Title

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ARE THERE SEPARATE POPULATIONS OF *HALOBATES* IN THE GULF OF MEXICO?

Lanna Cheng and John H. Wormuth

ABSTRACT

Various developmental stages of the pelagic insect *Halobates micans* were sorted from four series of neuston samples collected in the Gulf of Mexico and the Caribbean Sea by different institutions during various expeditions. Studies on seasonal occurrences and comparisons of developmental stage compositions suggest that in the Gulf of Mexico there is probably an indigenous population which presumably overwinters as eggs and may complete two or three generations each year between March and November.

The Gulf of Mexico is a rather discrete body of water bounded mainly by the continental USA and Mexico and open to the Caribbean at the south-east via the Yucatan Channel or the Straits of Florida. Although there is a certain amount of exchange of water between the Gulf and the Caribbean, the turn-over rate is thought to be very slow. The western Gulf of Mexico is characterized as an anticyclonic cell while the eastern Gulf is dominated by the Loop Current (Elliot, 1982). The movement of warm core rings is generally to the west. These rings have a life span of about 1 year and are formed with an annual frequency of up to four per year (Lewis et al., 1989). Murphy and Paskausky (1975) stated that there was little eastward movement of surface waters in the central and western Gulf of Mexico and that the circulation regimes of the Loop Current and the remainder of the Gulf of Mexico were distinct except for the anticyclonic eddies. We do not know whether distinct zooplankton populations can be maintained in the Gulf as distinct from those in the Caribbean or the Atlantic Ocean although we know many species of copepods, pteropods and euphausiids occur in all three regions (Owre and Foyo, 1972; Cummings, 1982; Wormuth, 1985 and unpubl.; Wiebe, 1976; Schroeder, 1971), but these are not surface-living species.

The ocean-skaters in the genus *Halobates* are pelagic insects living at the sea-air interface. They have a circumtropical distribution in the world's oceans, covering a range roughly between latitudes 40°N and 40°S (Cheng, 1973a; 1985; Cheng et al., 1986). Although *Halobates micans* has been reported from the Gulf of Mexico (Herring, 1961; Savilov, 1967; Scheltema, 1968; Cheng, 1973b), there has been no specific study on its occurrence there. In this paper we present data from three series of samples collected over a period of 5 years in the Gulf of Mexico and another series of samples collected from the Caribbean over a period of 10 years.

Materials and Methods

Our material came from four different surveys undertaken by different institutions. Sample series one through three came from the Gulf of Mexico. Those from the Caribbean constitute the fourth series. The collecting localities are shown in Figures 1 and 2.

Series 1 consisted of 25 neuston samples, all taken at approximately 2-h intervals, during a 2-day period, within a 2-mile (3.4 km) radius in the east-central Gulf, in August 1972, around 27°00'N and 86°00'W. The net used was a 10-net array consisting of a top skimmer, sampling only the top few cm of the ocean surface; nets 2, 3, 4, sampling the next 10-cm below the surface layer; nets 5, 6, 7, the 0.5-m layer; and nets 8, 9, 10, the 1-m layer (Maurer, pers. comm.). The net openings all measured

