# A Perspective on the Implications of USA Fisheries Policies on the Belize Fishing Industry

BEVERLY A. WADE[1] and E.A. ARIOLA[2]
*Belize Fisheries Department*
*Ministry of Agriculture, Fisheries and Cooperatives.*
*Princess Margaret Drive*
*Belize City, Belize*
[2]*Coastal Zone Management Authority and Institute*
*Princess Margaret Drive*
*Belize City, Belize*

ABSTRACT

The fishing industry in Belize contributes significantly to the country's national economy. In the year 2000, the fishing industry ranked as the fourth highest foreign exchange earner in Belize and contributed approximately 6% to the Gross Domestic Product. Total earnings amounted to 71.8 million Bze dollars of which the capture fisheries sector valued 24.3 million Bze dollars and the shrimp mariculture sector 47.5 million Bze dollars. This industry is considered to be successful and lucrative mainly because it has been able to maintain very high quality products and access to foreign markets through well-organized fishing cooperatives. Fisheries and other related policies of the United States of America over the years have influenced and thus impacted the fishing industries in Belize and the Caribbean, particularly in the aspects of trade and the development of traditional fisheries. As a result, several of Belize's fisheries policies and enabling legislations have been structured to make the most of US and other available markets. Compliance with policies formulated or supported by the US, have also highlighted Belize's political will to support the global efforts in the sustainable management of fisheries stocks and the conservation of endangered species. This in return has increased Belize's eligibility for foreign aid to facilitate its own national efforts in fisheries management. While acknowledging the aforementioned benefits, the challenges that confront Belize in adopting U.S policies should not be overlooked. The implementation of these policies has had some negative impacts on the fishing industry due mainly to financial and human resource constraints of the fishing cooperatives and Government of Belize for institutional strengthening and capacity building. It must also be noted that compliance with these policies have led to negative cultural consequences such as the restriction and in some instances the prohibition of traditional fishing for certain species.

KEY WORDS: Fishing industry, fisheries policies, fishing cooperatives

# Una Perspectiva Sobre las Implicaciónes de las Políticas de Pesquería Estadounidense Sobre la Industria Pesquera de Belíce

En el año 2000, la industria pesquera de Belíce se calificó en cuarto lugar con respecto a otros sectores en cuanto a la ganancia de divisas y contribuyo aproximadamente 6% al producto nacional bruto. En total se generó 71.8 millones de dólares Beliceña del cual 24.3 millones de dólares se atribuye a la pesca de captura y 47.5 millones de dólares al maricultura de camarón. La pesquería tiene éxito y se considera lucrativa principalmente porque mantiene alta calidad de productos y a la vez mantiene acceso a los mercados extranjeros a través de las cooperativas pesqueras. La política Estadounidense sobre pesquerías ha influenciado é impactado las industrias pesqueras de Belíce y el Caribe particularmente en los aspectos de comercio y el desarrollo de pesquerías tradicional. Como consecuencia de esto, algunas políticas y legislaciónes sobre pesquerías en Belíce han sido estructurada para tomar ventaja de los mercados en los Estados Unidos como en otros países. El hecho de que Belíce cumple con las políticas establecidas o apoyadas por los estados unidos manifiesta su voluntad política para apoyar los esfuerzos globales en el manejo sustentable de las pesquerías y en la conservación de las especies en peligro de extinción. A su vez, esto ha aumentado la elegibilidad de Belíce para ayuda exterior para facilitar su propio esfuerzos nacionales en el manejo de la pesca. Mientras que se reconoce los beneficios mencionados anteriormente, es muy importante reconocer los retos con los cuales Belíce es enfrentado por adoptar las políticas Estadounidense. La implementación de estas políticas ha demostrado impactos negativos en la industria pesquera debido a los constreñimientos económicos y de recursos humanos de las cooperativas pesqueras y el gobierno de Belíce para fortalecimiento institucional y de capacidades. Además, al cumplir con las políticas ha dado raíz a consecuencias culturales negativas tales como la restricción y en algunos casos la prohibición de pesca tradicional para algunos especies.

PLABRAS CLAVES: Pesqueria de Belice, coopertivas

## INTRODUCTION

Belize is located in the Western Caribbean just below the Yucatan Peninsula of Mexico and is bordered on the west and south by Guatemala (Figure 1). Belize has been blessed with numerous coastal resources, which have provided sustenance and an economic foundation for its human population. The most striking feature is the longest barrier reef in the Western hemisphere that supports a thriving fishing industry.


Figure 1. Belize barrier reef system

The Fishing Industry contributes significantly to the economy of Belize mostly from exports of lobster, conch, and shrimp. The Fisheries Sub-sector contributed 6% to Belize's Gross Domestic Product (GDP) in 2000. Export statistics for the year 2000, reflected earnings valued at Bze $71.8 million with lobster contributing Bze $18.8 million, conch Bze $4.86 million and marine farmed shrimp Bze $47.5 million (Appendix 1).

The sector is characterized as a commercially artisanal industry except for the industrial trawl fishery for shrimp. The artisanal fishing fleet is composed of open boats, sail sloops, and canoes. The industry is considered to be lucrative and successful mainly because of the good prices obtained on the foreign market and because most fishermen belong to one of the four main cooperatives. They play a dominant role in the industry and are entirely owned by local investors and fishermen that are the main shareholders.

The Belize Fishing Industry has been successful because of its ability to adapt to both local and global changes thus allowing it to capitalize on the benefits of certain policies and maintain the level of operations and activities in the sector necessary for its continued growth. It is envisaged, however, that the proliferation of more robust policies geared directly or indirectly towards the sector could have profound implications on the integrity and continued success of the fishing industry.

## Legislative and Management Framework

The laws governing the fisheries sector in Belize dates back to September 24, 1948. Through subsequent amendments, the Fisheries Ordinance, Chapter 133 of the laws of Belize, 1948 was consolidated into the Fisheries Ordinance, Chapter 174 of the laws of Belize, 1980. Since then further amendments have led to the current Fisheries Ordinance, Chapter 210 of the laws of Belize, Revised Edition 2000. Complimentary to the Fisheries Ordinance is the Fisheries Regulations, 1977 that has undergone several amendments with the most recent being the Fisheries Regulations of 1999.

The Belize Fisheries Department, Ministry of Agriculture, Fisheries, and Cooperatives was established in 1965. The department is responsible for administration and management of the fisheries resources in Belize. This mandate is guided by the principal objective to develop clear research policies and adequate, relevant, and systematic research and monitoring programs to generate information for policy formulation and decision-making. The Fisheries Advisory Board (FAB) comprised of fishermen and representatives of government and non-governmental organizations serve as an advisory body to the Minister of Agriculture, Fisheries, and Cooperatives. This body is very important and strong since it establishes the much needed check and balance between the bureaucratic Government of Belize (GOB) and the major stakeholders of the industry. Their presence and participation on the board gives direction to the fishing industry and sector.

