

BEAUFORTIA

INSTITUTE OF TAXONOMIC ZOOLOGY (ZOOLOGICAL MUSEUM)
UNIVERSITY OF AMSTERDAM

Vol. 43, no. 6

April 13, 1993.

BIOMETRIC VARIATION IN *SPADELLA CEPHALOPTERA* ON THE CANARY ISLANDS (CHAETOGNATHA)

ALEXANDRA T. C. BROERSE

Institute of Taxonomic Zoology, University of Amsterdam, P. O. Box 4766, 1009 AT Amsterdam, The Netherlands

Keywords: Chaetognatha, biometric variation, Canary Islands.

ABSTRACT

Specimens of *Spadella cephaloptera* from Tenerife, Gran Canaria and Gomera (Canary Islands) were compared biometrically in regards to morphometric and meristic characters. Variation exists among the populations on the islands as well as between the islands. The populations on Gomera seem more distinct from the populations on Tenerife and Gran Canaria than the two latter are mutually. An apparent decline in the number of adults occurs in July, which is related to a decrease in the number of eggs. A shortage of food can explain the reduced fecundity of the specimens. *S. cephaloptera* prefers habitats protected from the influence of waves.

INTRODUCTION

The genus, *Spadella* Langerhaus, 1880, is a benthic group of chaetognaths. There are still many gaps in our knowledge of this genus because the animals are small and easily overlooked, though relatively easy to collect. Because of their benthic habits, the populations of *Spadella* supposedly are rather isolated.

The aim of this study was to detect the differences between various populations of *S. cephaloptera* (Busch, 1851) collected from several locations along the coasts of Tenerife, Gran Canaria and Gomera (Canary Islands, Fig. 1). An attempt is made to explain the variation in bio-

metric features caused by distance (on and between the various islands), time (growth and population composition over time), and abiotic environmental factors. Also the presence of prey in the gut of *S. cephaloptera* in relation to these factors was studied.

MATERIAL AND METHODS

S. cephaloptera always occurs adhering to the surface of seaweed, rocks or coarse sand. The natural habitat is formed by protected pools and shallow bodies of water, which are not heavily disturbed by waves (John, 1933). *S. cephaloptera*

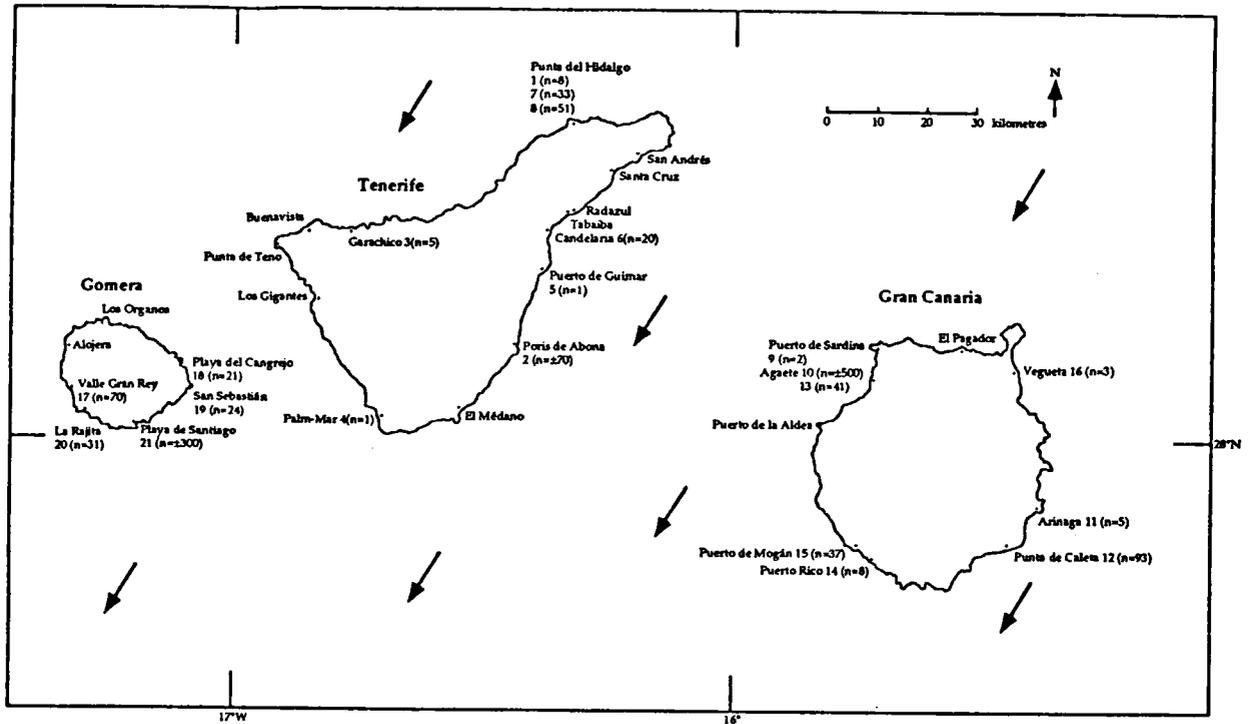


Fig. 1. The sample locations on Gomera, Tenerife, and Gran Canaria (n= number of caught specimens of *Spadella cephaloptera*) arrow: south-west directed current.

