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AN INTERNSHIP REPORT

PRELIMINARY REPORT ON THE RECRUITMENT OF PENAEID SHRIMP POSTLARVAE IN FLORIDA BAY

by

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Preliminary Report on the Recruitment of Penaeid Shrimp Postlarvae in Florida Bay.

Abstract of a Master's internship report at the University of Miami.
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Penaeid shrimp postlarvae were collected in two tidal channels in the Florida Keys, Whale Harbor Channel and Long Key Channel, from July 1997 to October 1998 as part of the ongoing NOAA- Florida Bay Recruitment Project. Two channel nets (1 mm and 2 mm) per sample site were used for the collection of pink shrimp postlarvae for three consecutive days in each new moon period. The nets were suspended about 0.5 m below the water surface. Nets were deployed late in the afternoon and retrieved early the next morning.

Twenty postlarvae were selected at random from each sample for measurement. The number of spines in the rostrum for all postlarvae was counted.

Farfantepenaeus spp. postlarvae were found all year round in Whale Harbor, with higher abundance between May and September, and a peak in July (39.47 postlarvae /1,000 m^3). In Long Key postlarvae were caught from May to October with a peak in August (36.5 postlarvae/ 1,000 m^3).

No significant difference in the size of postlarvae entering Florida Bay through Whale Harbor Channel and Long Key Channel was detected, but a slightly higher total length (9.4 mm) was found in Whale Harbor than in Long Key (9.24 mm). In Whale Harbor Channel TL increased from October (9.3 mm) to February (11 mm), followed by a decrease with a minimum (8 mm) in September.

The average number of rostral spines for all measured postlarvae was 4 (std = 1), their average total length was 9.13 mm (std = 1.25); The average carapace length + rostrum was 2.37 mm (std = 0.37); and the average carapace length – rostrum was 1.81 (std = 0.3). Significant correlations between those measures were found

Due to the on-going research, this project will continue until December 1999. Data that could help solve some questions at issue was not yet available at the moment of the writing of this report. Thus, environmental conditions including air temperature, sea surface temperature, salinity and wind were analyzed using data from former databases and research in the area.

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INTRODUCTION

This report brings to light a preliminary result of an ongoing research (1997-99) that is part of the NOAA-Florida Bay Recruitment Project of the University of Miami, financed by the National Oceanographic and Atmospheric Administration (NOAA). This program will provide much needed information on the spatio-temporal variability of settlement and recruitment of the settlement stages of important marine species and the underlying physical, meteorological and biological processes into Florida Bay along the Florida Keys.

The objective of the present research is to examine the inshore movement of pink shrimp postlarvae through two channel passages in The Florida Keys, namely Whale Harbor Channel (Upper Keys) and Long Key Channel (Middle Keys).

The pink shrimp, *Farfantepenaeus duorarum*, (Perez-Farfante and Kensley, 1997), previous *Penaeus duorarum*, composes the most valuable fishery resource in southwest Florida. Pink shrimp fishery over the Tortugas Ground averaged 4525 metric tons (t) of shrimp tails per year during 1960-80

(Nance and Patella, 1989). In 1983 was reported an estimated income of 22 million dollars from these fisheries (Costello et al, 1986; Criales and Lee, 1995).

Pink shrimp production in the Tortugas Ground is likely linked to survival and growth of postlarvae and juvenile in the nursery areas of Florida Bay, Whitewater Bay and adjoining coastal water. A disruption in nursery habitat functions such as freshwater diversion, seagrass mortality or nutrient inputs from human activities may have been causes of fluctuations in pink shrimp harvest (Rice, 1997).

It is known that inshore movement of the pink shrimp postlarvae are facilitated by currents and the selective use of tides (Koczy et al., 1960; Tabb et al., 1962; Beardsley, 1970; Costello et al., 1986). The migration route for pink shrimp postlarvae suggested for southwest Florida described that larvae were carried northeast by Florida Current from Dry Tortugas to Florida Keys, entering the nursery grounds of Florida Bay or continuing eastward carried by the current (Munro et al., 1968).

STUDY SITE

Florida Bay is an immense, wedge-shaped, shallow lagoon located at the southern of Florida Peninsula. It is bordered on the north by the Florida mainland and on the east, southeast, and south by the chain of the Florida Keys (Hoffmeister, 1974). The western portion of the bay opens into the Gulf of Mexico(Fig. 1). The area of Florida Bay, considering the western boundary of the bay as a line running from east Cape Sable to Marathon Key, comprises 2179 Km^2 (Scholl, 1966).

Florida Bay is a shallow lagoon. Many of the carbonate mudbanks that rise from the limestone floor are covered by less than 60 cm of water, and are exposed by low tide and wind effects. A network of mangrove keys and intersecting seagrass-covered mudbanks separates the Bay into semi-closed basins, 40 to 300 cm deep (Hudson, et al.1970).

The Florida Keys, seagrass-covered mudbanks, mangrove keys and shallow depths restricts water circulation in the bay, although there is an exchange through narrow channels and over the mudbanks. Water velocities in certain channels at peak flood tide may be as great as 7.4 Km/h, but decreases rapidly as the water enters the bay (Gorsline, 1963). Extensive penetration of tide water occurs only in the southern and western bay (Mc Callum and Stockman, 1964). In those areas, salinity and temperature are similar to nearby ocean water. The greatest salinity and temperature fluctuations occur along the northern border of the bay influenced by the freshwater runoff of the Everglades, one of the largest wetland ecosystems in the world.

In the Florida Bay area, sea level is lowest in the late winter and early spring and highest in the fall (Marmer, 1954). Predicted total ranges in the bay area vary from less than 15 cm in the eastern bay to 52 cm on the east side of Big Pine Key (Kissling, 1965) to 88cm near Cape Sable (Scholl, 1966).

Wind speed and direction are important determinant of water level, particularly in the tide-restricted portion of the bay (Price, 1967). Persistent strong winds lower water levels in up-wind areas and raise water levels in down-wind areas (Moore, 1953).

On the Florida Strait side of the Florida Keys there is open water circulation. The Upper Keys are separated by only a few narrow channels; channels become more numerous and wider in the Middle Keys. Along the outer shoreline of the Upper and Middle Keys substrates vary from exposed limestone bedrock to bedrock overlaid by a thin layer of carbonate sand or deep carbonate mud. The

Lower Keys are separated by numerous tidal channels oriented in a norwest southeast direction (Hoffmeister, 1982). Water circulation is less restricted than in the Interior zone of Florida Bay, salinities and temperatures are relatively stable due to marine influence from the Florida Straits and Gulf of Mexico (Costello, et. al, 1986).

Seagrasses are generally distributed along the keys in areas sheltered from excessive wave and current energy where sediment depths are adequate. Turtle grass, *Thalassia testidinum* colonizes over 95 % of the bottom of Florida Bay (Zieman et al, 1989). Shoal grass, *Halodule wrightii*, and manatee grass, *Syringodium filiforme* are also present in the bay. Seagrasses provide necessary habitat for juvenile shrimp. Shrimp postlarvae probably actively select areas of shoal grass for initial benthic settling. Early juveniles are closely associated with shoal grass as the primary habitat and may depend upon this species for survival (Costello et al, 1986).

ENVIRONMENTAL ISSUE

Florida Bay, like all other estuaries, is very dynamic in nature and high levels of freshwater input and large daily tidal fluctuations govern their physical attributes. Freshwater runoff into the estuary is essential for provision of nutrients and minerals, which support rich grass beds. These grass beds in turn serve as important habitats for many juvenile species as they increase protection from predation (Heck, 1977). Furthermore, freshwater input into the bay is vital to the establishment of strong salinity gradients, which can also act as barrier to many predatory species which may not be able to tolerate the lowered salinity (Gunter, 1961).

The Everglades, also known as the "River of Grass", is the freshwater supplier for the bay. Vast freshwater supplies that historically maintained the Everglades swamps have been diverted over the past 40 years, and especially the last 10, to supply the growing population of Miami and the rest of Dade County, and also for agriculture north of the Everglades. As result Everglades's ecosystem has changed, and in turn, made adjacent Florida Bay more saline.

A major source of pollutants is derived from land-based toxicants (pesticides, herbicides, and hydrocarbons) and nutrients (organic nitrogen, ammonia, nitrate, nitrite, phosphorus, and total organic carbon) (Lapointe and Clark, 1992). Wastewater and fertilizers are the source of nutrients. All adversely affect the Florida Bay ecosystem due to their higher solubility and the ability to be retained within sediment.

Significant point sources discharging treated wastewater directly to surface waters include 19 wastewater treatment facilities, 10 of which are domestic wastewater treatment plants. The largest of these is the Key West sewage treatment plant, actively discharging up to 10 million gallons per day into offshore waters.

Since1987, massive seagrass die-off, along with other ecosystem changes such algal blooms (Phlips and Badylak, 1996) and sponge mortality events (Butler et al., 1995) in Florida Bay have brought attention to the sensitivity of the ecosystem to disturbance.

The causes of seagrass die-off are not clear. The most popular hypotheses are related with the presence of hypersaline water that can reach 53 ‰ (Boyer et al., 1997).

Indirect evidence leads to eutrophication, the process by which nutrient-rich waters bring about a high level of biological production that leads to reduced dissolved oxygen. The seagrass die-off is hypothesized to be an essential link in the declining numbers of pink shrimp observed in the adult fishing grounds .As result huge losses have been suffered by the shrimp industry. Virtually all sponges, which are prime juvenile habitat, died under the algal blooms (Barley, 1993).

Significant causes also include pathogens, abnormally high salinities, temperatures, and disease. The likely theory of eutrophication results from an increase in the amount of nutrients from onshore septic system discharge, elevating levels of nitrogen with respect to phosphorus, and subsequently increasing the frequency of algae bloom. Other impacts of declining water quality have been increased fish kills, mangrove die-off, and declines in coral reef buildup. While tropical seagrass and coral reef ecosystems can tolerate some level of nutrient enrichment without serious ecological effects, chronic enrichment reduces dissolved oxygen (DO) levels and habitat viability. Reduced DO concentrations and either hypoxia or anoxia occur in eutrophic seagrass meadows, especially during warm or low-light periods, due to decreases in the photosynthesis / respiration ratio (Valiela et al, 1990).

SOME ASPECTS OF THE BIOLOGY OF THE PINK SHRIMP

The pink shrimp *Farfantepenaeus duorarum* stock located off the Dry Tortugas uses this area as spawning ground. Larvae are transported via the Florida Current to the estuaries located in Florida Bay and its surrounding areas, which serve as nursery grounds for the juvenile shrimp. Here juveniles grow and mature until the sub-adult stage of development at which point they migrate back to the Dry Tortugas grounds (Costello and Allen, 1966).

Pink shrimp progress through 11 larval stages as they develop from egg to first postlarvae (Ewald, 1965). These stages include 5 naupiliar, 3 protozoeal, and 3 mysis, and the minimum estimated time for completed larval development is 15 days under laboratory conditions. Survival rates of larval pink shrimp have been estimated, as they progress from the Dry Tortugas to the nursery grounds in the Florida Bay area, from 78.6 to 82.0% per day (Munro et al., 1968). Most postlarvae arrive in the nursery area in the six-spine stage of postlarval development (Tabb et al., 1962) after 35 days metamorphosis (Ewald, 1965). Around 0.05 % of the pink shrimp spawned would reach the nursery ground under these conditions. Of this portion, they estimate that around 6% would eventually reach the adult fishing grounds as indicated by commercial catches (Munro et al., 1968). Upon reaching the nursery grounds, the juveniles begin their maturation towards adulthood. They are mainly nocturnal animals, choosing to spend the daytime hours buried beneath the substrate (Wickham, 1966).

