AGARUM KELP BEDS AS NURSERY HABITAT OF SPOT PRAWNS, *PANDALUS PLATYCEROS* BRANDT, 1851 (DECAPODA, CARIDEA)

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ABSTRACT

The spot prawn, *Pandalus platyceros* Brandt, 1851, predominantly uses kelp beds of *Agarum* sp. as nursery habitat in waters of southern British Columbia. Census data indicate interannual fluctuations in numbers of shrimp settling into nurseries. Analysis of size samples indicates settlement primarily in May and June, with lesser rates of settlement through the summer. Growth of about 3 mm CL per month can occur through summer and fall, with juveniles apparently emigrating from nurseries, starting in the fall, at sizes of 16-20 mm CL. Juveniles which fail to reach such size before winter remain in the nursery habitat, with slower overall growth at about 1 mm CL per month. This difference in duration of residence in kelp bed nursery habitat, together with different juvenile growth rates, leads to the conclusion that the age of spot prawns at a given size will be variable. Due to this variable early life history and growth, length frequency modes of spot prawns could include a mixed age group.

ZUSAMMENFASSUNG

Die Tupfengarnele, *Pandalus platyceros* Brandt, 1851, verbringt ihre erste Lebenszeit vorwiegend in den Kelpfeldern (*Agarum* sp.) vor Britisch-Kolumbiens Südküste. Bestandserhebungen zeigen, daß die Zahl der Garnelen, die in den Kelpfeldern eintreffen, im Laufe des Jahres schwankt. Größenanalysen lassen erkenen, daß der Hauptzuzug in den monaten Mai und Juni erfolgt mit geringeren Zuzugsraten während des Sommers. Im Sommer und Herbst kann die Carapaxlänge um 3 mm pro Monat zunehmen. Offenbar verlassen im Herbst jene Jungtiere ihre Kinderstube, die eine Carapaxlänge von 16-20 mm erreicht haben, während jene, die dies nicht geschafft haben, vor Ort überwintern. In dieser Zeit verlangsamt sich ihr Wachstum und ihre Carapaxlänge nimmt nur um 1 mm pro Monat zu. Diese Unterschiede in der Wachstumsgeschwindigkeit während des Aufenthaltes in der Kinderstube führen zu dem Schluß, daß Tupfengarnelen der gleichen Größe nicht gleichalt sein und folglich sich auch nicht gleich lange in den Kelpfeldern aufgehalten haben müssen.

INTRODUCTION

The range of the spot prawn, *Pandalus platyceros* Brandt, 1851, extends from the Aleutian Islands to San Diego, California (Butler, 1980). Butler (1964) provided the most complete information on life history of the spot prawn, but his data do not include any juveniles smaller than 10 mm carapace length (CL). Barr (1973) reported the smallest benthic juveniles in southeastern Alaska to be 3-4 mm CL. Barr's animals were found on hard-bottom, nearshore areas, under *Laminaria* or *Agarum* kelp fronds or in rock crevices by day, coming out to forage at night. It has been unknown whether juveniles have uniform growth rates or uniform recruitment age. The present study provides data on relative abundance (over a period of seven years) and size (over three years) of juvenile spot prawns in *Agarum* beds at three locations in Howe Sound, southern British Columbia.

For Alaska, juveniles in shallow water (< 13 m depth, within the depth range of kelp beds) averaged 15 mm CL in spring (Barr, 1971). For British Columbia (Strait of Georgia) juveniles, taken by trawl in deeper water than Barr's juveniles (20-70 m depth, below the depth of occurrence of kelp) averaged 21 mm CL, also during spring (Butler, 1964). The results of the Alaska study indicate relatively slow growth in shallow nursery areas, whereas results of the British Columbia study indicate more rapid early growth by juveniles which have recruited to the adult population during their first year. It has not been demonstrated, however, whether all juveniles in British Columbia recruit to the adult population before overwintering. Furthermore, it is not known whether larger juveniles leave shallow water during their first year at Barr's Alaska site. Prior to the present study, no evidence has been found to corroborate a kelp bed nursery habitat for juvenile spot prawns in British Columbia.

This report includes the first time-series of data on newly settled juveniles in British Columbia, through their first year of life, until they leave shallow nursery habitat and recruit to the deeper, adult populations. Census data are presented on densities of juveniles at different sites within a given year, and from year-to-year. Data from trapping are presented on juvenile sizes and habitat preferences.