Table 1. Summary of previous studies on *Spadella cephaloptera*.

author	location	habitat	method
Owre (1972)	Bahamas	sandy bottom with <i>Thalassia</i> , <i>Syringodium</i> or algae	Ockelmann sledge, home made sledge
John (1933)	Plymouth, England	on sea weeds and small pebbles and rocks	shaking sea - weeds in bottles with seawater/ scraping up the soft bottom layer
Yosii & Tokioka (1939)	Inland sea, Misaki Japan	on <i>Zostera</i>	
Hernández & Jiménez (1986)	Tenerife, Canary islands	on sandy, muddy bottom with <i>Caulerpa prolifera</i>	net (200µm)
Ghirardelli (1968)	Naples, Italy	on prairies of <i>Posidonia</i>	
Furnestin & Brunet (1965,1968)	Marseille, France	on <i>Posidonia oceanica</i> and sand	benthic sledge for endofauna (between 0 to 5 cm in sediment)

Table 2. The localities on the islands and some features.

pop. nr.	location	date d/m/y	habitat	details	depth (in m)	no. of caught <i>Spadella</i> 's	
1	Tenerife	Punta del Hidalgo	2,10,22/5/91	tidal pools	several sea-weeds	0-1.5	8
2		Poris de Abona	27/5,30/6/91	harbour	on <i>Ceramium rubrum</i> & <i>Corallina mediterranea</i>	±3	±70
3		Garachico	26/5/91	tidal pools	shallow and deep pools	0-1.5	5
4		Palm-Mar	21/6/91	open water	exposed	±8	1
5		Puerto de Güimar	2/7/91	harbour	little exposed	2-4	1
6		Candelaria	4,10/7/91	harbour	sandy, little sea-weeds	2-3	20
7		Punta del Hidalgo	8/7/91	natural swimmingpool	shallow and deep pools	1.5-3.5	33
8		Punta del Hidalgo	11/7/91	natural swimmingpool	shallow and deep pools	1.5-3.5	51
9	Gran Canaria	Puerto de Sardina	29/5/91	tidal pools	several sea-weeds	1-4	2
10		Agaete (puerto de las Nieves)	29/5/91	harbour	on <i>Ceramium rubrum</i> & <i>Corallina mediterranea</i>	3-5	±500
11		Arinaga	30/5/91	harbour	sea-grasses grown with algae & several sea-weeds	2-3	5
12		Punta de Caleta	30/5/91	harbour	muddy, several sea-weeds	2-3	93
13		Agaete (puerto de las Nieves)	31/5/91	harbour	on <i>Ceramium rubrum</i> & <i>Corallina mediterranea</i>	3-5	41
14		Puerto Rico	1/6/91	harbour	sandy, polluted, sheltered	±3	8
15		Puerto de Mogán	1/6/91	harbour	muddy	3-8	37
16		Vegueta	1/6/91	harbour	very polluted	±3	3
17	Gomera	Valle Gran Rey	4/6/91	harbour	sheltered, sandy, algae on rocks	±4	70
18		Playa del Cangrejo	4/6/91	bay	exposed	0-4	21
19		San Sebastian	5/6/91	harbour	sandy, algae on rocks	2-5	24
20		La Rajita	5/6/91	harbour	exposed	2-6	31
21		Playa de Santiago	5/6/91	harbour	sandy, algae on rocks	2-6	±300

occurs circumglobally (Table 1), although Bieri (1991) suggests that the Japanese specimens might be a distinct species.

Almost all specimens of *Spadella cephaloptera* in this study were collected with a sledge with a mesh size of 200 µm. The sampling took place during May, June and July 1991. By slowly moving the net opening over the surface of the substrate and by sweeping a hand or a bristle in the direction of the net the loose plant and bottom material was caught into the net.

Collecting rocks (with or without algae) and washing these in a bucket filled with fresh or sea water didn't produce any chaetognaths. Some specimens were captured by collecting bits of sea weeds under water in a bag and shaking these in a bucket filled with sea water. The residue was

than filtered over a 200 µm filter. Immediately after filtering the residue was put into 4% formaldehyde.

In the laboratory the samples were checked for *Spadella*'s with the aid of a binocular microscope and than fixed in small tubes with 4% neutralised formalin.

Table 2 lists the localities of the collected material. Locality numbers 1, 2 and 6 are composed of samples of various dates, because the separate samples were too small for statistical analysis. The populations are indicated on a map (Fig. 1).

The following maturity stages were determined, based on the development of the ovaries and the testis (Russell, 1932 and Furnestin, 1957): stage I: male and female gonads not visible; stage II: testis developed, female gonads begin to develop; stage III: male and female gonads well