Growth rates of juveniles pink shrimp have been measured from 2 to 4 mm carapace length (CL) per month depending on the size of the animal. Tabb et al. (1962) found that for animals of 6 mm CL, growth rate was about 2mm CL per month and increased up around 3.5 or 4 mm until an animal reached around 20 mm CL in a period between 7 to 8 months before migration to Dry Tortugas grounds.

Pink shrimp attain sexual maturity at the sub-adult stage of development, at which point copulation may occur (Perez Farfante, 1969). Copulation occurs between a hard-shelled male and a soft-shelled female soon after the female has molted (Perez Farfante, 1969). Copulation occurs many times during the growth and development of the female, and is not directly associated with spawning (Perez-Farfante, 1969).

Ovary development has been characterized into four distinct stages: undeveloped, developing, nearly ripe, and ripe. Following the ripe stage, eggs are released, and generally appear opaque yellow-brown in color. The eggs are approximately 0.23-0.33 mm in diameter and are demersal in nature.

The number of eggs spawned per female varies greatly, but range of 9,333 to 174, 160 eggs per female has been observed under laboratory conditions (Cardona and Capo, 1992). Martosubroto, (1972) estimated an individual fecundity of 44, 000 to 534, 000 eggs in wild pink shrimps from the Tortugas Ground.

Spawning by pink shrimp on the Tortugas grounds has been suggested to occur year-round (Ewald, 1965). Cummings (1961) noted the occurrence of ripe females throughout the year in the Tortugas Ground with higher spawning activity from April through July, and attributed his findings to either year-round spawning, or ability by females to remain in the early ripe stage for a prolonged period. Munro et al. (1968) and Jones et al. (1970) both noted the presence of pink shrimp protozoeae throughout the year on the Tortugas grounds further confirming the theory of year-round spawning activity.

Although spawning is believed to be year round, a seasonal component has been associated with it. The changes in spawning rate appear to be temperature related, as peak in spawning have been reported following the arrival of warmer waters to the spawning grounds during the spring and summer months (Munro et al. 1968;Jones et al., 1970; Allen et al., 1980). Jones et al. (1970) found that larvae stages were scarce in the plankton in winter, but were more abundant in spring, summer and autumn.

METHODS AND MATERIALS

Two sampling stations were selected in two tidal passes between the Atlantic Ocean and Florida Bay: Whale Harbor (Upper Keys) and Long Key (Middle Keys) (Fig. 1). Samples were collected monthly during three nights of the new moon period from August 1997 to October 1998.

Two channel nets were maintained on separate moorings at two stations at each channel, and suspended about 0.5 m from the surface. Nets with 1mm-mesh size and 1.5 x 1m mouth were moored right into the entrance of the channel a few meters from the coastline, while nets with 2mm mesh size and 2m wide x 1m deep were moored farther into the Bay.

Each net have a 3 m long PVC pipe attached along the upper side to prevent the net from collapsing during slack tide and fouling on the mooring line (Fig. 2). Each net was equipped with a low speed rotor blade flowmeter.

Nets were deployed at sunset and retrieved early in the morning for a total of four samples /day.

Debris were removed and samples washed and fixed in 95 % ethanol solution for 24 hours; and transferred to 75% ethanol for subsequent identification. Each sample was sorted and penaeid shrimp postlarvae removed.

The total length (TL, from tip of rostrum to tip of telson), carapace length plus rostrum (Cl+r , from tip of rostrum to the posterior border of the carapace). and carapace length minus rostrum (CL-r, from the posterior orbital margin to the posterior border of the carapace) were measured to the nearest millimeter with an ocular micrometer. Twenty postlarvae were selected at random from each sample for measurement. The number of spines in the rostrum for all postlarvae was counted.

Volume of water filtered through the plankton nets was calculated as follows:

Volume (m^3) = Mouth area net x Distance in meters

Mouth area 1 mm mesh net = 1.5 m wide x 1 m deep = 1.5m^2

Mouth area 2 mm mesh net = 2 m wide x deep = 4m^2

$$\text{Distance in meters} = \frac{\text{difference in counts x rotor constant}}{999999}$$

Low speed Rotor Constant = 51, 020

Concentration was defined as the standardized catch in 1,000 m^3 of seawater and calculated as:

$$\text{Number of animals/ 1,000 m}^3 = \frac{N}{V} \times 1{,}000$$

N = number of postlarvae caught in net
V = volume filtered by net

Data Analysis. Average monthly concentrations of shrimp were calculated for each sample site to determine variations along the year. To reduce the influence of occasional large peaks, concentrations were transformed by log (x+1). Differences in catches between 1 and 2 mm mesh size were determined. Size distribution averages for postlarvae were calculated to establish ranges and average values. Results were compared between the four stations. Correlation between number of spines, TL, CL+rostrum and CL-rostrum were determined.

Environmental Data. Wind speed, Surface water and air temperature data was collected from SEAKEYS/Coastal-Marine Automated Network (C-MAN) DATA from NOAA Database for Long Key Station. Temperature readings are in Celsius and Wind speed in knots.

Daily average of water surface, air temperature and wind speed were calculated each month and correlated with postlarvae caught in one station (LKN).

RESULTS

A total of 4,424 postlarvae from 185 samples were sorted for a fifteen months-long monthly sampling program and 235 postlarvae were taken for meristic characteristics.

Farfantepenaeus spp. postlarvae were found all year round in the studied area (Fig. 3). From May 1998 to September 1998 abundance increases with peaks in July (WHN: 39.47/1,000 m^3) and August (LKN:36.5 / 1,000 m^3). Two other high values in WHN were found in December 1997 (11.82 postlarvae /1,000m^3) and October 1998 (11.75 postlarvae / 1,000m^3).

A marked difference was founded between the catch ability of channel nets with mesh 1mm and 2mm. In the stations LK the number of postlarvae caught by channel net mesh 1mm (LKN) was higher than those caught by the 2mm net (LKF) when both were active at the same time (Fig. 4). Similar condition appeared in WH stations (Fig. 5). Percent of total postlarvae caught in each station varied from 0.1in WHF to 57.2 in WHN (Fig. 6). The percent of postlarvae caught with 1mm mesh net during the period of study was different between sample stations with 41.6 % for LKN and 58.4 % for WHN. (Fig.7).

A seasonal difference in postlarvae abundance was found through the sampling period. Most postlarvae were caught during June – September period (30.03 / 1,000 m^3), while minimum postlarvae appeared from February to May (0.43 / 1,000 m^3)(Fig.8).

Average of number of spines in rostrum, TL, CL+ rostrum, and CL-rostrum for penaeid postlarvae are shown in Table 1. The number of rostral spines of the whole population of postlarvae varied from 2 to 6, with the highest frequency observed in 3 (Fig. 9). In LKF (2mm) and LKN (1 mm) the monthly average of rostral spines ranged from 3 to 6 (Fig. 12). In WHN (2 mm) average of rostral spines varied from 3 to 6. Minimum values were found between August and October 1998, and the maximum value was found in April (Fig. 14).

Total length for all sampled postlarvae average 9.0 mm (STD=1.3mm). From June to September TL average was 8.9 mm (STD = 1.15), and increased to 9.4 mm (STD = 1.13) in October – January. Maximum average TL was found in February – May (10.0 mm, STD = 1.63).
Frequency distribution of total length of sampled postlarvae is shown in Fig.10.

The average TL was 9.54 mm in stations with 2mm mesh nets (LKF), while the average for nets with mesh size 1mm (LKN) was 9.2mm (Fig. 13).

In WHN total length varied from a minimum of 8mm in September to a maximum of 11.1 mm in February and an average of 9.0 mm. (Fig. 14). The total length average in LKN was 9.2 mm, with a minimum of 7.9 mm in August 1997 and 10.9 mm in November 1997 (Fig. 16)

Average CL+rostrum for all sampled postlarvae was 2.0 mm (STD=0.4) and varied from 2.31 mm (STD = 0.4) in June – September to 2.57 mm (STD = 0.4) in February – May.

In WHN CL+ rostrum varied from a minimum of 2.04 mm in September to a maximum of 2.9 mm in February and an average of 2mm. In LKN CL + rostrum varied from 2.75 mm in November to 2.06 mm in August with an average of 2.4 mm (STD =0.3).

Average CL-rostrum was 2.0mm (STD=0.3mm), and varied from 1.76 mm (STD = 0.24) in June – September to 1.97 mm (STD = 0.37) in February – May. Frequency distribution of Carapace length-rostrum is shown in Fig. 11.

In WHN CL-rostrum varied from 1.69 mm in August to 2.22 mm in February, with an average of 2 mm (std = 0.2). In LKN CL – rostrum varied from 2.03 mm in November to 1.6 mm in August.

Variations of CL+ rostrum and CL- rostrum in WHN are shown in Fig.15. Monthly average CL+ rostrum and CL- rostrum for LKN are shown in Fig. 17.

Significative correlation between number of spines and TL, Cl+rostrum, and CL-rostrum were found (Table 2). Correlation between total length and number of rostral spines is shown in Fig. 19. Figure 20 shows the correlation between carapace length – rostrum and total length.

No difference in size of postlarvae entering the bay was found between LKN and WHN (Fig. 18).

Monthly average of water temperature oscillated between 19° C in February and 30.7° C in August with and average of 26.5° C during the year (Table 3). The lower sustained temperatures were found from the end of November to the end of April. Higher sustained temperature extended from the end of May to the end of September, period with the maximum number of postlarvae reported (Fig. 16). Nevertheless, a restricted relation between surface temperature and postlarvae were not found.

Monthly average of hourly wind speed taken from the SEA-MAN records for Long Key shows a maximum of 7.3 knots in April and a minimum of 4.2 knots in October, and an annual average of 5.8 knots. Wind direction varied from east to southeast most of the time (Table 3).

DISCUSSION

A species differentiation of postlarval stages of Farfantepenaeus spp (former *Penaeus spp).* is extremely difficult and is not feasible. Burkenroad (1939) and Costello and Allen (1966) reported *F. duorarum* as the dominant specie in Florida Bay. Chuensri (1968) determined that 99.5% of postlarvae caught elsewhere in south Florida were *F. duorarum.*

The abundance, distribution and migration of the pink shrimp postlarvae Farfante*penaeus duorarum* has been studied and recorded for Florida Bay in a number of earlier studies (Dobkins, 1961; Tabb et al, 1962; Beardsley, 1970; Costello et al, 1986).

Farfantepenaeus spp postlarvae were found at Whale Harbor channel all year round, with an abundant period from May to September 1998. Allen et al (1980) also reported postlarvae entering through Whale Harbor Channel year round but with maximum abundance from April to September. The lightly difference in periods of abundance could be assumed for yearly variations in meteorological and hydrological conditions, like tidal amplitude, temperature and wind stress (Hughes, 1972).

It is now established (Tabb, 1962; Hughes 1969b; Beardsley, 1970) that the inshore movement of postlarvae is facilitated by the selective use of tidal currents. During the active flood tide period postlarvae penetrate the water column above the substrate, being displaced in an inshore direction by the current. During the relatively inactive ebb tide period their movements may be confined to the substrate where, despite their downstream orientation, displacement by the current is minimal (Hughes, 1972).

