# Morphological Homogeneity of Shrimp *Farfantepenaeus notialis* (Pérez Farfante, 1967) in Colombian Caribbean Sea

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**ABSTRACT**

*Farfantepenaeus notialis* constitutes about 70% of the total shrimp catch in the Colombian Caribbean. In this study we examine morphological characteristics of *F. notialis* to investigate stock differentiation and discuss the importance of this information to fisheries management. The study was conducted in the Colombian Caribbean Sea from June to December of 2004 in four locations: the Uraba gulf (U), Morrosquillo gulf (M), Amansaguapos (AG), and La Vela cape (VC). Individual shrimp were measured according to ten body segments and sex determined. We used Non-metric Multidimensional Scaling (NMDS) ordination to generate two-dimensional plots of the morphometic indices between individuals of the different localities. The length-frequency distributions showed statistically significant differences between the measurements of both sexes, males were smaller than female in all measures. The NMDS of morphological differences between individuals (male/female) show strong overlapping and no clear separation between regions. We did not find morphometric variability between regions, which indicates a single population of *F. notialis*.

KEY WORDS: Shrimp; morphometric; Colombia

## Morfologica Homogeneidad del Camaron *Farfantepenaeus notialis* (Pérez Farfante, 1967) en el Mar Caribe Colombiano

*Farfantepenaeus notialis* constituye alrededor del 70% de las capturas totales de camarón de captura en el Caribe colombiano. En este estudio se examina las características morfológicas de *F. notialis* para investigar diferenciación de stocks y discutir la importancia de esta información para el manejo pesquero. El estudio fue realizado en el Caribe colombiano desde junio hasta diciembre de 2004 en cuatro localidades: el golfo de Uraba (U), golfo de Morrosquillo (M), Amansaguapos (AG), y cabo de la Vela (VC). Los individuos de camarón fueron medidos en diez segmentos del cuerpo y se determinó el sexo. Se utiliza Non-metric Multidimensional Scaling (NMDS) ordenación para generar gráficos en dos dimensiones de los índices morfométricos entre individuos de las diferentes localidades. Las distribuciones de frecuencia de longitud mostraron diferencias significativas entre las medidas por sexo, los machos fueron más pequeños que las hembras en todas las medidas. El NMDS de las diferencias morfológicas entre individuos (macho/hembra) mostro fuerte sobrelapamiento y no clara separación entre regiones. No se encontró variabilidad morfométrica entre regiones, lo cual indica una sola población de *F. notialis*.

PALABRAS CLAVES: Camarón, morfometría, Colombia

## L'Homogénéité Morphologique de la Crevette *Farfantepenaeus notialis* (*P*érez Farfante, 1967) dans la Mer des Caraïbes Colombiennes

*Farfantepenaeus notialis* constituent environ 70% des captures totales de crevettes dans les Caraïbes colombiennes. Dans cette étude, nous examinons les caractéristiques morphologiques des *F. notialis* pour enquêter sur la différenciation des stocks et discuter de l'importance de cette information à la gestion des pêcheries. L'étude a été menée dans la mer des Caraïbes colombienne de juin à décembre 2004 dans quatre lieux: le golfe d'Uraba (U), Morrosquillo Golfe (M), Amansaguapos (AG), et La Vela Cape (VC). Des crevettes individuelles ont été mesurées selon dix segments du corps et le sexe déterminé. Nous avons utilisé l'ordination Non-metric Multidimensional Scaling (NMDS) pour générer des parcelles bi-dimensionnelles des indices morphométiques entre les individus des différentes localités. Les distributions longueur-fréquences ont montré des différences statistiquement significatives entre les mesures des deux sexes, les mâles étaient plus petits que les femelles dans toutes les mesures. Le NMDS des différences morphologiques entre les individus (mâles / femelles) montrent un fort chevauchement et pas de séparation nette entre les régions. Nous n'avons pas trouvé la variabilité morphométrique entre les régions, ce qui indique une population unique de *F. notialis*.