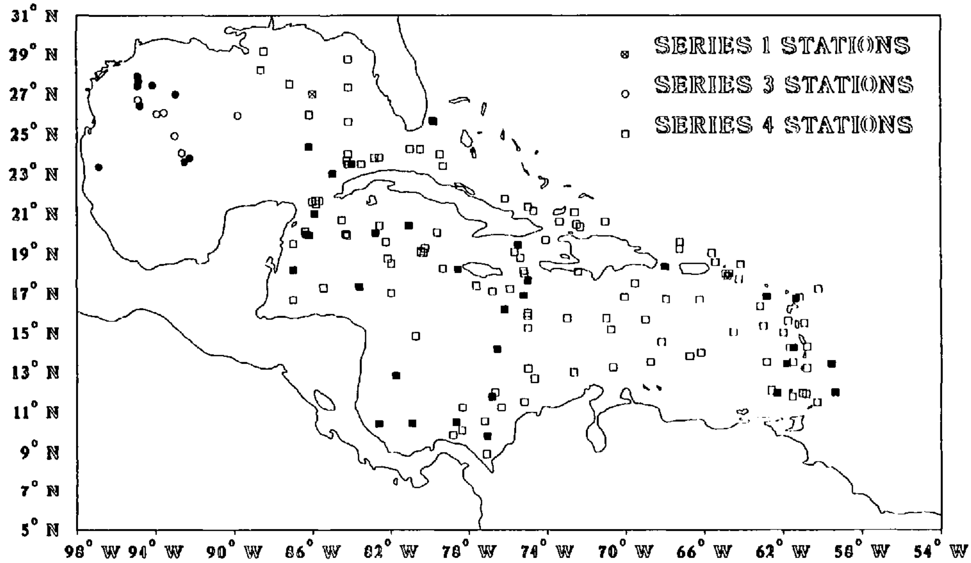

Figure 1. Location of all sampling sites for Series 1, 3 and 4. Except for Series 1 which has only one station, solid symbols denote positive tows, open symbols denote negative tows.

10 cm × 50 cm. Flowmeters attached between nets 3, 6 and 9 provided data by which areas or volumes of seawater sampled could be calculated. The net assembly was towed at about 2.7 km·h⁻¹ (1.5 knots) from a boom extending about 6.5 m from the starboard side of the vessel. Two styrofoam blocks attached to the upper net frame acted as a flotation device, allowing the skimmer to sample the sea-surface layer. Bridle lines attached to four corners of the net frame were arranged in such a way as to eliminate interference and turbulence from net mouths. A shock cord tied to the towing warp helped to dampen wave surges.

Series 2 was collected in 1976 and 1977 during the Bureau of Land Management Monitoring Survey (BLM) conducted by members of the Department of Oceanography, Texas A&M University. These were seasonal cruises with fixed neuston stations. Samples were collected with a neuston net towed at 2.4 kn. The net used in 1976 had a single opening 1-m × 2-m wide; it was replaced in 1977 by a net with a 1-m × 2 m-wide frame divided vertically into four equal nets, each 0.5 × 0.5 m. The flotation device was similar to that described above. The number of surface tows made and the duration of each cruise were variable. There were three seasonal cruises that sampled four transects running perpendicular to shore. On each of these transects there were three sampling stations. In addition, there were six monthly cruises that sampled all three stations on Transect II only (Fig. 2). In general, equal numbers of day and night tows were made during each cruise. A total of 108 tows were made in 1976 and 81 in 1977.

Series 3 consisted of 7 tows from 1972 and 9 tows from 1973 BLM surveys. The net used was similar to that of Series 2, but the stations sampled were farther out in the Gulf of Mexico (Fig. 1).

Series 4 was collected during the Caribbean Zooplankton Survey conducted by the Rosenstiel School of Marine and Atmospheric Science of the University of Miami between 1966 and 1975. *Halobates* was collected in the top net of the array used. The net opening was 75 cm in diameter. Details of the net operation and the cruises can be found in Owre and Low (1969) and Owre and Foyo (1972). A total of 225 tow samples has been sorted for this study. The time of year, the exact location, and the number of tows varied among the 14 cruises (Table 8). All sampling locations are given in Figure 1.

Although our samples came from various cruises conducted by different institutions at different times, all were collected by nets which sampled the surface water at approximately 2.5–3.0 km·h⁻¹ for periods between 30–60 min. Because we are only concerned with occurrences rather than densities, we have used actual numbers of insects collected. Where densities were calculated, the numbers given have been converted appropriately by adjusting for tow time and area sampled so that they are all comparable.

All insects were sorted from other plankton organisms and preserved separately in either 5% formalin or 70% ethanol. For Series 1, 3 and 4 the entire sample was sorted. For Series 2, when plankton densities were extremely high, only aliquots (¼ to ¹⁄₂₅₆) were counted.