A hypothesis by Hughes (1969a) expresses that the increase in salinity, correlated with the flood tide, elicts activity within the water column, whereas the decrease of salinity at the same time of ebb tide depresses activity with the reluctance of shrimp to move from water of higher to water of lower salinity, confined them to the substrate where they would more readily evade displacement by the current.

Rothlisberg and Church, (1994) found in North Australia that penaeid postlarvae occurring offshore migrate vertically on a diel pattern, being near the bottom by day and in the upper water column by night. As they grow larger and approach their estuarine nursery areas, their behavior changes and postlarvae become epibenthic and responsive to tides. They consider that the mechanism of postlarval delivery does not rely on the ability of postlarvae to perceive the proximity of the estuaries or any gradient in environmental factors, such as salinity and turbidity, but associated with a pressure response once the postlarvae become epibenthic. Further studies should be made to verify the usefulness of this model in the ecosystem of South Florida, which significantly differs from the Gulf of Carpentaria, where the model is proposed.

Data from the National Ocean Survey (NOS) Tide Tables indicates that tide amplitude near Marathon Key is 0.1 m increasing in 0.4 m to Miami and south toward Key West (0.2 m). This tidal value can be considered as a low range tide. Marmer. (1954) found that the maximum tides in Florida Bay occur between May and October, a period of the year with the highest abundance of postlarvae.

Transport processes in the Florida Keys also include the wind-driven circulation in shallow water areas on both the Atlantic and Gulf sides of the keys (Smith, 1994). Winds in the area shows a clear seasonal pattern with the summers dominated by weak, southeasterly trade winds, an a winter strongly influenced by weekly cold front passages associated with stronger, northerly winds (Wang et al, 1994). In this study predominant winds were southeast and east during most of the time.

Allen et al. (1980) consider that increasing wind from the east, southeast and south may increase the velocity of surface water on a flooding tide

The reason of the difference in the amount of postlarvae caught in Whale Harbor and Long Key channels is not clear. The different characteristics of the water flow through the channel passes could be one explanation. Smith (1998), found a quasi-steady inflow in Whale Harbor Channel, unlike the long-term net outflows found in all other tidal channels investigated in the Upper and Middle Keys. Inflow through Whale Harbor channel may be a result of a blocking effect by a series of mud banks that deflect water-moving eastward across Florida Bay. This inflow, in some manner permanent, could increase the inshore movement of postlarvae by flow tides.

In Long Key channel a long-term net outflow was reported by Smith (1994) in a 385-day time period, with a flow speed of 0.026 $m.seg^{-1}$ from the bay to the ocean, with considerable variability, including a possible seasonal cycle with maximum outflow in late winter and spring months, and low frequency reversals over time scale on the order of 1-2 weeks. Although we do not have specific data to believe any kind of relation between flow movement and postlarvae in this channel, there is a coincidence between period of maximum outflow (late winter and spring) and the lack of postlarvae in those months.

Average total length (TL) of all sampled postlarvae was similar to the size reported by Allen et al. (1980) for postlarvae entering Florida Bay (5 -10 mm) in the 2 to 6 rostral spine stage. The smaller postlarvae were caught in June – September (8.9 mm), when postlarvae were most abundant. The largest postlarvae were caught in February – May period (10.0 mm).

A positive correlation was found between number of rostral spines and total length (0.97), also between CL- rostrum and TL (0.97). Kutkuhn, (1966) suggested the relationship between total length and carapace length in peneid shrimps could be best described as linear in individuals up to 150 mm. Beyond this length definitive curvature indicates that increases in CL do not keep pace with increases in total length.

In stations with channel 1-mm mesh size nets the average TL was lightly higher than in 2-mm mesh size. The latter apparently permitted some escape of small postlarvae.

An analysis of length frequency based on total length (TL) in WHN sample site reveals two distinctly different size groups (Fig. 11). In May to September most postlarvae averaged 8.9 mm (STD = 1.15), whereas in October to April the average was 9.4 mm (STD = 1.13) and 10.0 mm (STD = 1.63) between February and May. Temple and Fisher (1967) report similar condition for the brown shrimp postlarvae entering Galveston Bay. Renfro and Brusher (Temple and Fisher, op.cit. 1961) reported that "although brown shrimp may spawn continually throughout the year, major period of spawning activity are in April to June and September to November. The absence of large catches of larval stages during January to March arises the possibility that this spring group of postlarvae is originated from a large spawning in the fall of the preceding year".

Cummins (1961) found the highest rate of pink shrimp spawning from April through July, but ripe and nearly ripe females were found at other time of the year as well, indicating that multiple spawning probably occurs. Biesla et al. (1983) also reported pink shrimp spawns year round.

The increment of postlarvae during May –September described in this report could be related to the higher rate of spawning in April-July. Allen et al, (1980) found a slight correlation between postlarvae abundance and surface water temperatures at Whale Harbor channel with the 67.6% of the postlarvae caught when temperatures exceeded 29.3°C.This could explain the smaller size of postlarvae entering the bay in summer and early fall.

The appearance of postlarvae in small amounts during late winter and spring could be motivated for two main different reasons or their combination: This class could represent the spawn from late fall and winter preceding year. That could explain its bigger sizes. Temple and Fisher (1967) also raised this question in relation in relation to brown shrimp postlarvae. They considered that young postlarvae must remain offshore either as larvae or postlarvae for a longer period than was suspected.

Criales and Lee (1995) found that pink shrimp postlarvae can be retained at the spawning area by recirculation in the Tortugas Gyre followed by movement onto the southwest Florida shelf and Florida Bay. This retention possible mix postlarvae with different sizes in different months.

The differences in size of postlarvae entering the bay could be a factor for further variation in juvenile's sizes. Yokel et al (1969) found that, on a yearly basis, emigrating shrimp to fishery ground range in size from 2 to 45 mm in carapace length. Such differences presumably cause delay in the arrival of the shrimp at a size large enough for the trawls to capture.

The conclusion of this project will explain some aspects that were exposed in this preliminary report as hypothesis. Nevertheless, the study of postlarval movement into nursery grounds will require a great effort and research due to the influence of multiple biological, oceanographic, meteorological, and ecological factors.

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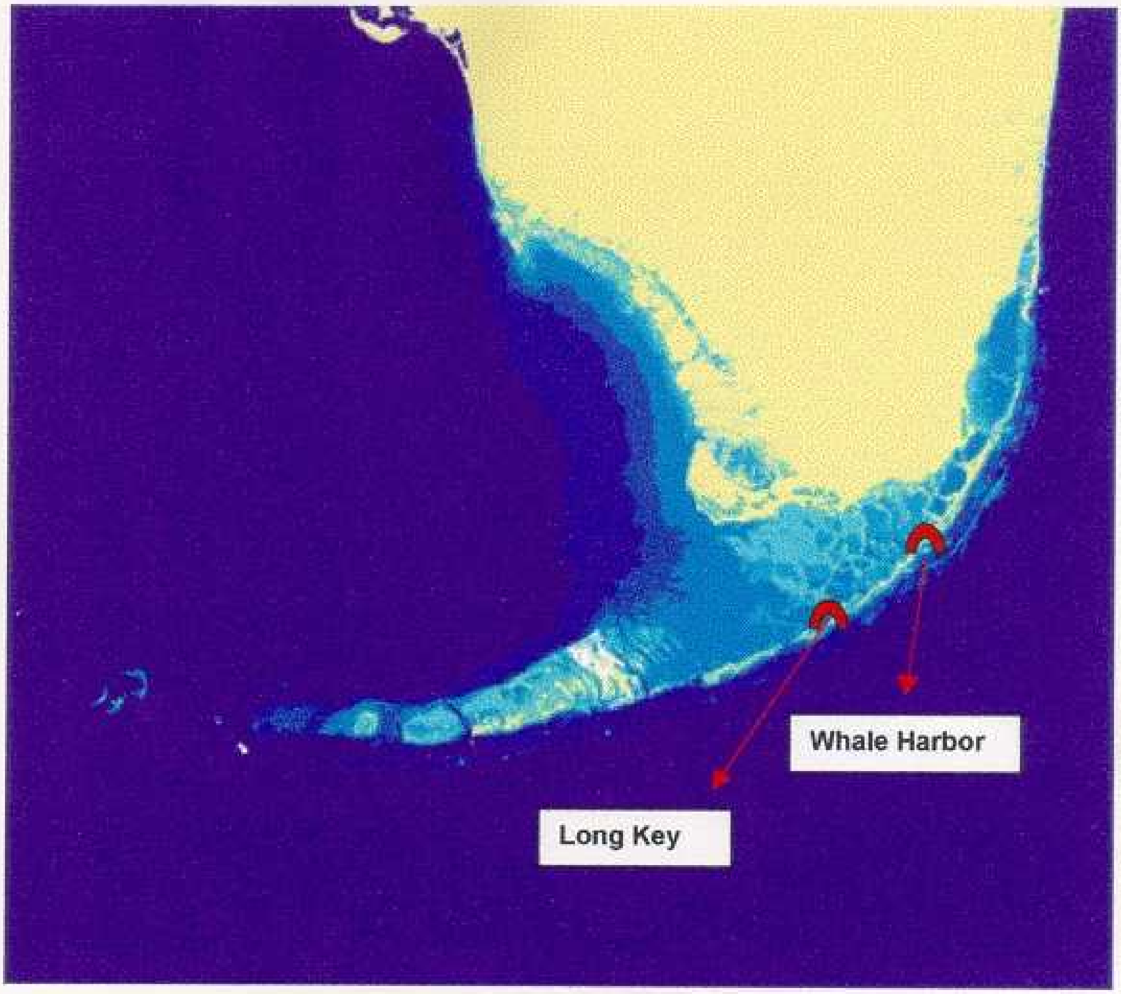


Figure 1. Florida Bay. Sample sites

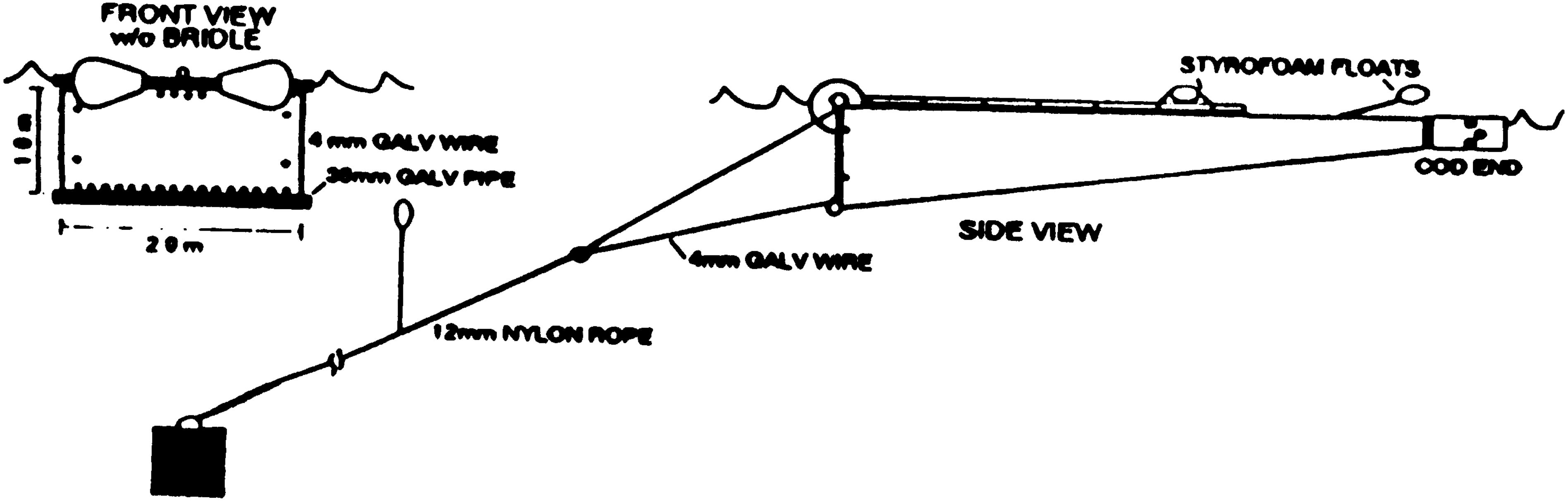


Figure 2. Schematic diagram of a channel net and their mooring (Taken from Shenker et al., 1993).