**The Belize Fishing Cooperatives**

The Belize Fishing Cooperatives could be regarded as one of the few true grassroots businesses in Belize. They are owned and managed by the fishermen who make up their membership. The primary objective of the Fishing Cooperatives is "to promote the economic and cultural welfare of its members by providing procedures and means for the efficient production, distribution, processing and sale of marine products through the united efforts and funds of its individual members" (Cooperatives of Belize By-Laws 1968).

Approximately 75 % of all full-time fishermen in Belize are members of one of the four Fishermen's Cooperatives, Northern, National, Placencia, and Caribeña or the recently formed Toledo Fishermen Cooperative. These cooperatives purchase, process, and export fisheries products on behalf of the fishermen making them direct beneficiaries of the benefits from sales.

The Fishing Cooperatives are considered the backbone of the fishing industry since they themselves have invested much of their earnings back into their operations, upgrading their facilities, and providing services to members and the communities. Furthermore, the fishing cooperatives are the businesses that provided the initial capital investments into the productive sectors of the communities of San Pedro, Ambergris Caye, Caye Caulker, and Placencia that are presently the most popular tourist destinations in the country.

Since their inception in the 1960s, the fishing cooperatives have advanced significantly the Belize Fishing Industry (Gordon 1986) and have thus become very important in the Belizean economy. Prior to the establishment of the cooperatives there were approximately 600 full-time fishermen. The number of fishermen escalated to 800 by the mid 1970s and subsequently to 3,000 in the year 2000. Concomitantly, in 1955 the total catch was 260,924 kg valued at Bze $191,635, and in 1979 the total catch was 534,061 kg valued at Bze $7,938,390 (Gordon 1986). In the year 2000, the Belize Fishing Cooperatives exported Bze $24,300,000.00 worth of seafood products.

**Impact of Fisheries Policies on the Belize Fishing Cooperatives**

The major success of the Belizean Fishing Cooperatives can be attributed directly to their ability to negotiate better markets and thus attain better economic yields for their marine products. In December 1995, the Hazard Analysis Critical Control Point (HACCP) became mandatory in Belize. This is an American food safety system that has been endorsed worldwide by many of the major importing countries, such as the European Union, Canada, Australia, Japan, Mexico, and most of the Caribbean and Central American countries. The Codex Alimentarius of the Food and Agriculture Organization has also given its endorsement to this food safety system.

Compliance with HACCP have allowed Belizean cooperatives to continue to compete and obtain access to lucrative markets while at the same time maintain its reputation of being the source of very high quality seafood products. However, HACCP has placed a significant strain on the cooperatives, considered as the corner stones of the Belize Fishing Industry. In addition to significant capital costs to gain HACCP certification, processors continue to experience significant financial outlays for renovations to their processing facilities in order to meet the required standards and maintain access to the markets they are dependent on. HACCP also gives more responsibility to the producers as it requires substantial investments in capacity building for personnel directly involved in processing. This also includes an additional increase in human resources by the Government of Belize for the training of such personnel in order to deliver essential services to the fishing cooperatives and to ensure proper monitoring and compliance with HACCP.

The queen conch, *Strombus gigas,* is the second most important marine species fished in Belize and is the second largest capture fishery. It is exported and distributed to the local market primarily by the Fishing Cooperatives. The queen conch is currently listed on Annex II of the Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES). Paragraph 2 (a) of this convention states that:

> "All species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subjected to strict regulation in order to avoid utilization incompatible with their survival".

Regulation of trade of the queen conch requires exporting countries to implement management measures such as quotas that have direct bearing on the future development of this traditional fishery in Belize. This in turn places an added challenge to the fishing cooperatives and the fishing industry in adapting to a possible reduction in the level of exploitation allowable for this species, which has been one of their main export commodities and is important to their economic stability.

Belize has also been able to reap the benefits of access to markets in the United States as a result of its compliance with other policies directly related to its fishing industry. On an annual basis, the Government of the United States certifies Belize to export captured shrimp to major importers. However, this certification is based on the condition that the trawlers operating in Belize (by the cooperatives) utilize a Turtle Exclusion Devise (TED). As a result, the Belize Fisheries Department, Ministry of Agriculture, Fisheries, and Cooperatives have made it a policy that TEDS are a requirement for the granting of a license to trawl in the waters of Belize. This policy is also currently in a draft statutory instrument awaiting approval and signature by the Minister of Agriculture, Fisheries, and Cooperative.

**Implications of International Agreements and Policies**

Belize's local policies towards the conservation of biodiversity through the sustainable management of its natural resource and the protection of unique and critical ecosystems and species has resulted in it being perceived as one of the leaders in the conservation of the worlds environments. Belize is also party to several international agreements and commissions including the 1982 United Nations Convention on the Law of the Sea (ratified on 13th August 1983), the Convention on International Trade in Endangered Species of Wild Flora and Fauna (ratified on 19th August 1976) and the Western Central Fisheries Commission (member since 1985) directly relevant to the environment and the Belize Fishing Industry.

As a result of this image, Belize has become eligible for substantial funding and resources to aid and facilitate its local efforts in the continued and successful conservation and management of its fisheries and other marine resources. Government and the Non-Governmental Organizations (NGOs) have received tremendous support with both financial and human resources for programs geared towards the conservation and management of these resources. Approximately 90 - 100% of most environmental NGOs' programs and supporting budgets are funded by international funds. Belize's recognition and acceptance by the international community also plays an important role when negotiating matters corresponding to other sectors. However, the adoption, implementation and compliance with these international agreements, commissions and policies have posed several challenges to Belize for instance:

i) *The Restriction and Prohibition of Traditional Fishing* — In 1996, Belize became party to the World Heritage Site Convention that resulted in the declaration of seven marine sites as world heritage sites (Appendix II). These seven sites include areas that were considered as important traditional fishing areas that fishermen are now either prohibited from fishing today or restricted with regards to the traditional fishing activities they once engaged in these areas. As a result the management of these areas have been met with great opposition and challenges. Fishermen in some areas such as the Blue Hole Natural Monument and the Half Moon Caye Natural Monument have been restricted from exploiting productive conch areas that have been fished traditionally by their last four generations. This prohibition or restriction has also led to the reduced access to certain species and thus traditional fisheries exploited by fishermen. Considering that fishing by different communities is usually area specific, some fishers restricted from fishing certain species from one area of the country will seldom move to another area to gain access to those species. Quite often, this is not an economically feasible option and is dependent on the type and scale of fishing activity traditionally engaged in by fishermen. In addition to this, fishermen have lost economic benefits from the sale of unique products derived from restricted species. Examples of these include but are not limited to jewelry and ornaments crafted from corals and the hawksbill turtle shell.