METHODS

Three study sites were selected to represent the geographic extent of rocky kelp reefs in southern Howe Sound, British Columbia (fig. 1), a region which supports a commercial fishery for spot prawns. Howe Sound adjoins the Strait of Georgia. Site A consisted of one large, discrete rock reef of about 50×30 m at 15-20 m depth, covered with *Agarum* and surrounded by deeper bottom without seaweeds. At site B, patchy *Agarum* beds were closely scattered over a large area of $\geq 10^4$ m^2 on small rocky ridges on a uniformly shallow, sandy bottom (ca. 10-15 m depth). At site C, six relatively small *Agarum* beds were distantly spaced at various depths along 1 km of shore, extending through several embayments and around a headland. Site C was in a major fjord channel with exposure to northerly outflow winds, whereas site A was exposed to prevailing SE or NW (winter versus summer) winds; site B was relatively protected from winds. All three sites experienced strong tidal currents. These sites encompassed a diverse range of hydrographic conditions and reef types which support *Agarum* beds in the study area.

Preliminary 20 min census dives were conducted in autumn of 1985 over different substrates at site C (fig. 1). These preliminary dives included *Agarum* beds, open sand bottom, bare rock, and *Laminaria* beds. Visual census dives provided the most reliable data on presence or abundance of prawns, but could

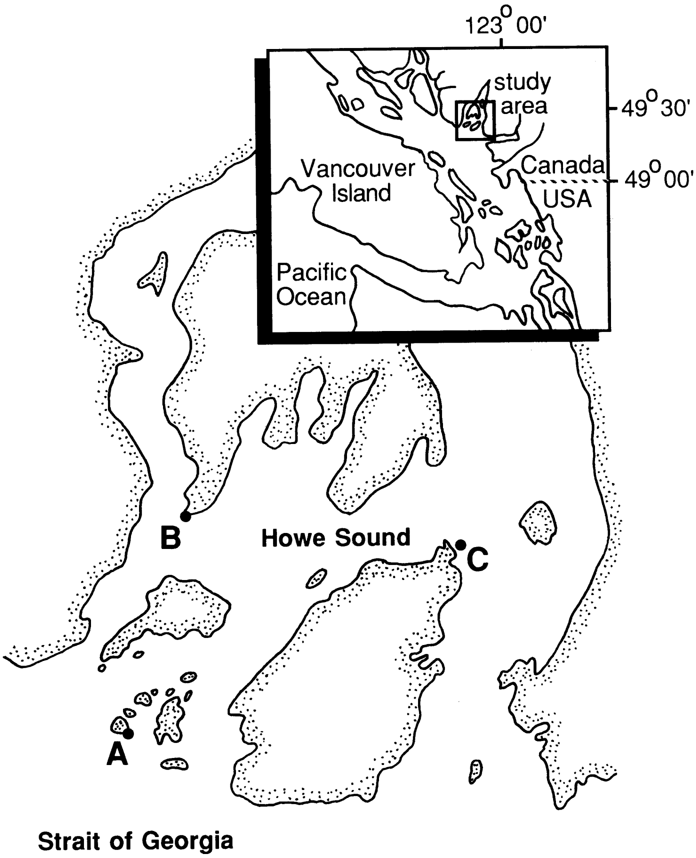

Fig. 1. Locations of study sites Howe Sound, Strait of Georgia, British Columbia: site A (SE Popham Island, 49°21′N 123°29′W), site B (Grace Islets, 49°26′N 123°27′W), and site C (Cates Bay, Bowen Island, 49°25′N 123°18′W).

not yield size data. Trapping was conducted to yield size data and information on foraging range in relation to kelp bed position. Trapping effort was supplemented with hand-netting of prawns to ensure that the smallest sizes would be included in sampling.

From 1986 to 1992, census dives were conducted each year, from June through December, in *Agarum* beds at sites A, B, and C (fig. 1). June is just after the season of peak larval settlement in southern British Columbia (unpublished data; Butler, 1964, 1980). Visual censusing of juvenile spot prawns under *Agarum* fronds was conducted in daylight by SCUBA divers. During a 20 min interval, a diver would slowly lift each *Agarum* frond and remain still while counting the juvenile prawns under the frond. To avoid double-counting of individuals, the diver would swim over adjacent fronds before resuming counting if escape responses had occurred.

