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Long-term observations on population structure and body dimensions of two grapsid crabs inhabiting a boulder-shore

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Abstract

The study site is a stony shore consisting of pebbles (1-5cm), cobbles (5-10cm) and boulders (>10cm) situated on sandy-silt, and gravelly substrate on a rocky sea shore at the western slopes of Mt. Carmel, Haifa. The study spread over a period of 16 years between 1984-1999. During this study period crabs were sampled for 29 months. The purpose of this study was to find out whether changes in the population structure or in the dimensions of the two grapsids, take place during such long period. The two most abundant crabs were the grapsids: *Pachygrapsus transversus* with 366 specimens, *P. marmoratus* with 262 specimens. A minor drop in numbers of both genders was seen in *P. transversus* during the 1990s. In *P. marmoratus* there was a noticeable increase in numbers of both genders in 1999. Only long-term observations could reveal these changes. The largest number of crabs was captured during spring (*P. transversus* males n=83, and *P. marmoratus* females n=39 respectively). The lowest number was during autumn and winter. The sex ratio varied during the study period. In *P. transversus* is mostly male-biased ranging from a low of 44% to a high of 67% males in the population. The opposite was seen in *P. marmoratus* population which is generally female-biased ranging between 50-100% females in the population. The body dimensions of both grapsid species varied over the years.
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Keywords: *Pachgrapsus*, Decapoda, Population ecology, Sex ratio, Carapace dimensions, Long-term study

Introduction

The stony (or rocky) beaches are unique in that they are ideal in sheltering many crab species. Thus, more crab species occur in the mid-littoral area of stony beaches (1, 14). Abele (1) found the highest number of decapod species in the rocky intertidal zone (78 species). Similar findings are reported by Beck (3) who found that the habitat structural complexity and the availability and size of refuges regulate to some extent the population size. The structure of the crab assemblage studied here was previously described (37).

The major factors determining the distribution of nine grapsid species were the presence of a suitable substrate, type of cover, salinity range and wave action (14). Thus, grapsids were found to shelter mainly in rocky crevices (9). Willason (39) found that physical factors such as salinity and siltation restrict settlement and survivorship in grapsids. *Pachgrapsus* spp. are the most common brachyuran crab species living in the marine rocky intertidal. Apparently they prefer to inhabit rocky shores between low and high-tide marks, between littoral and terrestrial areas (19). Flores and Paula (11) found that *P. marmoratus* was the most abundant species. Jones (21) suggested that *P. crassipes* progressed from a purely marine habitat towards a terrestrial existence by adjusting to conditions there. It occupies a higher position in the littoral zone than most crabs (19). It lowers its activity during low tides (2) but is capable of high speeds (3 m/hr) on ground (19). The littoral grapsid crab *P. transversus* has a wide distribution from the eastern Pacific to the Mediterranean (7). It actively moves between land and water (4). There is a correlation between resistance to desiccation and intertidal level (23). The grapsids have terrestrial habits and aerial respiration (26). *Pachygrapsus* crabs are found on land at low tide or in hypersaline lagoons. They are extremely well adapted to life in the upper intertidal zone of the rocky shores. Their main adaptations are their speed in moving on land, their ability to breathe air, and their omnivorous and opportunistic feeding. They are capable of regulating osmotic pressure under both hyper- and hypo-osmotic conditions and against increasing salt concentrations as found in lagoons. Thus, they survive in concentrated (185%) sea water thereby enabling survival in hypersaline lagoons, and in dilute seas water (50%), sustaining these osmotic gradients (15,17,18). These crabs can gain ions from hypertonic medium (16). The two *Pachygrapsus* species studied, were

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shown to be well adapted to the extreme variations in their internal osmolarity resulting from their aquatic-terrestrial life (38). The haemolymph osmolality of both *Pachygrapsus* crabs changed seasonally. Crabs were hypo-osmotic at salinities of 125-200% sea water. Dehydration caused a rise in haemolymph osmolality especially in *P. transversus* (38). In addition *Pahygrapsus* crabs are remarkable in their ability to withstand desiccation and can survive desiccation of up to 7% body weight (17) or up to 12-14% water loss (34). Apparently the behavioral selection of shelter appears to outweigh physiological costs associated with osmoregulation (27). Likewise, low winter temperatures reduced the number of brachyuran species (25). When this research project was undertaken, there was a threat of major development for tourists on the sea-shore area west of the city of Haifa, which continued for several years (1984-1999). With the accumulation of data it became apparent that indeed a change in the fauna takes place (37), and at least one species, *Xantho poressa*, appears to be already declining.