ii) *Cultural Implications* — In subscribing to agreements such as the Inter American Convention for the Protection and Conservation of Marine Sea Turtles and CITES, the commercial and subsistence fishing of marine sea turtles in Belize have been subjected to restrictive measures and, for the hawksbill turtle, totally prohibited. The hawksbill turtle and the other marine sea turtle have been a resource traditionally fished by several of our local Belizean ethnic groups, such as the Garífuna (culture of whom was proclaimed a Heritage to Humanity by UNESCO 2001), the Mestizos and the Creoles. The meat of these turtles has traditionally been a part of these ethnic groups' diets, but now they must adjust to this change. In the case of the Garífuna people in Belize, marine sea turtle has played a role in traditional rituals and as a result has great cultural importance for this particular group.

iii) *Impact on Available Resources* — Resources required to enforce these policies and agreements have been tremendous, especially on the institutions and organizations that have the legal mandate over the environment and the marine resources in Belize. In order to continue the trade of economically important species, such as the queen conch, *Strombus gigas,* Belize is expected to update status assessments of its stocks and prove to CITES that the exploitation of this species is being done in a sustainable manner. However, for most third world countries like Belize that lack both the financial and technical capacity, assessments of this nature are usually difficult to realize. Government's budgetary allocations for the management of its natural resources that include vital components such as monitoring, enforcement, and research are decreasing on an annual basis. For developing countries like Belize, it is becoming more and more difficult for Government to support these activities when they are faced with more pressing environmental, social, and economic issues.

## CONCLUSIONS

Thus far, the Belize Fishing Industry and associated cooperatives have been extremely flexible in adapting to past and present policies directly and indirectly related to the fisheries sector. However, with the effects of globalization there is concern regarding the industry's ability to further absorb and adapt to the direct, indirect, and potential impacts of this process. Increasing the vulnerability of the industry would compromise sustained economic growth of the sector. This could have serious repercussions on the social and economic status of the country of Belize. Such challenges to the fishing industry could also trigger the breakdown of infrastructure and institutional mechanisms already in place to facilitate the implementation of current and past policies and the management of marine resources. This in turn could tarnish Belize's reputation as an environmentally friendly nation in the international community and thus have negative implications on the sustainability of local efforts and programs.

The aforementioned need to be taken into consideration by developed countries when formulating policies and agreements that require substantial investments for their adoption and successful implementation by developing countries.

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**Appendix I.** Fisheries Production and Export Statistics (2000).

| Commodity | Production | Production exported (lbs) | Export Value (BZE dollars) |
|---|---|---|---|
| Fin Fish | 109,575.0 | 86,630.0 | 160,751.72 |
| Fish Fillet | 28,204.5 | | |
| Lobster Head Meat | 50,637.0 | 26,670.0 | 201,125.0 |
| Lobster Tail | 555,254.0 | 646,120.0 | 18,563,505.0 |
| Conch | 513,469.0 | 526,450.0 | 4,858,240.0 |
| Stone Crab Claws | 8,671.0 | 3,995.0 | 63,920.0 |
| Pink Sea Shrimp | 99,285.0 | 33,900.0 | 372,900.0 |
| White Farmed Shrimp | 8,002,118.0 | 5,027,351.5 | 47,458,177.59 |
| Squid | 555.0 | 6,127.0 | 57,975.98 |
| Others | | 10,226.0 | 93,487.73 |
| **Total** | **9,367,768.5** | **6,351,116.5** | **$71,830,083.02** |

Source: Belize Fisheries Department

# Morphometrics and Management of the Caribbean Spiny Lobster, *Panulirus argus*

THOMAS R. MATTHEWS, JOHN H. HUNT, and DOUGLAS W. HEATWOLE[1]
*Florida Fish and Wildlife Conservation Commission*
*Florida Marine Research Institute*
*2796 Overseas Hwy, Suite 119*
*Marathon, Florida 33050 USA*

ABSTRACT

The Caribbean spiny lobster, *Panulirus argus*, supports important fisheries throughout much of its range. As a result, spiny lobster stocks in most countries are almost or are already fully exploited. Spiny lobsters are one of the most studied animals in the Caribbean and fishery statistics are available from many countries, but there is no Caribbean-wide stock assessment. Effective management of this species requires that local scientific studies, national fishery statistics, and national fishery regulations be integrated into a regional fishery management policy. To that end, a comprehensive group of morphometric equations have been developed that will allow scientists, fishery managers, and law enforcement personnel from different countries to convert the various length and weight measurements. These equations are gender specific and allow conversions to be made between carapace length, tail length, total length, tail width, fresh and frozen tail weight, and fresh and frozen whole weight. The relationships between morphometric equations presented in other studies is also reviewed.

KEY WORDS: *Panulirus argus*, spiny lobster, morphometrics, minimum size limits

[1]*Present address: Ecology and Environment, Inc., 220 W. Garden St. Suite 404, Pensacola, FL 32501*

## INTRODUCTION

The Caribbean spiny lobster (*Panulirus argus* Latreille, 1804) is distributed throughout the Caribbean from Brazil to the United States and Bermuda. Spiny lobsters are fully exploited or over-exploited in much of this range (Cochrane and Chakalall 2001). The potential dependence of local populations on pan-Caribbean egg production requires that all countries exploiting this species develop management strategies that are consistent and promote sustainable yield (Lyons et al. 1981, Ehrhardt 1994). The purpose of this study was to develop a comprehensive group of morphometric equations to help scientists, fishery managers, and law-enforcement personnel from different countries interpret catch statistics and integrate international research in efforts to improve the management of the pan-Caribbean spiny lobster fishery.

Many countries with *P. argus* fisheries have compiled landings records and research results concerning their fishery. These databases contain valuable information about *P. argus* in different areas and years, but the parameters measured in these databases often differ from those currently in use or are inconsistent from country to country. The morphometric equations developed in this study were designed to facilitate comparisons between historical databases and their modern equivalents. Our equations should also assist modern researchers with the exchange of size-related information, regardless of the exact parameters recorded.

These morphometric equations can be used to facilitate the enforcement of different size and measurement parameters from different government agencies or nations. At present, carapace length is the preferred standard measure to assess lobster size because of its ease of measuring and inflexibility. (Smith 1958, Simmons 1975, Soares and Cavalcantes 1984, Florida Administrative Code 2001). Carapace length is also unaffected by cooking the lobster (Ibbott et al. 2001). However, use of carapace length as an enforcement parameter requires that lobsters be maintained whole. If landing or shipping lobsters in a whole condition is impractical, direct measurement of the tail must be as accurate as possible to sustain the intent of management strategies. Tail length measurements are inherently more variable than carapace measurements because of the flexible joints between the abdominal somites and the variable curve of the tail.

In this study, we used morphometric equations and confidence limits in two ways. First, we used the equations to reexamine historical databases and explore the differences between the morphometric equations developed in several regional spiny lobster fisheries in the Caribbean. Second, we evaluated which tail dimension most accurately predicts carapace length. Using these equations, researchers and enforcement personnel should be able to more reliably interpret research findings and be able to determine if a harvested lobster conforms to a specific carapace size limit from an examination of the tail.

