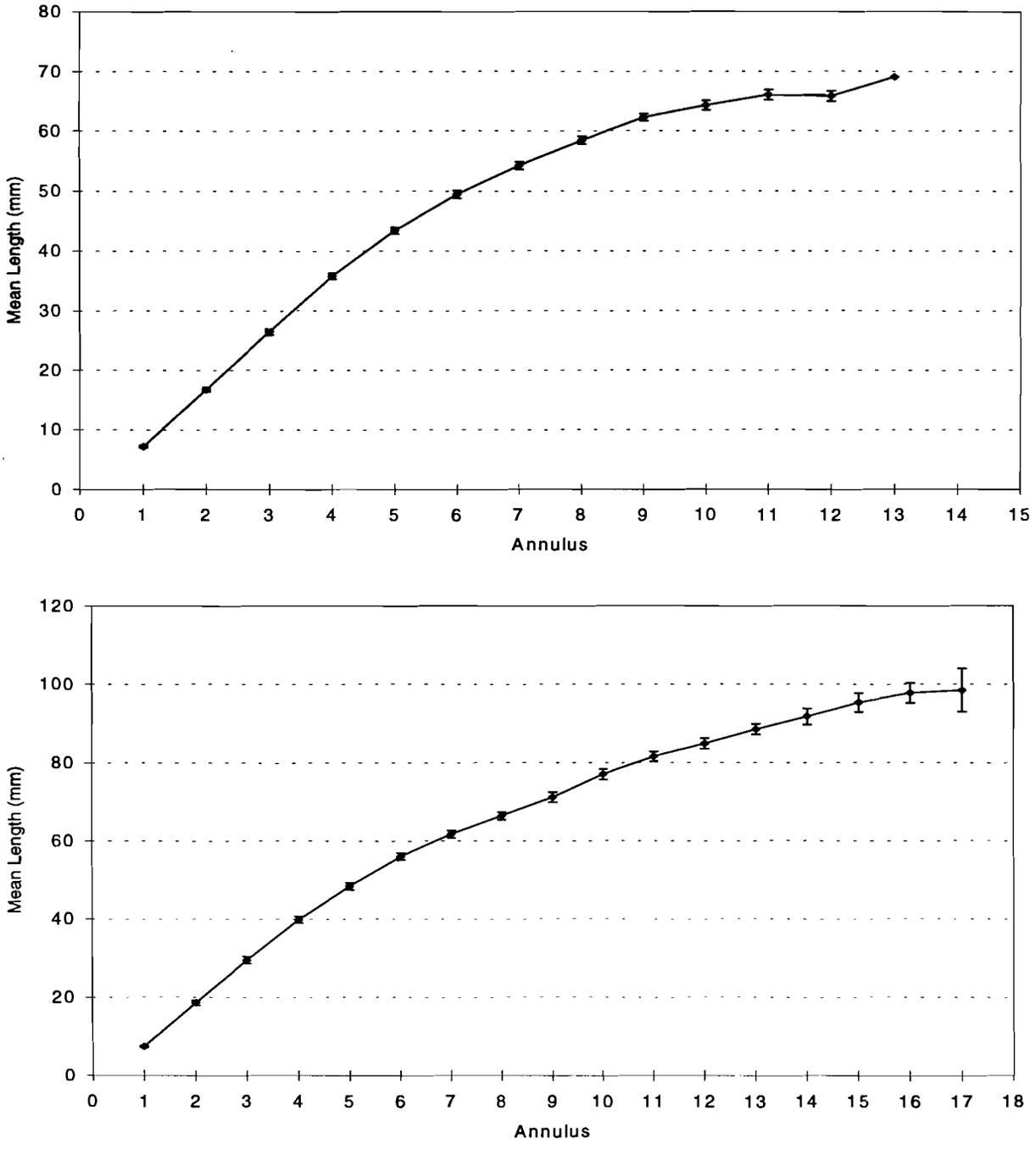

Figure 25. Growth curves for littleneck (upper panel) and butter clam (lower panel) shells dredged from Naden Harbour, September 1997. Error bars are +/- one standard error.