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OVIGEROUS SETAE AS AN INDICATOR OF REPRODUCTIVE MATURITY IN THE SPINY LOBSTER, *Panulirus argus* (LATREILLE)

Population statistics for palinurid lobsters obtained from remote-capture sampling methods, such as commercial slat-traps, are potentially subject to biases resulting from changes in the vulnerability of lobsters to traps. Catchability of lobsters may be influenced by size, status of molt, and reproductive condition (Morgan, 1974: 255; Newman and Pollock, 1974: 11; Kanciruk and Herrnkind, 1976: 429). *In situ* sampling of lobsters by divers has been conducted successfully in areas characterized by low fishing intensities and relatively high population densities (Herrnkind *et al.*, 1973; Peacock, 1974; Olsen *et al.*, 1975; Kanciruk and Herrnkind, 1976; Davis, 1977). This method of sampling, however, is not adaptable to extensive areas such as the Florida Keys where the population density of spiny lobsters (*Panulirus argus*) is reduced by heavy and sustained commercial and recreational exploitation pressures (Labisky *et al.* 1980). Consequently, the commercial slat-trap remains the most effective sampling device for assessing changes in heavily fished, low-density lobster populations.

Evidence supporting the variable catchability of reproductively active female lobsters in slat-traps is discordant. Davis (1975:675) found no evidence of trap avoidance by egg-bearing females during April in a relatively unexploited lobster population. However, Kanciruk and Herrnkind (1976:429), who studied the underwater behavior of egg-bearing females, suggested that slat-trap samples may underestimate the proportion of egg-bearers in a lobster population. If slat-traps do not yield representative samples of egg-bearing females, a more efficacious criterion is needed for assessing the reproductive status of females.

Three indices of reproductive maturity in *P. argus* are available: the presence of external eggs, spermatophores, and ovigerous pleopodal setae (Munro, 1974:14; Kanciruk and Herrnkind, 1976: 421). Evaluation of reproductive maturity in *P. argus* has been restricted principally to the presence of spermatophores and/or eggs (Davis, 1975:675; Munro, 1974:14; Peacock, 1974:123; Kanciruk and Herrnkind, 1976:421; Warner *et al.*, 1977: 170). To date, the presence of ovigerous setae has been used only once as a criterion of reproductive maturity in *P. argus* (FAO, 1968:17).

Ovigerous setae, which form on the distal segment of the paired bifurcated endopodite of the third through fifth abdominal pleopods of females (Crawford and DeSmidt, 1922:294; Buesa Mas, 1969:51), first develop at the molt coinciding with, or closely following, initial maturation of the ovaries (Felder, 1964:140), and become the sites for egg attachment (Crawford and De Smidt, 1922:294; Silberbauer, 1971:9). In contrast, the pleopods of immature females have undeveloped setae, incapable of carrying eggs.

This paper presents a comparative evaluation of three external indicators of reproductive maturity — eggs, spermatophores, and ovigerous setae, among female *P. argus* captured in commercial slat-traps in the lower Florida Keys during the 1976 reproductive season, and specifically assesses the usefulness of the presence of ovigerous setae as an indicator of maturity when traps constitute the most effective method for sampling an exploited lobster population.

METHODS

Lobsters were captured in commercial wooden slat-traps that were placed in five different habitats (three in the Atlantic Ocean and two in the Gulf of Mexico) in

the lower Florida Keys (Warner *et al.*, 1977) during the 5-month period, April-August, 1976. Each female was measured to determine size, expressed as carapace length (CL) in mm, and examined for the presence of eggs, spermatophores, and ovigerous setae.

Ovigerous setae were visually classified, following a series of precise measurements to establish class ranges, as undeveloped (0-3 mm in length), intermediate (4-8 mm), or ovigerous (9-13 mm). Although setae of intermediate length probably represented ovigerous setae that were broken by the cleaning action of the female chelae (see Fielder, 1964:140), we used the intermediate-length category as a buffer between the undeveloped and ovigerous categories, and excluded it from differentiating analysis.

