

The Utility of Artificial Collectors as a Technique to Study Benthic Settlement and Early Juvenile Growth of the Rock Crab, *Cancer irroratus*

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ABSTRACT

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Concurrent studies of planktonic larval density and benthic recruitment of *Cancer irroratus* were performed in Kochibouguac Bay, New Brunswick, from late May to mid-September 1981. Three artificial collector types were used; mop, box and Witham. All collector types were shown to sample settling *C. irroratus*. Although *Homarus americanus* is also abundant in this region, no settling stages or young juveniles were observed in the collectors. The most efficient collector appears to be the mop type, which should be tethered off the bottom to avoid excessive clogging on mud bottoms.

The usefulness of these collectors in the study of growth of these otherwise inaccessible stages was demonstrated using modal analysis of size-frequency histograms. In addition, the presence of 26 exuviae (2.5-58 mm carapace width) showed that juveniles of all sizes molt in these collectors.

The larval density data revealed a clear sequence of events, comprising the appearance of the first zoea larvae in early summer, the presence of a large megalopa peak in mid-July, followed immediately by the appearance of new recruits (\geq first crab stage) in the collectors. The use of such artificial collectors constitutes a promising technique in the study of benthic recruitment and early growth of *C. irroratus*.

INTRODUCTION

The study of life-history phases of commercial crustacean species prior to recruitment into the fishery is a prime research concern. In general, however, the collection and interpretation of data for pre-recruits, particularly larval and immediate post-settlement stages, remains problematic. For example, Scarratt (1964, 1973) failed to determine a useful predictive relationship between the abundance of Stage IV American lobster (*Homarus americanus*)

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larvae from plankton net tows, and subsequent commercial lobster stock size. Similarly, Stasko and Gordon (1983) failed to capture sufficient numbers of early-stage *H. americanus* to explain the preponderance of Stage IV larvae in their tows. In comparison, passive collectors designed to intercept crustacean larvae at settlement have provided less enigmatic results and have proved to be effective in estimating relative settlement strengths for the western rock lobster *Panulirus cygnus* (Phillips, 1972; Phillips and Hall, 1978). Furthermore, data on the catches from such collectors have proved successful in predicting recruitment into the western rock lobster fishery (Morgan, 1980; Morgan et al., 1982).

Compared to collectors, the more traditional sampling methods for juvenile crustaceans (essentially various forms of trawls — see Miller et al., 1980, for details) appear to select against early crab stages, may be difficult to operate effectively, and are prone to rapid fouling. To date, attempts to intercept settling stages of American lobster larvae on collectors have been unsuccessful (G.J. Sharp, Department of Fisheries and Oceans, Halifax, N.S., personal communication, 1985). However, while evaluating collectors for American lobster, B. Vezina (unpublished data, 1979) serendipitously succeeded in capturing early benthic stages of the rock crab (*Cancer irroratus*). The rock crab forms the basis for a small (≤ 500 t per annum) although persistent fishery in Atlantic Canada, with the bulk of the landings coming from the Northumberland Strait (Scarratt and Lowe, 1972; Elner, 1985).

The purpose of the present work was to design and field-test three collector types to study settlement and the biology of early juvenile stages of the rock crab. Collectors are demonstrated to be an effective tool for elucidating settlement dynamics and gathering information on behaviour and growth during these cryptic life-history phases.

MATERIALS AND METHODS

Location and description of area

The study was conducted in Kouchibouguac Bay, on the northern limit of the Northumberland Strait (Fig. 1). This area was chosen because rock crab larvae are known to be seasonally abundant (Scarratt and Lowe, 1972). The study area consisted of a shallow (< 18 m) bay, approximately 32 km long and 9.5 km wide (Kranck, 1967). Surface temperatures vary seasonally between 3 and 20°C, and salinity varies between 27 and 29‰ from May to September (Lauzier, 1957). The dominant substrate types are sand and sand-rock (Kranck, 1967). Dense beds of seagrass (*Zostera marina*) are present during the summer months.

