Distribution and Seasonal Occurrence of Larval Pelagic Stages of Spiny Lobsters (Palinuridae, *Panulirus*) in the Western Tropical Atlantic

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RESUMEN

Fases larvales juveniles de *Panulirus* (filosoma y puérulas) han sido indentificadas en tomas de plancton realizadas por el Servicio National de Pesquerías Maritímas y el Departamento de Recursos Naturales de la Florida. Además, se han examinado registros bibliográficos, y el número total de records estudiados suman 13,770 especímenes. Estos especímenes fueron examinados para determinar su distribución temporal y geográfica en base al desarrollo larval. Además, 8,854 especímenes fueron medidos para determinar la relación largo-fase larval.

La mayor parte de los especímenes fueron colectados en Agosto (44%) y los menos fueron colectados durante los meses de invierno: Diciembre, Enero, Febrero y Marzo (7%). Esto puede reflejar, en parte, una mayor intensidad de captura más que una mayor abundancia. Hay once fases larvales además de la fase puerula y la mayor parte de nuestro material eran de fase VII (33%). La gama de la longitud para cada fase fué también determinada, y los resultados muestran una considerable superposición de tamaños entre las fases. Las razones de ello pudieran ser el de efectos mulfiespecíficos, dado que la filosoma corrientemente puede solo ser indentificada a nivel genérico o tasas de crecimiento diferencial pudieran ser un factor.

INTRODUCTION

Young stages of the spiny lobster (*Panulirus argus*) have long and complicated larval stages. The larval stages are planktonic and pelagic, spending from 6 to 9 months in the surface layers of the oceans drifting with the currents (Johnson, 1960; Ingle et al., 1963). There are 11 larval stages, termed phyllosome stage I through XI, followed by a puerulus stage (Lewis, 1951). The puerulus stage is a metamorphosed larval lobster, which closely resembles the adult, and is, essentially, a transparent miniature. This stage settles to the bottom and takes up benthic habits. Phyllosome stages I to XI do not resemble adult lobsters in the least, but are similar to one another, and the stages represent molt changes. These phyllosomes are easily identifiable to their respective stage and to their respective genus. Unfortunately, it is currently not possible to identify Atlantic *Panulirus* phyllosomes to species.

Many collections of phyllosomes and puerulus stages have been made as part of routine plankton surveys. Among these collections have been a large number by research vessels of our agency and its predecessor (the Bureau of Commercial Fisheries), the Florida Department of Natural Resources, and the University of Miami. Not all plankton collections made by these organizations have been sorted specifically for phyllosomes, but we assembled all those that were sorted, and that material plus published references form the basis for this report. These data are examined from the point of trying to understand distribution and abundance over space and time in the western Atlantic.

Table 1. Numbers of *Panulirus* spp. examined by stage and by month

	STAGE												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	PU	TOTAL
January	0	4	6	5	16	61	62	32	7	7	2	3	205
February	3	10	21	11	11	38	83	52	3	5	2	0	239
March	0	0	0	7	4	10	60	48	42	8	12	9	200
April	937	44	15	17	15	33	32	10	3	3	0	26	1135
May	36	11	13	50	57	80	27	2	1	2	1	9	289
June	476	80	42	144	77	72	42	12	3	1	1	67	1017
July	177	281	239	214	221	346	629	107	71	40	32	29	2386
August	272	126	143	328	631	1052	3087	287	62	30	22	36	6076
September	63	36	56	59	49	79	122	39	20	11	13	3	550
October	31	75	44	168	145	135	113	18	8	16	9	67	829
November	1	4	22	17	35	82	116	50	31	13	2	110	483
December	29	7	9	11	17	79	128	32	8	3	4	34	361
TOTAL	2025	678	610	1031	1278	2067	4501	689	259	139	100	393	13770

The very long duration of larval drift presents problems in determining the source of recruits and the probable dispersal of spawned products from areas of adult concentrations. Richards and Goulet (1977) developed a surface drift model to give some insight into this problem.

The purpose of this paper is to summarize the results of examining plankton collections from the ichthyoplankton surveys of our laboratory and plankton samples of the Florida Department of Natural Resources. The phyllosomes and pueruli from these samples and from some literature records totalled 13,770 specimens.

In addition, 8,854 of the specimens were measured to gain some understanding of their growth within stages and between stages.