## METHODS

We collected fifty intermolt lobsters of each sex for each 5-mm carapace-length (CL) size class between 50 and 100 mm. The majority of the lobsters were collected in the middle Florida Keys between June 1985 and July 1986. An additional 215 lobsters from the same location were collected and measured during December 1989 to complete the data set. Measurements were taken of carapace length, total length, tail length, and tail width. Weights were obtained for whole lobsters, tails only, and frozen tails. Weights were not determined for individuals with numerous missing appendages. All measurements were made to the nearest mm with Vernier calipers, and all weights were measured to the nearest 0.1 g using a triple beam balance.

The carapace (head, body, or front section) was measured from the anteriormost edge (front) of the groove between the supraorbital spines (horns) directly above the eyes, then along the middorsal line (middle of the back) to the rear edge of the dorsal part of the carapace, excluding any translucent membrane. The tail (segmented portion) was detached from the carapace, placed dorsal-side up, and measured lengthwise along the middorsal line (middle of the back) from the anteriormost portion of the exoskeleton of the first abdominal somite to the farthest extension of the tail fan (telson or uropod, whichever was greater). These measurement criteria are consistent with Florida Administrative Code, Chapter 68B-24, Spiny Lobster (Crawfish) and Slipper Lobster. Total length was measured from the anterior edge of the carapace between the supraorbital spines to the farthest extension of the tail fan. This measurement was made by placing the lobster dorsal-side down on a measuring board, with the anterior margin of the carapace between the supraorbital spines held against a nail that delineated zero on the measuring board. Tail width was measured across the second abdominal somite immediately posterior to the spines on the abdominal segment. Measurements were made in a straight-line and did not incorporate the curve of the carapace or tail. After total weight and tail weight were determined, tails were individually bagged, frozen, and reweighed (with the bag removed) so that frozen weight could be determined.

The relationships between pairs of morphometric variables were determined by using type II least-squares regressions (SAS® 1988). Transition points in the morphometric relationships were determined by optimizing residuals (Lovett and Felder 1989). Significant differences in regression analyses were determined by analysis of covariance ($P < 0.05$) (Snedecor and Cochran 1989). To better support law enforcement applications and allow compatibility with historic databases, equations incorporating both sexes are reported regardless of any differences revealed by the analysis of covariance. Analysis of covariance was also used to compare equations developed for lobsters from different locations in the Florida Keys.

Total weight:carapace length and total length:carapace length regression lines were plotted to compare regression equations from different areas and to identify discrepancies in morphometric equations between different studies. Limited access to the raw data from many historic studies precludes more formal statistical analysis.

## RESULTS AND DISCUSSION

Significant differences ($P < 0.05$) exist between sexes for most of the morphometric equations examined. The tail weight:tail length and tail weight:tail width relationships and their reciprocals, tail length:tail weight and tail width:tail weight relationships, are the only equations that did not have differences related to gender. Dimorphic growth for *P. argus* has been identified in all studies that had adequate sample sizes (for review, see Lyons et al. 1981). The gender-specific morphometric equations and the combined-sex equations (both genders included) for length:length comparisons are presented in Table 1. The length:weight equations and their reciprocals, the weight:length equations, for total and tail weight are given in Tables 2 and 3, and the length:frozen weight and frozen weight:length equations are given in Table 4. Tail weight:total weight equations and their reciprocals are given in Table 5. These tables were designed to present a large number of morphometric equations concisely and for all equations, except the male carapace length-to-tail length equations for dimorphic growth, $R^2$ values are greater than 0.9334 and are not reported further.

**Table 1.** Length and width regression equations for *Panulirus argus* from Florida.

| Variables[1] | Sex[2] | Regression Equation[3] |
|---|---|---|
| Carapace Length : Total Length | B | TTL=2.67*CL+13.30 |
| | M | TTL=2.51*CL+22.19 |
| | F | TTL=2.80*CL+6.32 |
| Total Length : Carapace Length | B | CL=0.37*TTL-4.99 |
| | M | CL=0.40*TTL-8.85 |
| | F | CL=0.36*TTL-2.26 |
| Tail Length : Total Length | B | TTL=1.56*TL-5.72 |
| | M | TTL=1.57*TL-5.26 |
| | F | TTL=1.57*TL-7.89 |
| Total Length : Tail Length | B | TL=0.64*TTL+3.67 |
| | M | TL=0.64*TTL+3.36 |
| | F | TL=0.64*TTL+5.04 |
| Tail Length : Carapace Length B | | CL=0.58*TL-7.13 |
| | M | CL=0.62*TL-10.95 |
| | F | CL=0.56*TL-5.07 |
| | M<73mm | CL=0.58*TL-5.66 |
| | M>73mm | CL=0.62*TL-9.48 |
| Carapace Length : Tail Length B | | TL=1.71*CL+12.19 |
| | M | TL=1.60*CL+17.52 |
| | F | TL=1.79*CL+9.08 |
| | M<73mm | TL=1.73*CL+9.79 |
| | M>73mm | TL=1.62*CL+15.38 |
| Carapace Length : Tail Width B | | TW=0.59*CL+2.66 |
| | M | TW=0.54*CL+4.80 |
| | F | TW=0.61*CL+1.66 |
| Tail Width : Carapace Length B | | CL=1.71*TW-4.54 |
| | M | CL=1.84*TW-8.85 |
| | F | CL=1.63*TW-2.70 |

[1] All equations for male and females were significantly different ($P < 0.05$).
[2] B = both sexes included, M = male, F = female
[3] TTL= total length, CL= carapace length, TL = tail length, TW = tail width.

Table 2. Total-weight regression equations for *Panulirus argus* from Florida.

| Variables[1] | Sex[2] | Regression Equation[3] |
|---|---|---|
| Carapace Length : Total Weight | B | $TTWT=0.001989*CL^{2.80327}$ |
| | M | $TTWT=0.002229*CL^{2.77012}$ |
| | F | $TTWT=0.001839*CL^{2.82810}$ |
| Total Length : Total Weight B | T | $TWT=0.00003671*TTL^{3.00056}$ |
| | M | $TTWT=0.00002080*TTL^{3.10922}$ |
| | F | $TTWT=0.00005812*TTL^{2.91274}$ |
| Tail Length : Total Weight | B | $TTWT=0.00008379*TL^{3.06710}$ |
| | M | $TTWT=0.00005494*TL^{3.17957}$ |
| | F | $TTWT=0.00001059*TL^{3.03328}$ |
| Tail Width : Total Weight | B | $TTWT=0.003820*TTL^{2.97976}$ |
| | M | $TTWT=0.002580*TTL^{3.09175}$ |
| | F | $TTWT=0.004410*TTL^{2.93167}$ |
| Total Weight : Carapace Length | B | $CL=9.1975*TTWT^{0.35673}$ |
| | M | $CL=9.0640*TTWT^{0.36100}$ |
| | F | $CL=9.2734*TTWT^{0.35359}$ |
| Total Weight : Total Length | B | $TL=30.0684*TTWT^{0.33327}$ |
| | M | $TL=32.0479*TTWT^{0.32162}$ |
| | F | $TL=28.4571*TTWT^{0.34332}$ |
| Total Weight : Tail Length | B | $TL=20.9218*TTWT^{0.32393}$ |
| | M | $TL=21.8696*TTWT^{0.31451}$ |
| | F | $TL=20.4409*TTWT^{0.32968}$ |
| Total Weight : Tail Width | B | $TW=6.47799*TTWT^{0.33580}$ |
| | M | $TW=6.85046*TTWT^{0.32344}$ |
| | F | $TW=6.36063*TTWT^{0.34110}$ |

[1] All equations for male and females were significantly different ($P < 0.05$).
[2] B = both sexes included, M = male, F = female
[3] TTWT = total weight, TTL= total length, CL= carapace length, TL = tail length, TW = tail width.

