

LONG-TERM VARIATIONS IN NUTRITIONAL CONDITION OF *PANULIRUS ARGUS* (DECAPODA: PALINURIDAE) IN CUBA: ANALYTICAL AND MORPHOLOGICAL APPROACHES

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Nutritional condition indices have been frequently used as morphophysiological indicators to study variations on lobster's physiology and energy reserves. This study was aimed to determine long-term spatio-temporal variations in nutritional conditions of *Panulirus argus* (hereinafter – lobster), considering two indices, namely the analytic Blood Refractive Index (BRI) and the morphometric Kcl (total weight / carapace length relationship). Information from eleven sites in the Caibarién region, sampled in 2010–2015, and twelve sites in the Batabanó region, sampled in 2011–2017, were named as the Current Period. Morphometric data for Kcl estimation, including 1987–1988 in the Caibarién region, and 1981–1993 in the Batabanó region, were grouped as the Past Period. Temporary variations were determined comparing Past and Current periods at each region. Spatial variations were determined by comparing the data between the two regions. For analysed lobsters in the Current period, we determined BRI = 14.3, Kcl = 7.0 in the Caibarién region, and BRI = 15.2, Kcl = 7.0 in the Batabanó region. For the Past period, the Kcl value was 5.8 and 6.3 in the Caibarién and Batabanó region, respectively. Both Kcl and BRI indices were higher for male individuals. This could be associated with the reproductive process, and intrinsic morphometric differences between sexes could influence though. Morphometric parameters were higher for the Current Period. Spatial variations of morphometric parameters were significantly different for the Past Period, which were attributed to different environmental conditions in each region. The BRI index was higher in the Batabanó region, which was possibly associated with the better status of the benthic communities and the better water quality. Present results contribute to understanding lobster's nutritional condition in natural habitats, mainly in the Caibarién region, where few studies have been carried out to date.

Key words: crustaceans' energy reserves, decapods, ecophysiology, morphophysiological indices, spiny lobster

Introduction

The use of morphophysiological indices to quantify lobsters' metabolism variations has been a developed topic since the middle of the XX century. Recently, it has been resumed, within the framework of ecophysiology, for the study of several crustaceans like crabs, shrimps, and spiny lobsters, with highly commercial interest (Rainbow, 1997; Perera et al., 2007; Fitzgibbon et al., 2017a,b; Goncalves et al., 2021). Nutritional condition indices can be listed among the most used morphophysiological indicators for studying lobsters' physiology and the impact of environmental variations on metabolism and energy reserves of these crustaceans (Simon et al., 2015, 2016; Lopeztegui-Castillo, 2021; Wang F., 2021; Wang S. et al., 2021). Nutritional condition in marine crustaceans has been defined as the magnitude, to which organisms have accumulated energy reserves substances that allow normal physiological function and growth (Moore et al., 2000). In addition, it has been interpreted as the consequence of the interactive biotic and abiotic factors, which determine the habitat quality (Lopeztegui-Castillo et al., 2012b).

The Sabana-Camaguey archipelago (SCA) is in the central-eastern region of the northern coast of Cuba. Due to the tourism development, a lot of hotels and hydrotechnical structures have been built to support touristic activities, which includes snorkeling and Self Contained Underwater Breathing Apparatus diving, hiking, sport fishing, and surfing. Consequently, people influx and anthropogenic impacts gradually increased (Alcolado et al., 1999, 2007; Betanzos-Vega et al., 2013; Martínez-Daranas et al., 2021). Additionally, geographic location of coasts, keys, and coral reef barriers in the SCA cause a naturally limited circulation of inner waters. Also, rivers damming, causeways construction and the natural narrowness of this shelf, contribute limiting waters circulation and increasing the environmental stress (Montalvo-Estévez et al., 2008, 2010; Puga et al., 2013; Cobas et al., 2015; Martínez-Daranas et al., 2021).

Due to its natural, archaeological, and scientific values, the SCA was appointed by the Ministry of Science, Technology and Environment of Cuba, as a high priority area for biodiversity con-

servation. Because of their valuable resources of biodiversity and its vulnerability to pollution from shipping activities, the SCA was declared by the International Maritime Organization as a Sensitive Marine Protected Area being the second approved region after the Great Australian Barrier Reef. The SCA is currently proposed as a Special Region of Sustainable Development, also including some defined areas, like Buena Vista Bay, designated as a Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization. Recently (2002), four RAMSAR sites (Buena Vista Biosphere Reserve, North Wetland of Ciego de Ávila, North Wetland of Camagüey, and Rio Maximo Wildlife Refuge) were designated within the SCA area (Alcolado et al., 2007).

Panulirus argus (Latreille, 1804) (hereinafter –lobster) supports commercial fisheries from Rio de Janeiro (Brazil) to North Carolina (USA). This species is the most valuable fishery resource of Cuba (Alzugaray et al., 2018; Baisre, 2018), where the Gulf of Batabanó is the most important fishery area (Cruz et al., 1990; Puga et al., 2005, 2013). Most of the studies describing nutritional condition of lobster from the Gulf of Batabanó have included the relationship between the total weight and the total length of the lobster (Ktl), as a nutritional condition indicator (Buesa, 1965; Lopeztegui-Castillo et al., 2012a,b; Lopeztegui-Castillo & Capetillo-Piñar, 2021). Nevertheless, several studies around the world have used the relation between total weight and carapace length (Kcl) to estimate lobster's nutritional condition (Lozano-Álvarez et al., 2017; Martínez-Calderón et al., 2018).