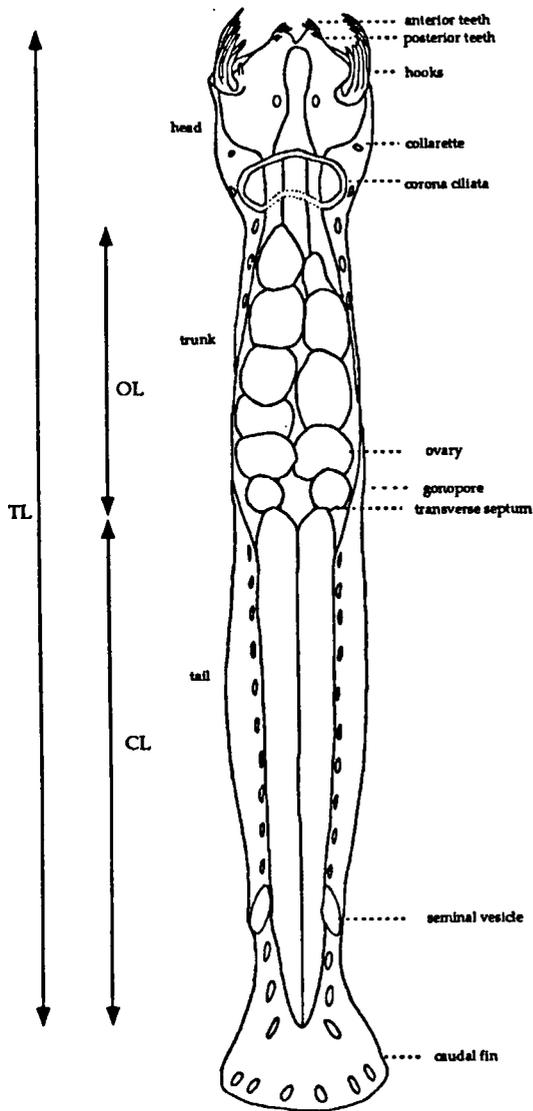


Fig. 2. Drawing of a *Spadella cephaloptera*.

TL = total length
 CL = caudal length
 OL = ovarian length

developed.

Measurements and counts were made for the following morphometric and meristic characters (Fig. 2): total length (TL) in mm, caudal length (CL) in mm and ovarian length (OL) in mm (mean length of the two ovaries is used). For the number of hooks, anterior and posterior teeth the mean numbers on the left and right side of the specimens are used. Caudal percentage (C%; CL

in relation to TL) and ovarian percentage (O%; mean OL in relation to TL) were also calculated. For all the populations and islands a mean value and standard deviation were calculated (spreadsheet program EXCEL 3.0) for all the morphometric and meristic characters.

A non-parametric Kruskal-Wallis test was assigned for analysis of the populations on the three islands (Tenerife, Gran Canaria and Gomera) separately and for analysis of the three islands mutually. This non-parametric test by ranks was used, because not all data fulfil the condition of normal distribution. It also reduces the probability of making a Type I statistical error. Whenever a significant statistic was observed, *a posteriori* non-parametric Mann-Whitney U test was performed to determine how any of the two compared pairs of samples differed (Sokal & Rohlf, 1969).

For the analysis of the biometric factors in time three groups of populations, collected in May, June and July, were compared. Because the locations, the number of populations, and the time between the periods are unequal no statistical tests were executed; and only the mean values and percentages of the characters are given.

For the values of the morphometric and meristic characters a Spearman correlation coefficient was determined and a significance test was assigned. All the statistical analyses were executed in Statview and Statworks.

For each population the prey percentage was calculated. This was determined by noting the number of specimens that had one or more prey in their gut in relation to the total number of specimens.

RESULTS

Total length, caudal length, caudal percentage, ovarian length, and ovarian percentage increase as *Spadella cephaloptera* grows older. Only on Tenerife is there a slight decrease in caudal percentage from sexual stage II to III. The number of hooks increases for all the three islands from stage I to II, but slightly decreases from stage II to III. The number of anterior and posterior

teeth increases from stage I to II as well as from stage II to III.

On all the islands the majority of the animals were in stage III (64% on Gran Canaria to 73% on Tenerife). On Gran Canaria and on Gomera the smallest percentages of specimens were in stage I (11% & 5%). On Tenerife there were more animals in stage I (14%) than in stage II (13%). This is because almost all specimens in population number 6 (Candelaria) were in stage I.

The statistical comparison (Kruskal-Wallis test) among the populations on each of the three islands did not reveal a clear view of the values of the biometric characters. On Tenerife all the characters in stage I and II showed no significant heterogeneity. In sexual stage III the total length, caudal length and ovarian length showed significant variation. When all the specimens of the three sexual stages together were compared, all characters revealed significant heterogeneity. On Gran Canaria and Gomera there were no significant differences in the characters in stage I. The morphometric characters that showed heterogeneity on Gran Canaria in stage II were ovarian length, number of hooks, and number of posterior teeth. In stage III significant variation was found in the total length, ovarian length, number of hooks, number of anterior and posterior teeth. A comparison of the three sexual stages together revealed heterogeneity in ovarian length, number of hooks and number of anterior teeth. On Gomera significant differences in stage II were found in total length, caudal length, and number of hooks. In stage III differences occur in total length, caudal length and ovarian length, number of hooks and number of posterior teeth. In the total number of specimens heterogeneity was found in total length, caudal length and ovarian length, and number of hooks.

The specimens on Tenerife have the lowest mean total length and caudal length. However, the number of hooks and posterior teeth are higher than on Gran Canaria and Gomera. The number of anterior teeth of the specimens on Tenerife is higher than on Gran Canaria but lower than on Gomera.

The mean total length of the specimens on Gran Canaria is higher than on Tenerife, but the caudal percentage and ovarian percentage are lower.

The specimens on Gomera have the highest mean total length, caudal length, caudal percentage, ovarian length, and ovarian percentage. The ovarian length and ovarian percentage increase rapidly from sexual stage II to III. It is striking that the mean number of anterior teeth in all sexual stages is much higher than on the other islands.