**Table 3.** Tail-weight regression equations for *Panulirus argus* from Florida.

| **Variables**[1] | **Sex**[2] | **Regression Equation**[3] |
|---|---|---|
| Carapace Length : Tail Weight | B | $TWT=0.0007762*CL^{2.76273}$ |
| | M | $TWT=0.0011139*CL^{2.66606}$ |
| | F | $TWT=0.0006205*CL^{2.82756}$ |
| Total Length : Tail Weight | B | $TWT=0.00001518*TTL^{2.95717}$ |
| | M | $TWT=0.00001239*TTL^{2.99242}$ |
| | F | $TWT=0.00001962*TTL^{2.91217}$ |
| Tail Length : Tail Weight[*ns] | B | $TWT=0.00003424*TL^{3.04245}$ |
| | M | $TWT=0.00003154*TL^{3.06013}$ |
| | F | $TWT=0.00003575*TL^{3.03269}$ |
| Tail Width : Tail Weight[*ns] | B | $TWT=0.001434*TTL^{2.94439}$ |
| | M | $TWT=0.001298*TTL^{2.97468}$ |
| | F | $TWT=0.001438*TTL^{2.93963}$ |
| Tail Weight : Carapace Length | B | $CL=13.3570*TWT^{0.36196}$ |
| | M | $CL=12.8153*TWT^{0.37509}$ |
| | F | $CL=13.6238*TWT^{0.35366}$ |
| Tail Weight : Total Length | B | $TL=42.6089*TWT^{0.33616}$ |
| | M | $TL=43.6335*TWT^{0.33418}$ |
| | F | $TL=41.3428*TWT^{0.34339}$ |
| Tail Weight : Tail Length[*ns] | B | $TL=29.3589*TWT^{0.32868}$ |
| | M | $TL=29.5720*TWT^{0.32678}$ |
| | F | $TL=29.2590*TWT^{0.32974}$ |
| Tail Weight : Tail Width[*ns] | B | $TW=9.2404*TWT^{0.33963}$ |
| | M | $TW=9.3409*TWT^{0.33617}$ |
| | F | $TW=9.2642*TWT^{0.34016}$ |

[1] All equations for male and females were significantly different ($P < 0.05$) unless indicated by [*ns].
[2] B = both sexes included, M = male, F = female
[3] TWT = tail weight, TTL= total length, CL= carapace length, TL = tail length, TW = tail width.

**Table 4.** Frozen-tail-weight regression equations for *Panulirus argus* from Florida.

| Variables[1] | Sex[2] | Regression Equation[3] |
|---|---|---|
| Carapace Length : Frozen Tail Weight | B | $FWT=0.001948*CL^{2.5474}$ |
| | M | $FWT=0.001780*CL^{2.5555}$ |
| | F | $FWT=0.001095*CL^{2.6937}$ |
| Total Length : Frozen Tail Weight | B | $FWT=0.0000430*TTL^{2.7622}$ |
| | M | $FWT=0.0000330*TTL^{2.8091}$ |
| | F | $FWT=0.0000520*TTL^{2.7270}$ |
| Tail Length : Frozen Tail Weight[*ns] | B | $FWT=0.0000670*TL^{2.9052}$ |
| | M | $FWT=0.0000625*TL^{2.9199}$ |
| | F | $FWT=0.0000690*TL^{2.8877}$ |
| Tail Width : Frozen Tail Weight[*ns] | B | $FWT=0.002268*TTL^{2.8258}$ |
| | M | $FWT=0.002307*TTL^{2.8259}$ |
| | F | $FWT=0.002208*TTL^{2.8285}$ |
| Frozen Tail Weight : Carapace Length | B | $CL=12.9574*FWT^{0.36951}$ |
| | M | $CL=12.7389*FWT^{0.37765}$ |
| | F | $CL=13.7272*FWT^{0.35283}$ |
| Frozen Tail Weight : Total Length | B | $TL=42.6751*FWT^{0.33862}$ |
| | M | $TL=42.7389*FWT^{0.33917}$ |
| | F | $TL=42.9267*FWT^{0.33853}$ |
| Frozen Tail Weight : Tail Length[*ns] | B | $TL=30.4160*FWT^{0.32456}$ |
| | M | $TL=29.9693*FWT^{0.32506}$ |
| | F | $TL=30.1141*FWT^{0.32407}$ |
| Frozen Tail Weight : Tail Width[*ns] | B | $TW=8.62522*FWT^{0.35366}$ |
| | M | $TW=8.57275*FWT^{0.35383}$ |
| | F | $TW=8.68980*FWT^{0.35355}$ |

[1]All equations for male and females were significantly different ($P< 0.05$) unless indicated by [*ns].
[2]B = both sexes included, M = male, F = female
[3]FWT = frozen tail weight, TTL= total length, CL = carapace length, TL = tail length, TW = tail width.

**Table 5.** Weight:weight regression equations for *Panulirus argus* from Florida.

| Variables[1] | Sex[2] | Regression Equation[3] |
|---|---|---|
| Tail Weight : Total Weight | B | TTWT=3.07*TWT-1.13 |
| | M | TTWT=3.31*TWT-17.37 |
| | F | TTWT=2.90*TWT-2.71 |
| Total Weight : Tail Weight | B | TWT=0.32*TTWT+3.86 |
| | M | TWT=0.29*TTWT+7.61 |
| | F | TWT=0.33*TTWT+1.76 |

[1]All equations for male and females were significantly different (P< 0.05) unless indicated by 'ns'.
[2]B = both sexes included, M = male, F = female
[3]TW = tail weight, TTWT= total weight.

Sexual dimorphism is a common phenomenon among crustacea (Gray 1929, for review, see Hartnoll 1982). For *P. argus*, the greater length and girth of the male carapace are the primarily responsible for the differences in the male and female morphometric equations. The male carapace increases in length disproportionately with increasing total size. A distinct transition point is apparent in the carapace length:tail length equation. Males greater than 73 mm CL have a disproportionately larger carapace than do smaller males and all females (Figure 1).