The main objective of this study was to follow any long-term changes in a population of grapsid crabs inhabiting a single pebble shore. By following both population structure, dynamics, changes in sex ratio as well as changes in body dimensions (indicative of population aging) over several years it was hoped that valuable data would be collected which can not otherwise be evaluated in studies conducted over shorter time periods.

Methods

The study area was a stony shore consisting of pebbles (1-5cm), cobbles (5-10cm) and boulders (>10 cm) situated on a sandy-silt, and gravelly substrate at the western slopes of Mt. Carmel in a small, shallow bay, partly protected from the south by a wall constructed by the Israel Oceanographic Institute, Shiqmona, and from the north-west by a rocky shelf. The study was conducted during 29 months over a period of 16 years between 1984-1999 all in exactly the same site. Temperature ranged between 16-28^{0}C during the study periods, and the tidal range was up to 25cm. During this study, 44 collecting trips took place in which the entire population of crabs in this site was sampled.

Species (ref #)	**Sampling**		**Duration Years (Months)**
Goniopsis cruentata (6)	monthly	C	(14)
Pachygrapsus crassipes (20)	monthly	3	
P. marmoratus (11)	monthly	N 1	
P. marmoratus (current study)		**N**	**(21)**
P. transversus (current study)		**N**	**(21)**
P. transversus (9)	monthly	C 1	
Aratus pisonii (8)	monthly	C 2	
Hemigrapsus edwardsi (31)	monthly	C	(15)
H. penicillatus (12)	monthly	N	(15)
H. penicillatus (13)	bimonthly	C	(13)
H. penicillatus (32)	fortnightly	C	(17)
Sesarma pictum (32)	fortnightly	C	(17)
Helice crassa (29)	monthly	C	(13)
H. crassa (22)	monthly	C	(21)
H. japonica (30)	monthly	C 1	
Plagusia dentipes (36)	monthly	C 1	

C– consecutive years; N – not in sequence

Table 1 - Frequency of sampling and duration of measuring dimensions in some grapsids previously reported in literature.

The study site 20 x 20m was exposed only at low tide. Two observers worked their way each from opposite corners, turning over all cobbles and boulders and hand-collecting any crabs found underneath. The same sampling technique was used throughout this long -term study. During low- tide many crabs remained under boulders, cobbles, or pebbles situated on the sandy, gravelly substrate. Small cobbles are known to move more frequently with the tide than larger ones (13). During diurnal low tide periods most small and medium sized crabs selected cobbles as refuge from predation (28,33). When overturning boulders, the mobile crab species respond to overturning by moving onto the other side of the boulder or away from it into the surrounding area (5). Usually sampling was carried out at intervals over one month thus not affecting sampling method (5).

The crabs were then taken to the laboratory (a 20 min ride) and each housed individually in a finger bowl containing sea water under seasonal ambient temperature and light conditions. They were then released within 1-2 days into a similar area adjacent to the study site. Handling of the crabs was minimal: during capture, and during measurements. No crab died during this long research period.

The crabs were sexed, registered, and measured. Maximum carapace width (CW) and length (CL) were measured to the nearest 0.05mm with a Vernier Caliper, and mass (±0.01mg) with a Mettler electronic balance. The temporal changes in population and sex ratio of the four more abundant crab species are described here. Analysis of data also included analysis of numbers captured during different seasons rather than monthly captures.

Results

In the two grapsid crab species studied here, there was generally no significant relationship between number of collecting visits and number of crabs (Figure 1). Thus a large number of collecting visits in 1984 (n=13) yielded less numbers of *P. transversus* males and females (22 and 29 respectively) than did a small number of visits (n=5) in 1986 (83 and 70 respectively).

The highest number of crabs captured per visit was during 1986, in *P. transversus* males (14.8spec/vst). The highest number of gapsid crabs was captured during spring (for *P. transversus* males n=88, and for *P. marmoratus* females n=66)(Figure 2).