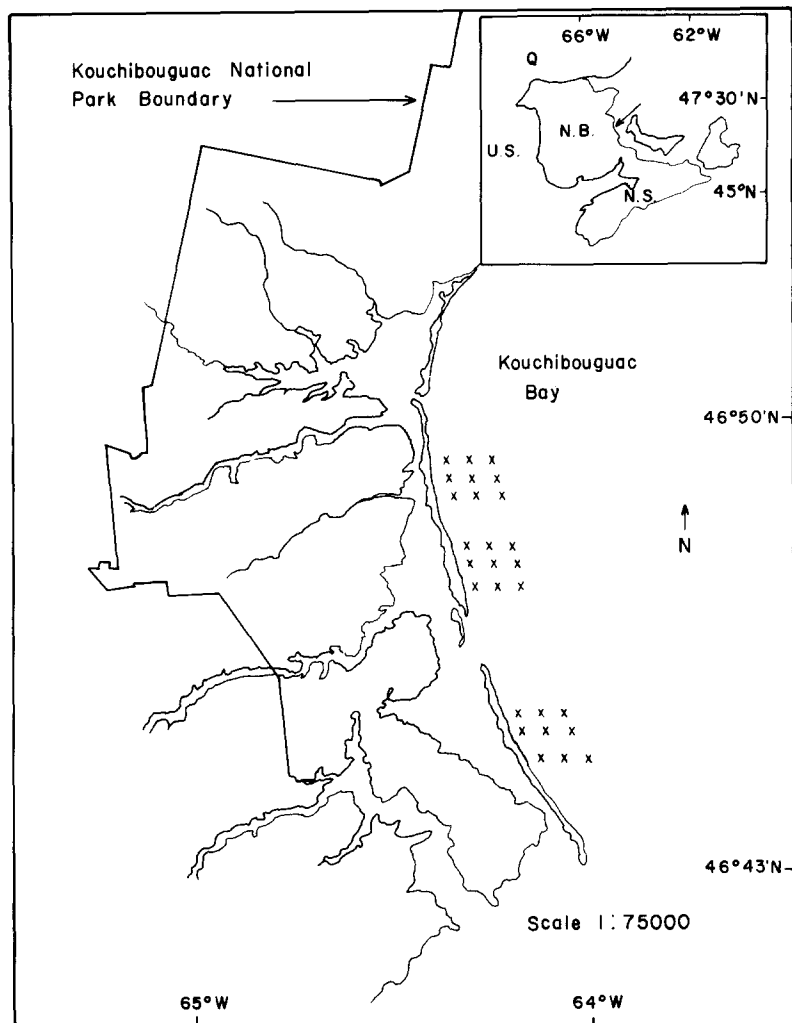


Fig. 1. Map of the study area, showing the location of collector sites (regional map shown in insert).

Larval sampling

Both larval and juvenile sampling were carried out from 26 May to 14 September 1981. Larvae were sampled between 09.00 and 17.00 h at 2–3-week intervals from 1 June to 21 July, and then at approximately 1-week intervals from 23 July to 14 September using a Neuston net as described by Stasko and Gordon (1983). The upper 0.15 m of the water column was sampled with a circular tow at 1 kn for 10 min. The volume filtered was determined using the net dimensions and the time and speed of the net, as use of a current meter

was precluded because of the fouling incurred by seagrass. Three tows were performed over bottom depths of 2, 5 and 8 m, representing the majority of bottom depths in Kouchibouguac Bay, for a total of nine tows at each sampling. The plankton was preserved in neutral formalin-seawater (10%).

Plankton samples were examined using a stereomicroscope, and the *C. irroratus* larvae of each stage were counted. In those samples where the larval density was high, dilution and sub-sampling were performed.

Juvenile sampling

The three types of collectors were all 0.61 m long \times 0.61 m wide, with different heights (Fig. 2). The "box" type collector, similar to that used by Serfling and Ford (1975), was filled with empty blue mussel (*Mytilus edulis*) shells. The Witham collector surfaces were made of half-rolled polypropylene indoor-outdoor carpeting (Witham et al., 1968), while the mop-type collector surfaces were made of teased hemp fibres (Phillips, 1972). The collectors were tethered to the substrate by a concrete block, and each collector was attached to a marker buoy at the water surface.