More than twenty nutritional condition indicators have been described for crustaceans (Lopeztegui-Castillo, 2021). However, some analytical methods, like hemolymph refractive indices, and some morphometrics, like body weight/body length relationships, have been recommended to carry out field studies, basically because they are inexpensive, non-destructive, and relatively simple, fast, and feasible (Oliver & MacDiarmid, 2001; Briones-Fourzán et al., 2009; Gutzler & Butler, 2017). Nevertheless, these indices could differently reflect nutritional condition changes, based on the involved methodology and the temporary scale of the factors causing such changes (Robertson et al., 2000; Lopeztegui-Castillo, 2021).

Lobster's catches in the Caibarién region, at the central sector of the SCA, constitute 85% of

the total lobster catches in this shelf. But it has decreased to 66% in respect to the highest production period (1984–1989), when an average of 1656 ton were annually captured (Morales & Puga, 2008; Morales et al., 2013). The Caibarién fishing region has been exposed to several natural and anthropogenic stressors which have significantly disturbed benthic communities, including seagrasses, lobsters, and their food items (Lopeztegui-Castillo et al., 2021b; Martínez-Daranas et al., 2021). This study was aimed to determine the long-term spatio-temporal variation in nutritional conditions of commercial individuals of the lobster from the Caibarién and Batabanó fishing region. To determine differences between sexes, two nutritional condition indices are considered, one analytic and one morphometric.

Material and Methods

Study area description and location of the sampling sites

In the Caibarién region, eleven sampling sites were located both near to the shelf edge and in inner waters, based on the areas previously studied (Alcolado et al., 1998, 1999, 2007) and considering the main lobster's fishing zones (Fig. 1). Considering similar criterion, twelve sampling sites were situated in the Gulf of Batabanó (Fig. 2), where previous studies reported useful baseline information (Alcolado, 1990; Capetillo-Piñar et al., 2015). Based on the information provided by the National Center for Protected Areas of Cuba, all sampled sites in the Caibarién region, and 42% of sampled sites in the Batabanó region belong to areas which have been categorised as National Parks, Ecological Reserves, Wildlife Sanctuaries, or Protected Areas with Managed Resources (Ruiz-Plasencia et al., 2019). That means that 70% of the sampled sites were located within, or extremely near to Protected Areas.

Sampling has been carried out in 2010, 2011, 2013 and 2015 in the Caibarién region, and in 2011, 2014, 2015, 2016 and 2017 in the Batabanó region. Sites 1, 3, 9 and 10 (inner sites in Caibarién region) were sampled in 2010–2015. The other sites in this region were sampled only in 2015. All information registered in the XXI century (2010–2015 in the Caibarién region and 2011–2017 in the Batabanó region) was named as the Current Period.

Nutritional condition indices

Total body weight (TW) / carapace length (CL) relationship was calculated (Kcl, $g \times mm^{-1}$)

and used as a morphometric indicator of lobster’s nutritional condition (Robertson et al., 2000; Lozano-Álvarez et al., 2017). Higher values of Kcl mean that lobsters are gaining weight faster than size, which is nutritionally desirable. Based on the proportionally direct relationship between hemolymph (blood) refractive index and hemolymph total protein concentration (Wang & McGaw, 2014), the blood refractive index (BRI, $g \times dl^{-1}$) was determined and used as an analytic indicator of lobster’s nutritional condition (Moore et al., 2000). Using sterile 3-cc syringes (one per lobster), the hemolymph was extracted from the pericardial sinus, which has a mid-dorsal position in the lobster’s cephalothorax. Immediately after extraction, the hemolymph was placed on a hand-held Fisher Brix (0–50%) refractometer.

Lobsters were sampled immediately after their capture on commercial ships. We analysed only lobsters without external signs of moulting, reproduction, or diseases, and with having all their corresponding body parts (appendices). Lobsters were sexed, measured, and weighed according to Cruz (2002). A Vernier caliper (± 0.1 mm) was used to measure the carapace length,

and the total body wet weight was determined by a technical scale (± 0.1 g).

Origin and processing data

BRI was determined only for the Current Period in both regions (Caibarién and Batabanó). Nevertheless, for the Batabanó region, several morphometric data have been recorded, which were used comparatively. For 1981, 1983, 1988 and 1993 in the Batabanó region, and for 1987 and 1988 in the Caibarién region, the total body weight and carapace length data were collected from fisheries records archived in the Fisheries Research Center. These years were named as Past Period.

The applied Shapiro-Wilks test failed exploring for data normality. Then, non-parametric tests were selected for processing data. Paired comparisons between sexes (male vs. female) and regions (Batabanó region vs. Caibarién region) were carried out by Mann-Whitney U-test. Long-term variations were two scales determined, one comparing the Past and the Current periods (temporary scale), and one comparing between periods regions (spatial scale). The data were analysed using STATISTICA 10 (StatSoft, Inc., 2011).