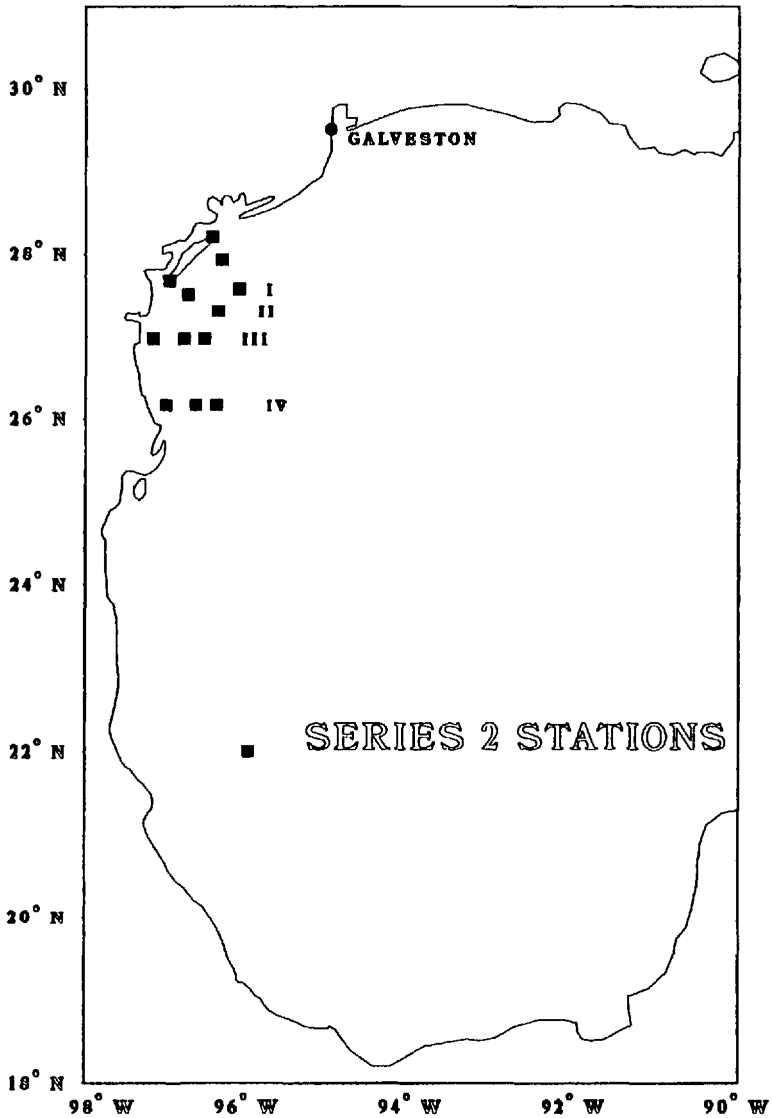

Figure 2. Locations of Series 2 sampling sites showing transect locations.

Results

The insects from all four series have been identified as *Halobates micans,* so far the only known ocean-skater in the Atlantic. *Halobates* is a typical hemipteran, with five nymphal stages. The nymphs resemble adults in general external morphology but are smaller. Sexes are not distinguishable until the final instar, and different instars can be distinguished only by body size or by lengths of various appendages (Cheng and Maxfield, 1980). Adults, however, can be easily sexed by differences in external genitalia (Cheng, 1973b).

In our samples, although adults, as well as nymphs, of all five stages were present in all the series, the numbers (or densities) of insects caught and the population compositions for the various cruises were quite different (Tables 1, 2, 7, 8). They are discussed separately.

SERIES 1. Specimens of *Halobates micans* were caught in all 25 tows, with numbers ranging from 1 to 95 per tow. The skimmer (net 1) caught sea-skaters during every tow; nets 2, 3, 4, immediately below, caught insects about 50% of the time (11, 12 and 10 positive tows respectively); whereas the six lowest nets caught only two *Halobates* (once each for nets 7 and 8). Since sea-skaters are wingless and not known to dive, they are confined to the sea-air interface throughout their life cycle. Thus, it is not surprising to find that almost all were caught by the skimmer. Although nets 2, 3 and 4 were supposed to sample the uppermost 10-cm layer, they apparently broke the sea-surface about half of the time, probably due to turbulence. The lowest nets presumably caught insects only as the net assembly was at the surface at the beginning or end of each tow. In both instances where insects were caught by these nets (one cast skin for net 7 and one adult female for net 8), specimens were also caught by the skimmer.