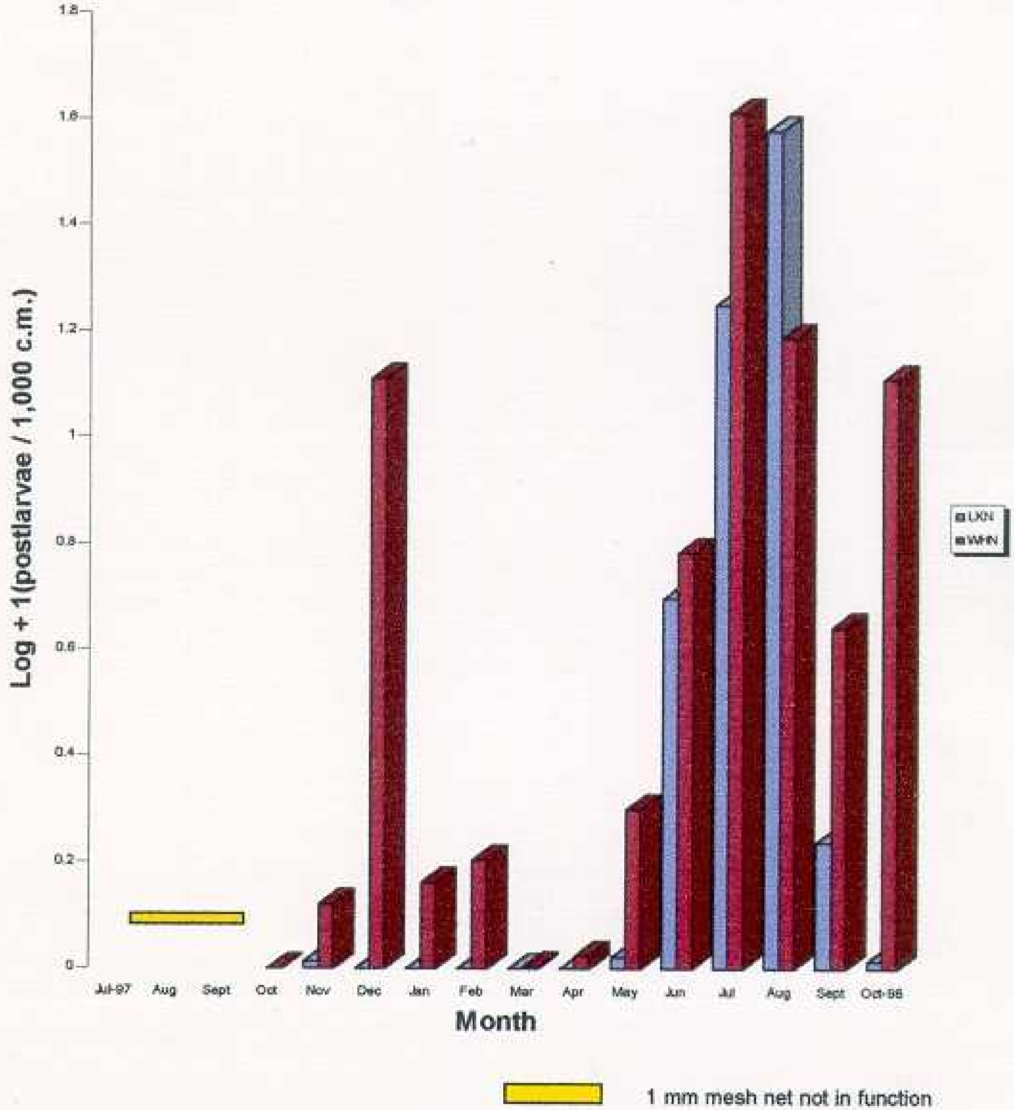


Figure 3. LKN and WHN. Monthly abundance of postlarvae.

LKN: Long Key Channel net near the bridge (1mm mesh size)

WHN: Whale Harbor Channel net near the bridge (1mm mesh size).

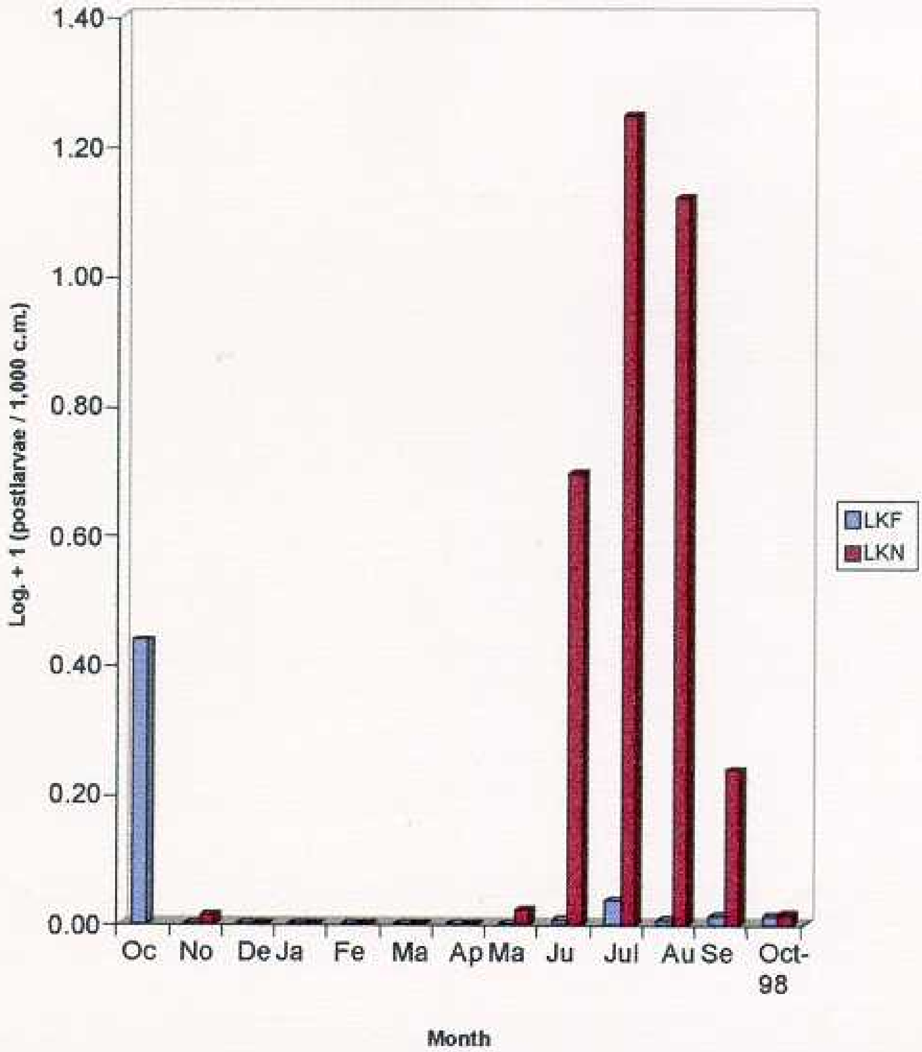


Figure 4. Monthly abundance of postlarvae between nets with different mesh size. LKF: 1mm, LKN: 2 mm.

LKF: Long Key Channel net farther from the bridge (2 mm).
LKN: Long Key Channel net near the bridge (1mm).

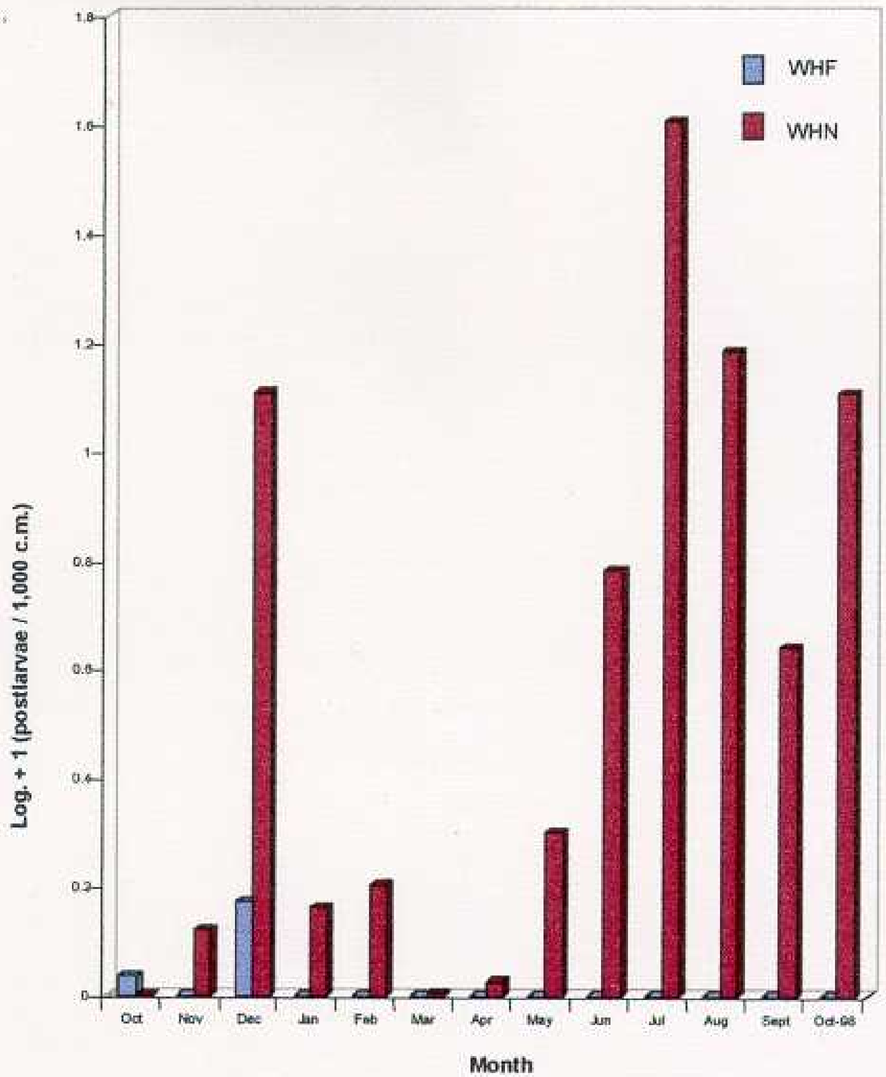


Figure 5. Monthly abundance of postlarvae between mesh different size. WHF: 2 mm, WHN: 1 mm.

WHF: Whale Harbor Channel net farther from the bridge
WHN: Whale Harbor Channel net near the bridge.