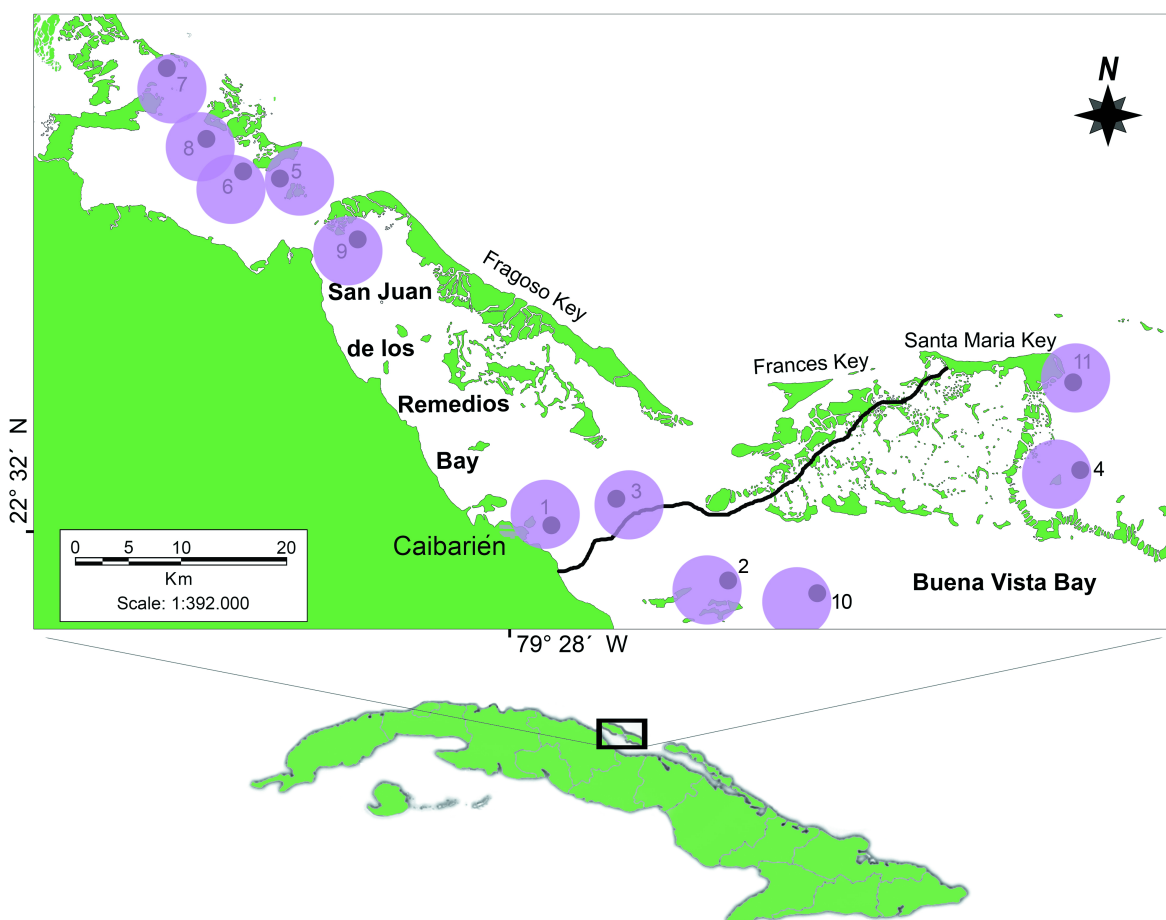


Fig. 1. Study area and location of the eleven sampled sites in the Caibarién fishing region, central sector of Sabana-Camaguey archipelago, Cuba. Coloured sites are located within Protected Areas.

Results

Lobster’s nutritional condition indices in the Caibarién and Batabanó regions

A total number of 10 551 individuals of the lobster were measured. That makes it possible to

certainly estimate the morphometric nutritional condition index (Kcl) in the Caibarién and Batabanó fishing regions. Based on the hemolymph, extracted from 4980 lobsters, the BRI index was consistently determined (Table 1).