Collector sites and sampling

Twenty-seven collectors (9 of each type) were originally anchored at the sites indicated in Fig. 1, which were representative of the depths found in the bay. Due to the dominance of the sand-rock substrate, 18 collectors were placed on this substrate while 9 were placed on the mud substrate, which was very densely covered with *Z. marina*. In the course of the sampling period, many collectors were lost due to storms, and most of the mud-substrate collectors were completely covered over. By August, only 1 mop-type collector remained on the mud substrate, while 9 collectors (2 mop, 3 Witham and 4 box-type) remained on the sand-rock substrate.

The collectors were carefully pulled from the water by SCUBA divers and surface workers at approximate weekly intervals. No detachment of settled crabs was observed during these manipulations. After a thorough search, all crabs found in the collectors were placed in jars containing 10% neutral formalin in seawater. Carapace width (CW: maximum distance between the tips of the antero-lateral spines) was measured to the nearest 0.1 mm using Vernier calipers.

Due to the preceding constraints, relative collector efficiencies were only compared for those collectors on the sand-rock substrate. Catch per unit effort (CPUE) was standardized and defined as the number of juveniles present in the collectors per soak-day; the CPUE of each collector type was tested for significant differences using a 1-way Kruskal-Wallis analysis (as no assumptions could be made regarding the normality of the data).