A statistical comparison (Kruskal-Wallis test, Table 3) of the morphometric characters among the three islands revealed heterogeneity in stage I for total length, caudal length, number of hooks and number of anterior teeth; in stage II for ovarian length, number of anterior and posterior teeth; and in stage III for total length, caudal length and ovarian length, number of hooks and number of anterior and posterior teeth; and for the total number of specimens for total length and caudal length, number of hooks and number of anterior and posterior teeth.

An *a posteriori* comparison (Mann-Whitney U test, Table 4) of the specimens, in sexual stage III and in total, of the islands mutually, showed the following results: the numbers of anterior and posterior teeth of the specimens in total were significantly different between Tenerife and Gran Canaria. In stage III, only the number of posterior teeth showed heterogeneity. All the characters in stage III and in the total number of specimens showed significant differences between Tenerife and Gomera. With regards to Gran Canaria and Gomera all characters, except the number of posterior teeth, revealed heterogeneity in stage III, and in the total number of specimens.

The morphometric characters were tested on independence with the "Spearman correlation of ranks test" for the total number of specimens (Table 5). The caudal length and the ovarian length are highly correlated with the total length. The number of hooks is only significantly, negatively correlated with the total length in stage III. The number of anterior teeth is not correlated with the total length only in stage I and the number of posterior teeth is also not correlated in

Table 3. Statistical comparison (Kruskal-Wallis test) of the morphometric characters among three islands.

<i>sexual stage</i>	total length (in mm)	caudal length (in mm)	ovarian length (in mm)	no. hooks	no. ant. teeth	no. post. teeth	
<u>Ten-GC-Gom</u>	<u>H</u>	<u>H</u>	<u>H</u>	<u>H</u>	<u>H</u>	<u>H</u>	
I	11.68**	10.35**	0.00 ns	7.41*	7.17*	1.41 ns	
II	1.27 ns	0.84 ns	31.85**	2.13 ns	9.80**	5.41 ns	ns : not significant
III	14.40**	18.26**	12.30**	27.47**	21.11**	22.74**	* : 0.01 < p ≤ 0.05
total	8.92*	11.87**	4.21 ns	23.67**	37.90**	22.75**	** : p ≤ 0.01

Table 4. Statistical comparison (Mann-Whitney U test) of the biometric features of *Spadella cephaloptera* among the islands, mutually. *ts*: sample statistic of t-distribution

<i>sexual stage</i>	total length (in mm)	caudal length (in mm)	ovarian length (in mm)	no. hooks	no. ant. teeth	no. post. teeth
<u>Ten-GC</u>	<u>ts</u>	<u>ts</u>	<u>ts</u>	<u>ts</u>	<u>ts</u>	<u>ts</u>
III	1.43 ns	1.48 ns	0.84 ns	0.22 ns	1.50 ns	3.03**
total	0.25 ns	0.19 ns	-	0.46 ns	2.23*	3.58**
<u>Ten-Gom</u>						
III	3.87**	4.26**	4.27**	4.54**	2.00*	3.81**
total	2.65**	2.97**	-	3.64**	2.44*	3.59**
<u>GC-Gom</u>						
III	2.06*	2.77**	2.47*	3.89**	3.84**	0.06 ns
total	2.34*	2.96**	-	3.37**	5.11**	0.03 ns

ns : not significant
 * : 0.01 < p ≤ 0.05
 ** : p ≤ 0.01

Table 5. Correlation of the biometric characters of *Spadella cephaloptera*.

<i>sexual stage</i>	total (n=719)	I (n=75)	II (n=159)	III (n=485)
<i>comparison</i>				
tot l. x caudal l.	0.97**	0.95**	0.92**	0.92**
tot l. x ovarian l.	0.57**	-	0.28**	0.64**
tot l. x no. hooks	-0.05 ns	-0.03 ns	0.00 ns	-0.12**
tot l. x no ant. teeth	0.29**	0.06 ns	0.16*	0.18**
tot l. x no post. teeth	0.17**	0.10 ns	0.24**	0.03 ns
no hooks x no ant. teeth	0.03 ns	0.24 ns	0.09 ns	0.06 ns
no hooks x no post. teeth	0.11**	0.27*	0.17*	0.14**
no ant. teeth x no post. teeth	0.11**	0.08 ns	-0.03 ns	-0.06 ns

ns : not significant
 * : 0.01 < p ≤ 0.05
 ** : p ≤ 0.01

Table 6. Prey presence per island and per sexual stage. (n= number of observations in each sample)

population	prey % per sexual stage						total
	I	II	III	total	total	total	
TENERIFE	13.3	(n=30)	3.8	(n=26)	14.2	(n=127)	12.6
GRAN CANARIA	3.1	(n=32)	8.4	(n=71)	14.8	(n=189)	12.0
COMERA	12.5	(n=16)	26.3	(n=57)	15.6	(n=173)	17.9
total	9.0	(n=78)	14.3	(n=154)	14.9	(n=489)	

Table 7. Mean values of the biometric characters of the northern and southern populations.