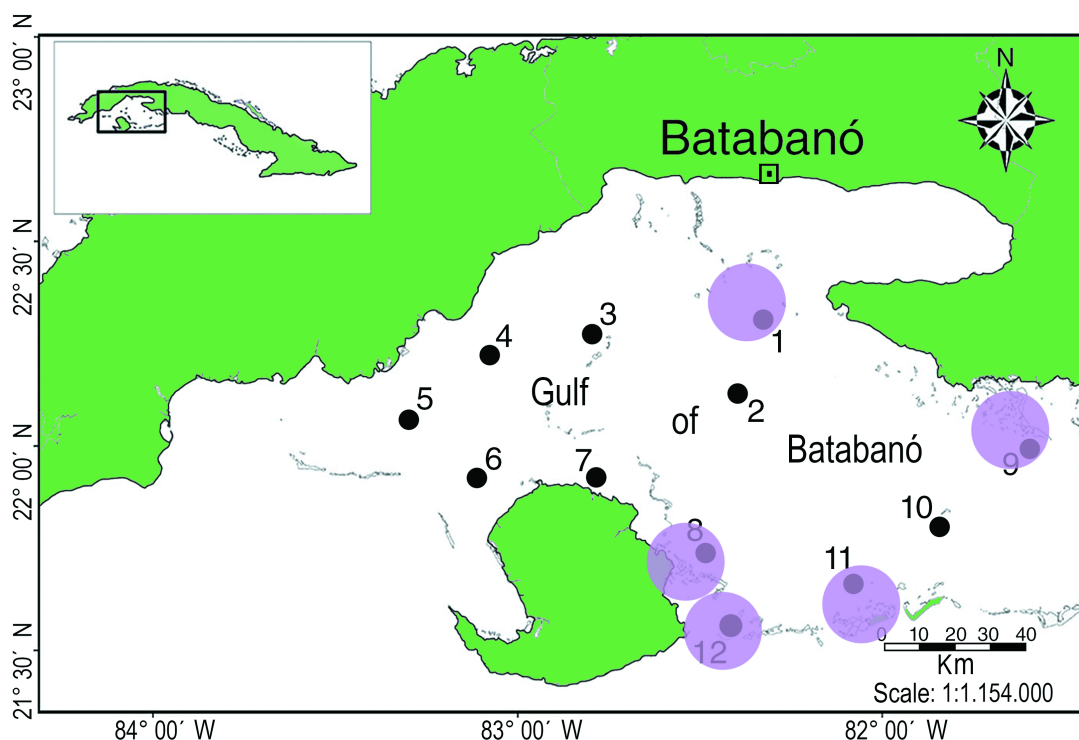


Fig. 2. Study area and location of the twelve sampled sites in the Batabanó fishing region, southwestern shelf of Cuba. Coloured sites are located within or extremely near to Protected Areas.

Table 1. Descriptive statistics of variables analysed for the Current and Past periods in the Caibarién and Batabanó fishing regions

Indicators	N	Mean	Median	Minimum	Maximum	Standard Deviation
(Caibarién region, Current Period)						
CL (mm)	1380	92.8	93.2	69.0	128.5	13.4
TW (g)	1380	658.4	651.8	191.2	1041.0	187.9
BRI	1380	14.3	14.3	4.6	28.8	4.3
Kcl	1380	7.0	7.1	2.6	10.1	1.4
(Batabanó region, Current Period)						
CL (mm)	3600	92.9	93.1	69.0	130.0	12.0
TW (g)	3600	656.6	652.0	190.1	1058.0	187.2
BRI	3600	15.2	15.2	4.7	29.9	4.3
Kcl	3600	7.0	7.1	2.2	10.4	1.3
(Caibarién region, Past Period)						
CL (mm)	2448	80.4	80.0	69.0	120.0	8.7
TW (g)	2448	471.5	450.0	225.0	1260.0	145.6
Kcl	2448	5.8	5.6	3.5	10.6	1.1
(Batabanó region, Past Period)						
CL (mm)	3123	86.1	83.0	69.0	154.0	18.2
TW (g)	3123	561.8	500.0	183.3	1575.0	278.4
Kcl	3123	6.3	6.0	2.0	16.6	1.9

Note: N – total number of sampled lobsters, CL – carapace length, TW – total body weight, Kcl – morphometric nutritional condition index, BRI – blood refractive index.

Differences between regions, or periods, were numerically unremarkable. Nevertheless, statistical analysis detected significant ($p < 0.05$) cases. Long term temporary variations (between Past and Current periods) showed significant differences for all morphometric parameters measured in the Caibarién and Batabanó fishing regions. It was higher in the Current Period (Table 2).

By grouping the sites sampled inside each region, it was found that the long-term spatial variations (comparison between the Caibarién and Batabanó fishing regions) showed significant differences for all morphometric parameters measured in the Past Period. For the Current Period, non-significant differences were found (Fig. 3).

Table 2. Mann-Whitney U-test ($p < 0.05$) comparing lobster’s (*Panulirus argus*) morphometric indicators between the Past and Current periods in the Caibarién and Batabanó regions, Cuba

Indicators	Caibarién region (N = 3828)			Batabanó region (N = 6723)		
	Z	U	p	Z	U	p
TW (g)	-29.01	702 009	0.001 >	-23.69	3 741 063	0.001 >
CL (mm)	-30.07	736 805	0.001 >	-23.81	3 732 020	0.001 >
Kcl	-26.59	816 283	0.001 >	-23.57	3 750 825	0.001 >

Note: N – total number of sampled lobsters, CL – carapace length, TW – total body weight, Kcl – morphometric nutritional condition index.