To obtain size data on prawns, trapping was conducted with cone traps (Boutillier, 1985) in 1987 and 1988 at site A; there was also limited trapping effort at site B in 1988. Size data were also obtained by hand-netting prawns at all three sites. Hand-netting proved more practicable than trapping for all sites.

Mesh size of traps was 3 mm opening diameter. Trapping along a transect from inside to outside the kelp bed involved divers setting three traps: one 10 m inside the *Agarum* bed, one immediately inside the edge of the bed, and one 10 m outside the bed (18 replicates). To more closely define habitat fidelity, these transects were repeated at site A (3 replicates) with the traps 3 m apart. Traps were baited with punctured cans of sardines and were fished for 24-48 h.

Small juvenile prawns were hand-netted by scuba divers from 1987-1989. The hand-nets, designed for sweeping on the bedrock under kelp fronds, were 2 mm mesh, the bag 85 cm long, and the net mouth 15 × 45 cm with a 45 cm handle attached to the narrow end. Loose *Agarum* was put in the end of the net bag as cover for prawns. A kelp frond was slowly lifted, the prawns swept into the net, and its mouth rapidly raised and twirled to prevent escape.

Prawns were preserved in 10% buffered formalin. Carapace lengths (CL) were measured to 0.05 mm with vernier calipers, from the posterior left orbit to posterior dorsal carapace margin. Sizes of trapped versus hand-netted prawns were only considered comparable for data where samples were obtained simultaneously or within three days at the same time (see table II). Values of CL for netted and trapped prawns were compared by ANOVA, using Scheffe's F-test with S = .05. For the text figures, trap and net samples were lumped together.

RESULTS

Visual counts indicated that juvenile spot prawns in Howe Sound occurred under *Agarum fimbriatum* Harvey and *Agarum cribrosum* Bory in summer and fall. During six preliminary census dives (1985), juvenile spot prawns were not seen outside *Agarum* beds, including beds of *Laminaria saccharina* (L.) Lamouroux, the other dominant kelp, which occurred shallower than *Agarum*. During February and March (1988), juveniles were discovered under cobble adjacent to a storm-depleted *Agarum* bed at site A. Also, prawns occurred on open sand patches within an area of extensive *Agarum* patches at site B.

Average counts are summarized in table I. At each site, the highest average counts, from 1986 to 1992, occurred in 1987. For site C, counts from 1985 were higher than in any other year; comparable data are not available for the other sites. Within each year from 1986 to 1991, except 1990, the highest average counts were obtained at site B. In 1990, however, low counts for sites A and B were possibly indicative of a year-class failure in the vicinity of these sites. In 1991, settlement of juveniles was again normal at sites A and B. Low juvenile settlement at site C in 1991 was apparently related to extensive depletion of the kelp at this site by northerly storms during the preceding winter; sites A and B are protected from such storms. Low overall abundance occurred in 1992.

TABLE I

Average visual census count of *Pandalus platyceros* Brandt larvae for different sites and years (n = number of 20 min counts)

Year	n	Site A Avg. ± S.D.	n	Site B Avg. ± S.D.	n	Site C Avg. ± S.D.
1985					16	52.4 ± 86.5
1986	36	37.6 ± 38.6	4	71.8 ± 29.2	8	15.1 ± 11.6
1987	28	150.1 ± 60.8	2	284.0 ± 40.9	14	31.4 ± 70.6
1988	18	21.8 ± 32.5	6	42.0 ± 23.0	15	20.1 ± 22.1
1989	24	12.4 ± 17.6	12	58.4 ± 26.0	18	19.0 ± 47.6
1990	6	0.8 ± 1.4	10	0	14	20.8 ± 34.8
1991	8	39.0 ± 22.0	16	56.0 ± 56.8	12	3.5 ± 6.9
1992	6	19.7 ± 3.4	10	12.8 ± 13.3	12	5.1 ± 5.4

The smallest juveniles trapped at site A were 3-4 mm CL in June of 1987 (fig. 2). Prawn larvae caught in plankton tows immediately over *Agarum* beds at site C in May of 1987 averaged 3.2 ± 0.6 mm CL (unpublished data). Settlement continued at site A through June, after which no individuals less than 5 mm CL were found. Six prawns 18-22 mm CL in July and August 1987 are presumed to have been 1-year age, overwintered in the nursery habitat. From January through May 1988, 128 yearling prawns from 10-21 mm CL were captured in the nursery habitat. Catches of yearling prawns, 12-21 mm CL, in June and July of 1988 were accompanied by only two underyearlings (5 and 8 mm CL). By September 1988, however, settlement had occurred at site A, with subsequent growth of underyearlings through fall of 1988. A marked settlement of underyearlings was evident in June of 1989.