northern populations: Punta del Hidalgo (1,7,8), Garachico (3)

southern populations: Punta de Caleta (12), Arinaga (11), Puerto Rico (14)

sexual stage	total l. (in mm)	caudal l. (in mm)	caudal% l. (in mm)	ovarian l. (in mm)	ovarian%	no. hooks	no. ant. teeth	no. post. teeth
I								
north	2.19±0.28	1.14±0.17	51.80±2.71	0.00	0.00	7.86±0.36	2.86±0.53	1.20±0.63
south	2.77±0.40	1.37±0.18	49.69±2.67	0.00	0.00	7.50±0.63	2.53±0.55	0.65±0.67
II								
north	3.00±0.28	1.56±0.16	52.08±2.14	0.20±0.13	6.70±4.11	8.09±0.30	3.00±0	1.55±0.50
south	3.11±0.42	1.53±0.21	49.32±2.26	0.09±0.15	3.05±5.35	7.78±0.57	3.03±0.61	0.78±0.73
III								
north	3.74±0.37	1.93±2.12	51.57±2.72	0.70±0.23	18.51±5.40	8.05±0.46	3.25±0.47	1.95±0.21
south	4.21±0.62	2.12±0.35	50.25±2.73	0.97±0.33	22.64±6.08	7.82±0.60	3.26±0.51	1.38±0.71
Total								
north	3.43±0.66	1.77±0.36	51.66±2.65	0.55±0.34	14.62±8.56	8.03±0.44	3.16±0.47	1.82±0.41
south	3.75±0.83	1.88±0.39	49.99±2.70	0.65±0.50	15.34±11.50	7.75±0.62	3.08±0.60	1.14±0.78

stage III. There is no significant correlation between the number of hooks and the number of anterior teeth, but there is correlation between the number of hooks and the number of posterior teeth. The numbers of anterior and posterior teeth are only (positively) correlated, as we determine the correlation coefficient of the total number of animals.

The prey percentage was calculated per population and per island (Table 6). In stage I the prey percentage among the islands varies from 3.1% to 13.3% and in stage II from 3.8% to 26.3%. The prey percentage in stage III is approximately constant on the three islands (14.2 to 15.6%). On Gomera, the prey percentage of the total number of specimens reaches the highest level (17.9). On Tenerife the prey percentage is 12.6 and on Gran Canaria 12.0.

A comparison in each sexual stage shows that in stage I only 9.0% of the specimens have a prey. In stage II the percentage is 14.3 and in stage III it is 14.9%.

To indicate differences in biometric characters over the largest latitudinal distance, four northern populations on Tenerife were compared with the southern populations on Gran Canaria (Tables 7 and 8). The total length of the southern populations is in stage I, II, III higher than the length of the northern populations. Only in stage II are the differences not significant. The caudal length is significantly higher in the southern populations in stage I and III. The caudal percentage is in all stages lower in the southern populations than in the northern populations. The ovarian length is only significantly higher in stage III

Table 8. Statistical comparison (Mann-Whitney U test) of the biometric characters in the northern and southern populations.

n1: number of specimens in northern populations
n2: number of specimens in southern populations
Us: Mann-Whitney sample statistic
ts: sample statistic of t-distribution

<i>sex. stage I</i>	n1,n2	Us	ts	Signifi- cance	<i>sex. stage II</i>	n1,n2	Us	ts	Signifi- cance
total l.	14, 20	251.5	—	**	total l.	11, 18	108.0	—	ns
caudal l.	14, 20	230.0	—	**	caudal l.	11, 18	112.5	—	ns
ovarian l.	14, 20	140.0	—	ns	ovarian l.	9, 15	94.5	—	ns
no. hooks	14, 20	185.0	—	ns	no. hooks	11, 18	127.5	—	ns
no. ant. teeth	14, 20	179.5	—	ns	no. ant. teeth	11, 18	104.5	—	ns
no. post. teeth	10, 20	142.5	—	ns	no. post. teeth	11, 18	135.0	—	ns

<i>sex. stage III</i>	n1,n2	Us	ts	Signifi- cance	<i>total</i>	n1,n2	Us	ts	Signifi- cance
total l.	72, 68	3608.0	4.84	**	total l.	97, 106	6204.5	2.54	*
caudal l.	72, 68	3338.0	3.71	**	caudal l.	97, 106	5754.0	1.47	ns
ovarian l.	72, 68	3547.5	4.58	**	ovarian l.	94, 103	5454.0	1.53	ns
no. hooks	72, 68	2851.5	1.68	ns	no. hooks	97, 106	3795.0	2.64	**
no. ant. teeth	72, 68	2493.0	0.19	ns	no. ant. teeth	97, 106	4558.0	0.63	ns
no. post. teeth	72, 68	3547.5	4.58	**	no. post. teeth	97, 106	2520.5	5.63	**

ns : not significant
* : 0.001 < p ≤ 0.05
** : p ≤ 0.001

in the southern populations. The ovarian percentage varies in the same way as the ovarian length. The number of hooks is lower for all stages in the southern populations, but only if the total number of specimens is compared are the differences significant. The number of anterior teeth does not differ significantly between the northern and southern populations. The number of posterior teeth in stage II and in the total number of specimens is significantly lower in the southern populations.

In the northern populations 14.4% of the specimens are in sexual stage I, 7.2% in stage II and 78.1% in stage III. In the southern populations 15.5% of the specimens are in sexual stage I, 16.4% in stage II and 68.1% in stage III.

The prey percentage of the southern populations is higher (15.1%) than in the northern populations (9.3%).