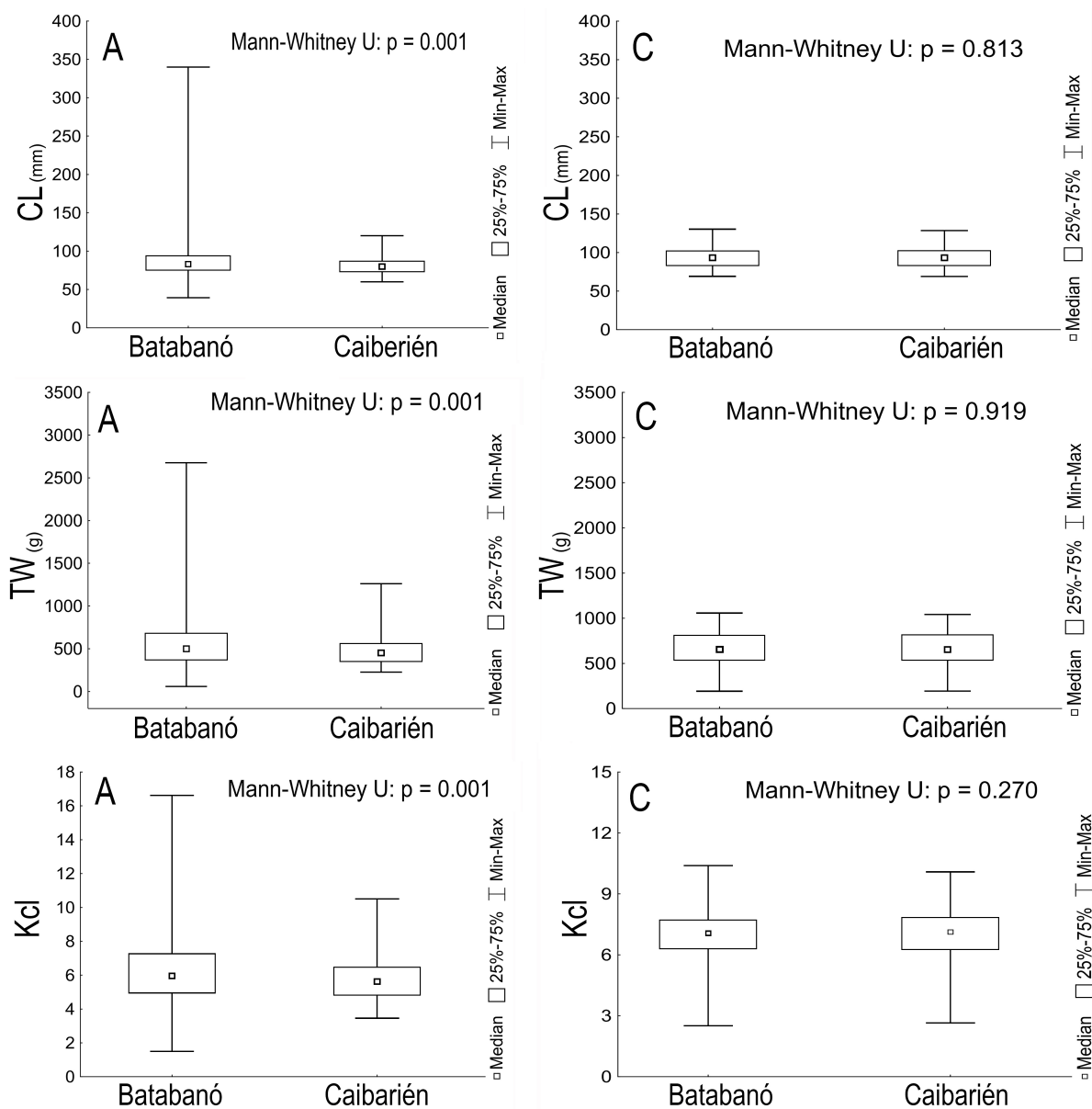


Fig. 3. Morphometric indicators estimated for *Panulirus argus*, and compared between the Caibarién and Batabanó fishing regions (Cuba), in the Past (A) and Current (C) periods. Designations: CL – carapace length, TW – total body weight, Kcl – morphometric nutritional condition index.

Despite these morphometric similarities between lobsters from each region in the Current Period, the analytic BRI index showed significant differences, demonstrating a higher average value in the Batabanó region. Nevertheless, temporal inferences respecting the Past Period could not be made, since the BRI index was assessed only for the Current Period (Fig. 4).

Males and females of lobsters showed different nutritional condition in both regions. Both (Kcl

and BRI) nutritional condition indices detected significant differences between sexes. For male lobsters, higher values were found in both the Caibarién and Batabanó fishing regions (Fig. 5).

Discussion

In the Past Period, lobster’s nutritional condition, analysed by Kcl, was higher in the Batabanó region than in the Caibarién region. In the Current Period, only BRI detected nutritional conditions to be higher in the Batabanó region, suggesting that each region has had a different environmental impact through time. Additionally, this could be partially due to methodological differences between the applied methods. Kcl and BRI indices could be differently affected by environmental factors. Kcl variation requires time for the occurrence of processes affecting lobsters’ weight and size. Conversely, BRI detects rapid changes in the concentration of circulating proteins, which could be caused by the impact of factors varying in a short-term temporal scale. Consequently, both indices differently expose lobster’s nutritional condition, which results from the interaction of factors determining habitat quality (Oliver & MacDiarmid, 2001; Lopeztegui-Castillo & Capetillo-Piñar, 2021).

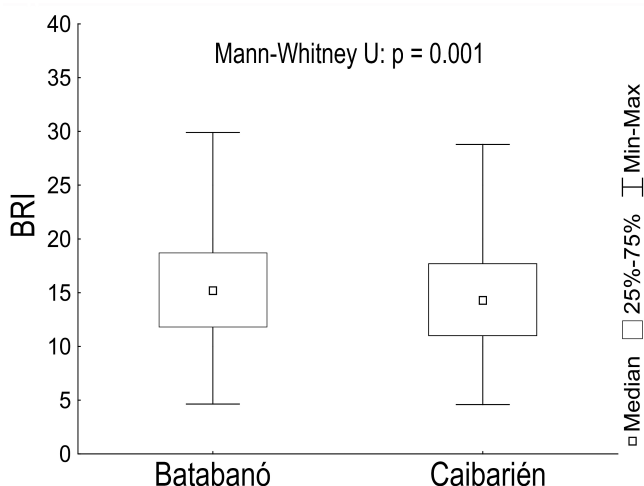


Fig. 4. Blood refractive index (BRI) for *Panulirus argus*, compared between the Caibarién and Batabanó fishing regions (Cuba) in the Current Period.