Collections of prawns at sites B and C were less regular than at site A, but similar trends may be discerned in figs. 3 and 4. Settlement in early 1987 at site B was followed by growth of juveniles through that year (fig. 3), then yearlings predominated at this site from April through July of 1988. As at site A, underyearlings appeared to have settled late in 1988 at site B. The mean size of 9.5 ± 2.4 mm CL in August 1988 at site C (fig. 4) was lower than that (15.9 ± 4.1) at site B in July 1988 (fig. 3). The August 1988 size at site C was similar, however, to those for September 1988 at sites A (10.1 ± 2.7) and B (10.9 ± 1.7) (figs. 2-3). The larger size in July 1988 at site B was due to the presence of large individuals, presumably overwintered yearlings, which may have emigrated by September.

Analysis of trapping data for site A reveals that juvenile prawns were captured almost exclusively within the *Agarum* bed there. In the 18 sets with traps at 10 m intervals, catches averaged 50.1 ± 46.5 (mean ± S.D.) inside the bed versus 4.9 ± 6.3 at the edge. None were caught outside the bed. Higher catch rates were achieved at the edge of the bed with traps set at 3 m intervals. In the

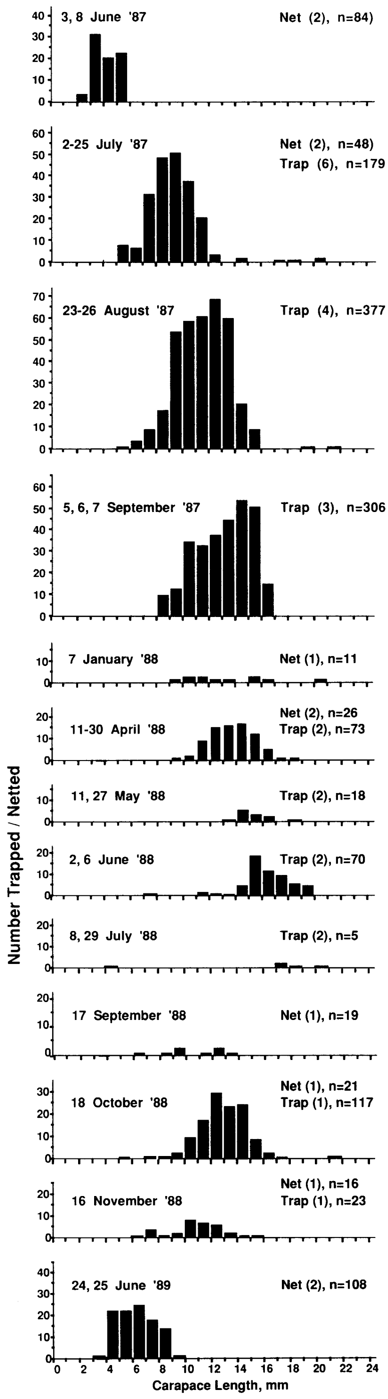

Fig. 2. Carapace lengths (CL, mm) of juvenile *Pandalus platyceros* Brandt, 1851 caught in the *Agarum* nursery at site A during 1987, 1988, and 1989. Each graph is labelled according to whether data are for hand-netted or trapped shrimp, or both, along with numbers of samples and sample sizes.