There were 13 day tows (taken between 0600 and 1800) and 12 night tows (between 1800 and 0600). Although all tows caught insects, there was a dramatic difference in the numbers of insects caught between day and night tows with 85% of the total being collected in the night (Table 1). This day/night difference was primarily due to net avoidance by *Halobates* and has also been observed in other studies (Cheng, 1973c; Cheng and Enright, 1973).

The areas of sea-surface sampled by net 1 varied between 500 and 686 m^2. Using this figure we calculated that the highest density of *Halobates* in our sampling area was 0.16 m^{-2} or 1.6×10^5 km^{-2}. The mean density was 3.9×10^4 km^{-2}, almost 10 times higher than those reported for similar latitudes in the Atlantic Ocean (John, 1982; Stoner and Humphris, 1985; Table 9).

Altogether, 524 *Halobates* specimens were caught, including adults and nymphs of all 5 stages. Numbers of individuals of each stage are given in Table 1. There were also 40 cast skins, 21 belonging to the final (fifth)-instar and the rest more or less evenly distributed among the four earlier instars. The majority (69.4%) of the nymphs belonged to the first-instar, many evidently newly hatched from eggs and not quite tanned. Among the older nymphs about 20% were also newly molted individuals. If we assume that the skins collected in our tows had to have been cast during the previous two-hour period, there was evidently a "molting peak" between 0530 and 1130 (50% of the skins were collected between 0730 and 1330; Table 1). In a population of the coastal *Halobates mariannarum* studied in the laboratory, the insects molted between 0500 and 1100 (Cheng, 1981). In our samples, 75% of the cast skins were collected between 0130 and 1300, indicating that, in nature, the insects probably molted mostly between midnight and noon. During molting insects are more vulnerable to predators, as they cannot skate normally until the cuticle has been tanned. There may be an advantage in molting during the morning hours if predators are less active then. Known predators of oceanic *Halobates* include several species of seabirds and surface-feeding fish (Cheng and Harrison, 1983).

SERIES 2. Although samples were collected almost monthly during the BLM surveys in 1976 and 1977, there were no samples for January and May in 1976 or for February, June and October in 1977. The total numbers of neuston tows taken for each month during the 2 years, the numbers of positive tows, and the compositions of *Halobates* populations for each month are given in Tables 2 and 3. The total number of insects collected in 1976 was almost 18 times as high as in 1977. We have no explanation for this large difference. We have examined temperature and salinity data from each year, but find no evidence of any hy-

Table 1. Number and developmental stages of *Halobates micans* per tow collected over a 48 h period at 27°N 86°W, Gulf of Mexico (Series 1)

Tow (No.)	Time (h)	Developmental stages (%) I	II	III	IV	V	Adults	Total insects	Cast skins
1	0800	83	4	4	0	4	4	23	3
2	1132	73	0	0	0	0	27	11	3
3	1330	67	0	11	0	0	22	9	5
4	1530	50	0	33	0	0	17	6	2
5	1730	0	0	50	0	0	50	2	2
7	2132	23	7	5	2	11	53	57	2
8	2333	19	0	11	0	6	64	36	1
9	0130	4	13	4	2	9	67	45	0
10	0333	10	3	3	0	3	81	31	0
11	0530	12	7	5	2	7	67	43	1
12	0730	67	33	0	0	0	0	3	0
13	0931	60	0	0	0	0	40	5	3
14	1132	67	17	0	0	0	17	6	1
15	1335	0	0	33	33	0	33	3	2
16	1530	0	0	0	0	67	33	3	0
18	1930	60	0	0	0	0	40	5	1
19	2130	19	10	0	0	5	67	21	1
20	2334	54	11	5	3	3	24	37	1
21	0130	83	0	1	1	0	15	95	4
22	0331	47	17	8	3	0	25	60	5
23	0540	0	0	0	6	11	83	18	0
24	0746	0	0	0	0	100	0	1	1
25	0931	0	0	0	0	0	100	4	2
Total		40	6	5	2	5	43	524	40