RESULTS AND DISCUSSION

The presence of ovigerous setae on 1,214 female lobsters from the lower Florida Keys was correlated with increasing carapace length ($r = 0.89$, 56 df, $P < 0.05$), whereas the proportion of females with undeveloped setae concurrently exhibited the inverse relationship ($r =$

-0.91 , 56 df, $P < 0.05$). The differences in mean CL of females in each setae category also reflected this relationship between size and setae length (Table 1). The mean size of females with undeveloped setae was significantly smaller (71.4 mm CL) than that of females with either intermediate (77.8 mm CL) or ovigerous setae (80.2 mm CL).

Reproductive activity in *P. argus* females was associated with the attainment of ovigerous setae. Comparatively, 26% of the 1,214 females examined exhibited ovigerous setae, 13% spermatophores, and 4% eggs (Table 2). All 53 egg-bearing females possessed spermatophores and ovigerous setae, and 156 (97%) of 161 spermatophore-bearing females possessed ovigerous setae (Table 2). Thus, if the reproductive physiology of *P. argus* is similar to that of the spiny lobster, *Jasus novaehollandiae* (= *lalandei*, auct.) (Fielder, 1964:139) and other crustaceans (Charniaux-Cotton, 1960:433; Highnam and Hill, 1977:231), the development of ovigerous setae in *P. argus* females very likely parallels ovarian maturation.

Reproduction of lobsters in the Florida Keys occurs primarily in the Atlantic offshore reef habitats; virtually none occurs in non-reef habitats (Table 2). Of all fe-

TABLE 1. Size distribution of female lobsters exhibiting undeveloped, intermediate, and ovigerous pleopodal setae in the lower Florida Keys, April-August, 1976.

Carapace Length (mm)	Number of Females	Percentage of Females Bearing		
		Undeveloped Setae	Intermediate Setae	Ovigerous Setae
<65	179	97 (174) ^{a/}	2 (4) ^{a/}	1 (1) ^{a/}
65 - 70	172	87 (150)	3 (6)	9 (16)
70 - 75	247	68 (168)	8 (19)	24 (60)
75 - 80	269	58 (155)	12 (33)	30 (81)
80 - 85	196	49 (97)	12 (23)	39 (76)
85 - 90	95	37 (35)	13 (12)	51 (48)
90 - 95	36	42 (15)	14 (5)	44 (16)
95 - 100	12	17 (2)	8 (1)	75 (9)
> 100	8	0 (0)	0 (0)	100 (8)
Total	1214	66 (796)	8 (103)	26 (315)
Mean CL ± SE	74.2 ± 0.3	71.4 ± 0.3 ^{b/}	77.8 ± 0.7 ^{c/}	80.2 ± 0.4 ^{d/}

^{a/}Sample sizes are within parentheses.

^{b,c,d/} An ANOVA revealed that the differences in CL among lobster with undeveloped, intermediate, and ovigerous setae were statistically significant ($F = 132.95$, 2 and 1211 df, $P < 0.05$). Means designated by different letters are statistically significant.

TABLE 2. Comparison of measures of reproductive activity among female lobsters from different habitats in the lower Florida Keys, April-August, 1976 (adapted from Gregory, Labisky, Combs: unpublished ms.).

	Habitat Sites					Total
	Gulf Mid-depth	Gulf Shallows	Atlantic Shallows	Atlantic Patch Reef	Atlantic Deep Reef	
Number of Females	305	127	139	378	265	1214
Percentage with: ^{a/}						
Eggs	0 (0)	0 (0)	0 (0)	4 (15)	14 (38)	4 (53)
Spermatophores	0 (0)	0 (0)	4 (5)	11 (41)	43 (115)	13 (161)
Ovigerous Setae	8 (23)	6 (7)	17 (23)	24 (91)	65 (171)	26 (315)

^{a/} All females with eggs exhibited both spermatophores and ovigerous setae, and 156 (97%) of all 161 females with spermatophores exhibited ovigerous setae; hence, the percentages and sample sizes (within parentheses) are essentially cumulative within columns — from top to bottom.

males with ovigerous setae, 83% were associated with the Atlantic reef habitats. The occurrence of ovigerous setae on some Gulf females (7%) may have reflected: (1) the precocial attainment of physiological reproductive "readiness", prior to moving to the Atlantic reef breeding grounds; (2) movement of mature females to the Gulf after spawning in the Atlantic; or (3) the retention, by some mature females, of ovigerous setae from the previous reproductive season (Sutcliffe, 1953:177).