MOTS CLÉS: Crevette, morphométriques, Caribe, Colombie

## INTRODUCTION

Penaeid shrimps inhabit tropical and subtropical shallow waters on the continental shelf (May-Kú *et al*. 2005), and constitute an important resource for fisheries near to the equatorial region (King 2007). The one to two year life cycle of a typical penaeid species is complex (Dall *et al*. 1990), involving the spawning of adults off the sea and larvae migration into the nursery regions which include coastal lagoons, mangroves, and estuaries (García and Le Reste 1987). The nursery regions provide food (Lee 1999, Loneragan and Bunn 1999) and refuge against predators (Minello and Zimmerman 1991). The migration is denominated estuarine phase that is when the post-larvae enters to the mouth of the rivers, remain until juvenile stage and then migrate toward the sea as sub-adults, characterized by quickly growth and continuous migration to adult area offshore (Dall *et al*. 1990). The migration comprises an estuarine phase when the post-larvae populations enter the mouths of the rivers, remain until the juvenile stage and then migrate toward the sea as sub-adults, and is a period characterized by quick growth and continuous migration (Dall *et al*. 1990). The pink shrimp *Farfantepenaeus notialis* is found in the Caribbean Sea from Quintana Roo Mexico to Río de Janeiro Brazil, and the west coast of Africa, from Mauritania to Angola (Carpenter 2002). The shrimp fishery in the Colombian Caribbean provides the most important source of economic activity in the continental shelf, significant employment and revenue is generated. The target species of this fishery are *Farfantepenaeus notialis* (Pérez Farfante 1967), *Farfantepenaeus brasiliensis*, (Latreille 1817), *Farfantepenaeus subtilis* (Pérez Farfante 1967) and *Litopenaeus schmitii* (Burkenroad 1936), with *Farfantepenaeus notialis* constituting ~70% of the total shrimp catch. The landings for the shrimp fishery in this region can be described as a typical unmanaged fishery (Hilborn and Walters 1992, King 2007). The development of this commercial shrimp fishery may be described in stages (Figure 1): Commercial exploitation of shrimp starts in the beginning of the 1970s, fishing effort (days of fishing) was less active but the catch rate (landings in tons) larger, thus the CPUE was significantly higher. As fishing effort increased in the beginning of the 1980s during the fully exploited stage, catches fluctuated and the CPUE showed a small decrease. An over -exploitation stage was reached about the mid 1980s when fishing effort and catch rate increased and during the first five years of the 1990s when CPUE, fishing effort and catch fluctuated. In 1990 fishing effort fell drastically, but was again increased in 1991 and the CPUE fell. In the collapse stage, catch rates fell drastically, but fishing stabilized by the end of 1990s and the CPUE decreased drastically. The recovery stage can be described as comprising the beginning of 2000 when fishing decreased as commercial fishers left the fishery activity, catches rates were significantly lower and the CPUE showed a small increase. Despite the importance of the shrimp fishery in the Colombian Caribbean, there is a lack of necessary information on the population dynamics in this region. For example in order to design sustainable management strategies, fishery managers in Colombia need to know whether they are dealing with single or multiple populations of *F. notialis*. In this study we examine the morphological variability of pink shrimp *F. notialis* with regard to stock differentiation which are vital to efficient fishery management.

Figure 1.

## MATERIALS AND METHODS

The morphometric study of pink shrimp (*F. notialis*) was conducted in the Colombian Caribbean Sea (Figure 2) from June to December of 2004 in four sample locations: Uraba gulf (U), Morrosquillo gulf (M), Amansaguapos (AG) and La Vela cape (VC).

Figure 2.

The pink shrimp were measured using ten segments of the body to the nearest 0.1 mm, total wet weight (W) to the nearest 0.01 g and sexes were determined (Figure 3): total length (TL), body length (BL), rostrum length (RL), first abdominal segment length (FSL), carapace length (CL), diagonal carapace length (DCL), first abdominal segment height (FSH), antennal spine width (ASW), hepatic spine width (HSW) and first abdominal segment width (FSW) (Tzeng *et al*. 2001, Tzeng and Yeh 2002).

Figure 3.