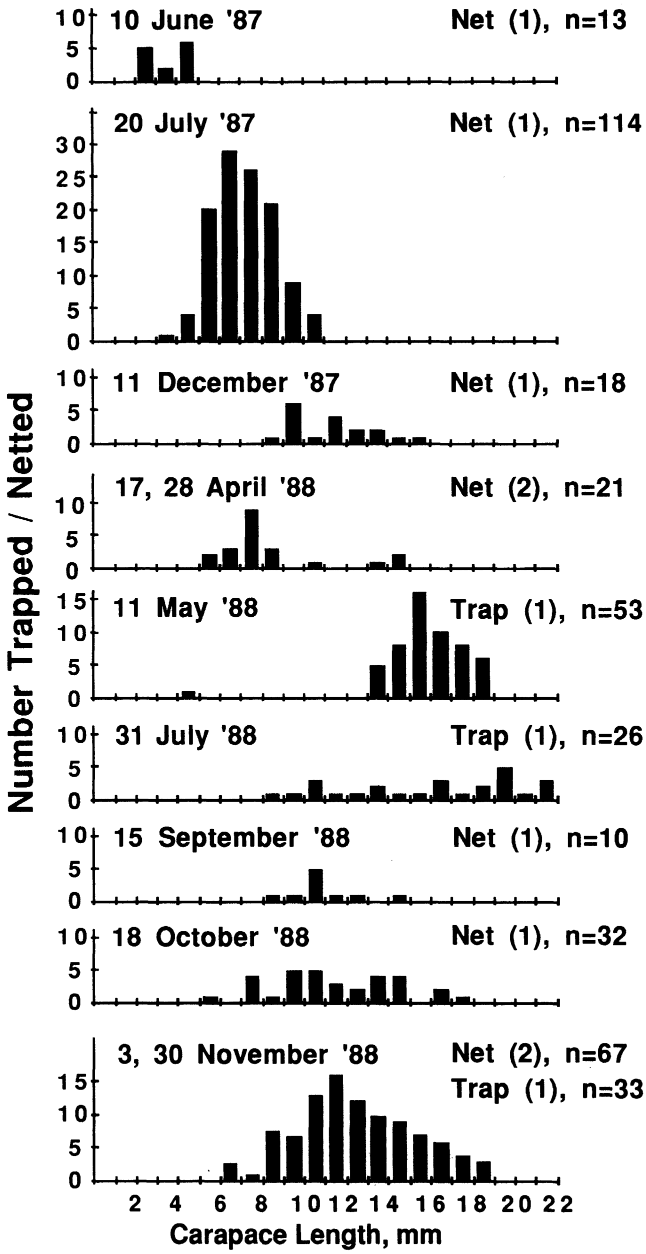

Fig. 3. Carapace lengths (CL, mm) of juvenile *Pandalus platyceros* Brandt, 1851 caught in the *Agarum* nursery at site B during 1987 and 1988. Each graph is labelled according to whether data are for hand-netted or trapped shrimp, or both, along with numbers of samples and sample sizes.

three sets at 3 m intervals, catches averaged 62.0 ± 13.5 inside the bed versus 38.7 ± 18.9 at the edge, and 1.3 ± 0.6 outside the bed.

At site B, trapping yielded juvenile prawns both inside and outside of the kelp patches. Site B has extensive, patchy kelp beds: the long trap-line was deployed with the middle trap at the edge of a kelp patch, but all three traps were relatively close to kelp, owing to its patchy distribution. A total of 58 prawns