RESULTS

Numbers of Phyllosomes and Pueruli

The numbers of phyllosomes and pueruli examined by stage and by month are given in Table 1. In considering the differences in number for each stage, several factors enter in. The few number of older phyllosomes — stages IX, X and XI — may reflect the results of natural mortality since these are rather large structures which could fall easy prey to predators. Stages I through IV are rather small organisms, which can be missed by sorters. However, we found a high number of stage I phyllosomes which reflect a few samples with large numbers. The puerulus specimens were not from plankton tows and cannot be compared with stages I through XI. The distribution of phyllosomes and pueruli by month reflects the intensity of collection during summer months rather than an index of abundance. All stages were present in nearly every month of the year, except for stage I in January and stages I, II and III in March. Stage VII phyllosomes were the most abundant because they are large and easily seen. The appearance of large numbers of stage V, VI, VII and VIII phyllosomes in July and August indicates spawning early in the year if slow growth is true. Slow growth has been deduced from relative abundance of phyllosomes in plankton collections, but even with our extensive numbers growth cannot be inferred because of sampling bias, lack of negative sampling data and lack of quality control of sorting procedures.

Size of Stages of Phyllosomes

We measured 8,854 of our specimens to gain some understanding of the relation of size to stage. Stages represent different morphometric and developmental stages as the phyllosomes grow and molt. The growth and molting process is dynamic whereas the different stages represent static types that occur during this process. We were also concerned about the stage-size relationship because the *Panulirus* phyllosomes represent more than one species.

Length was measured from the anteriormost part of the cephalothorax between the base of the eyestalks to the posteriormost part of the abdomen. The results of these measurements are given in Table 2. The ranges, means and standard deviations are shown in Figure 1. While there is great overlap in range and mean between each stage, there is no overlap of standard deviation. From this it would appear that there is little, if any, interspecific difference in size within stages. The modes of each stage were unimodal which also reflects rather uniform size

Table 2 Results of analysis of size of *Panulirus* spp. by stage

	STAGE											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	PU
No. measured	2008	620	575	968	1056	1547	1219	393	125	74	57	212
Mean	1.598	2.192	2.991	3.925	5.095	6.629	9.191	13.186	16.983	19.796	25.872	19.252
Std. deviation	0.074	0.137	0.279	0.363	0.455	0.695	1.391	1.755	1.971	2.481	4.045	8.708
Std. error	0.002	0.005	0.012	0.012	0.014	0.018	0.040	0.088	0.176	0.288	0.536	0.598
Median	1.6	2.2	3.0	3.9	5.0	6.6	9.0	13.0	16.6	19.6	25.0	17.2
Midrange	1.60	2.25	3.00	4.15	5.65	6.35	11.40	14.55	17.95	22.60	30.10	41.00
Smallest	1.3	1.6	2.0	3.1	3.9	3.6	6.1	9.3	12.5	15.8	19.7	15.0
Largest	1.9	2.9	4.0	5.2	7.4	9.1	16.7	19.8	23.4	29.4	40.5	67.0

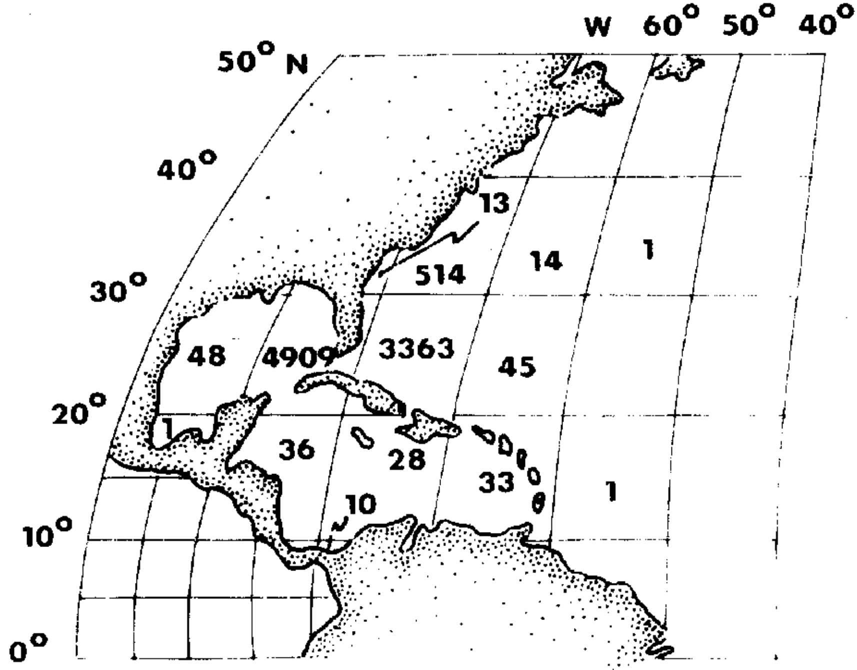

Figure 1. Range, mean and standard deviation of length of phyllosomes of *Panulirus* spp. by stage.

frequency distributions within stages. Specimens are encountered where a subjective decision must be made whether or not a specimen should be placed in one of two stages. Since the means are found nearer the lower part of the range in stages VII through XI, there is a definite trend that the decision to place specimens in lower stages is most common (Fig. 1).