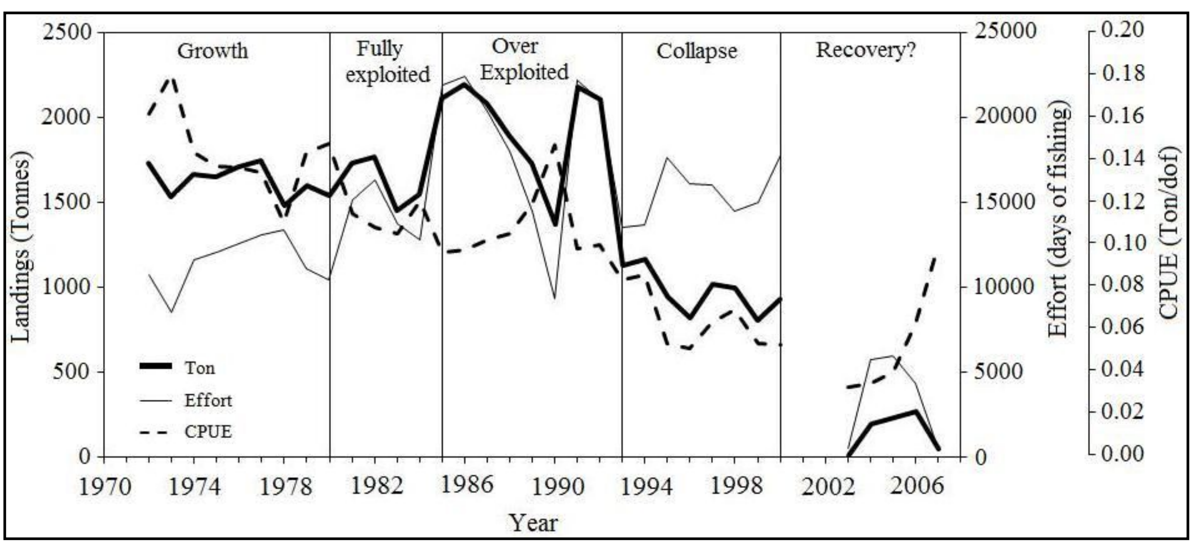


**Figure 1.** Development of shrimp fishery in Colombian Caribbean in stages (source: INDERENA, INPA and INCODER Colombian fisheries management institutes).

Five macroscopic maturity stages were determined visually:

i) Immature, translucent ovaries,
ii) In development, opaque ovaries,
iii) Almost mature, ovaries yellow orange color,
iv) Mature, very enlarged ovaries olive color sometimes brown, and
v) Spawned, empty ovaries.

The ANOVA One-Way was used to establish significant differences among sex (female and male) of each measurement, once the normality and homogeneity variance assumption were verified with the log-transformed data. We used the Hotelling's $T^2$ test for differences between means of CL by region for both females and males. Hotelling's $T^2$ is the multivariate extension of the common Student's t-test, which is used in multivariate hypothesis testing (Gotelli and Ellison 2004, Manly 2004). Measurements of the body were standardized using BL, which normalizes the individuals to the overall mean standard length to correct for correlation with body size (Tudela 1999, Salini *et al*. 2004, Pinheiro *et al*. 2005, Kristoffersen and Magoulas 2008). The measurement was adjusted by the following allometric equation

$\hat{Y} = aX^b$, such that the standardized value of this variable of an individual of size Xi is give by,

$$M_c = M_x \left[ \frac{\overline{BL}}{BL_i} \right]^b$$

Where: $\overline{BL}$ is the overall mean body length, b is the slope, within areas, on logarithms of Mx and BL.

This standardization normalizes the individuals in a sample to a single, arbitrary size, common to all samples, and maintains the individual variation (Tudela 1999). Morphometric characteristics were analyzed using multivariate analysis. We used Non-metric Multidimensional Scaling (NMDS) ordination to generate two-dimensional plots of the morphometic indices between individuals of the localities, because NMDS is robust in representing the high dimensional data as indicated by the stress values (Gotelli and Ellison 2004, Manly 2004, Sin *et al*. 2009). Analysis of similarity (ANOSIM) (Clarke 1993) was carried out to test the degree and significance of differences between groups in terms of morphometric indices in the NMDS plot. ANOSIM output is a test statistic (R) that is equal to 1 if all individuals within regions are more similar to each other than to any individual in another region and 0 if there is no difference between regions. Then, we calculated the percentage contribution of each morphological measure to the overall difference between regions by means of the Similarity Percentages (SIMPER) procedure (Gotelli and Ellison 2004).

## RESULTS

A total of 1094 specimens of *F. notialis* were measured between June and December of 2004: 44 individuals from Uraba (28 female, 16 male), Morrosquillo 385 individuals (159 female, 226 male), Amansaguapos 160 individuals (97 female, 63 male) and La Vela cape 505 individuals (283 female, 222 male). The length-frequency distributions for each morphometric measurement are illustrated separately for each sex (Figure 4). Statistically significant differences (ANOVA test) between the measurements of both sexes were found (Figure 4), revealing sexual dimorphism ($p = 0.00$) in all morphometric characters characteristics, the males were smaller than females in all measurements.