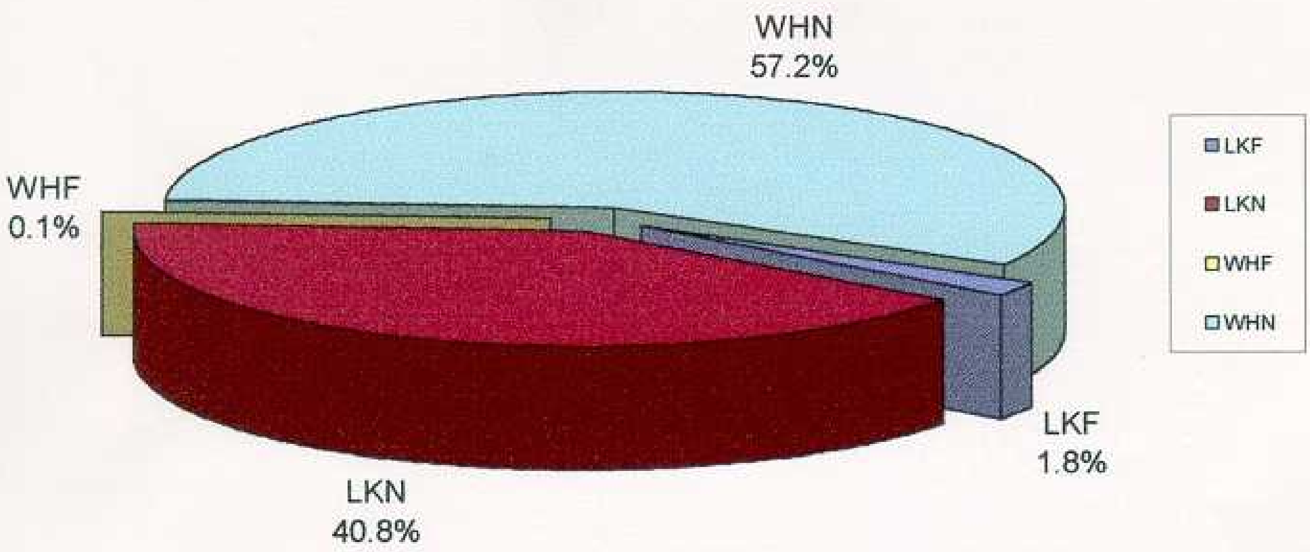


Figure 6. Percent of total abundance of postlarvae per sample site.

LKF: Long Key Channel net farther from the bridge, (2mm).
LKN: Long Key Channel net near the bridge, (1mm).
WHF: Whale Harbor Channel farther from the bridge, (2mm).
WHN: Whale Harbor Channel net near the bridge, (1mm).

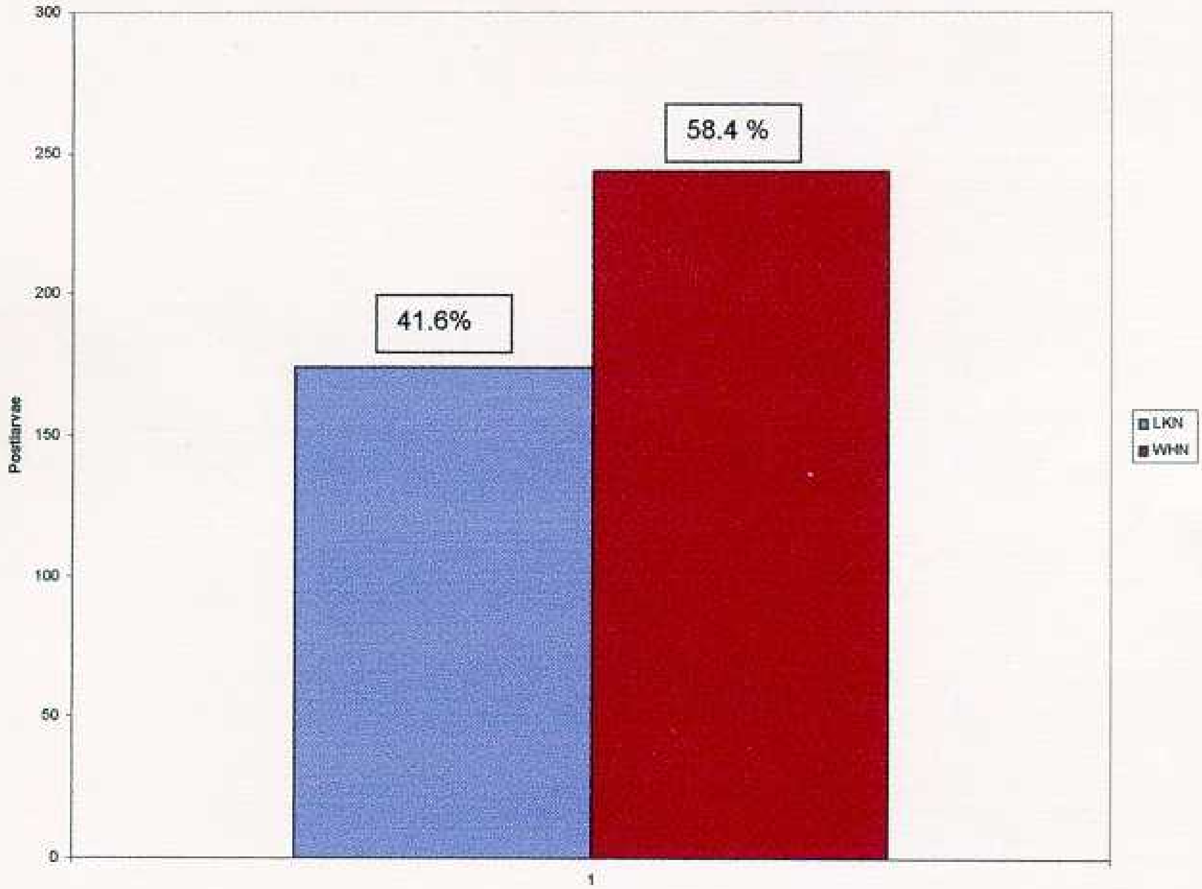


Figure 7. Total postlarvae caught per sample site.

LKN: Long Key Channel net near the bridge (1mm).
WHN: Whale Harbor Channel net near the bridge (1mm).

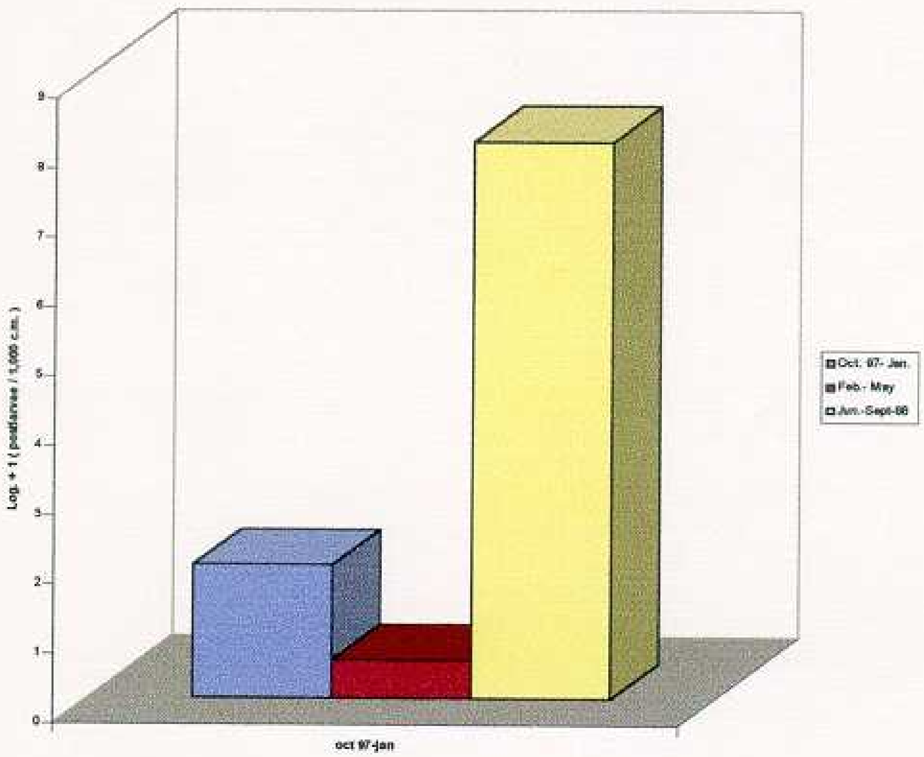


Figure 8. Seasonal abundance of postlarvae.