The Atlantic Deep Reef habitat is obviously the area of maximum reproductive effort for lobsters in the lower Florida Keys (Table 2). Within this area, the proportion of females with ovigerous setae was substantially greater, in all size classes, than the corresponding proportion of females with eggs or spermatophores (Table 3). Two aspects of this finding merit elaboration. First, the minimum size at which females first exhibited ovigerous setae, spermatophores, or eggs varied — being 64, 67, and 71 mm CL, respectively. Second, two-thirds of the Deep Reef females were reproductively mature as evidenced by the presence of ovigerous setae in the 70-75 mm CL size-class; the majority of females, however, did not exhibit spermatophores or eggs until attaining about 80 mm and 95 mm CL, respectively. These observations evince that the assessment of reproductive maturity in female lobsters is mark-

edly influenced by the criteria employed. Thus, the evidence presented in this paper, though not confirmed by parallel histological studies, suggests strongly that the presence of ovigerous setae offers a reliable criterion for assessing the proportion of reproductively mature *P. argus* females in a population.

In summary, our data revealed that females with ovigerous setae were several-fold more abundant in trap samples than females bearing either spermatophores or eggs, or both. Thus, the use of ovigerous setae, in conjunction with eggs and spermatophores, as an indicator of reproductive maturity would substantially enhance trap-sampling efficiency, *i.e.*, a higher proportion of reproductively mature females would be detected in any given sample collection, thereby reducing the size of samples necessary to measure various parameters of reproduction. Also, the temporal availability to traps by females bearing ovigerous setae, which are present throughout the complete intermolt interval of 56-150 days (Travis, 1954:444) and probably the entire reproductive season, is greater than that for either eggs or spermatophores — the latter criteria usually being in external evidence for about 30 days (Sutcliffe, 1952:66) and 64-95 days (Kanciruk and Herrnkind, 1976:427), respectively.

The potential for using the presence of ovigerous setae as evidence of reproductive maturity in female *P. argus* is suffi-

TABLE 3. Size distribution of female lobsters exhibiting external eggs (E), spermatophores (S), and ovigerous setae (O) in the Atlantic Deep Reef habitat of the lower Florida Keys, April-August, 1976.

Carapace Length (mm)	Number of Females	Percentage of Females Bearing ^{a/}		
		E	E and/or S	E, S, and/or O
< 65	10	0 (0)	0 (0)	10 (1)
65 - 70	30	0 (0)	20 (6)	37 (11)
70 - 75	57	11 (6)	44 (25)	65 (37)
75 - 80	67	10 (7)	42 (28)	61 (41)
80 - 85	58	17 (10)	47 (27)	74 (43)
85 - 90	20	25 (5)	60 (12)	85 (17)
90 - 95	11	27 (3)	64 (7)	82 (9)
95 - 100	6	67 (4)	83 (5)	100 (6)
> 100	6	50 (3)	83 (5)	100 (6)
Total	265	14 (38)	43 (115)	65 (171)
Mean CL ± SE	77.6 ± 0.5	84.1 ± 1.4 ^{b/}	80.5 ± 0.8 ^{c/}	79.8 ± 0.6 ^{c/}

^{a/} See footnote, Table 2; percentages and sample sizes (within parentheses) are cumulative within rows — from left to right.

^{b,c/} An ANOVA revealed that the differences in CL among lobsters with E, E and/or S, and E, S, and/or O were statistically significant (F = 3.88, 2 and 321 df, P < 0.05). Means designated by different letters are statistically significant.

ciently great to warrant careful consideration in future research investigations. To this end, the priority research need is to ascertain, via histological studies, the correlation between ovarian maturation and setal development.

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