The CL showed an increase in size with a decrease of

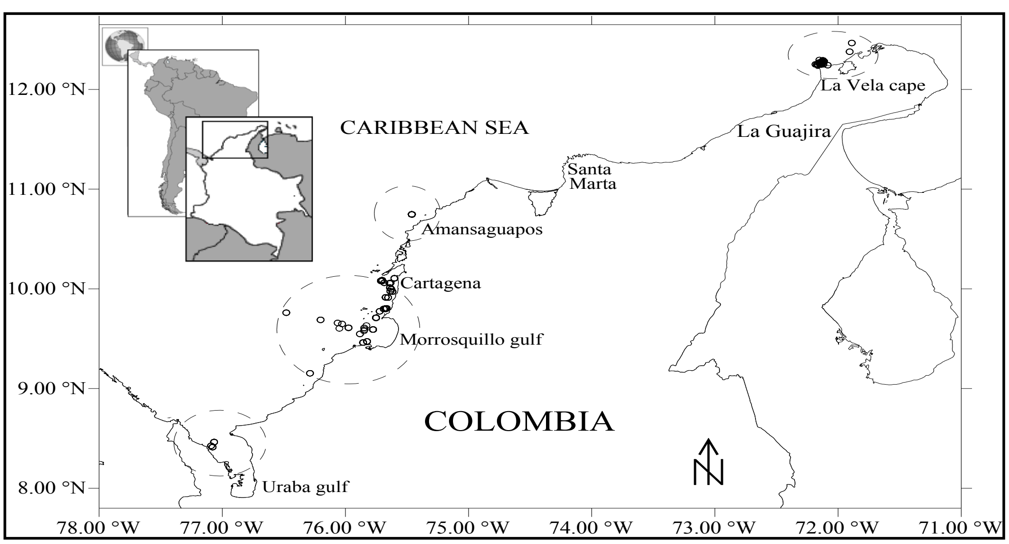


**Figure 2.** Locations in Colombian Caribbean Sea where pink shrimp (*F. notialis*) samples were obtained: Uraba gulf (U), Morrosquillo gulf (M), Amansaguapos (AG) and La Vela