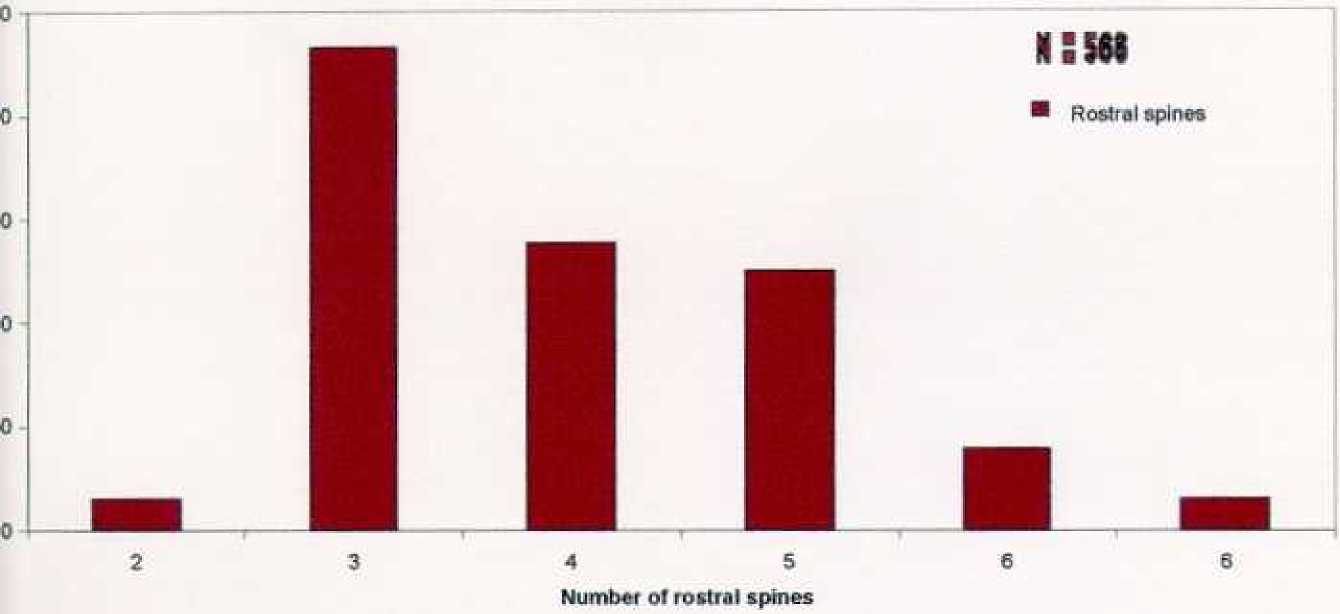


Figure 9. Frequency distribution of rostral spines

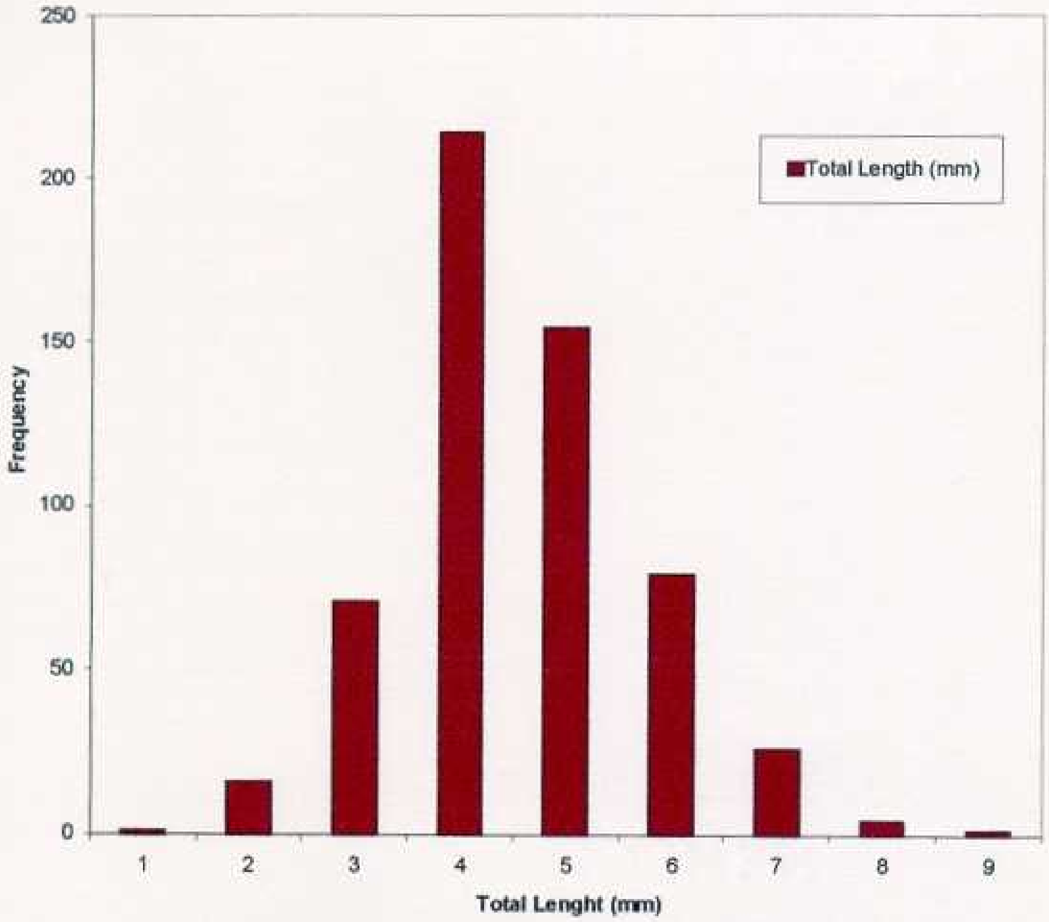


Figure 10. Frequency distribution of Total Lenght

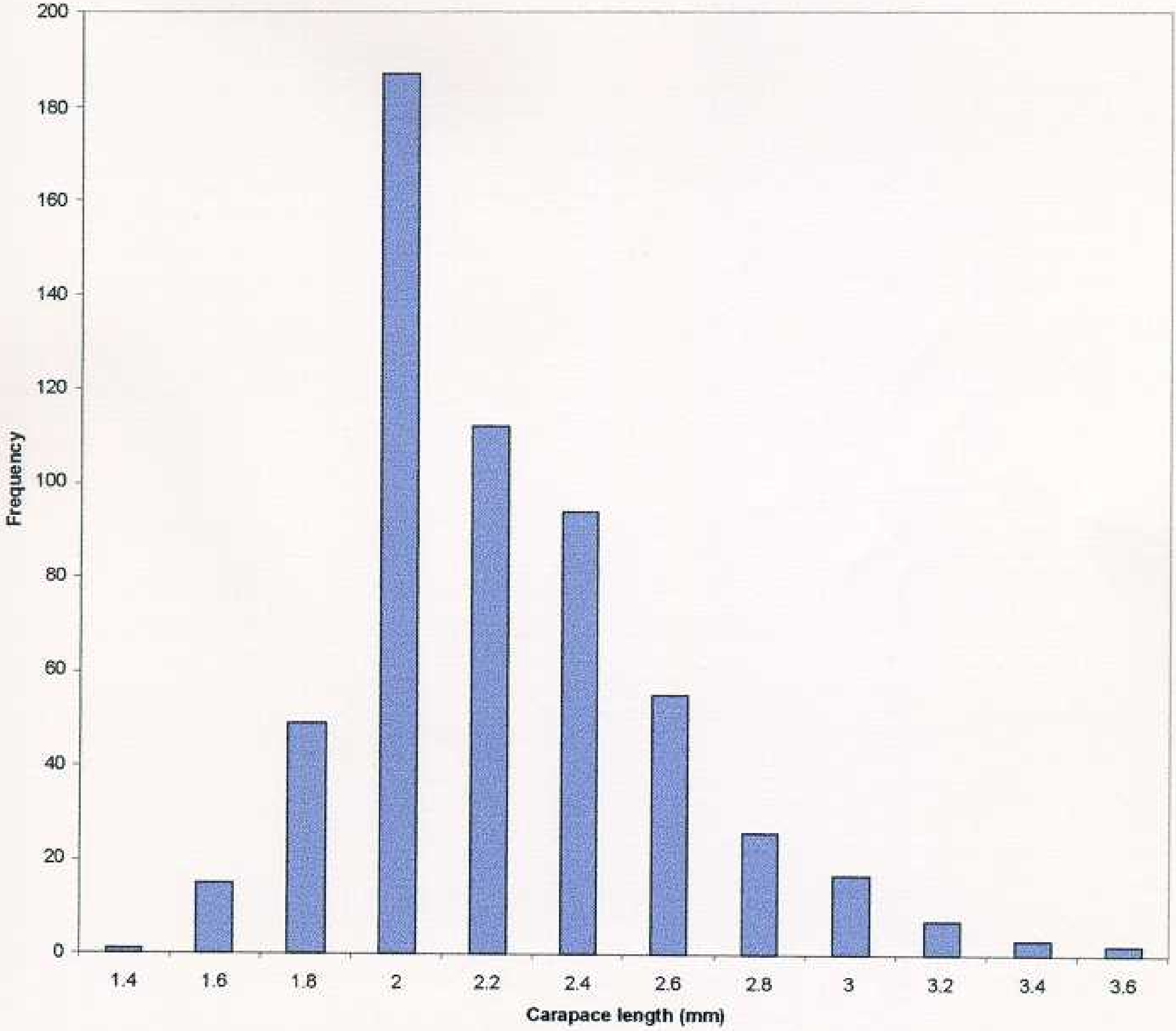


Figure 11. Frequency distribution of Carapace length – rostrum. net: 1mm

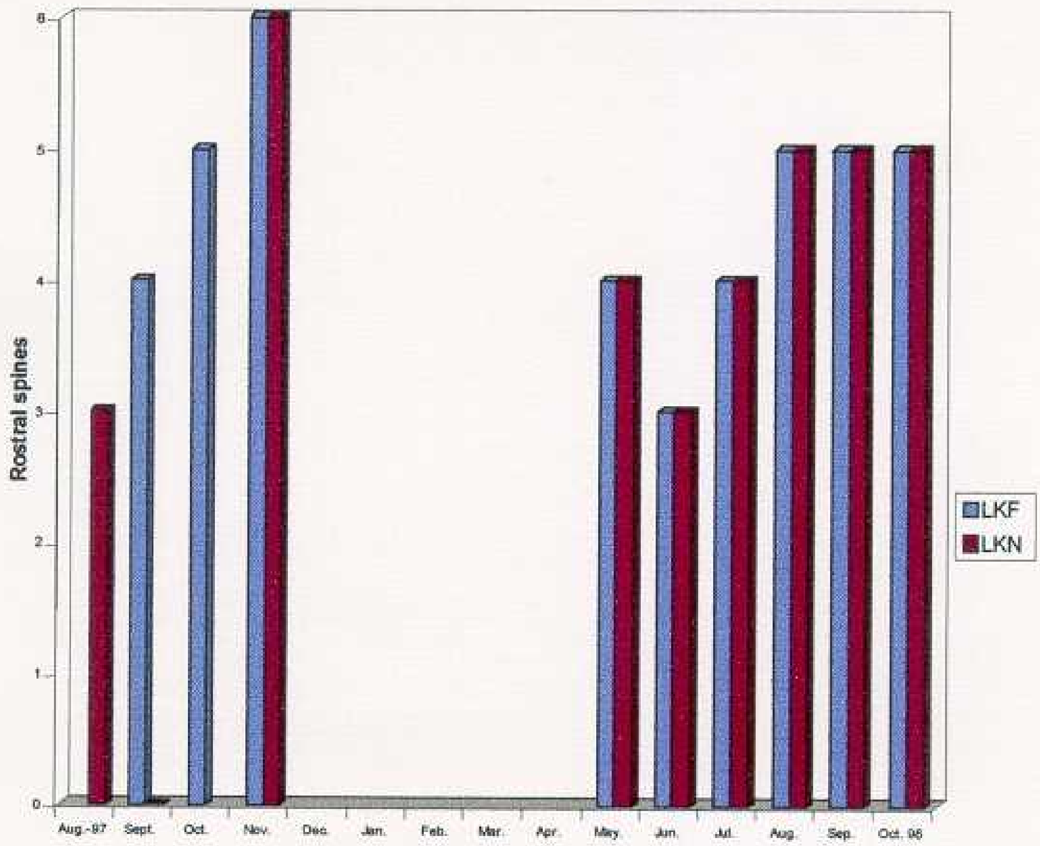


Figure 12. LKN and LKF. Monthly average rostral spines

LKN: Long Key Channel net near the bridge, (1mm).

LKF: Long Key Channel net farther from the bridge, (2 mm).

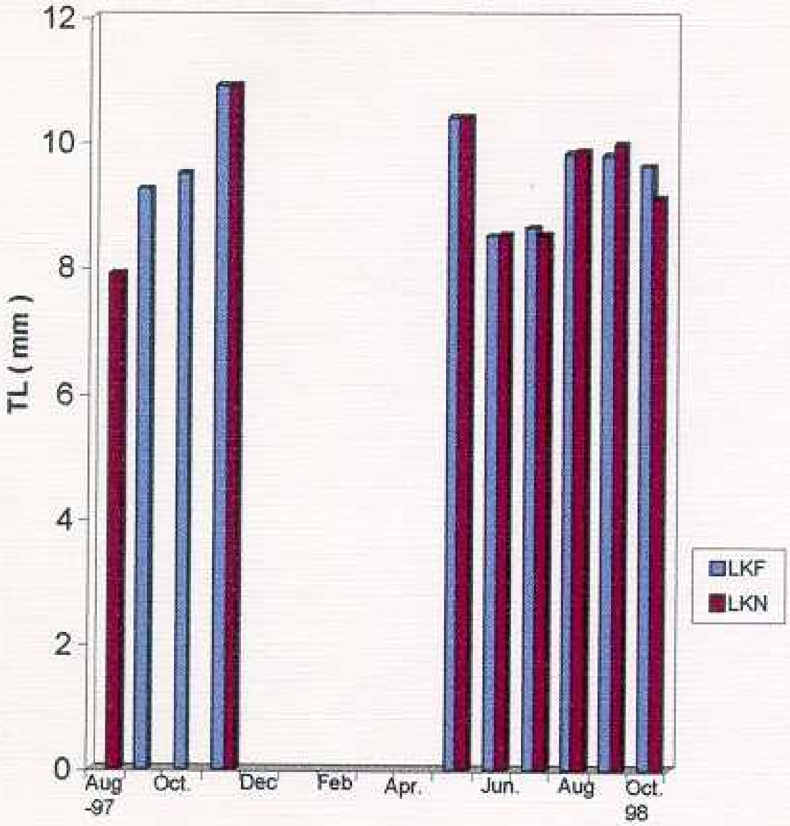


Figure 13. Monthly average in Total Length (mm).