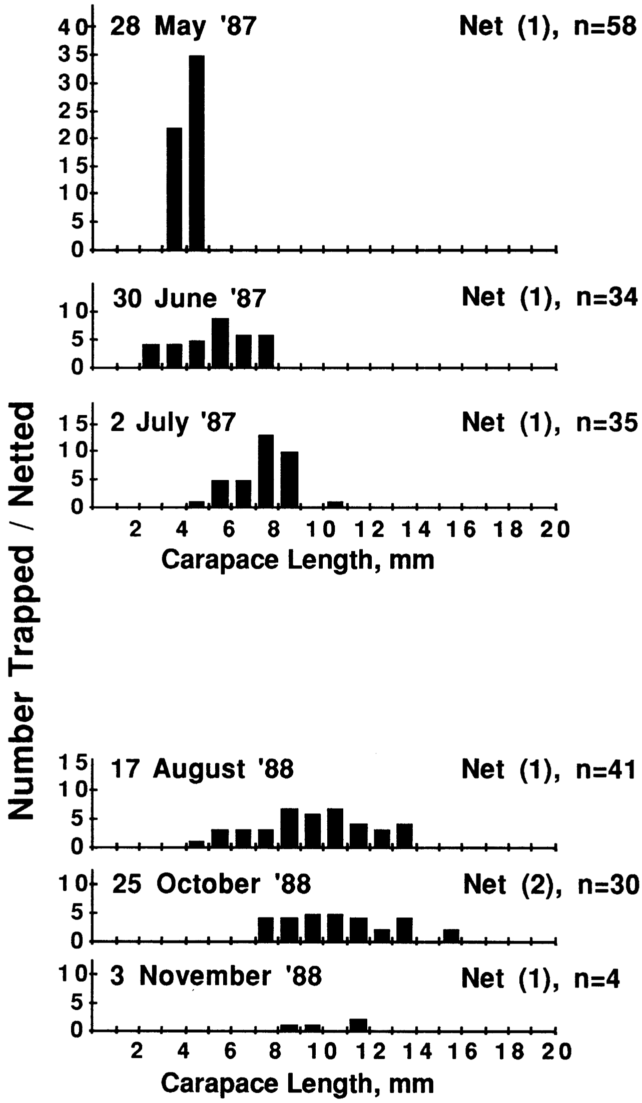

Fig. 4. Carapace lengths (CL, mm) of juvenile *Pandalus platyceros* Brandt, 1851 caught in the *Agarum* nursery at site C during 1987 and 1988. For site C, all data are for hand-netted shrimp. Graphs list numbers of samples and sample sizes.

was trapped outside the kelp patches, 6 at the edges, and 15 inside the kelp bed (averages 29, 3, and 7.5).

Size of trapped versus hand-netted prawns was compared (table II). Trapped juveniles were significantly larger than hand-netted shrimp in two out of four sets of samples.

DISCUSSION

Review of the visual census data in table I will indicate that the start of captures in 1987 coincided with a strong year-class in Howe Sound, relative to the years 1986-1992. Similar patterns of size occurrence were evident at all three sites in 1987 and 1988, with 1987 juveniles dominant in the nursery areas until mid-1988 (figs. 2-3). The evidence for late settlement in 1988 without substantial overwintering through to summer of 1989 (fig. 2), suggests overwintering may be associated with strong year-classes such as that of 1987. The proportion which grow slowly and overwinter may increase in years with high densities of juveniles in the nursery habitat.

The interannual variability in densities at nursery sites occurred consistently across the three sites from 1986 through 1989 (table I). The nearly complete disappearance of prawns from sites A and B in 1990, however, was not matched at site C and remains unexplained, whereas storm-damage to kelp apparently caused the 1991 failure at site C. The low abundance in 1992 coincided with an El Niño event, although no causal relation is documented.

Juvenile prawns which settled in May and June appear to have grown rapidly through the summer to sizes of 17 mm CL and over. By early fall, the size frequency distributions (fig. 2) became truncated at larger sizes, which is interpreted as indicating migration of underyearlings >17 mm CL to deeper water.

TABLE II

Carapace length (CL, mm) for juvenile spot prawns captured by hand-netting versus trapping. Scheffe F-test values for ANOVA

Date	Site	Method	n	Range	Mean	S.D.	F-test
11-14 Apr. 1988	A	trap (1)	61	9.0-18.4	13.8	2.0	2.2 ns
		net (2)	26	9.6-17.7	13.1	2.1	
18 Oct. 1988	A	trap (1)	117	9.9-22.6	14.1	1.9	14.5*
		net (1)	21	4.0-16.4	12.3	3.1	
16 Nov. 1988	A	trap (1)	23	6.7-13.2	10.9	1.7	0.07 ns
		net (1)	16	7.4-15.6	10.7	2.5	
30 Nov. 1988	B	trap (1)	33	6.5-17.9	13.1	2.9	6.9*
		net (1)	36	6.9-18.4	11.4	2.4	

* = S = .05, ns = not significant

The prawns which emigrated from the kelp bed nursery were of different age classes, the summer emigration consisting of yearlings and the late autumn emigration of underyearlings. The extent to which overwintering in nursery kelp beds related to slow growth in juveniles which settled in spring, as opposed to those which hatched late and settled in summer, remains unquantified.

Overwintering may involve seasonally reduced growth rates. The data in fig. 2 indicate a growth rate of about 3 mm CL per month during summer of 1987. Overwintered juveniles at site A in early June of 1988, however, averaged growth of about 1 mm CL/month.

Any one modal size group in the adult population in southern British Columbia may contain members of two year classes, those which recruited to the adult population during their first autumn and others which recruited during their second year of life. Juveniles reaching 20-22 mm CL emigrate from the nursery, regardless of season, and considerable numbers emigrate at 17-19 mm during autumn. The present data support the observation of Butler (1964) that prawns in this area leave nurseries at just over 20 mm, whereas Barr (1973) reported juveniles of up to 25 mm in nurseries in Alaska.