Distribution of Phyllosomes

Accurate locations were determined for 9,015 specimens. These specimens were combined in 10° squares for analysis as shown in Figure 2. The numbers by stage and by month for these 10° squares are given in Tables 3 through 16. Most of the phyllosomes are from the two 10° squares that bisect the Straits of Florida, because this is where sampling effort, principally by the Florida Department of Natural Resources, was greatest. From examining these data again, the preponderance of summer sampling is reflected in the numbers of phyllosomes. We do not see trends that indicate growth could be determined from these data because of numbers increasing in successive stages over successive months. The distribution of *Panulirus* adults is widespread throughout the area which reflects the widespread distribution of the young stages.

Future Research on Phyllosomes

Several problems remain unanswered about the early life stages of *Panulirus*.

Table 3. Number of phyllosomes by stage and pueruli for each month from 10° square bounded by latitude and longitude given. Months with no specimens are excluded.

	STAGE											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Puerulus
20-30° N 080-090° W												
January	0	4	5	15	0	55	44	24	6	6	1	3
February	3	7	16	0	0	3	1	0	0	0	0	0
March	0	0	0	2	1	2	11	15	11	2	9	9
April	937	38	10	7	6	9	10	3	2	3	0	11
May	14	0	1	0	0	0	0	0	0	0	1	5
June	469	77	38	116	54	55	33	5	3	0	0	33
July	3	4	12	23	7	29	62	15	18	9	9	26
August	215	61	49	192	368	288	172	60	17	7	17	7
September	50	14	11	28	24	34	81	30	19	7	3	2
October	31	71	27	125	101	75	31	9	3	2	2	5
November	0	0	0	0	9	11	16	7	3	0	0	6
December	29	7	8	7	15	42	56	13	8	3	3	16
20-30° N 070-080° W												
January	0	0	1	0	1	5	12	6	1	1	1	0
February	0	3	3	3	13	34	40	9	1	2	2	0
March	0	0	0	0	0	2	3	1	1	0	0	0
April	1	0	2	8	8	23	16	3	0	0	0	0
May	19	10	10	48	57	80	24	2	1	2	0	0
June	5	3	4	26	22	17	9	7	0	1	0	0
July	150	219	165	107	73	188	118	26	1	1	2	0
August	43	15	64	72	136	337	148	50	18	5	5	0
September	13	21	45	29	25	44	25	0	0	0	1	0
October	0	0	16	43	35	51	64	4	1	2	0	0
November	1	4	22	16	24	71	96	43	28	13	2	7
December	0	0	1	5	2	32	61	19	0	0	1	0
30-40° N 070-080° W												
July	22	52	60	62	49	37	67	13	11	6	3	0
August	0	1	6	21	14	59	25	0	0	0	0	0
October	0	0	0	0	1	2	2	0	0	0	1	0
00-10° N 080-090° W												
April	0	3	3	1	0	1	1	1	0	0	0	0
30-40° N 060-070° W												
July	0	0	0	0	2	2	2	0	0	0	0	0
August	0	1	1	0	0	0	4	2	0	0	0	0