LKN: Long Key Channel net near the bridge, (1mm).
LKF: Long Key Channel net farther of the bridge, (2mm).

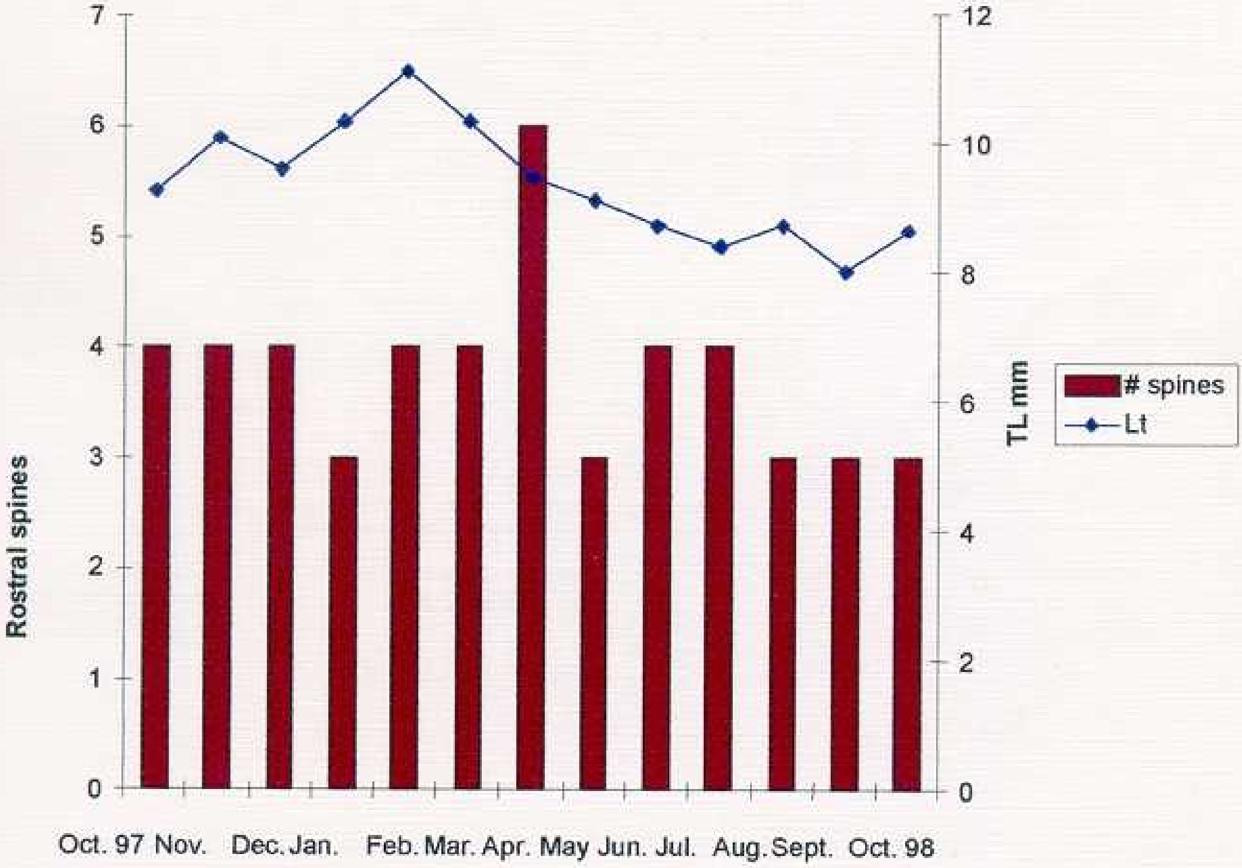


Figure. 14. WHN. Monthly Variation TL and rostral spines

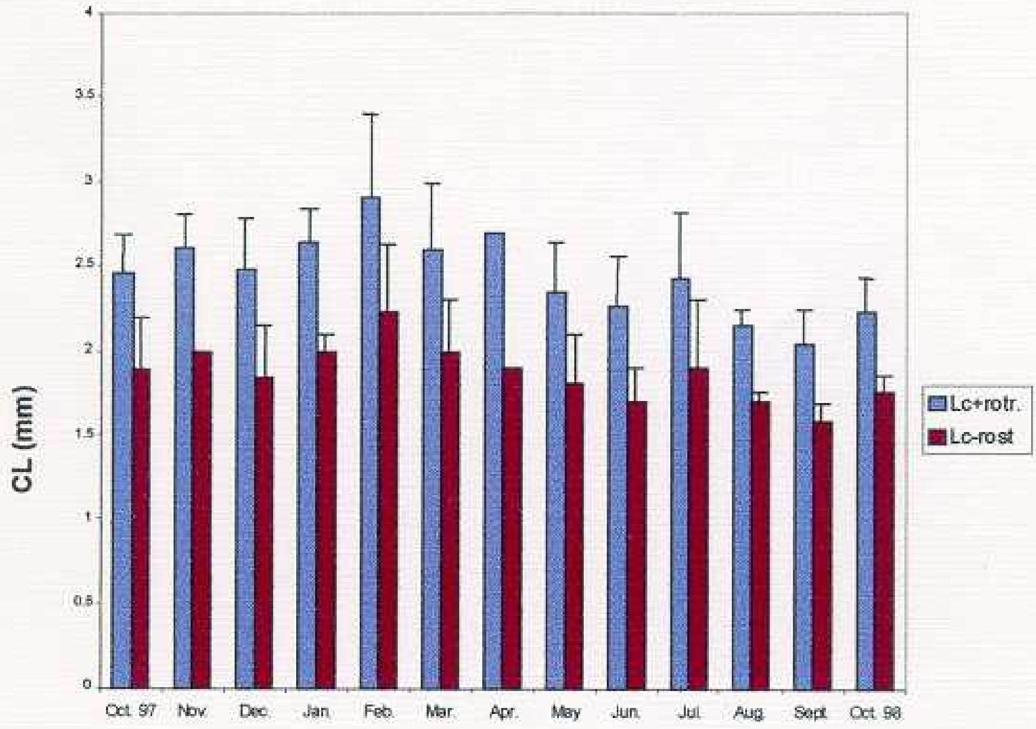


Figure 15. WHN. Monthly Average CL+ rostrum and CL - rostrum

CL: Carapace length

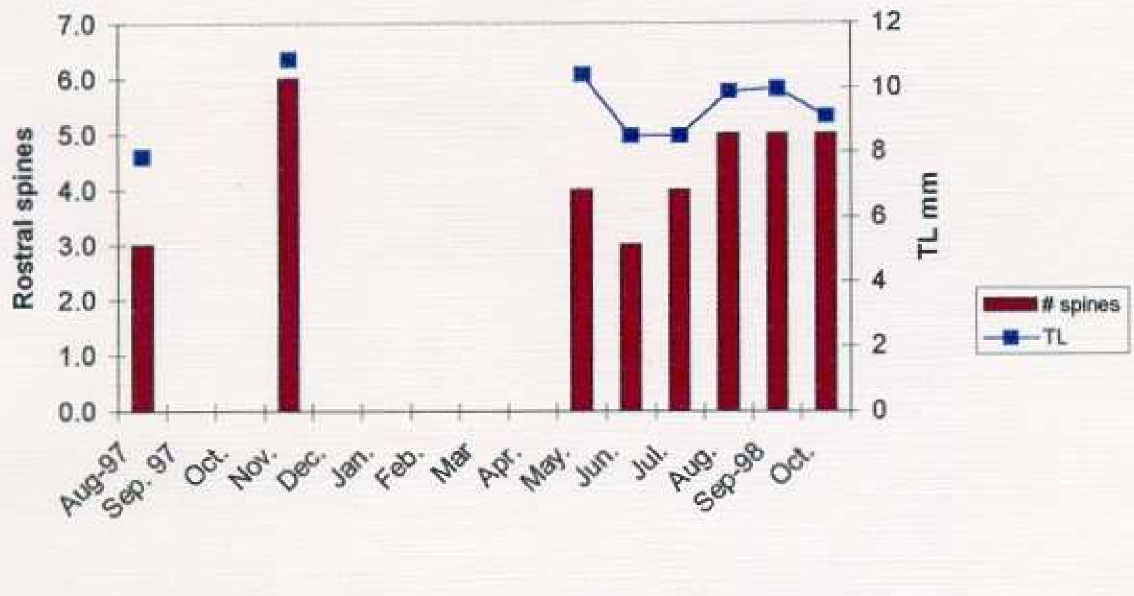


Figure 16. LKN Monthly Variation Rostral Spines and TL

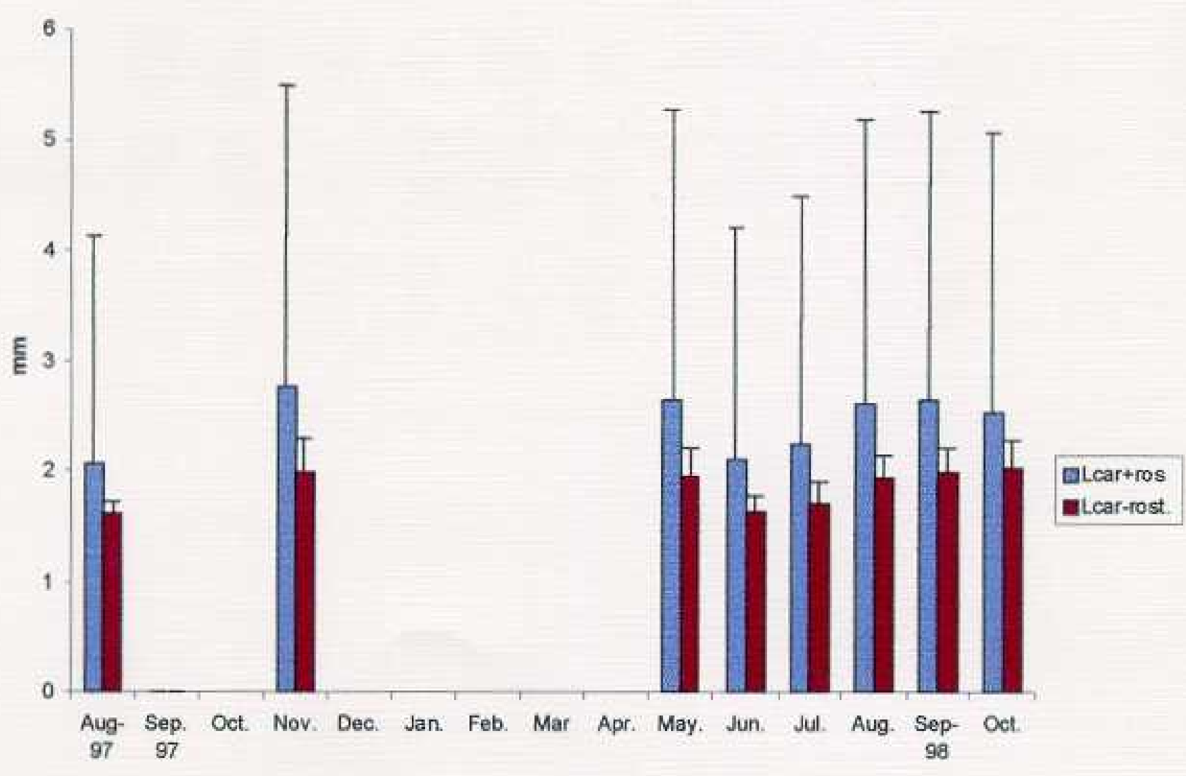
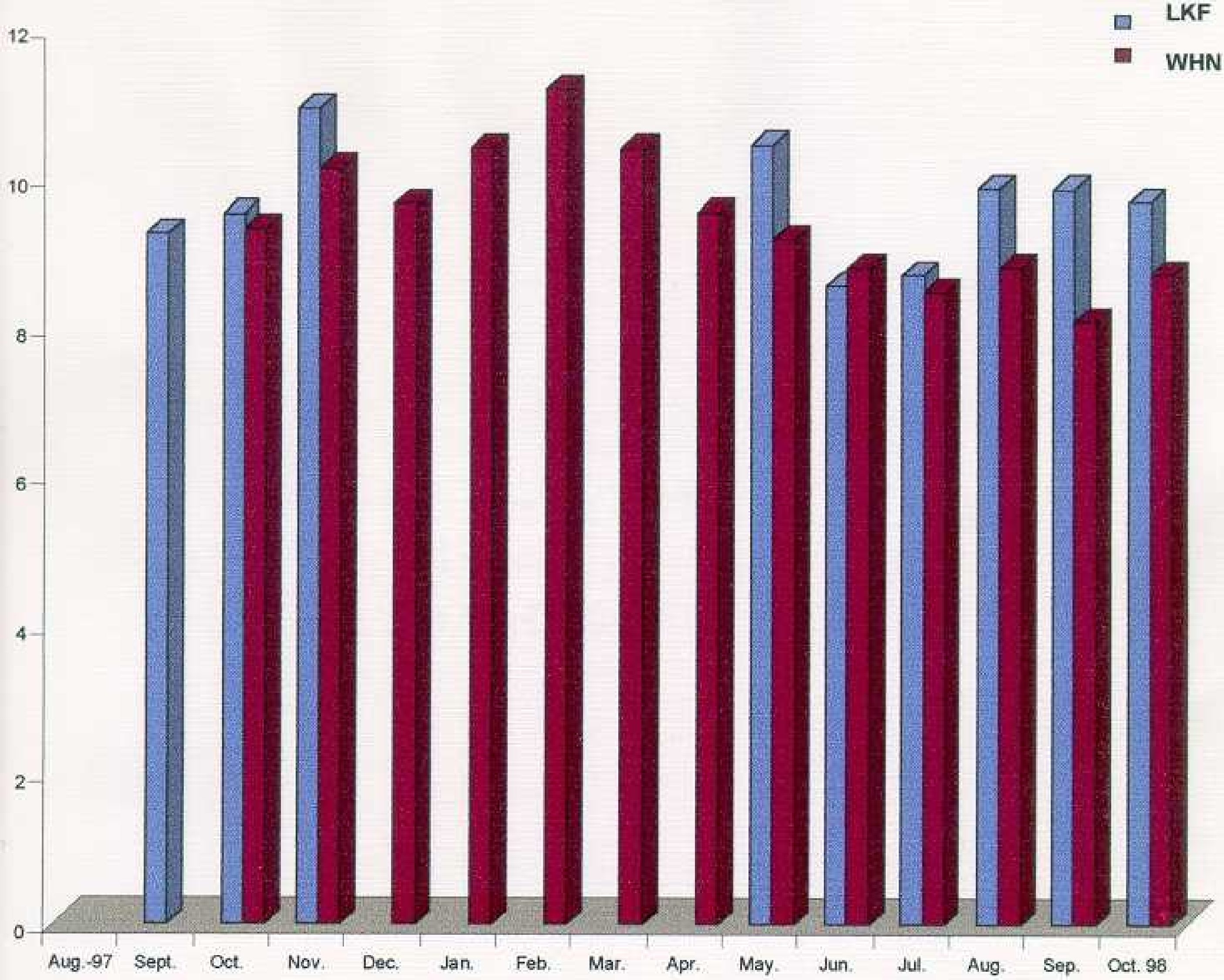


Figure17. LKN Monthly Average CL+rostrum and CL-rostrum



LKN: Long Key Channel near the bridge, (1mm)
WHN: Whale Harbor Channel near the bridge, (1mm)

Figure 18. LKN and WHN. Monthly Variation in Total Length (TL)

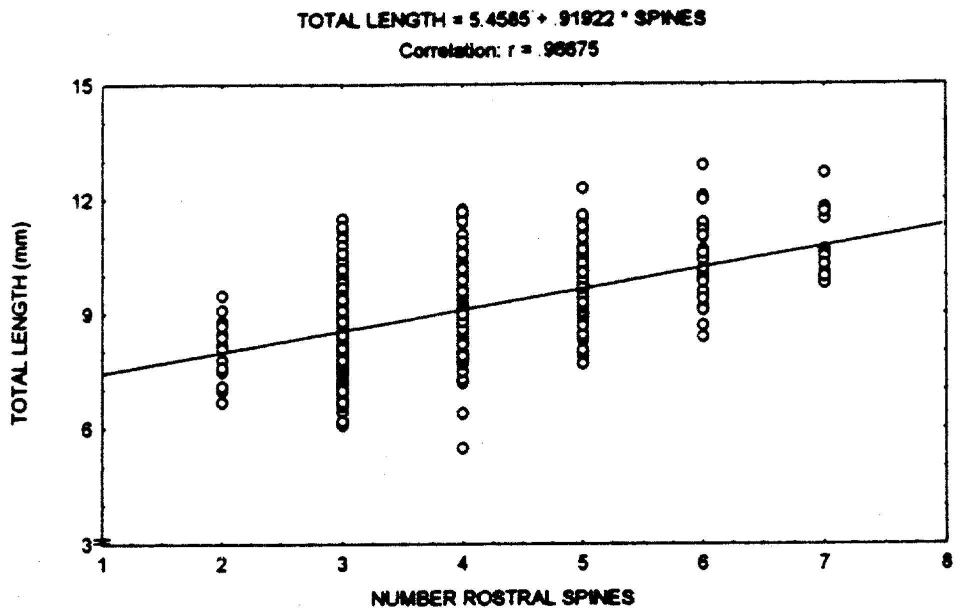


Figure 19. Correlation between Total length and number of Rostral spines

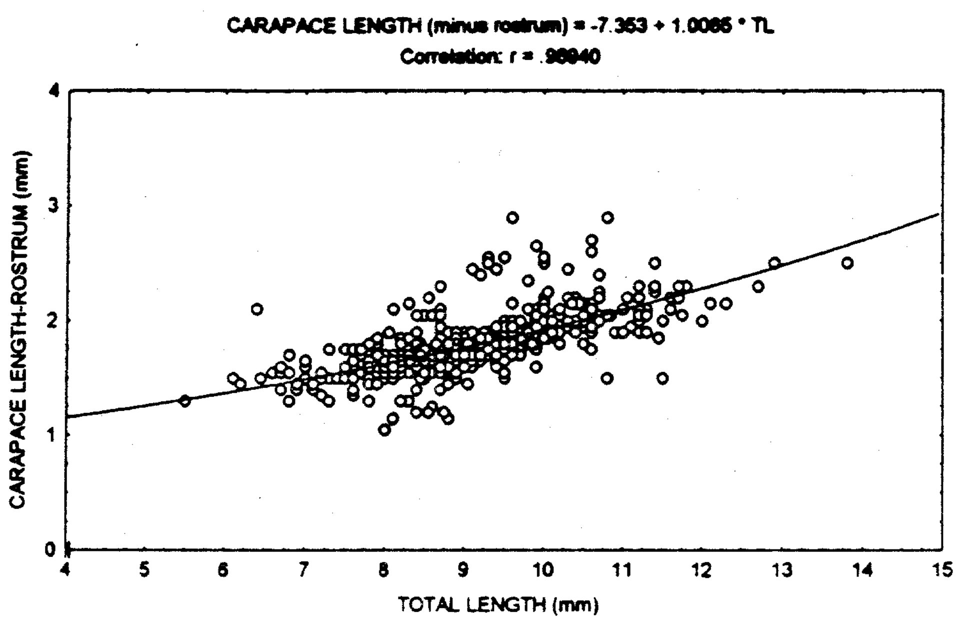


Figure 20. Correlation between Carapace length – rostrum and Total

length

Table 1. Average and Standard Deviation of four meristic characteristics of peneid postlarvae

	Average spines	STD	Total Length (mm)	STD	CL+rostrum (mm)	STD	CL – rostrum (mm)	STD
LKN	4	1	9.2	1.34	2.4	0.3	1.81	0.2
LKF	5	1	9.54	0.92	2.63	0.44	1.95	0.24
WHN	4	1	9.0	1.2	2.0	0.4	2.0	0.3