There is a variability in sex ratio of both *P. transversus* and *P. marmoratus* over the years (Figure 3). The sex ratio in *P. transversus* is mostly male-biased ranging from a low of 44% to a high of 67% females in the population. The opposite was seen in *P. marmoratus* population which is generally female-biased ranging between 50-100% females in the population.

Changes in body dimensions were noticeable over the years (Figure 4). There was no remarkable difference in their magnitude.

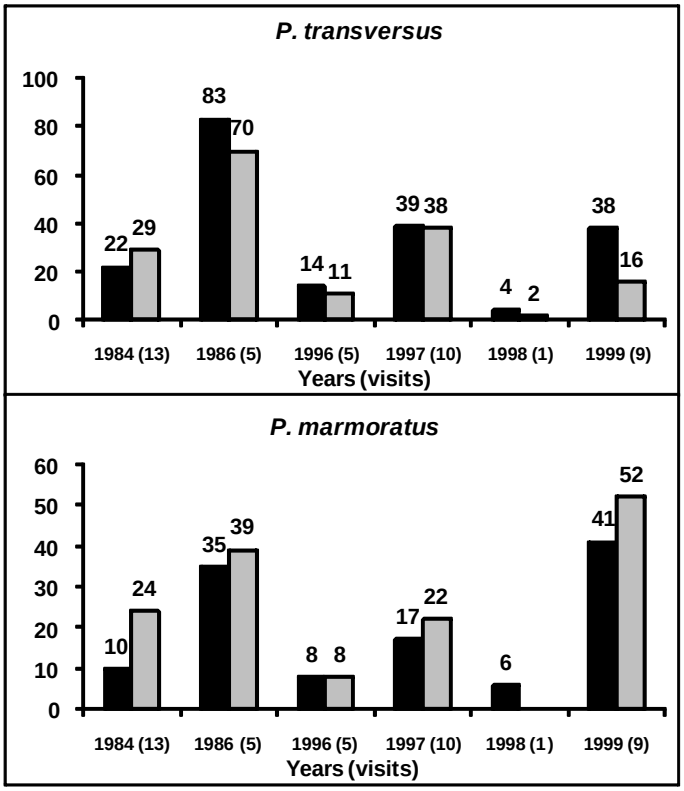

Figure 1 - Number of male (black bar) and female (grey bar) grapsids collected over the years

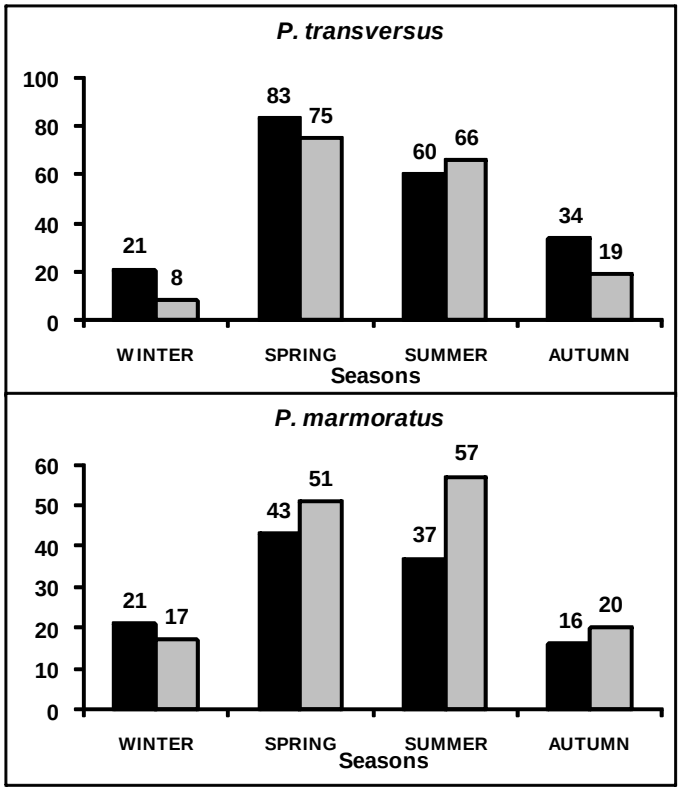

Figure 2 - Number of male (black columns) and female grapsids captured during the seasons