Allometric growth is often associated with sexual maturity in crustaceans (Teissier 1960, Wenner et al. 1974, Hartnoll 1982). Some authors have suggested suggest that female *P. argus* have positive allometric tail growth (Khandker 1963, Munro 1983), presumably to facilitate egg bearing. Results from our study indicate that female tail length does not increase in disproportion to increased carapace length (Figure 1). Increased carapace growth for male lobsters larger than 73-mm CL may be indicative of the onset of sexual maturation. This transition point in males does not indicate that females also mature at this size nor does it imply that males can successfully mate at this size. The 73 mm CL maturation estimate for male lobsters in this study is one of the smallest reported for this species. Additional research that uses direct observations of gonadal development and addresses the potential growth inhibition from both Florida's more temperate climate than other Caribbean locations and the periodic confinement of 15% of sublegal-sized lobsters in traps should be conducted to better determine male reproductive maturity.

Male mating success may depend on behavioral and size constraints that do not develop until after reproductive maturity. The evidence for behavioral or size constraints delaying reproductive activity was supported by Hunt and Lyons' (1986) observation that molt increments do not decrease in male lobsters until after 85 mm CL. The decreased growth rate might indicate a shift in energy use corresponding to the onset of reproductive activity. There is also no difference in male allometric growth between Florida Bay and the Atlantic Ocean lobsters (P>0.05), but Florida Bay has a very low occurrence of female lobsters with spermatophores or eggs and is not considered to be an area used for lobster reproduction. This lack of reproductive activity among lobsters with secondary sexual characteristics in Florida Bay indicates that other factors influence reproductive success in male lobsters.

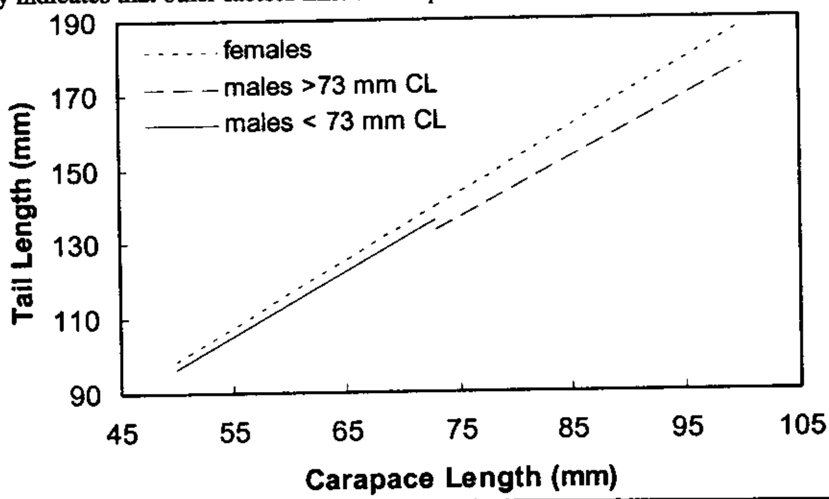


**Figure 1.** Regression of tail length on carapace length for male and female *Panulirus argus* from Florida. Location of transition point for males (73 mm CL) was selected to maximize randomness of combined residuals. No transition point was apparent for females.

Haughton and Shaul (1989) reported that in Jamaica, there are allometric growth differences in male *P. argus* carapace length:telson length equations at 69 mm CL. The presence of this transition point in Jamaica adult lobster population suggests that similar growth and maturation pressures exist in both Jamaica and the Florida Keys. The 4 mm difference between the two transition-point estimates may be due to Haughton and Shaul's (1989) use of telson length and our use of tail length.

Detailed analysis of morphological differences between the sexes can lead to a better understanding of the ecology and behavior of many animals. For a commercially important species like *P. argus*, morphometric differences have a more practical use. The variation in size between males and females may cause a disproportionate number of one sex to be harvested in fisheries where size limits are the principal management tool (Cobo de Barany et al. 1972, Simpso 1976). Disproportionately high numbers of males are captured in most *P. argus* fisheries, and the male-to-female sex-ratio in the landings may be as high as 1.5 to 1 (Creaser 1952, Buesa Mas 1965, Simpson 1976, Lyons et al. 1981, Munro 1983). The impact of harvesting up to 50% more males than females could affect egg production by limiting the sperm availability (MacDiarmid and Butler 1999).

## POPULATION COMPARISONS

Comparison of weight:length morphometric equations from throughout the Caribbean do not indicate population level differences among spiny lobsters from different areas in the Caribbean. Visual comparisons of the weight:length morphometric equations from different areas (Table 6) revealed no weight-to-length differences throughout the range of this species with the exception of Olsen and Koblic's (1975) weight:length equation from St. John. However, Olsen and Koblic's (1975) equation (Table 6) does closely resemble the equation representing female lobster in Columbia (Squires and Riveros 1978). No satisfactory explanation is apparent to explain the discrepancy in Olsen and Koblic's (1975) findings, but their reported lack of any difference between weight:length morphometric equations for male and female may have been caused by unequal number of male and female lobsters and larger male lobsters in their sample. Olsen and Koblic (1975) indicate that in some locations males comprised 75% of the population and males averaged 20 mm CL larger than females. The flatter slope of the lines generated from equations that combined both sexes was caused by the disproportionate number of large males in those samples. Farrugio's (1975) data from Martinique included 1.5 times more males than females (22 and 14 respectively) greater than 100 mm CL. While Correa (1987) did not combine his male and female equations, he did have 2.3 times more males than females (496 and 214 respectively) greater than 115-mm CL. Correa's (1987) range of samples of large female lobsters greatly exceeded the range observed in Florida and may have contributed to the relative flatter slope for the equation he reported. The abundance of large males in these data sets used to create combined sex equations introduced a bias into the equations that was avoided in the Florida equations by sampling equal numbers of male and female lobsters in each size class.

Comparison of length:length morphometric equations from throughout the Caribbean also do not indicate population level differences among spiny lobsters from different areas. A visual comparison (Figures 2 and 3) of the carapace length:total length equations (Table 7) reveals two things of note:

i) Total lengths for lobsters from Cuba are larger than those of lobsters with similar carapace lengths from other locations and,
ii) The regression line for female lobsters from Cuba has a higher slope. The differences in both Cruz et al.'s (1981) equations seems to originate from the same source.

Cruz et al. (1980) defined total length to include the portion of the carapace that extends forward of the eyes to the base of the antennuals. The carapace length discrepancy between Cuban measurements and measurements from other locations is more pronounced in larger lobsters and results in a greater slope in the Cuban carapace length:total length regression equation for female lobsters (Figure 3). Among male lobsters, the measurement difference between the Cuban and Florida regression equations decreases with increased male size. (Figure 2). The dimorphic growth of the male carapace apparently obscures the relative size of the carapace length measurement discrepancy apparent in equations for male lobsters.