WHF	3	1	8.6	0.8	2.1	0.17	1.7	0.1
ALL	4	1	9.0	1.3	2.0	0.4	2.0	0.3

Table 2. Correlation between some meristic characteristics.

	Total length (mm)	CL + rostrum (mm)	CL – rostrum (mm)
Number of rostral spines	0.97	0.97	0.97
Total length	-	0.7	0.69

P < .05, n = 574

Table 3. Average of environmental parameters during the sampling period measured at Long Key station (SEAKEYS / C-MAN, NOAA)

Sample	Date	Wind Direction	Wind Speed (knots)	Sea surface Temperature (°C)	Postlarvae Log. (Post/1,000m3+1)
LKN 1	11-01-97	SSW	4.7	24.8	0.17
LKN 2	11-02-97	SSW	7.0	24.4	0
LKN 5	11-29-97	SSW	5.9	23.9	0
LKN 7	11-30-97	SSW	5.9	23.3	0
LKN 9	02-25-98	ESE	5.2	21.5	0
LKN 10	02-26-98	SSE	6.0	19.0	0
LKN 11	02-27-98	ESE	6.4	22.3	0
LKN 14	04-25-98	ESE	7.2	23.5	0
LKN 16	04-26-98	ESE	7.3	23.2	0
LKN 18	04-27-98	ESE	5.4	23.5	0
LKN 19	05-24-98	ESE	4.5	28.2	0
LKN 20	05-25-98	ESE	6.9	29.2	0
LKN 21	05-26-98	ESE	7.1	28.9	0.17
LKN 25	07-22-98	-	6.2	29.1	1.72
LKN 26	07-23-98	-	6.3	29.1	1.76
LKN 27	07-24-98	ENE	5.1	30.0	2.2
LKN 28	08-20-98	ESE	6.02	30.7	1.68
LKN 29	08-21-98	ENE	6.9	29.7	1.5
LKN 30	08-22-98	ENE	4.3	29.4	1.82
LKN 31	09-19-98	S	5.2	28.3	0
LKN 32	09-20-98	SSW	4.6	28.7	0.75
LKN 33	09-21-98	SSE	3.4	30.8	0.53
LKN 34	10-19-98	ESE	7.2	27.1	0.06
LKN 35	10-29-98	ENE	4.2	27.8	-