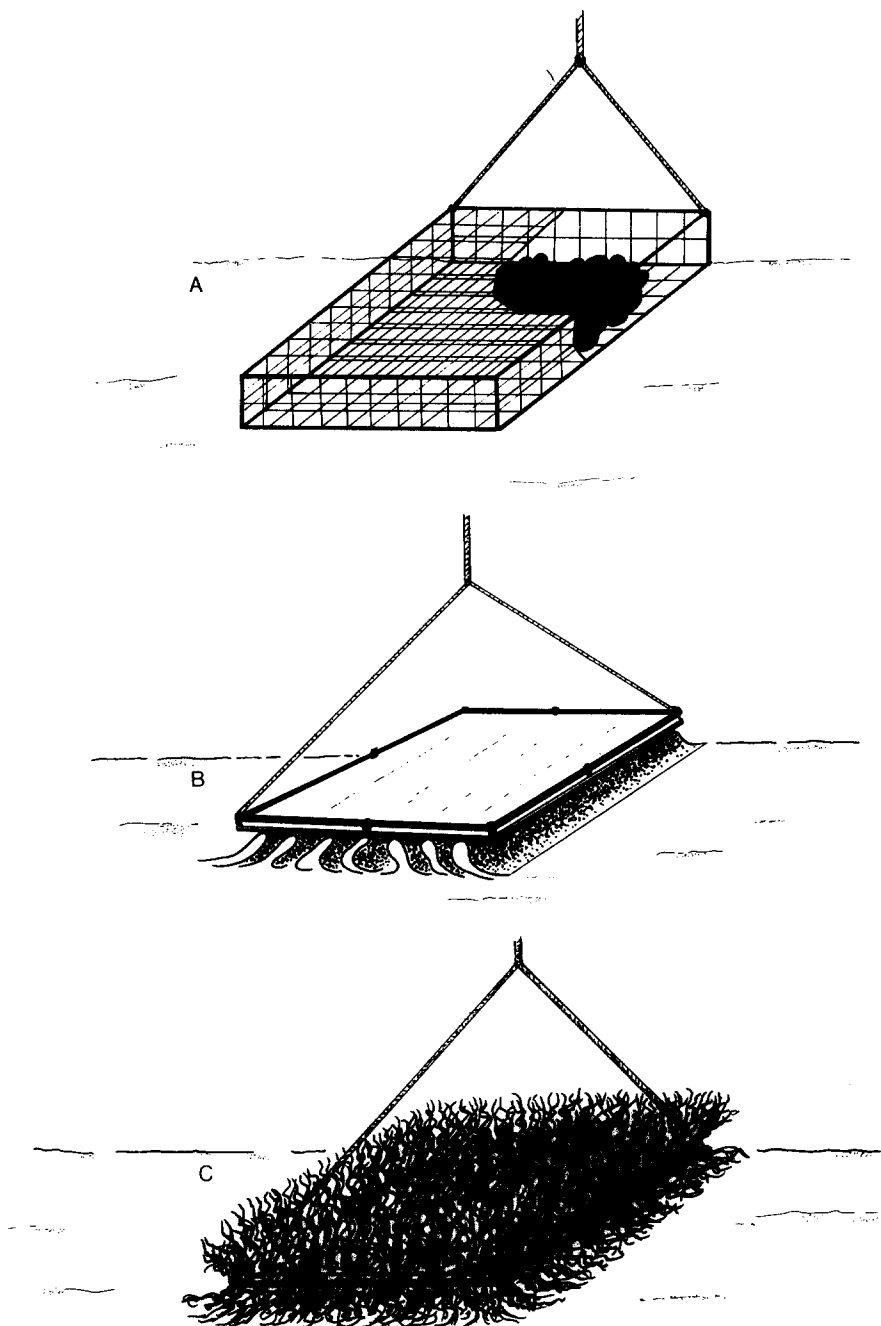


Fig. 2. Scale representation of artificial collectors. Lengths and widths = 0.61 m. Heights: (A) box, 0.15 m; (B) Witham, 0.25 m; (C) mop, 0.35 m.

Growth

As evidenced by the size-range of crabs found in the collectors compared to the number of soak-days (3–10), many crabs recruited to the collectors following the initial settlement peaks were exogenously-metamorphosed individuals from undeterminable substrate types. Most of the growth thus occurred outside of the collectors and was therefore assumed to be independent of collector type, location or substrate. Data from all collectors were thus pooled for growth study. Juveniles were defined as post-megalopa crabs ≤ 60 mm CW.

Size-frequency histograms were constructed for each of the 4 months of the sampling period, in order to follow the size progression of any eventual modes. In addition, an interactive computer programme, POLYMODE (MacDonald and Pitcher, 1979), was used to discriminate component normal distributions in a size-frequency histogram constructed for all juveniles less than 6 mm CW.

RESULTS

Larval densities and dominant stages

The mean daily larval densities and dominant larval stages ($> 60\%$ of all *C. irroratus* larvae) of the May–September sampling period are shown in Fig. 3 (a detailed breakdown of larval stage densities may be found in Chiasson, 1984). Zoea larvae first appeared in early June, with a small peak in mid-June and a large peak on 23 July (Fig. 3). A large, predominantly megalopa peak occurred on 4 August, and small peaks were again observed on 20 August (zoea and megalopa) and 1 September (zoea).

CPUE of recruits (sand-rock substrate)

Although juvenile crabs (≤ 60 mm CW) were present in the collectors before the July megalopa peak, these were assumed to be late-metamorphosed animals of the previous year which had grown little over the winter. Indeed, such individuals were observed as early as 26 May, whereas the first zoea larvae had not yet appeared. The CPUE of recruits shown in Fig. 3 represent those recruits which were present in the collectors following the first megalopa peak on 23 July.

The first young of the year appeared in the Witham collector on 29 July, 7 days after the first megalopa peak. The next sampling (11 August) showed juveniles present in all collectors, with the maximum CPUE of the entire sampling period being observed in the mop-type collector. Smaller CPUE values were recorded for all three collector types in late August and mid-September.