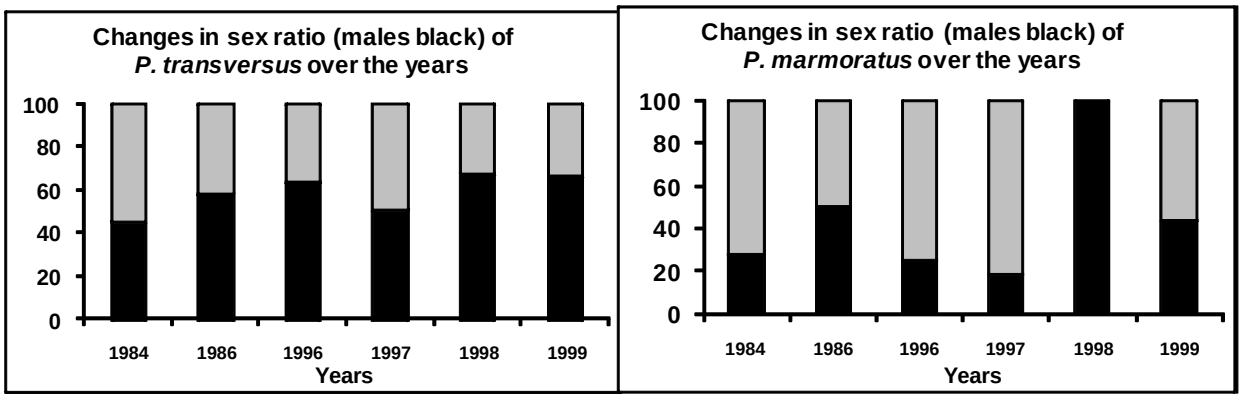

Figure 3 - Percent changes in sex ratio of P. transversus and P. marmoratus over the years