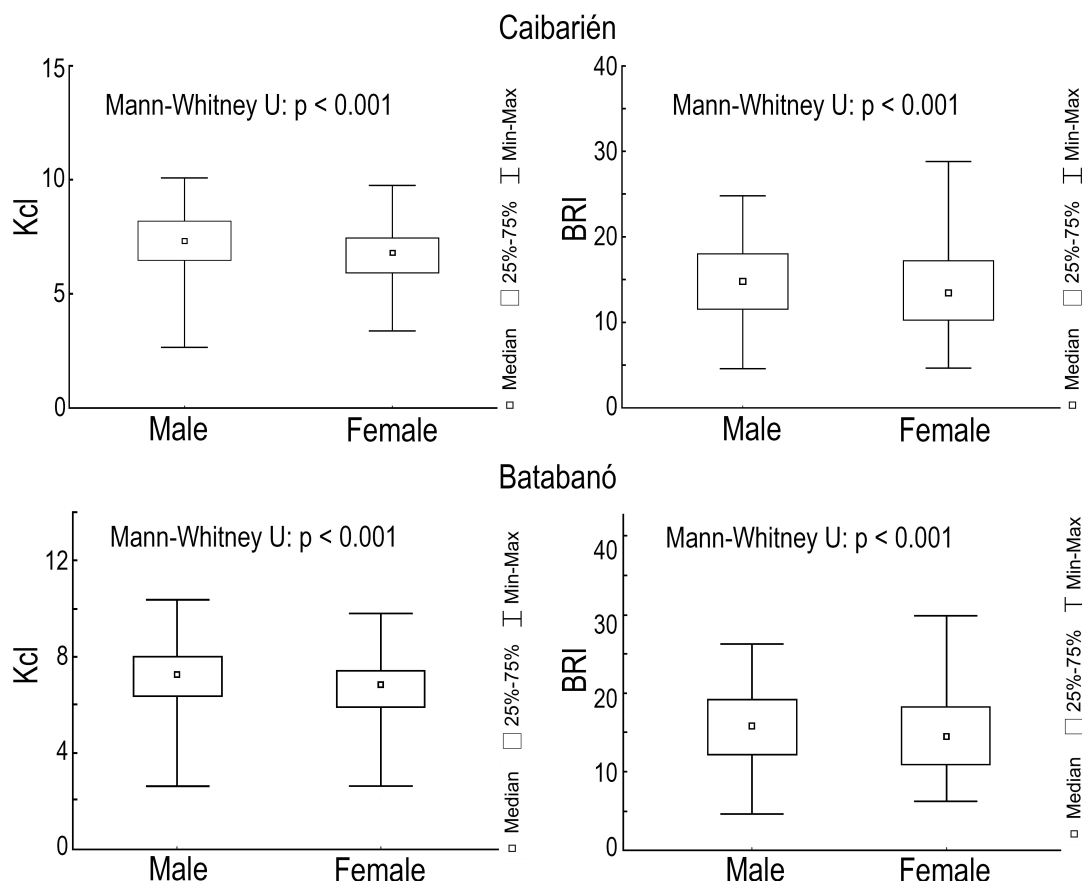


Fig. 5. Nutritional condition indices for males and females of *Panulirus argus* during the Current Period, in the Caibarién and Batabanó regions, Cuba. Designations: Kcl – morphometric nutritional condition index, BRI – blood refractive index.

Variations in lobster's nutritional condition have been reported as a seasonal process depending on lobster's reproduction and moult cycles (Perera et al., 2007; Rodríguez-García et al., 2015; Simon et al., 2015). In addition, food availability, diseases, and lobster's abundance could make vary lobster's energy reserves and the nutritional stage (Lozano-Alvarez & Aramoni-Serrano, 1996; Briones-Fourzán et al., 2009; Rotllant et al., 2014; Lopeztegui-Castillo et al., 2021a). Among other environmental factors affecting the organism's nutritional condition, the salinity, dissolved oxygen, temperature, noise, and ocean acidification processes have been studied intently (Fitzgibbon et al., 2017a,b; Harrington & Hamlin, 2019; Lopeztegui-Castillo, 2021). However, any factors determining lobster's habitat quality can potentially affect the nutritional condition, if it varies in the necessary magnitude or if its influence remains for the required time. Turbidity variations, which quasi-permanent focuses at both sides of the causeways and with higher values in Buena Vista Bay (Betanzos-Vega et al., 2013), could also affect lobster's feeding and energy substances reserved. Variation in each factor will affect the nutritional condition in a typical way, which will be detected, depending on the sensitivity and characteristics of the indicators and used methods (Robertson et al., 2000; George, 2001; Lopeztegui-Castillo, 2021).

Methodological differences between BRI and Kcl have been well analysed and interpreted based on the study scale (field or laboratory), temporary scale (long or short term), and other biological parameters like morphometric differences between sexes (Wang & McGaw, 2014; Gutzler & Butler, 2017; Lopeztegui-Castillo, 2021). The morphometric Kcl index depends on the magnitude, in which lobster's weight and length vary. Such variation could take some days (for an individual level) or some months (for a numerous lobster group). Conversely, lobster's blood protein concentration could change in a few minutes, which could be almost immediately detected by the analytic BRI index. Changes in blood protein concentration may instantly reflect environmental conditions. That is why this methodology can be unreliable when only a few animals (< 30) are used (Oliver & MacDiarmid, 2001; Lopeztegui-Castillo et al., 2012b). However, when BRI average value results from measuring several lobsters, it reflects the real and generalised habitat quality (Moore et al., 2000; George, 2001; Oliver & MacDiarmid, 2001; Lopeztegui-Castillo et al., 2012a,b; Lopeztegui-Castillo, 2021).