Numerous other organisms were also found in the collectors, including (in decreasing order of abundance): amphipods, echinoderms, polychaetes, small

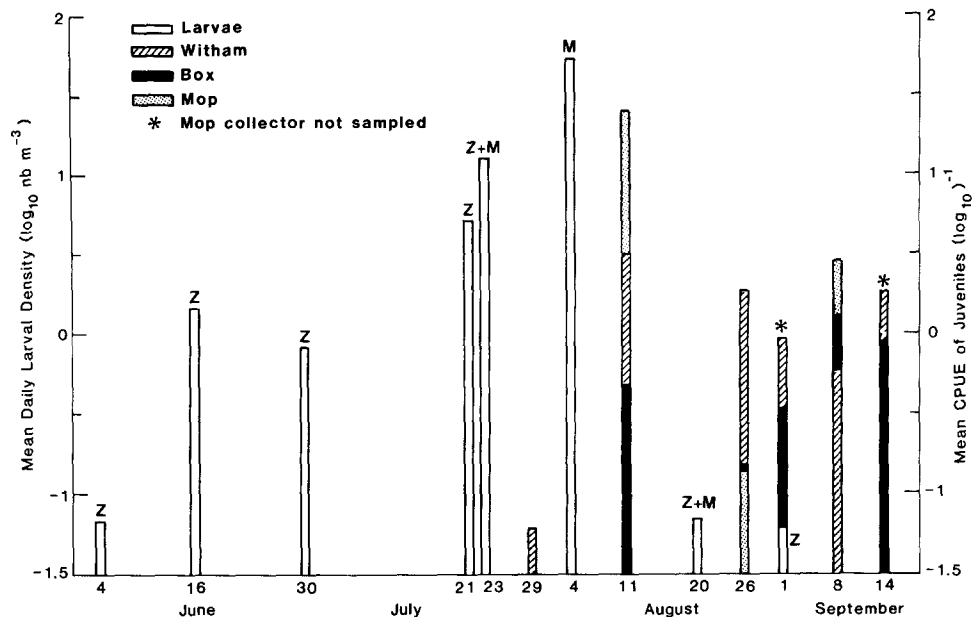


Fig. 3. Mean daily larval densities and mean CPUE of juveniles. Z=zoael stage dominant (60% of all crab larvae); M=megalopa stage dominant.

teleosts, hermit crabs, bivalves, isopods and shrimp. Five American lobsters (19.0–72.7 mm carapace length) were recovered from the mop collector, six from the Witham collector, and none from the box collector. No newly-settled lobsters were observed in any of the collectors.

Relative collector efficiencies

No significant difference was found in the mean CPUE values of the three collector types tested on the sand-rock substrate ($P > 0.05$). However, this could be a result of the under-representation of the mop-type collector due to clogging and loss in storms, as mentioned previously. In fact, the two largest mean CPUE were recorded for mop-type collectors (54 on mud substrate, 26 on sand-rock); all other CPUE were less than 4. A plot of the CPUE values of the individual collectors (Fig. 4) reveals a clear gradation of collector efficiency immediately following the large megalopa peak of 4 August, with the mop-type collector at 25.5, followed by the Witham collector at 3.5 and 1.9, and finally the box-type collector at 0.9 recruits per soak-day. The CPUE values were low, with no clear pattern for the remainder of the sampling period.

Growth

The total of 2008 *C. irroratus* captured by the collectors had a size-range of 2.1–118.2 mm CW ($\bar{x} = 9.2$ mm, $s = 11.6$ mm). The monthly growth of juveniles