drographic anomalies which might indicate the influence of warm core eddies. For both years the insects were either absent or occurred in very low numbers during the cooler months (November to March). When data for the 2 years are combined it can be clearly seen that occurrences increased in frequency towards the summer months and peaked in September (Table 4). This correlates well with a rise in surface temperature.

Table 2. Number of neuston tows collected by month and population composition of *Halobates micans* from four nearshore transects, Gulf of Mexico (Series 2, 1976)

1976 month	Total No. tows	Percent positive tows	Total insects	Developmental stages (%) I	II	III	IV	V	Adults
Jan	0	0	0	—	—	—	—	—	—
Feb	19	0	0	—	—	—	—	—	—
Mar	11	18	672	57	24	19	0	0	0
Apr	6	0	0	—	—	—	—	—	0
May	0	0	0	—	—	—	—	—	—
June	24	42	2,488	18	20	14	41	3	3
July	5	60	688	72	0	9	19	—	—
Aug	6	83	1,616	8	22	10	36	19	6
Sep	12	75	2,972	46	11	14	19	8	2
Oct	12	33	394	23	20	19	17	13	8
Nov	6	17	16	—	100	—	—	—	—
Dec	6	0	0	—	—	—	—	—	—
Total	107	32	8,846	33	16	14	27	7	3

Table 3. Number of neuston tows collected by month and percentage population composition of *Halobates micans* from four nearshore transects, Gulf of Mexico (Series 2, 1977)

1977 month	Total No. tows	Percent positive tows	Total insects	Developmental stages (%) I	II	III	IV	V	Adults
Jan	14	0	0	—	—	—	—	—	—
Feb	0	0	0	—	—	—	—	—	—
Mar	7	0	0	—	—	—	—	—	—
Apr	6	4	117	2	4	3	55	38	0
May	15	5	100	12	52	14	6	16	0
June	0	0	0	—	—	—	—	—	—
July	6	3	91	21	19	46	12	2	0
Aug	6	0	0	—	—	—	—	—	—
Sep	15	8	182	83	17	—	—	—	—
Oct	0	0	0	—	—	—	—	—	—
Nov	6	1	16	0	100	0	0	0	0
Dec	6	0	0	—	—	—	—	—	—
Total	81	21	506	36	24	12	16	12	0

For each season, samples were generally collected along each of four transect lines, and there were three stations on each transect. For 1976, we found significant differences between transect 1 and the remaining three transects (Table 5). The percentage of positive tows (22% versus 32–44% for other transects) as well as number of insects caught per tow (62 versus 205–349) were much lower for transect 1. Among the different 1977 transects we found no significant differences in the number of insects caught per tow (19–29). However, for transect 1 the percentage of positive tows (44%) was much higher than for transects 2 and 3 (19% and 20% respectively; Table 5).

When we examined data on a "per station" basis we found significant differences in the percentage of positive tows between station 1 and stations 2 and 3. For both years, this percentage (17% and 15% respectively) was much lower for station 1 than for stations 2 (42% and 33%) or 3 (39% and 30%; Table 6). This is perhaps due to the fact that station 1 was closest to shore, where under normal conditions ocean-skaters are not known to occur. They are found near shore only following storms with strong on-shore winds (Cheng, 1985). Although the frequency of

Table 4. Combined monthly neuston tows for 1976 and 1977 and percentages of tows with *Halobates micans*, Gulf of Mexico (Series 2)

Month	Total No. tows	% Positive
Jan	14	0
Feb	19	0
Mar	18	11
Apr	13	39
May	15	33
June	24	42
July	11	55
Aug	12	42
Sep	27	63
Oct	12	33
Nov	12	17
Dec	12	0
Total	189	29.6