Butler (1964) presumes recruits of about 22 mm CL to be one year old. Barr (1971, 1973) reported juvenile spot prawns in Alaska to reach only 15 mm CL during their first year, then to recruit after a second year in the nearshore nursery. The range of possible age at a given size (fig. 5) lies between that for the maximum early growth rate indicated by Butler (1964) and that for the slowest growth rate of those prawns in the present study which remained in the nursery through their second summer. Longer residence on nursery grounds yields a growth rate comparable to that in later life (fig. 5); it thus appears that only the most rapidly growing individuals fit the early life history pattern described by Butler (1964). The 1987 year-class in Howe Sound encompassed this range of early growth rates and times of emigration from the *Agarum* nursery. Size is thus not as clear an indicator of age as separate length frequency modes in the adult population might suggest. Skúladóttir (1981) discussed the consequence of different interpretations of age-at-size in terms of sustainable fishery yields for *Pandalus borealis* Krøyer, 1838; for *P. platyceros*, the present data suggest an older average age than evident from Butler (1964) and, therefore, lower sustainable fishery yield.

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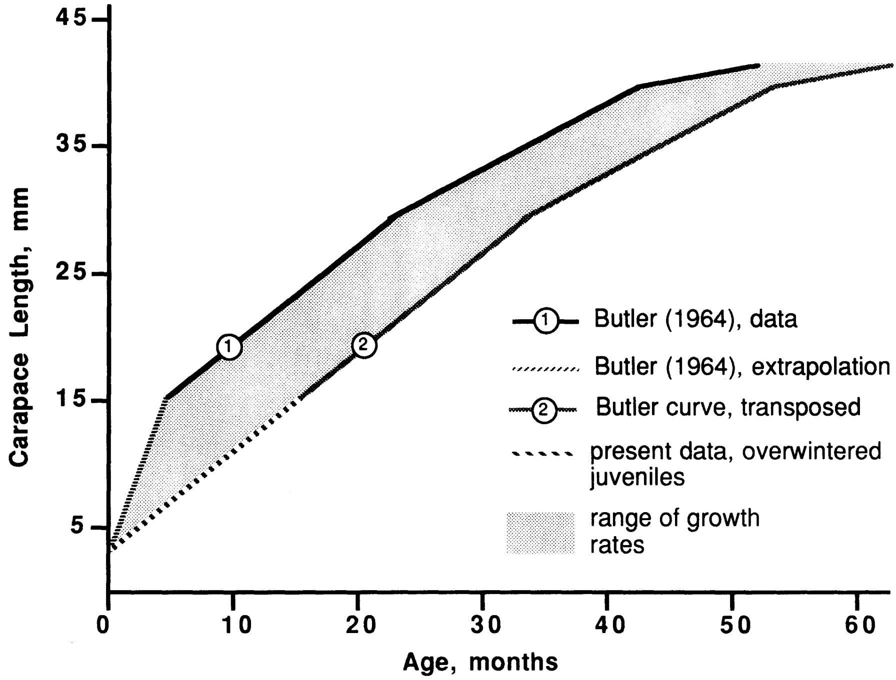

Fig. 5. Growth rate of pre-recruitment *Pandalus platyceros* Brandt, 1851 from present data together with post-recruitment growth curve from Butler (1964). The shaded area indicates the range of early growth rates, resulting in the range of possible ages at given size for adults.

REFERENCES

BARR, L., 1971. Methods of estimating the abundance of juvenile spot shrimp in a shallow nursery area. Trans. American Fish. Soc., **100**: 781-787.

——, 1973. Studies of spot shrimp, *Pandalus platyceros*, at Little Port Walter, Alaska. U.S. natn. mar. Fish. Serv. mar. Fish. Rev., **35** (3-4): 65-66.

BOUTILLIER, J.A., 1985. Important variables in the definition of effective fishing effort in the trap fishery for the British Columbia prawn *Pandalus platyceros* Brandt. Journ. Shellfish Res., **5**: 13-19.

BUTLER, T.H., 1964. Growth, reproduction, and distribution of pandalid shrimps in British Columbia. Journ. Fish. Res. Board Canada, **21**: 1403-1452.

——, 1980. Shrimps of the Pacific coast of Canada. Canadian Bull. Fish. aquat. Sci., **202**: 1-280.

SKÚLADÓTTIR, U., 1981. The deviation method. A simple method for detecting year-classes of a population of *Pandalus borealis* from length distributions. In: T. FRADY, (ed.), Proceedings of the International Pandalid Shrimp Symposium, Kodiak, Alaska, Feb. 13-15, 1979. Sea Grant Report, **81-3**: 283-306.

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