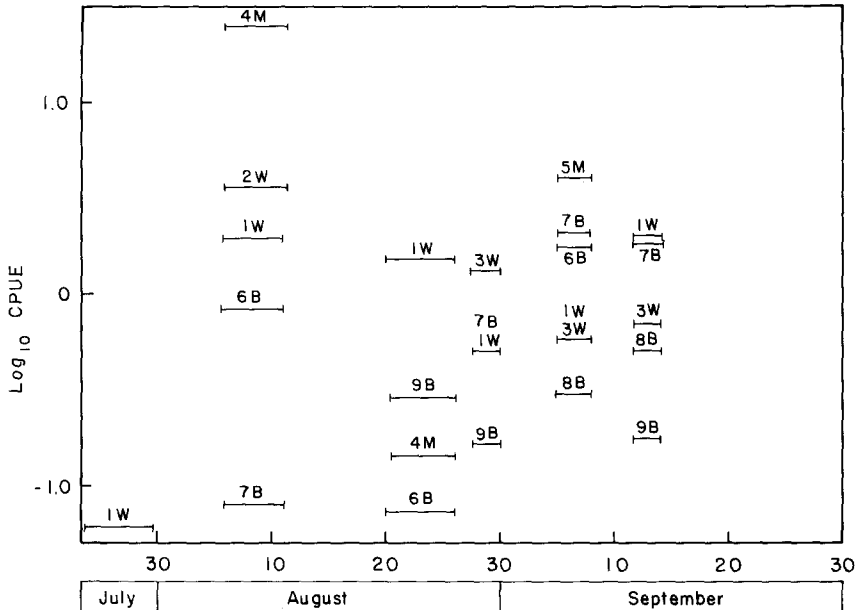


Fig. 4. CPUE and total effort (number of soak-days) for individual collectors. Codes are collector identification numbers followed by abbreviations for collector type: B, box; W, Witham; M, mop.

(all collectors combined) is shown in Fig. 5. In the first month (26 May–22 June), a bimodal distribution indicated the presence of 10–25-mm CW crabs. This distribution progressed in the following month, with the bulk being of the size-range 15–28 mm CW. In the third month (22 July–19 August), the distribution progressed somewhat further, and was reduced in proportion to a new distribution of crabs ≤ 10 mm CW. This peak represented the recruits of the year, and in the following month it appeared quite clearly, with a well-defined distribution of crabs ≤ 14 mm CW. The previous distribution was residual at this point.

A smaller-scale size–frequency histogram for crabs ≤ 6 mm CW is shown in Fig. 6. The component normal distributions are also shown in this figure (as calculated using the POLYMODE program), allowing the corresponding instar stages I–IV to be identified in Fig. 6 (as deduced from data by Krouse, 1976).

A total of 26 *C. irroratus* exuviae were observed in the collectors over the 4-month sampling period. Most of these were recovered in the weeks preceding the megalopa and young-of-the-year peaks, probably representing molts from juveniles of the previous year (14–58 mm CW of exuviae). However, six small exuviae (2.5–5.6 mm CW) were observed on 11 August, which also corresponded to the first major settlement peak (Fig. 3).

DISCUSSION

The present field studies demonstrated that all three types of larval collector tested were able to intercept settling *C. irroratus* larvae as well as attract larger

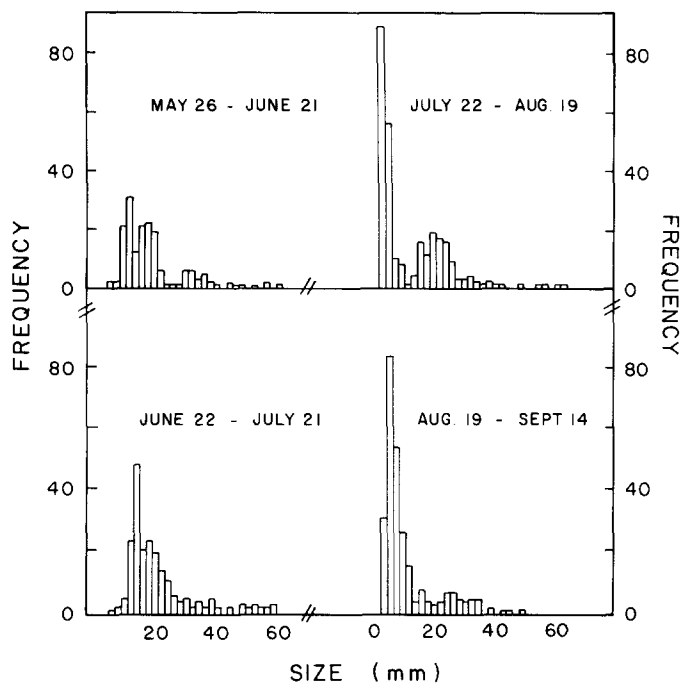


Fig. 5. Mean monthly size-frequency distributions for *C. irroratus* juveniles found in collectors (all collectors combined).