Lobster's abundance and distribution have been used as an efficient bioindicators of habitat conditions and can massively contribute to the ecosystem-based management approach (Valavi et al., 2009; Briones-Fourzán et al., 2019; Ghafari & Fitrianti, 2021). Based on the present results, using the lobsters' nutritional condition as an additional habitat quality indicator, could be acceptable and recommended only when analytical indices are used, like BRI, varying in a short-term scale depending on contemporary habitat resources. The lobster's metabolism and nutritional condition could be affected by the food availability (quantitative and qualitative), the presence of contaminants, like microplastic or heavy metals, stress induced by salinisation or turbidity, and many others environmental factors that determine habitat quality (Chou et al., 2003; Cau et al., 2023; Kampouris et al., 2023).

The lobster's nutritional condition was higher in males than in females. It was found in both regions and for both indices detected. These differences have been reported by almost all previous studies on lobster populations in Cuba (Buesa, 1965; Lopeztegui-Castillo et al., 2012a,b; Lopeztegui-Castillo & Capetillo-Piñar, 2021). Consequently, it can be assumed as a natural common phenomenon at least on the Cuban lobster population. Environmental changes should have been sufficiently remarked to affect the nutritional condition of male and female lobsters. Consequently, both nutritional condition indices changed despite distinct sensibility and methodological differences between them. No significant differences between diets of both sexes have been reported for this species in Cuba (Herrera et al., 1991; Martínez-Coello et al., 2015). Hence, nutritional condition differences must be attributed to each sex physiology and behaviour. The nutritional condition of juveniles of the lobster in a Mexican reef lagoon did not show differences between sexes (Briones-Fourzán et al., 2009). In fact, juveniles of both sexes use to co-exist in the same habitat. Nevertheless, adult lobsters could acquire habits with different seasonal variation for each sex (Cruz et al., 1990). Food availability, predator abundance, seagrass density, physical structure of the sea bottom and shelter availability could determine movements and behavioural differences between adult males and females (González-Sansón et al., 1991; Lozano-Alvarez et al., 2017; Lopeztegui-Castillo, 2021). Consequently, lobster's growth, weight gains and the accumulation of the energetic reserves could be different between sexes.

The nutritional condition Kcl index was higher in the Current Period. This contradicts the deterioration observed in benthic communities and seagrasses, which constitute food for lobsters, which have significantly decreased in the Batabanó region (Arias-Schreiber et al., 2008; Cerdeira-Estrada et al., 2008; Lopeztegui-Castillo & Capetillo-Piñar, 2008; Hidalgo-Rodríguez & Areces-Mallea, 2009; Lopeztegui-Castillo & Martínez-Coello, 2020; Lopeztegui-Castillo et al., 2021a) and in the Caibarién region (Hidalgo et al., 2015; Lopeztegui-Castillo et al., 2021b; Martínez-Daranas et al., 2021). The morphometric nature of Kcl could contribute explaining this apparent contradiction, it can vary mostly resulting from changes in lobster's population parameters like weight and length. Increment of mean size and size at first maturity on the Cuban lobster population have been reported as a consequence of fishing pressures (de León, 2005). Similar results have been reported for *Panulirus cygnus* RW George, 1962 populations, which density has been decreased, because of intensive fishing pressure (Chittleborough, 1979). Also, it was similarly reported for the *Jasus lalandii* (H. Milne Edwards, 1837) population and for other *Jasus* species (Beyers & Goosen, 1987). Basically, larger lobsters could produce and release a higher number of eggs (Pollock, 1991, 1993, 1995). Since variations of food availability in the natural habitat do not have a direct and immediate impact on the Kcl index, which could be impacted by many others morphometric parameters, this index should be prudently used as nutritional condition indicator.

However, other authors have attributed to an increased mean size and size at first maturity, to recruitment fails (Baisre, 2000a,b). In the Cuban lobster population, recruitment fails have been documented from 1990, resulting essentially from natural meteorological events like intensive hurricane, and a decreased nutrient concentration at the coastal zone (Baisre, 2000a,b, 2006). Additionally, the Cuban coastal zone has been impacted by other tropical processes like sewage water input, bottom trawling, and mangrove cutting (Baisre & Arbolea, 2006; Vales-García & Aguilar-González, 2021). Even caffeine has been recently reported as an important contaminant in the coastal zone (Vieira et al., 2022). It is a reason why it should be included in further studies considering that most of the Cuban people are used to drinking a lot of coffee. These factors impacting lobster's population parameters have intensified from 1990 (Alzugaray et al., 2018; Puga et al., 2013), decreasing

in carrying capacity of marine ecosystems, particularly in nursery areas. The *Puerulus* settlement has been consequently affected, reinforcing bottleneck processes, and causing changes in lobster's population dynamics (Puga et al., 1991; Parrish & Polovina, 1994; Baisre, 2000a,b).