**Table 6.** Survey of length:weight relationships for *Panulirus argus*. All units were reported in mm or g. Relationships not expressed in equation format were either graphs or examples for specific size classes.

| Location | Sex[1] | Relationship[2] | Reference |
|---|---|---|---|
| Jamaica | B | $TTWT=0.00271*CL^{2.736}$ | Munro 1983 |
| Florida | B | $TTWT=0.00422*CL^{2.64091}$ | Lyons *et al.* 1981 |
| | M | $TTWT=0.00315*CL^{2.69934}$ | |
| | F | $TTWT=0.00361*CL^{2.68379}$ | |
| Jamaica | M | $TTWT=0.00316*CL^{2.71}$ | Haughton and King unpbl. |
| | F | $TTWT=0.00499*CL^{2.62}$ | |
| St. John | B | $TTWT=0.0021*CL^{2.778}$ | Olsen and Koblic 1975 Martinique |
| | M | $TTWT=0.0023*CL^{2.77}$ | Clairouin 1980 |
| | F | $TTWT=0.0021*CL^{2.80}$ | |
| Venezuela | M | $TTWT=1.45143*CL^{2.694114}$ | Cobo de Barany *et al.* 1972 |
| | F | $TTWT=1.5749*CL^{2.66933}$ | |
| Colombia | M | $TTWT=0.00516*CL^{2.578}$ | Squires and Riveros 1978 |
| | F | $TTWT=0.00221*CL^{2.7921}$ | |
| Belize | B | $TWT=0.0012*CL^{2.689}$ | Wade *et al.* 1999 |
| Brazil | M | $TTWT=0.0000514*TTL^{2.968}$ | de Amorim Borges 1964 |
| | F | $TTWT=0.0000865*TTL^{2.859}$ | |
| Martinique | B | $TTWT=0.000203*TTL^{2.707}$ | Farrugio 1975 |
| | M | $TTWT=0.0002339*TTL^{2.687}$ | |
| | F | $TTWT=0.000168*TTL^{2.733}$ | |
| St. Kitts | M | $TTWT=0.0000347*TTL^{3.04}$ | Reid 1989 |
| | F | $TTWT=0.0000275*TTL^{2.65}$ | |
| Venezuela | M/F | TTWT:CL | Khandker 1963 |
| Panama | B | TTWT:CL and TTWT:TTL | Butler and Pease 1965 |
| Florida and Bahamas | B | TTWT:CL and TTWT:TTL | Smith 1948 |
| Florida | M/F | TTWT:CL | Smith 1958 |
| Bermuda | M/F | TTL:TTWT | Creaser 1952 |
| Florida | B | TTL:TTWT | Dawson and Idyll 1951 |
| Puerto Rico | B | TTWT:CL | Feliciano 1958 |
| Bahamas | M/F | TTWT:CL | Simpson 1976 |
| San Andrés | M/F | TTL:TTWT | Sanchez-Aponte and Sanchez 1985 |
| Florida | M/F | TTWT:TTL | Schroeder 1924 |
| Belize | M/F | TWT:TTL and TWT:CL | Weber 1968 |

[1]B=both sexes included, M=males, F=females
[2]CL=carapace length, TWT= tail weight, TL = tail length, TTL = total length, TTWT = total weight

**Table 7.** Survey of length:length relationships for *Panulirus argus*. All units were reported in mm. Citations are presented for references presenting morphometric data that lacked specific equations.

| Location | Sex[1] | Relationship[2] | Reference |
|---|---|---|---|
| Martinique | M | $TTL=4.00*CL^{0.91}$ | Clairouin 1980 |
| | F | $TTL=3.25*CL^{0.97}$ | |
| Colombia | M | TTL=2.34*CL+47.9 | Squires and Riveros 1978 |
| | F | TTL=2.40*CL+39.4 | |
| Cuba | B | TTL=2.5402*CL+36.35 | Cruz et al. 1981 |
| | M | TTL=2.5197*CL+32.84 | |
| | F | TTL=2.9290*CL+9.87 | |
| San Andrés | M | TTL=2.19*CL+2.23 | Sanchez-Aponte and |
| | F | TTL=2.49*CL-0.20 | Sanchez 1985 |
| St. Kitts | M | TTL=2.28*CL+38.3 | Reid 1989 |
| | F | TTL=2.19*CL+4.40 | |
| Providencia | M | TTL=2.520*CL+23.39 | Correa 1987 |
| | F | TTL=2.208*CL+39.35 | |
| Antigua | M | TTL=2.61*CL | Peacock 1974 |
| | F | TTL=2.91*CL | |
| Brazil | M | ln(TTL)=0.86*ln(CL)+1.61 | Soares and |
| | F | ln(TTL)=0.94*ln(CL)+1.29 | Cavalcantes 1984 |
| Brazil | M | CL=0.423*TTL-9.32 | de Amorim Borges 1964 |
| | F | CL=0.366*TTL-1.255 | |
| Martinique | B | CL=0.415*TTL-9.977 | Farrugio 1975 |
| | M | CL=0.405*TTL-10.989 | |
| | F | CL=0.413*TTL-11.000 | |
| Jamaica | M | CL=2.44*TSL-23.27 | Haughton and Shaul 1989 |
| | F | CL=1.62*TSL+4.01 | |
| Venezuela | M | TTL=2.708*CL+3.8 | Cobo de Barany et al. 1972 |
| | F | TTL=2.969*CL+3.6 | |
| Venezuela | M | CL=0.32(TTL-22.2)+7.7 | Khandker 1963 |
| | F | CL=0.29(TTL-21.4)+7.1 | |
| Bermuda | M/F | CL:TL and TTL:CL | Creaser 1952 |
| Florida | B | TL:TTL | Dawson and Idyll 1951 |
| Puerto Rico | B | TTL:CL | Feliciano 1958 |
| Pan Carib. | M/F | TTL:CL | Smith 1958 |
| Belize | B/M/F | TL:CL (multiple equations) | Wade et al. 1999 |

[1]B=both sexes included, M=males, F=females
[2]CL=carapace length, TL = tail length, TTL = total length, TSL = telson length

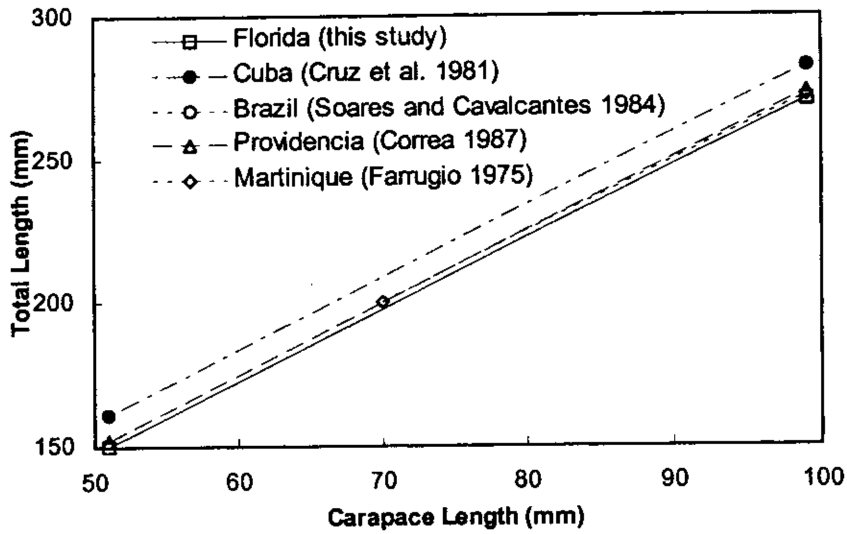


**Figure 2.** Comparison of regressions of total length on carapace length for male *Panulirus argus* in select locations. Regressions for Florida, Brazil, Providencia, and Martinique are indistinguishable between 70 and 100-mm CL, emphasizing the consistency of many of the morphometric equations from different locations.