A comparison of the characters in time showed the following results: the total length, caudal length, caudal percentage, ovarian length, and ovarian percentage of sexual stage II reaches the highest values in period 3 (July). However, in sexual stage III the mean values of the total length, caudal length and ovarian length are much lower in period 3 than in period 1 (May) and 2 (June). In period 1 and 2 the caudal percentage increases as the specimens grow older, but in period 3 it decreases from stage II to III. In general there is a decrease in the mean values of the morphometric characters from May to July. In the meristic values (number of hooks, anterior and posterior teeth) no general pattern in time is noted (Table 9).

In period 1 and 2 there is a continuous increase in ovarian percentage as the specimens grow bigger. In length class 2.5-3.0 mm and

3.0-3.5 mm the ovarian percentage in period 2 is much lower than in period 1, but in length class 4.0-4.5 mm and 4.5-5.0 mm the percentage of period 2 exceeds period 1. In period 3 there is an increase in the three lowest length classes, but in length class 4.0-4.5 mm the ovarian percentage decreases from 18.5 to 17.8 %. Specimens in length class 4.5-5.0 mm were not collected in period 3 (Fig. 3).

The number of animals in sexual stage I increases in time from 5.2% in May, 5.3% in June to 25.0% in July and decreases in sexual stage III from 81.8% in May and 70.3% in June to 59.6% in July.

The number of animals with prey in the gut is 14.3% in period 1, 17.9% in period 2 and 11.5% in period 3.

Table 9. Mean values and standard deviation of the biometric characters in time.

character	sex. stage	period	2	3
		populations	populations	populations
		1	2	3
		2,10,22,26&27-5	4&5-6	4,8,10 &11-7
		1-2-3	17-21	6-7-8
total length	I	2.21±0.35	2.56±0.31	2.27±0.24
	II	2.80±0.23	2.95±0.33	2.97±0.27
	III	3.99±0.40	4.02±0.40	3.68±0.32
	total	3.75±0.66	3.68±0.65	3.22±0.67
caudal length	I	1.09±0.11	1.29±0.18	1.17±0.14
	II	1.44±0.09	1.52±0.19	1.55±0.16
	III	2.06±0.23	2.09±0.23	1.90±0.20
	total	1.93±0.36	1.91±0.36	1.66±0.36
caudal %	I	49.52±2.43	50.36±2.27	51.49±2.09
	II	51.54±2.42	51.40±2.19	51.94±1.86
	III	51.62±1.96	52.00±2.24	51.51±2.67
	total	51.50±2.12	51.76±2.26	51.57±2.41
ovarian length	I	0.00	0.00	0.00
	II	0.15±0.15	0.04±0.87	0.20±0.12
	III	0.85±0.25	0.97±0.27	0.66±0.19
	total	0.72±0.37	0.62±0.45	0.42±0.33
ovarian %	I	0.00	0.00	0.00
	II	5.23±4.79	1.33±3.15	6.58±3.66
	III	21.22±5.47	21.52±5.83	17.74±4.97
	total	18.04±8.61	15.44±10.67	11.63±8.83
no. hooks	I	8.25±0.50	7.77±0.81	8.04±0.45
	II	8.20±0.42	8.05±0.59	8.19±0.40
	III	8.26±0.47	7.85±0.63	8.02±0.47
	total	8.25±0.46	7.89±0.63	8.05±0.45
no. ant. teeth	I	2.50±0.58	3.04±0.52	2.92±0.39
	II	3.10±0.57	3.27±0.53	3.06±0.25
	III	3.38±0.52	3.49±0.55	3.24±0.47
	total	3.30±0.56	3.42±0.56	3.13±0.44
no. post. teeth	I	0.67±0.58	0.85±0.55	1.17±0.70
	II	1.80±0.42	1.26±0.69	1.50±0.52
	III	2.00±0.24	1.72±0.54	1.93±0.25
	total	1.92±0.38	1.56±0.63	1.69±0.54

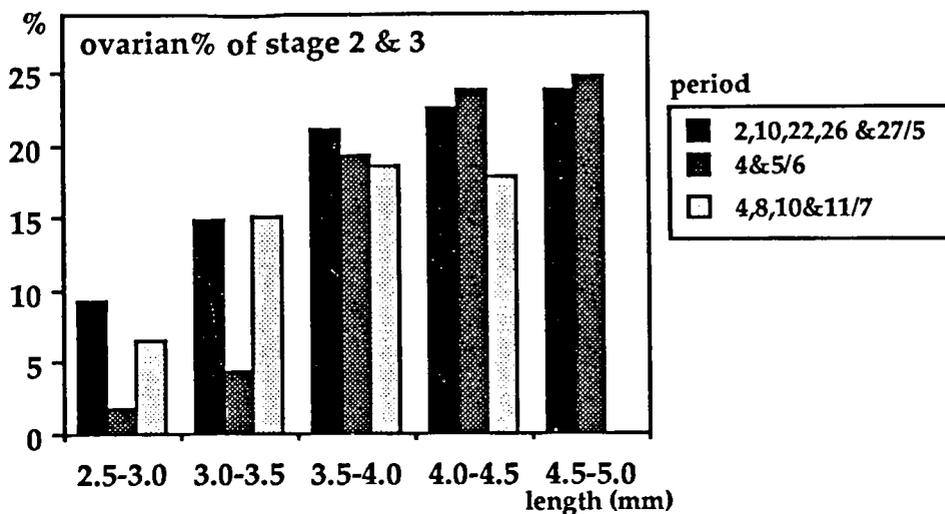


Fig. 3. The distribution of the ovarian percentage over the total length classes of *Spadella cephaloptera* in time. Only the animals of sexual stage II and III are used.