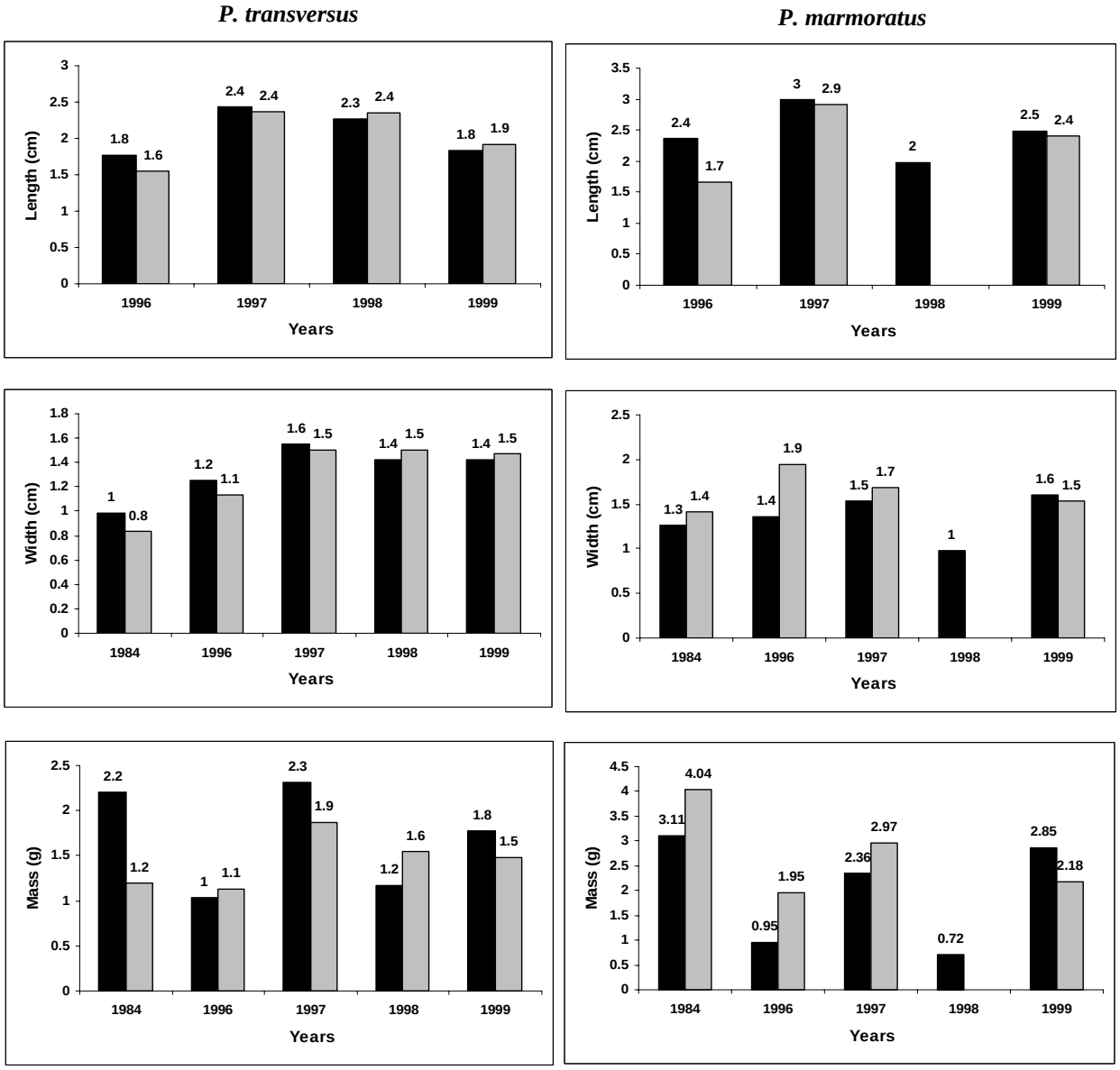

Figure 4 - Changes in body dimensions of two graspid crabs over the years

Species (reference #)	CW	CL	Mass
Goniopsis cruentata (6)	+	+	
Aratus pisonii (8)	+		
Helice crassa (22)	+		
H. crassa (29)	+		
H. japonica (30)	+		
Panopeus herbsti (24)	+		
Eurypanopeus depressus (24)	+		
Plagusia dentipes (36)	+		
Pachygrapsus transversus (9)	+	+	
P. transversus (10)	+		
P. transverses (this study)	+	+	+
P. marmoratus (11)	+		
P. marmoratus	+	+	+
P. crassipes (19)	+		
Hemigrapsus penicillatus (12)	+		
H. penicillatus (13)	+		
H. penicillatus (32)	+		
H. edwardsi (31)	+		
Sesarma pictum (32)		+	
S. haematocheir (35)		+	

Table 2 - Allometric measurements in some grapsids previously reported in literature

Discussion

This paper describes the fluctuations in population structure and changes in body dimensions over the years. In the literature, of sixteen long-term studies (see Table 1), ten lasted over one year, and in these monthly measurements were taken. In twelve of these studies measurements were taken continuously during the study period.

The fluctuations in population structure could be naturally-occurring and are not necessarily a consequence of any man made event that happened in preceding years. Indeed no such event was recorded in the study site during the study time. There are, however, alternate explanations for what can cause fluctuation in population size as was found in this study. For example, a change in the availability of food at any phase in the crabs' life cycle or alternatively, a new predator preying on any phase in the life cycle of the crabs. This will result in a change in juvenile recruitment rate. It can also be caused by changes in ambient conditions such as temperature (maximum, minimum or range), salinity or substrate affecting any stage in the crabs' metamorphosis. Interestingly, Abele (1) found that temperature, salinity ranges, and tidal exposure were of less significance than was the substrate. On the other hand, Willason (39) concluded that physical factors such as salinity and siltation restrict settlement and survivorship in grapsids. There is also evidence that low winter temperatures reduced the number of brachyuran species (25). Despite all these possibilities, no such changes in salinity, temperature siltation or substrate were recorded in this site during the intervals of this study over the years.

The annual variations described in sex ratio and population structure in this study were also similarly noted by Flores and Negreiros-Fransozo (9). In their study, for six months the sex ratio was biased towards the male and during the rest of the year the M:F sex ratio was 1:1. Variability in sex ratios could be accounted for by differential mortality of one gender caused either by differential predation with females are greater risk or commercial selection of the larger females because of their enhanced market value. Another cause could be favoring of one gender over the other in reproduction. There are several long-term studies in which growth and changes in size classes were studied in grapsid (Table 2). In most studies only CW was measured, in a few also CL and in two studies all three parameters were measured, mass included.