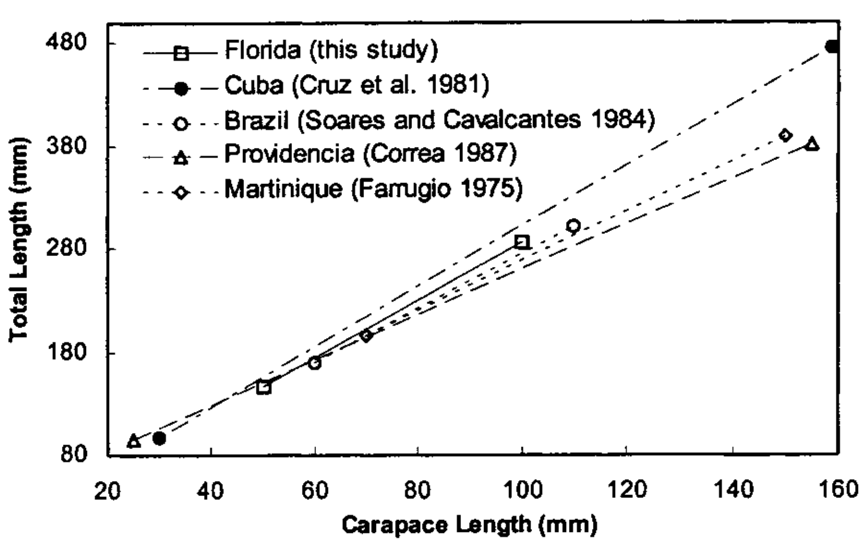


**Figure 3.** Comparison of regressions of total length on carapace length for female *Panulirus argus* in selected locations.

Several equations reported in Table 7 are not included in the visual comparison (Figures 2 and 3) because of small sample sizes or incomplete methodological explanations in the original paper. Of these, the total length:carapace length regression line for female lobsters in Venezuela has a slope similar to the regression line for Cuban females (Cobo de Barany et al. 1972), and Sanchez-Aponte and Sanchez (1985) reported a line with a slope similar to but with an intercept 20 mm lower than other estimates. The methods used by Cobo de Barany et al. (1972) and Sanchez-Aponte and Sanchez (1985) to measure length is not clearly defined, but may more closely follow the methods described by Cruz (1981) and account for the reported differences in the morphometric equations developed in from those studies (Cruz pers. comm.).

Recent mitochondrial DNA evidence supports a hypothesized pan-Caribbean population, with the possible exception of a Brazilian subspecies (Silberman et al. 1994, Sarver et al, 1998). The similarity of total weight:carapace length equations throughout the range of *P. argus* could also be considered circumstantial evidence for a single Caribbean-wide population. At least, similar morphometric relationships suggest that similar environmental forces are acting on *P. argus* throughout its range. The deviation of Cruz's (1980) total length:carapace length regressions from regressions from other areas (Figures 2 and 3) appears to be related to the method he used to measure total length, but the possibility that a semi-isolated population of lobsters in Gulf of Batabano requires more direct examination (Cruz pers. comm.). The slope differences in the female total length:carapace length regressions (Figure 3) may be artifacts of specific studies and do not have a consistent trend correlated with latitudinal or physical oceanographic features. Unfortunately, without the original measurements used to create the equations that produced the regression lines, it is impossible to determine whether these slopes are significantly different.

## ENFORCEMENT CRITERIA

The state of Florida requires that harvested lobsters have a carapace length greater than 3 inches (76.2 mm) or that the tail length be greater than 5.5 inches (139.7 mm) once separated from the carapace (Florida Administrative Code 2001). Florida Fish and Wildlife Conservation Commission officers currently use a gauge to determine the length of the carapace and tail. The gauge is used to obtain a straight-line measure that does not account for the curvature of the exoskeleton. This measuring technique is consistent with the methods used in this study. Results from our study indicate that a 76 mm CL lobster will have a 142 mm (5.59 inches) tail length using the general CL to tail length equation that does not consider the gender of the lobster. Using this equation, fewer than 5% of lobsters with a CL of 76 mm would have a tail length less than 139 mm (5.47 inches), which conforms to the tail length size limit as currently enacted.

Problems commonly occur with the enforcement of different size limits for *P. argus* because size limits may vary from country to country. Enforcement personnel are often required to determine whether a lobster tail, which is removed from the carapace, conforms to a specific legal standard. A conservative way to resolve this problem is to use 95% confidence limits to define the smallest CL that would represent more than 95% of the tails of a specified length. Determination of the lower bound of the 95% confidence interval for the CL from a specified tail length is calculated using the equation :

**carapace length = (0.566 * tail length) - 6.52**

Because the carapace of the lobster is often discarded during processing, there is considerable interest in determining the most appropriate and reliable method to measure lobster size using only the tail. Tail length measurements are not as precise as carapace measurements because the tail is jointed and flexible. In the *Panulirus marginatus* fishery in Hawaii, tail width was a better indicator of CL than tail length (Uchida et al. 1980). In our study, tail length is slightly more accurate as an estimator of carapace length than is tail width, despite the relative inflexibility of the tail somite. Seventy-six-mm CL lobsters are expected to have a tail width of 48 mm. Ninety-five percent confidence limits suggest that a tail width of 46 mm is expected to occur in 5% of tails removed from 76-mm CL lobsters. A 46 mm tail width corresponds to a 72 mm CL lobster and a 139 mm tail length corresponds with a 73 mm CL lobster. However, tail width may be less susceptible to measurement error because of possible confusion when using a straight-line or curve-of-the-tail measurement method. Adoption of tail width as a measurement standard is also an attractive alternative to the tail-length standard because to accurately determine tail length, the lobster must be sacrificed and the tail removed from the carapace. Tail width, on the other hand, can be measured while the lobster is alive, allowing the release of undersized individuals. Tail width as the criteria for a minimum size regulation offers the advantage of being a single measurement that is applicable when the lobster is in both whole condition and once the tail has been separated from the carapace. A single measurement criteria, like tail width, would eliminate the somewhat complicated application of regression equations and 95% confidence limits required to ascertain if a lobster tail once removed from the carapace conforms to a minimum legal carapace size. Regrettably, measuring tail width is more difficult than measuring carapace length; particularly on live lobsters, because of the rapid and forceful contractions of the tail during handling. Ultimately, the determination of which measurement criteria is better for a specific area may depend on the experience of the lobster fishermen and the proportion of the fishery that land tails separated from the carapace.

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