CONCLUSIONS AND DISCUSSION

In the Canary Islands, the benthic chaetognath *Spadella cephaloptera* can be found in several kinds of habitats; but all these are protected from the influence of the waves.

The greatest abundance of *S. cephaloptera* occurs in harbours, with a protected bay. Some natural swimming pools are also good breeding places although the lower abundance here is due to human activity having a negative influence on the habitat. In tidal pools, which form the natural habitat, *S. cephaloptera* is not abundant, because of the fact that during low tide no refreshment of water takes place. So the temperature in the shallow pools can increase rapidly and oxygen concentrations decrease. Chaetognaths have a high respiratory level (Reeve, 1966) and thus require a constantly high oxygen level.

S. cephaloptera occurs in large numbers on *Ceramium rubrum* and several other red seaweeds, as well as on brown seaweeds and green algae that grow on rocks or seaweeds. Contrary to the findings of Yosii & Tokioka (1939), Ghirardelli (1968) and Owre (1972) the species was rare on sea grasses.

Furnestin & Brunet (1965, 1968) found that specimens collected on sand had a smaller size

than specimens collected on sea-grasses. This could explain the deviation in length of *S. cephaloptera* in Candelaria. The habitat of this population was sandy and with hardly any seaweed.

Spadella cephaloptera material in this study has a length range from 1.69 to 5.61 mm. John (1933) found that new-born juveniles are 1.5 mm long. Thus approximately the total length range of this species is represented in this study. Hernández & Jiménez (1986) examined one population from Tenerife in a natural swimming pool (in Barranco Hondo) in April 1986, and reported a minimum size of 2.5 mm and a maximum size of 4.0 mm.

Caudal length is positively correlated with total body length. Hernández & Jiménez (1986) found that the caudal percentage of the specimens in Barranco Hondo varied from 33.3% to 60%. In this study, the caudal percentage had a somewhat smaller range: 40.4% to 60.2%, increasing slightly with the total length, whereas Hernández & Jiménez (1986) found a decrease in caudal percentage with length (from 52.5% in stage I to 42.9% in stage III).

Ovarian length is positively correlated to total body length. According to Ghirardelli (1959) the specimens are approximately one month old

when the oögenesis and spermatogenesis begin (depending on the season). It takes another month before the eggs are mature. The development of the ovaries starts when the length reaches 2.5 to 3.0 mm. The ovarian percentage ranged from 0% to 33.3%, with an average value in stage III of 28.6%. In this study the mean value in stage III (on Tenerife) is 19.63% while the maximum percentage reached 38.6%.

On the three islands, which were sampled an increase was found in the mean number of hooks from sexual stage I to II. A decrease was noticed from stage II to III. This is caused by the demolition of the hooks as the specimens age. At a certain point in the development of a chaetognath the hooks become more fragile than before and start to break.

The mean number of anterior and posterior teeth increases with age. They are not as fragile as the long hooks. It is striking that the number of hooks is correlated with the number of posterior teeth, but not with the number of anterior teeth.

In sexual stage I only 9.2% of the juveniles have a prey in their gut. This low percentage can be explained by the fact that the youngest animals do not yet feed (Ghirardelli, 1968). In stage II and III this percentage is 14.6% and it remains that high in stage III.

A statistical comparison between the different populations of the three islands reveals that within the island populations many differences in biometric characters are present. This suggests that interaction between the populations on an island does not happen on a large scale, though some interaction between immediately neighbouring populations may be present. The distances between several populations are less than 1 km and loose seaweed (with *Spadella*) can easily reach another population.

The southern populations from Gran Canaria have a longer total body length and caudal length and a lower caudal percentage than the northern populations on Tenerife. It is striking that the number of anterior teeth does not differ significantly, but the number of posterior teeth in the south is lower (significant in stage III and in total) than in the north.

On the islands a powerful trade wind is active from north to south. Because of the altitude of the islands, the water masses south of the islands are protected from the wind. North of the islands the trade wind can disturb the season-correlated thermocline (present in June). In the disturbed areas, cold nutrient-rich water can reach shallower water levels. North of the islands higher biomasses of plankton are found (Van Lenning & Van Oppen, pers. comm.). This difference in hydrology can explain the biometrical differences. Because of the prevailing south-westerly current it is more probable that specimens from Tenerife reach the littoral zone of Gran Canaria than visa versa. The likely great genetic diversity on Gran Canaria could have led to a better adjusted population with larger animals and a higher reproduction.

In the southern populations a larger number of animals occur with a prey in their gut, probably due to the difference in length between the two compared groups. The higher plankton abundance north of the islands does not result in a higher prey percentage in the chaetognaths. It seems that the trade wind does not have a big influence on the coastal zones of the ocean.