Large lobsters could come from deeper areas where food availability is not a limiting resource. In those cases, the increment of the mean lobster size implies a lobster mean weight increment. Therefore, this could cause an increased Kcl. The probability of finding large lobsters coming from deeper water is higher on shelf edge sites (González-Sansón et al., 1991). Such sites are numerous in the Caibarién region because of the narrowness and the strategy location of the fishing areas. Accordingly, a different magnitude of Kcl variation was found between periods, detecting significant differences ($p < 0.05$) in the Past period, and only slightly differences ($p > 0.05$) in the Current period. This means that Kcl variation is higher in the Caibarién region (1.5 units) than in the Batabanó region (1.1 units), possibly caused by a different environmental impact in the regions. The number, diversity, and magnitude of environmental factors, impacting coastal marine ecosystems, were higher in the Caibarién region (García-García et al., 2008; Montalvo-Estévez et al., 2008, 2010, 2013, 2014). The unfavourable environmental conditions in the Caibarién region could have caused moving fishing areas to the shelf edges, increasing the probability of finding larger lobsters. Also, the incipient improvement of habitat conditions on some sites of the Caibarién region contributes to a less affected lobster's nutritional condition. Such incipient improvement has been potentially attributed to the effectiveness of multiple management measures, like increasing Protected Areas (Lopeztegui-Castillo et al., 2021b).

By providing information about lobster's nutritional condition in natural habitats of the Caibarién fishing region, our results constitute a usefulness baseline. Due to no standardisation among the numerous methods determining nutritional condition in crustaceans, it would be needed and recommended to analyse variations more than pointed values in each study (Gutzler & Butler, 2017; Lopeztegui-Castillo, 2021). Nevertheless, the environmental deterioration in the Caibarién region confers both variations and point value importance, as references of lobster's nutritional condition in polluted and anthropised coastal zone sites (Alcolado & Espinosa, 1996; Lopeztegui-Castillo et al., 2021b; Martínez-Daranas et al., 2021). In addition to the information,

gradually provided by previous studies developed in Cuba (Lopeztegui-Castillo et al., 2012a,b, 2023; Lopeztegui-Castillo, 2021; Lopeztegui-Castillo & Capetillo-Piñar, 2021), Kcl index was locally estimated, by improving the comparison of results. Based on this, it is suggested that the Kcl index is not an efficient indicator of truly lobsters' nutritional condition.

Conclusions

Lobster's nutritional condition has been typically higher in the Batabanó region than in the Caibarién region. Nevertheless, only BRI currently detected significant differences, suggesting that both regions have had a different environmental impact through time. Methodological differences between indices could partially influence though. Long-term temporary variations showed an increased Kcl index in both fishing regions. The morphometric nature of the Kcl index could contribute to explaining this increment, by resulting from changes in lobster's population parameter, such as weight and length, which could change because of intensive fishing pressure.

The lobster's nutritional condition, which could be used as an additional habitat quality indicator based on the BRI results, was higher in males than in females. In fact, this can be assumed as a natural common phenomenon at least in the Cuban lobster population, possibly resulting from reproductive processes and local feeding regime. Being remained through the time, differences between sexes suggest that regional environmental changes should have been remarked enough to affect the nutritional condition of male and female lobsters. Consequently, both nutritional condition indices changed despite distinct sensibility and methodological differences between them.

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ДОЛГОВРЕМЕННЫЕ ИЗМЕНЕНИЯ УСЛОВИЙ ПИТАНИЯ *PANULIRUS ARGUS* (DECAPODA: PALINURIDAE) НА КУБЕ: АНАЛИТИЧЕСКИЕ И МОРФОЛОГИЧЕСКИЕ ПОДХОДЫ

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Индексы условий питания часто использовались в качестве морфофизиологических индикаторов для изучения изменений в физиологии и энергетических запасов лобстеров. Целью данного исследования было определение долговременных пространственно-временных изменений условий питания *Panulirus argus* (далее – лобстер) с учетом двух индексов, включая аналитический показатель преломления крови (BRI) и морфометрический Kcl (отношение общего веса к длине панциря). Информация с одиннадцати участков в регионе Кайбарьен, отобранных в 2010–2015 гг., и двенадцати участков в регионе Батабано, отобранных в 2011–2017 гг., была обозначена как современный период. Морфометрические данные для оценки индекса Kcl, включающие 1987–1988 гг. в регионе Кайбарьен и 1981–1993 гг. в регионе Батабано, были сгруппированы как прошлый период. Временные изменения были определены путем сравнения современного и прошлого периодов в каждом регионе. Пространственные изменения определялись путем сравнения данных между регионами. Для проанализированных особей лобстера в текущий период были определены значения индексов BRI = 14.3, Kcl = 7.0 в регионе Кайбарьен и BRI = 15.2, Kcl = 7.0 в регионе Батабано. За прошлый период значение индекса Kcl составило 5.8 и 6.3 в регионах Кайбарьен и Батабано соответственно. Индексы Kcl и BRI были выше для самцов лобстера. Это может быть связано с процессом размножения. Однако на это могут влиять внутренние морфометрические различия между самцами и самками. Значения морфометрических показателей были выше для современного периода. Пространственные изменения морфометрических показателей статистически значимо различались для прошлого периода, что было связано с разными природными условиями в каждом регионе. Индекс BRI был выше в регионе Батабано, что, вероятно, связано с лучшим состоянием донных сообществ и лучшим качеством воды. Полученные результаты способствуют пониманию условий питания лобстера в естественной среде обитания, главным образом, в регионе Кайбарьен, где на сегодняшний день проведено мало исследований.

Ключевые слова: десятиногие ракообразные, лангуст, морфофизиологические индексы, экофизиология, энергозапасы ракообразных