crabs already on the bottom. Subsequently, crabs were able to live and molt on the collectors, as evidenced from cast exuviae. Actual CPUE patterns, reflecting the rate of larval recruitment to the benthos, were highly variable both between individual collectors on any given sampling occasion and for given collectors over time. The maximum CPUE on sand-rock substrate occurred on a mop collector in early August (25.5 crabs/day), with a clear gradation of collector efficiency from Witham- to box-types in the same sampling period. In later sampling, CPUE values demonstrated no statistically significant superiority of any collector type. However, given the patchy nature of larval distribution, small sample sizes and the probable passive action of the collectors, the lack of a clear relationship is not surprising. Overall, the mop collector was judged to be the most successful in capturing *C. irroratus*. However, the mop has the disadvantage of becoming clogged and ineffective on mud; future investigators should consider using mop collectors tethered off the bottom to reduce both clogging and colonization by larger post-settlement crabs and lobsters.

The exact behavioral basis of settlement on the collectors is unknown. Nevertheless, it is likely that collector action is passive, with late-stage larvae periodically sampling the bottom and establishing themselves when the essential features for settlement, such as are provided by a collector, are located.

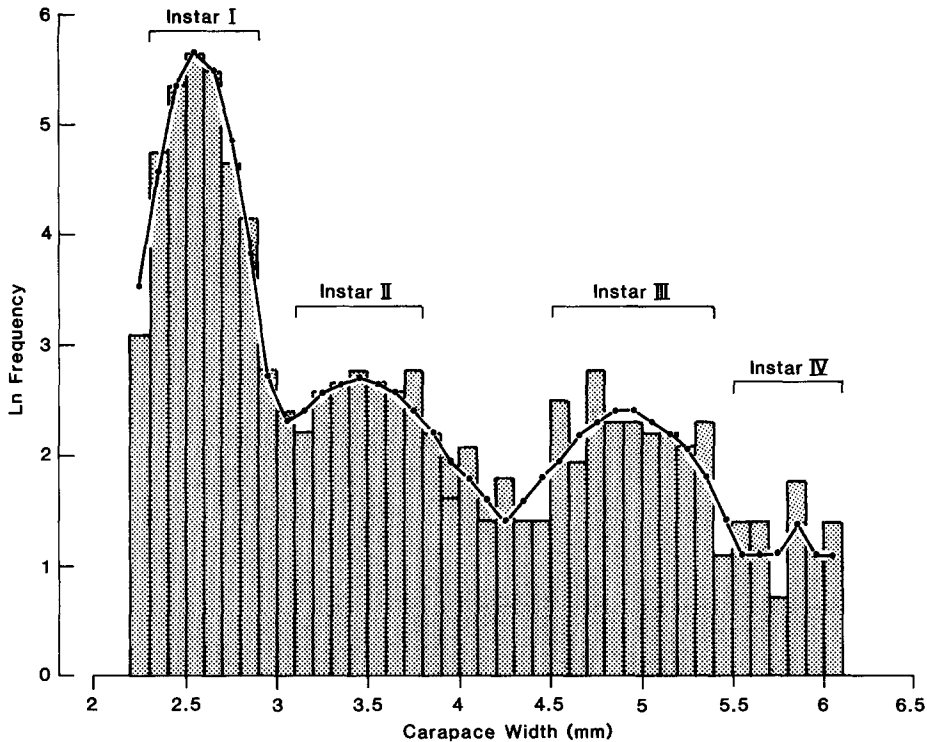


Fig. 6. Size-frequency histogram of all *C. irroratus* ≤ 6 mm CW found in the collectors over the 4-month study period, with component normal distributions as calculated by the POLYMODE programme. Instar stages are indicated as deduced from data by Krouse (1976).

The capacity of all collector types on all of the substrates to harbor *C. irroratus* suggests the larvae and young juveniles are not specific in their choice of bottom type. In contrast, large numbers of American lobster larvae would have been settling out of the water column in the same area and over the same time-period as *C. irroratus* (Scarratt, 1973) and yet none were captured in the collectors. It would seem, therefore, that *H. americanus* larvae have more highly specific substrate preferences or markedly different settlement behavior compared to *C. irroratus*. Eleven *H. americanus* discovered on the mop ($n=5$) and Witham ($n=6$) collectors were considerably above early-settlement sizes, and had presumably simply taken shelter in the structures.