Table 3. Continued

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	Puerulus
20-30° N												
090-100° W												
March	0	0	0	0	1	2	4	3	0	3	0	0
June	0	0	0	1	0	0	0	0	0	0	1	0
July	0	0	0	1	2	2	6	1	2	3	2	0
August	4	0	0	0	0	0	1	0	2	2	0	0
October	0	0	0	0	0	0	3	0	0	1	1	0
20-30° N												
090-100° W												
February	0	0	0	4	0	1	26	14	0	0	0	0
10-20° N												
060-070° W												
February	0	0	2	0	0	0	0	0	0	1	0	0
March	0	0	0	1	0	0	1	0	0	0	0	0
August	0	0	0	0	0	0	1	0	0	0	0	0
September	0	0	0	0	0	1	5	7	1	4	9	0
10-20° N												
070-080° W												
February	0	0	0	1	0	0	2	0	0	0	0	0
March	0	0	0	0	0	2	0	7	4	2	0	0
April	0	2	0	1	1	0	1	0	0	0	0	0
July	0	0	0	0	0	0	1	1	1	1	1	0
10-20° N												
080-090° W												
March	0	0	0	4	2	2	1	0	1	0	0	0
April	0	1	0	0	0	0	3	3	1	0	0	0
May	0	1	2	2	0	0	1	0	0	3	0	0
July	0	0	0	0	0	1	1	1	0	0	0	0
November	0	0	0	0	2	0	4	0	0	0	0	0
30-40° N												
080-090° W												
August	0	0	0	0	1	0	0	0	0	0	0	0
October	0	0	2	1	4	1	4	0	0	0	0	0
10-20° N												
090-100° W												
August	0	0	0	0	0	0	0	0	0	1	0	0
10-20° N												
050-060° W												
March	0	0	0	0	0	0	0	1	0	0	0	0
30-40° N												
050-060° W												
October	0	0	0	0	0	0	1	0	0	0	0	0

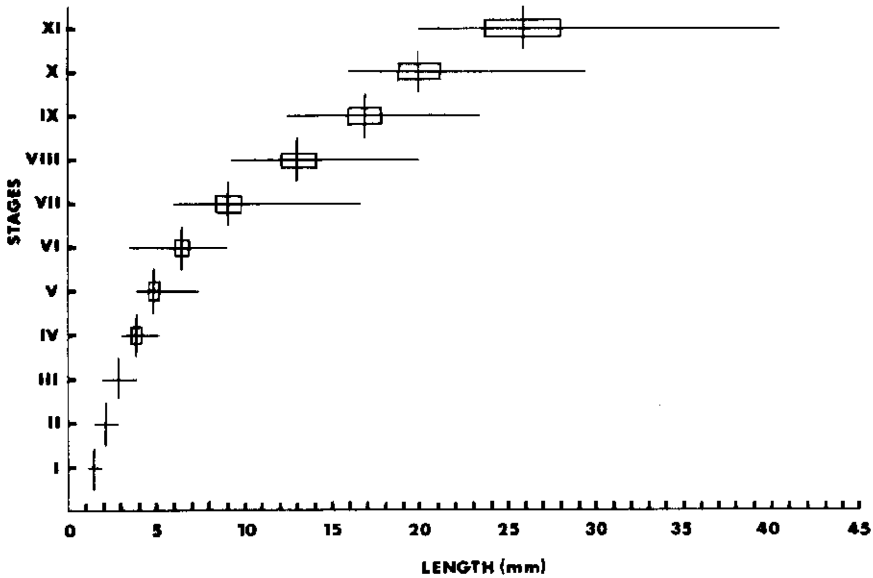

Figure 2. Distribution of numbers of phyllosoma and pueruli of *Panulirus* spp. by 10° square in the tropical western Atlantic Ocean.

First, a study is needed to determine specific identities of specimens. We noted differences among specimens that should be pursued. Specimens in perfect condition are needed. Second, growth of phyllosomes must be determined. If growth proceeds slowly as presumed, recruitment could come from far upstream. If growth is faster than presumed or occurs differentially, this could have serious management implications. Finally, future collecting should consider the absence of phyllosomes as well as presence to quantify the time of spawning and abundance of phyllosomes. Attention to these three questions will be of benefit to those engaged in management of adults stocks.

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LITERATURE CITED

Ingle, R.M., B. Eldred, H.W. Sims and E.A. Eldred.
1963. On the possible Caribbean origin of Florida's spiny lobster populations. Tech. Ser. Fla. Board Conserv. No. 40: 12 pp.

Johnson, M.W.
1960. Production and distribution of larvae of the spiny lobster *Panulirus interruptus* (Randall) with records of *P. gracilis* Streets. Bull. Scripps Inst. Oceanogr. 7(6): 413-62.

Lewis, J.B.
1951. The phyllosoma larvae of the spiny lobster *Panulirus argus*. Bull. Mar. Sci. Gulf Caribb. 1(2): 89-103.

Richards, W.J. and J.R. Goulet, Jr.
1977. An operational surface drift model used for studying larval lobster recruitment and dispersal. Pages 363-374 *in* H.B. Stewart, Jr., ed. Cooperative Investigations of the Caribbean and Adjacent Regions. II. Symposium on Progress in Marine Research in the Caribbean and Adjacent Regions. Caracas, Venezuela, 12-16 July 1976. Papers on Fisheries, Aquaculture and Marine Biology. FAO Fish. Rep. No. 200 :547 pp.