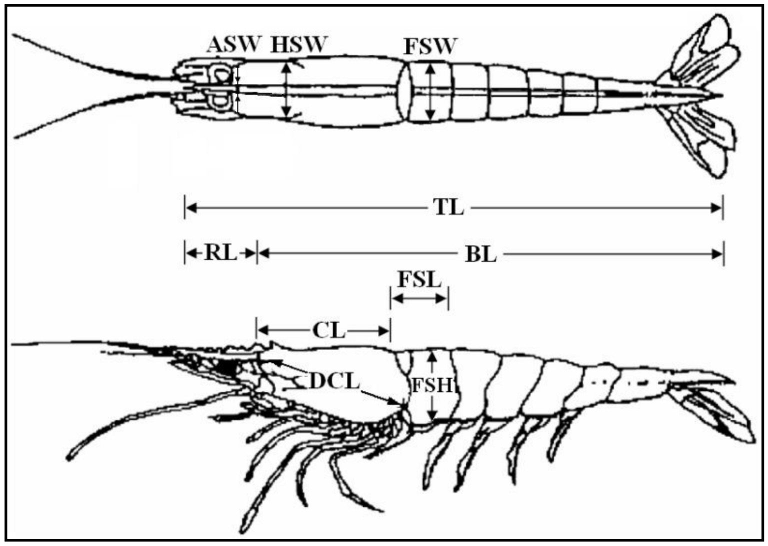


**Figure 3.** Diagram of a pink shrimp showing the body segments measured (Tzeng et al 2001).

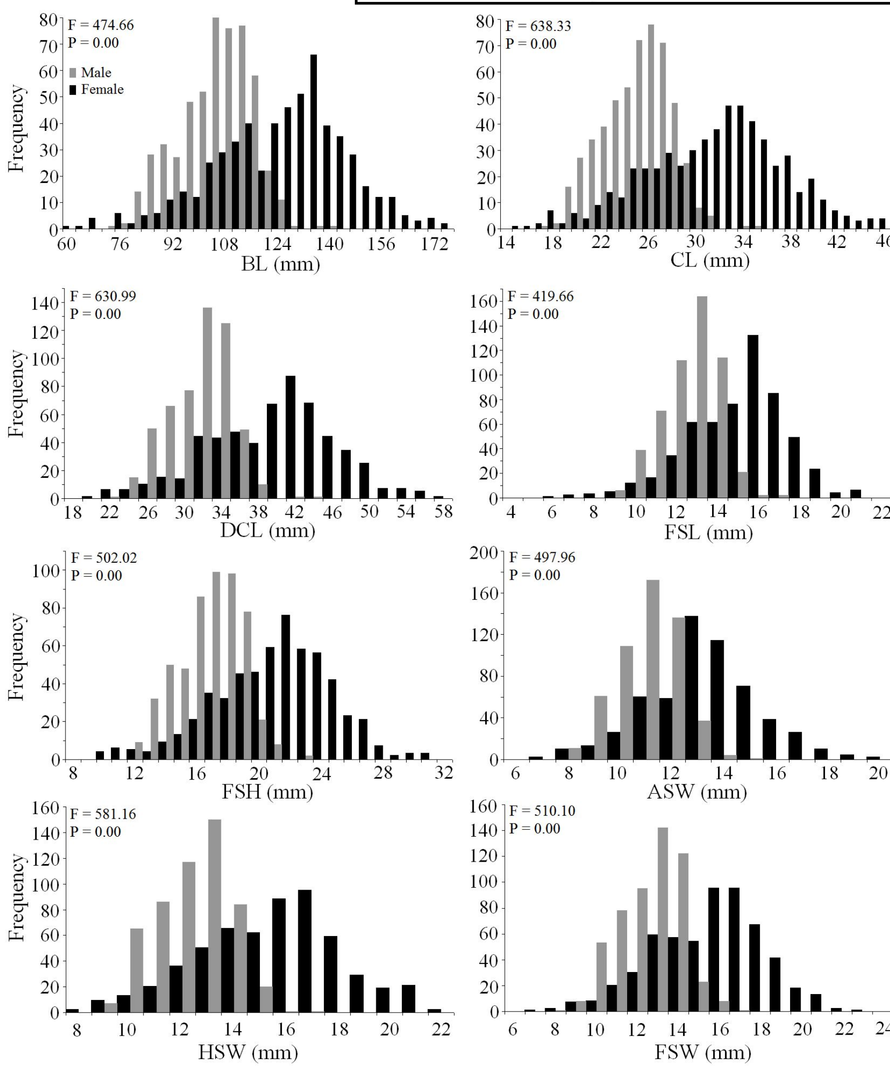


**Figure 4.** Histogram of the morphometric body parts measured (mm) by sex for *F. notialis*. One way ANOVA test (F value and p value) for differences between the two sexes for each measurement.

latitude (Figure 5), the larger individuals were found mainly in the south of the study area (Uraba, Morrosquillo and Amansaguepos) and otherwise smaller individuals were located more towards the north of the Colombian Caribbean (La Vela Cape in La Guajira region). The CL of the females differs significantly between the regions La Vela Cape, Uraba and Morrosquillo, but does not differ significantly for males between Uraba and Morrosquillo (Table 1).

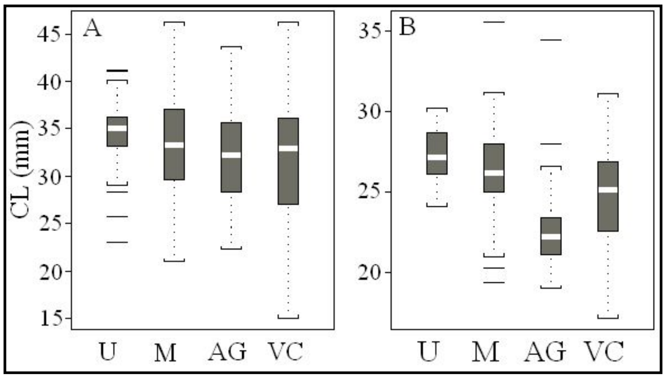


**Figure 5.** Box plot of the CL discriminated by regions for female (A) and male (B) of *F. notialis*

**Table 1.** Hotelling's $T^2$ test for differences in CL by region according to sex for *F. notialis*. * = p < 0.001.

| Group | CL Female | CL Male |
|---|---|---|
| U – M | 0.42 | 0.17 |
| U - AG | 0.08 | **0.00*** |
| U - VC | **0.01** | **0.00*** |
| M - AG | 0.10 | **0.00*** |
| M - VC | **0.00*** | **0.00*** |
| AG - VC | 0.35 | **0.00*** |