Although the chaetognath faunal differences between the islands should be treated with great care, some noticeable changes occur. Between Gomera and Tenerife and between Gomera and Gran Canaria all biometric differences, which have been found in mature specimens (stage III) and in all specimens (stage I, II and III; except the number of posterior teeth), were significant. Between Tenerife and Gran Canaria there were no differences (if all populations were compared); except for the number of posterior teeth. It seems that most of the biometric characters in Gomera populations deviate from the other two islands. Perhaps there is an exchange of genetic material between Tenerife and Gran Canaria, but to a lesser extent with Gomera. This is rather surprising, because the distance between Gomera and Tenerife is much smaller than between Gran Canaria and Tenerife. It is possible that because of the small size of Gomera, wandering chaetognaths or floating eggs from the other islands have a lower chance to hit the coastal zone. The

strong south-west directed current probably prevents the specimens of *Gomera* from reaching the more north-east situated islands.

Ghirardelli (1959) mentioned a decrease of the total length in a *S. cephaloptera* population from late spring to summer. Also in this study a decrease in mean total and caudal length was noted from May to July. The percentage of mature specimens decreases from 81.8 to 59.6%. A very high percentage (25%) of animals in July is in sexual stage I.

There is also a decrease through time in ovarian length and ovarian percentage. Ghirardelli (1959) explains this decline by a decrease in the number of eggs. This could explain the decrease in adults. In June, the ovaries mature very slowly if the specimens are small, but when they become adults the ovaries mature very quickly and the ovarian length reaches the highest maximum length. In July, the ovarian percentage has its highest value as the specimens are only half grown. When the animals grow bigger the ovarian percentage decreases. The prey percentage in this period is relatively low and probably there is a shortage of food. Whenever a shortage of food develops or other conditions deteriorate the individuals of *Spadella* have to divide the available energy. They grow bigger to increase their competitive position in regards to the members of the same species or they increase the numbers of offspring (large ovary length).

ACKNOWLEDGEMENTS

I wish to express my gratitude to Dr A. C. Pierrot-Bults and Prof. Dr S. van der Spoel of the University of Amsterdam and Prof. Dr M. Ibáñez Génez of the University of La Laguna on Tenerife for the assistance during my research. I also thank R. G. Moolenbeek for assistance during fieldwork on Tenerife. My thanks also go to K. van Lenning and E. Martín Suarez for their help and pleasant company.

REFERENCES

- BIERI, R., 1991. Systematics of the Chaetognatha. In: Bone, Q., H. Kapp & A.C. Pierrot-Bults, eds.: The biology of chaetognaths. Oxford science publications: 122-137.
- BONE, Q., H. KAPP & A.C. PIERROT-BULTS, 1991. Introduction and relationship of the group. In: Bone, Q., H. Kapp & A.C. Pierrot-Bults, eds.: The biology of chaetognaths. Oxford science publications: 1-4.
- BUSCH, W., 1851. Beob. über Anat. und Entwick. wirbellosen Thiere. Chatogn. Berlin.
- HERNANDEZ, F. & S. JIMENEZ, 1986. Biometric observations on *Spadella cephaloptera* in Tenerife (Canarias). Bol. Mus. Mun. Funchal, **38**: 220-242.
- FURNESTIN, M.L., 1957. Chaetognaths et zooplankton du secteur Atlantique Marocain. Rev. Trav. Inst. Pêch. marit., **21**: 113-356.
- FURNESTIN, M.L. & M. BRUNET, 1965. Sur une station à *Spadella cephaloptera* dans le golfe de Marseille. Rapp. Comm. Int. Mer Médit., **18**: 445-450.
- FURNESTIN, M.L. & M. BRUNET, 1968. Sur une nouvelle mention de *Spadella cephaloptera* dans le golfe de Marseille. Rapp. Comm. Int. Mer Médit., **19**: 471-473.
- GHIRARDELLI, E., 1959. Habitat e biologia della riproduzione nei chaetognati. Arch. Oceanogr. Limnol., **11**: 287-304.
- GHIRARDELLI, E., 1968. Some aspects of the biology of the chaetognaths. Adv. Mar. Biol., **6**: 271-375.
- JOHN, C.C., 1933. Habitat, structure and development of *Spadella cephaloptera*. Quart. J. micr. Sci., **75**: 625-696.
- OWRE, H.B., 1972. Marine biological investigations in the Bahamas. The genus *Spadella* and other Chaetognatha. Sarsia, **49**: 49-58.
- PARRY, D.A., 1944. Structure and function of the gut in *Spadella cephaloptera* and *Sagitta setosa*. J. Mar Biol Ass U. K., **26**: 16-36.
- PIERROT-BULTS, A.C. & V.R. NAIR, 1991. Distribution patterns in Chaetognatha. In: Bone, Q., H. Kapp & A.C. Pierrot-Bults, eds.: The biology of chaetognaths. Oxford science publications: 86-116.
- REEVE, M.R., 1966. Observations on the biology of a chaetognath. In: Barnes, H., ed.: Some contemporary studies in marine science. George Allen & Unwin, London: 613-630.
- RUSSEL, F.S., 1932. On the biology of *Sagitta*. J. mar.

biol. Ass. U. K., **18**: 131-160.
SOKAL, R.R. & F.J. ROHLF, 1969. Biometry. W.H.
Freeman, San Francisco.
YOSII, N. & T. TOKIOKA, 1939. Notes on Japanese

Spadella (Chaetognatha). Annot. Zool. Japan, **18**: 267-
275.

Received: 13 May, 1992