The fact that no megalopas were found in the collectors indicates that larval to juvenile metamorphosis takes place rapidly after settlement. Inspection of monthly size-frequency histograms shows well-defined modes. The first major modal group, apparent between the end of May and mid-August, probably represents individuals which had settled to the benthos during the preceding year and subsequently moved onto the collectors. Young-of-the-year crabs first appeared in August. This seasonal appearance agrees with observations on the

advent of megalopas in the plankton samples in late June–early August, and also the culture work by Sastry and McCarthy (1973) which indicates that the megalopa stage lasts 14–30 days at 15°C. Krouse (1976) found that young-of-the-year initially appeared during September 1972 and late August 1973 and 1974 in the intertidal zone of East Boothbay, Maine, U.S.A. The histograms (Fig. 5) show a gradual progression in size for each of the modal groupings through the sampling period.

Polymodal analysis of the accumulated size–frequency histogram allowed calculation of actual growth-increments of early juvenile stage (≤ 6 mm CW, Fig. 6). The mean carapace widths of the first four instars were: I, 2.6 mm; II, 3.5 mm; III, 4.9 mm; IV, 5.9 mm. Instar sizes computed by this procedure are similar to actual carapace width measurements on cultured post-larval crabs of known instar stage given by Krouse (1976): I, 2.6 mm; II, 3.7 mm; III, 4.6 mm; IV, 5.9 mm. However, actual growth increment (20.4–40%) for post-larval crab instars II–IV from the collectors were generally less than those given by Krouse (1976) for the cultured crabs (28.3–42.3%) and for intertidally-collected wild crabs (35.3–46.6%). Such differences may be related to available diet, as metamorphosed juveniles in some or all collector types may have been restricted to feeding on a few species of fouling organisms low in biomass. Similarly, substrate-related influences cannot be ruled out.

The date of first appearance of *C. irroratus* larvae in Kouchibouguac Bay (4 June) is in fair agreement with the mid-June date determined by Scarratt and Lowe (1972) from plankton tows in the same area. Larval densities varied greatly among stations on the same sampling date. Such patchiness, which characterizes many pelagic larvae, may be explained by both active and passive mechanisms (see Harding et al., 1982, and Cobb et al., 1983, for general discussion of the phenomenon). The peak zoeal density of 43.3 larvae m^{-3} for *C. irroratus* in Kouchibouguac Bay is comparable to maximum abundances of approximately 60 larvae m^{-3} found by Dittel and Epifanio (1982) and Brookins and Epifanio (1985) off Delaware. Surface swarming of megalopas, with densities of 250.1 larvae m^{-3} , in Kouchibouguac Bay in early August was hitherto unreported for this species.

Although the larval sampling schedule was not directed at lunar phases, it is noteworthy that the dominant megalopa peak of 4 August was observed following the new moon of 31 July. Similarly, post-larval settlement for the spiny lobster, *Panulirus argus*, occurs monthly during the new moon–first quarter period (Marx and Herrnkind, 1985).

Data in Scarratt and Lowe (1972) on the numbers of *C. irroratus* larvae caught in standardized plankton tows in Kouchibouguac Bay indicate that mean density in 1962 was approximately 2 larvae m^{-3} , with a maximum mean weekly value of 5.1 larvae m^{-3} ; densities in 1963 were approximately 11 times less than in 1962. Peak periods of larval abundance appeared to be in August and September for both 1962 and 1963, somewhat later than determined in the

present study. Given that the collectors are probably functioning in a non-random manner, future collector deployment programs could provide longer time-series of data to help elucidate the year-to-year variations in settlement strength suggested by comparison of the 1962, 1963 and 1981 larval data sets. With such data and an understanding of growth, settlement behavior and mortality factors, it may ultimately be possible to relate collector CPUE to the subsequent abundance of adult *C. irroratus*; a forecasting capability could thus be developed as has been done for western rock lobsters (Morgan et al., 1982).

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