A total of 570 females were analyzed to determine different maturity stages, were 42.98%, corresponds to immature and the mature to 57.02% of the total. Figure 6 shows NMDS for *F. notialis* females which illustrates variability in stages of maturity; and depicts differences in levels of maturity by morphometric measurements. The plot shows that all maturity groups are similar, the Global R is 0.01 (p = 0.87) which means that there is no difference between maturity stages. The ANOSIM (R and P) (Table 2) for maturity group shows that all groups had lower values of R, close to zero and the SIMPER (SIMilarity PERcentages) routine (Average disimilarity) shows just < 1.35% of disimilarity. This analysis demonstrates that maturity stages of females did not confound the morphometric differentiation in *F. notialis*.

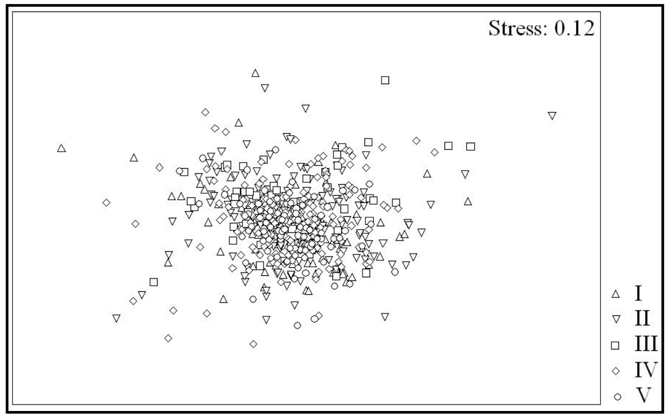


**Figure 6.** Non-metric Multidimensional Scaling (NMDS) plot on the morphometric indices of *F. notialis*, grouped according stages of maturity for females.

The NMDS for both males and females (Fig. 7) show a global R close to zero, meaning there is no significant difference (p = 1.00). The multivariate analysis of morphological differences between the male and female individuals shows a strong overlapping and no clear separation between the regions: Uraba (U), Morrosquillo (M), Amansaguapos (AG) and la Vela cape (VC). Also, all R values between regions (Table 3) for males and females are close to zero (p > 0.28) and the SIMPER analysis shows the average dissimilarity is very low.

**Table 2.** Results of ANOSIM and SIMPER to test differences between stages of maturity for females of *F. notialis*. * = p < 0.001.

| | ANOSIM | | SIMPER |
|---|---|---|---|
| Maturity group | R | P | Av. Dissimilarity |
| I – II | 0.03 | 0.90 | 1.32 |
| I – III | 0.05 | 1.00 | 1.32 |
| I – IV | 0.06 | 0.98 | 1.27 |
| I – V | 0.07 | 1.00 | 1.13 |
| II – III | 0.01 | 0.66 | 1.29 |
| II – IV | 0.01 | 0.92 | 1.24 |
| II – V | -0.04 | 0.00* | 1.14 |
| III – IV | 0.04 | 0.86 | 1.23 |
| III – V | 0.12 | 1.00 | 1.13 |
| IV – V | -0.05 | 0.00* | 1.07 |

## DISCUSSION

Knowledge of stock structures of a species is a basic prerequisite for effective and successful management of a fishery as well as to be able to implement rebuilding programs in collapsed fisheries (Begg *et al*. 1999, King 2007). A stock is considered to be a group of individuals with unique phenotypic attributes, but sexual dimorphism, timing of sampling, allometric growth, and the state of maturity may confound the morphological relationships (Tzeng *et al*. 2001). The samples analyzed in this study showed different stages of maturity for females. However, in this case the maturity does not seem to have affected the patterns of similarity between the samples in the NMDS analysis. The analysis demonstrates that the morphometric indices are not affected by the particular stage of maturity