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References

1. Abele LG. Species diversity of decapod crustaceans in marine habitats. *Ecology* 55: 156–161. 1974.
2. Batie RE. Rhythmic locomotor activity in the intertidal shorecrab *Hemigrapsus oregonensis* (Brachyura: Grapsidae) from the Oregon coast. *Northwest Sci* 57: 49–56. 1983.
3. Beck MW. Size-specific shelter limitation in stone crabs: a test of the demographic bottleneck hypothesis. *Ecology* 76: 968–980. 1995.
4. Burnett LE, McMahon BR. Gas exchange, hemolymph acid-base status, and the role of branchial water stores during air exposure in

three littoral crab species. *Physiol Zool* 60: 27 -36. 1987.
5. Chapman MG, Underwood AJ. Experiments on effects of sampling biota under intertidal and shallow subtidal boulders. *J Exp Mar Biol Ecol.* 207: 103–126. 1996.
6. Cobo VJ, Fransozo A. Relative growth of *Goniopsis cruentata* (Crstacea, Brachyura, Grapsidae), on the Ubatuba Region, São Paulo, Brazikl. BIheringia Ser Zool Porto Alegre 84: 21-28. 1998.
7. Cuesta JA, Schubart CD. Morphological and molecular differentiation between three allopatric populations of the littoral crab *Pachygrapsus transversus* (Gibbes, 1850) (Brachyura; Grapsidae). *J Nat Hist* 32: 1499-1508. 1998.
8. Diaz H, Conde JE. Population dynamics and life history of the Mangrove crab, *Aratus pisonii* (Brachyura, Grapsidae) in a marine environment. *Bull Mar Sci* 45: 148-163. 1989.
9. Flores A, Negreiros-Fransozo ML. On the population biology of the mottled shore crab *Pachygrapsus transversus* (Gibbes, 1850) (Brachyura, Grapsidae) in a subtropical area. *Bull Mar Sci* 65: 59–73. 1999.
10. Flores A, Negreiros-Fransozo ML. Allometry of the secondary sexual characters of the shore crab *Pachygrapsus transversus* (Gibbes, 1850) (Brachyura, Grapsidae. Crustaceana, *Crustaceana* 72: 1051-1066. 1999.
11. Flores AAV, Paula J. Population dynamics of the shore crab *Pachygrapsus marmoratus* (Brachyura: Grapsidae) in the central Portuguese coast. *J Mar Biol Assoc U.K.* 82: 229-241. 2002.
12. Fukui Y. Comparative studies on the life history of the grapsid crabs (Crustacea, Brachyura) in habiting intertidal cobble and boulder shores. Publication of the Seto Marine Biology Laboratories 33: 121-62. 1988.
13. Fukui Y, Wada K. Distribution and reproduction of four intertidal crabs (Crustacea, Brachyura) in the Tonda river estuary, Japan. *Mar Ecol Progr Ser* 30: 229-241. 1986.
14. Griffin DJG. The ecological distribution of grapsid and ocypodid crabs (Crustacea: Brachyura) in Tasmania. *J Anim Ecol* 40: 597–621. 1971.
15. Gross WJ. An analysis of response to osmotic stress in selected decapod Crustacea. *Biol Bull* 112: 43-62. 1957.
16. Gross WJ. Potassium and sodium regulation in an intertidal crab. *Biol Bull* 114: 334-347. 1958.
17. Gross WJ. The effect of osmotic stress on the ion exchange of a shore crab. *Biol Bull* 116: 248-257. 1959.
18. Gross WJ. Osmotic tolerance and regulation in crabs from a hypersaline lagoon. *Biol Bull* 121: 290-301. 1961.
19. Hiatt RW. The biology of the lined shore crab, *Pachygrapsus crassipes* Randall. *Pac Sci* 2: 135 –213. 1948.
20. Hines AH. Allometric constraints and variables of reproductive efforts in Brachyuran crabs. *Mar Biol* 69: 309-320. 1982.
21. Jones LL. Osmotic regulation in several crabs of the Pacific coast of North America. *J Cell Comp Physiol* 18: 79–92. 1941.
22. Jones MB. Reproductive ecology of the estuarine burrowing mud crab *Helice crassa* (Grapsidae). *Estuarine and Coastal Marine Science* 11: 433-443. 1980 .
23. Kensler CB. Desiccation resistance of intertidal crevice species as a factor in their zonation. *J Anim Ecol* 36: 391–406. 1967.
24. McDonald J. Divergent life history patterns in the co-occurring intertidal crabs *Panopeus herbstii* and *Eurypanopeus depressus* (Crustacea: Brachyura: Xanthidae). *Mar Ecol Prog Ser* 8: 173 -180. 1982.
25. Mantelatto FLM, Fransozo A. Brachyuran community in Ubatuba Bay, northern coast of Sao Paulo state, *Brazil J Shellfish Res* 19: 701–709. 2000.
26. Masunarı S, Dubiaski-Silva J. Crustacea decapoda da praia rochosa da ilha do Farol, Matinhos, Parana. II. Distribuicao espacial de densidade das populacoes. *Rev Brasil Zool* 15: 643–664. 1998.
27. McGaw IJ. Impacts of habitat complexity on physiology: Purple shore crabs tolerate osmotic stress for shelter. *Est Coast Shelf Sci* 53: 865-876.