**Table 3.** Results of ANOSIM and SIMPER to test differences among localities males and females of *F. notialis*.

| Region group | ANOSIM | | | | SIMPER | |
|---|---|---|---|---|---|---|
| | R (F) | R (M) | P (F) | P (M) | Av. Diss. (F) | Av. Diss. (M) |
| U - M | -0.01 | 0.22 | 0.47 | 1.00 | 1.13 | 1.18 |
| U - AG | -0.04 | 0.05 | 0.28 | 0.70 | 1.34 | 1.38 |
| U - CV | 0.05 | 0.20 | 0.80 | 0.99 | 1.15 | 1.28 |
| M - AG | 0.18 | 0.23 | 1.00 | 1.00 | 1.39 | 1.22 |
| M - CV | 0.03 | 0.02 | 0.97 | 1.00 | 1.15 | 1.05 |
| AG - CV | 0.22 | 0.18 | 1.00 | 1.00 | 1.35 | 1.26 |

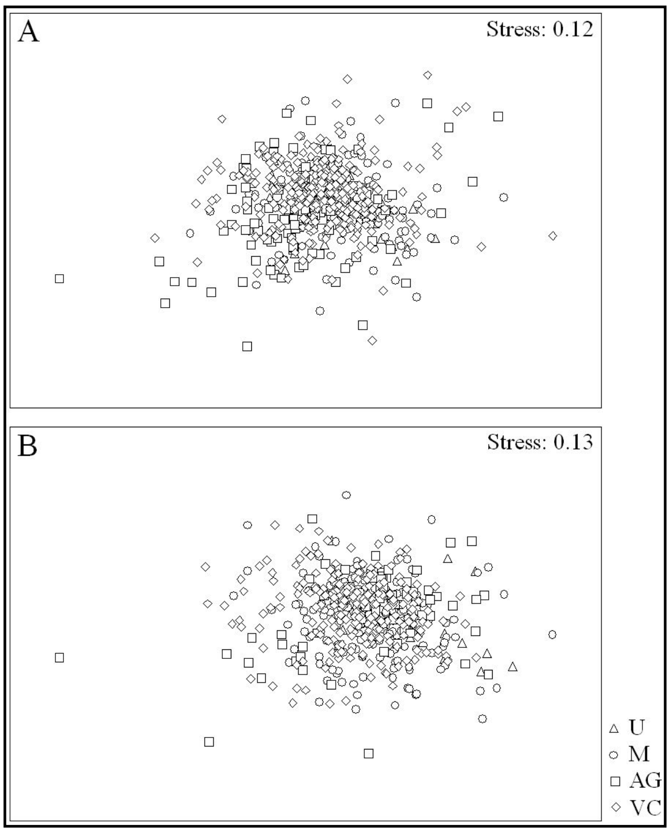


**Figure 7.** Non-metric Multidimensional Scaling (NMDS) plot on the morphometric indices of *F. notialis*, grouped according to localities for A) female and B) male.

of the female. Regional environmental factors (i.e. upwelling) tend to influence the phenotypic characteristics (Swain and Foote 1999, Begg and Waldman 1999, Kristoffersen and Magoulas 2008). Different regions show different sizes, the northern shrimps of *F. notialis* are smaller than from the south, and this characteristic is possibly influenced by the increase of temperature southward of the study area. However, the morphometric similarity of individuals of *F. notialis* along the Colombian Caribbean Sea seems to indicate that environmental conditions did not induce different morphologies in individuals of different localities. Morphometric data of *F. notialis* showed a great homogeneity between different geographical regions, indicating the existence of a single population along the Colombian Caribbean Sea from the morphometric point of view. With this work we provide the first complete view, to this date, of the pink shrimp *F. notialis* stock structure and fishery dynamics, based on morphometric, historic landings and biologic data in the Colombian Caribbean Sea. The identification and knowledge of shrimp stock must be based on more than a single methodology and should comprise other stock identification approaches such as life-history (rate growth, recruitment, etc) and genetic analysis (Begg and Waldman 1999, Cadrin 2000). The shrimp fishery in the Colombian Caribbean is a typical case in which high exploitation, combined with non-existent fisheries management, have resulted in the significant depletion of shrimp stock. It has been seriously negatively impacted by overfishing, where spawning stock is also reduced to a level in which the number of recruits produced is insufficient to maintain the population. Additionally, due to the low levels of spawning stock, reproduction and survival is reduced (Allee effect) by the inability to find mates, to resist predators or to withstand environmental fluctuations (King 2007). To aid in the recovery of this shrimp fishery, the task to be carried out in the near future is a direct stock assessment and fishing management should be directed towards maintain fishing effort until spawning populations show signs of full recovery.

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