2001.
28. Navarrete SA, Castilla JC. Resource partitioning between intertidal predatory crabs: interference and refuge utilization. *J Exp Mar Biol Ecol* 143: 101-129. 1990.
29. Nye PA. Reproduction, growth and distribution of the grapsid crab *Helice crassa* (Dana, 1851) in the southern part of New Zealand. *Crustaceana* 33: 75-89. 1977.
30. Omori K, Shiraishi K, Hara M. Life histories of sympatric mud-flat crabs, *Helice japonica* and *H. tridens* (Decapoda: Grapsidae), in a Japanese estuary. *Journal of Crustacean Biology* 17: 279-88. 1997.
31. Pellegrino CR. The role of desiccation pressures and surface area/volume relationships on seasonal zonation and size distribution of four intertidal decapod Crustacea from New Zealand: implications for adaptation to land .*Crustaceana* 47: 251-268. 1984.
32. Pillay KK, Ono Y. The breeding cycles of two species of grapsid crabs (Crustacea: Decapoda) from the north coast of Kyushu, Japan. *Marine Biology* 45: 237-240. 1978.
33. Richards RA. Habitat selection and predator avoidance: ontogenetic shifts in habitat use by the Jonah crab Cancer borealis (Stimpson). *J Exp Mar Biol Ecol* 156: 187-197. 1992.
34. Santos MCF, Suadicani SO, Martinez CBR, Lobo ES. Rates of water loss in four crabs from different habitats. *Comp Biochem Physiol* 85A: 309-312. 1986.
35. Tanaka M, Hara M. Ecology of *Sesarma* (*Holometopus*) *haematocheir* (de Haan) in Amakusa. II. Growth rates. *Publ Amakusa Mar Biol Lab* 9: 77-92. 1988.
36. Tsuchida S, Watanabe S. Growth and reproduction of the grapsid crab *Plagusia dentipes* (Decapoda: Brachyura). *Journal of Crustacean Biology* 17: 90-97. 1997.
37. Warburg MR, Amar KO, Davidson D, Sayag L, Schwartz Y, Tudiver B, Yifrach H. Long-term study on a brachyuran crab community (Crustacea: Decapoda) inhabiting a boulder shore in the Eastern Mediterranean: Relative abundance. *Zool Middle East* 41: 71-80. 2007.
38. Warburg MR, Goldenberg S, Tudiver B. Osmotic and ionic regulation in two *Pachygrapsus* crabs, under varying salinities and dehydration. *Comp Biochem Physiol* 86 A: 761-765. 1987.
39. Willason SW. Factors influencing the distribution and coexistence of *Pachygrapsus crassipes* and *Hemigrapsus oregonensis* (Decapoda: Grapsidae) in a California salt marsh. *Mar Biol* 64: 125–133. 1981.