Table 5. Comparisons of *Halobates micans* population composition by transect, Gulf of Mexico (Series 2)

Year	Transect	Total No. tows	Percent positive tows	Total insects	Developmental stages (%)					
					I	II	III	IV	V	Adult
1976	I	18	22	248	23	26	3	3	26	19
	II	54	31	3,482	31	20	12	24	9	4
	III	18	39	2,360	30	12	16	40	1	1
	IV	18	44	2,788	40	14	14	21	9	3
Total		108	33	8,878	33	16	14	27	7	33
1977	I	9	44	94	51	49	0	0	0	0
	II	53	19	260	11	18	18	30	23	0
	III	10	20	58	79	21	0	0	0	0
	IV	9	55	94	65	18	15	2	0	0
Total		81	26	506	36	24	12	16	12	0

occurrence of insects at each station was very similar between the two years, insect abundance was very different. There were 10–15 times more insects caught per tow in 1976 than in 1977. There was also a considerable difference in insect abundance between day and night tows at the same station. This difference was more pronounced in 1976 than in 1977 (Table 6).

The population composition of the samples showed some seasonal succession of developmental stages (Tables 2, 3). For 1976 there might have been two generations between March and October, since there were two peaks for fourth-instar nymphs, in June and August, but for 1977 during the same period there was only

Table 6. Comparison of *Halobates micans* population compositions by station (Series 2) (D = day; N = night)

	Total No. tows	Percent positive tows	Total insects	Developmental stages (%)					
				I	II	III	IV	V	Adult
(1976)									
Sta. 1-D	18	22	608	61	3	6	31	0	0
Sta. 1-N	18	11	1,088	0	18	6	47	24	6
Total 1	36	17	1,696	22	12	6	41	15	4
Sta. 2-D	18	39	1,008	30	11	19	24	8	8
Sta. 2-N	18	44	3,302	33	18	17	26	56	1
Total 2	36	42	4,310	1,386	697	746	1,112	256	113
Sta. 3-D	18	28	536	19	27	13	15	13	12
Sta. 3-N	18	50	2,304	47	16	13	21	3	1
Total 3	36	39	2,840	41	18	13	20	5	3
(1977)									
Sta. 1-D	19	16	96	50	17	13	4	17	0
Sta. 1-N	8	13	59	19	8	54	19	0	0
Total 1	27	15	155	38	14	28	10	10	0
Sta. 2-D	18	33	141	55	42	0	4	0	0
Sta. 2-N	9	33	112	7	21	0	43	29	0
Total 2	27	33	253	34	33	0	21	13	0
Sta. 3-D	18	39	80	50	15	20	3	13	0
Sta. 3-N	9	11	18	0	28	0	61	11	0
Total 3	27	30	98	41	17	16	13	12	0

one peak. However, we still do not know how long each developmental stage takes in nature, since no one has been successful in rearing open-ocean *Halobates* in the laboratory through a complete generation. Recent estimates of nymphal development time for *H. germanus,* another pelagic species, based on seasonal field data from the Indian Ocean suggest that each stadium could take less than one week at a sea-surface temperature of 29°C (Cheng et al., 1990). However, nymphal development period is strongly dependent on environmental temperature (Cheng, 1981).

In 1976 our earliest seasonal sample collected in March consisted of 57% first-instar nymphs. These could have hatched from just a few egg masses on flotsam, since *Halobates* eggs are known to be laid in the thousands on floating material (Andersen and Polhemus, 1976; Cheng, 1973a). No insects were collected in April and May, but by June the majority of insects in the samples were already in their fourth instar. Assuming the original population was sampled, this would allow some 60 days for three molts or about 20 days per instar, a period much longer than that reported by Cheng et al. (1990). Although the seawater temperatures recorded for the latter half of 1976 and 1977 were similar (July to December), the mean for the first half of the year was somewhat lower in 1977 (17.5°C for 1977 and 20°C for 1976). This could easily account for the slower development of nymphs as indicated by specimens in the area sampled.

SERIES 3. During 1972 and 1973 seasonal neuston samples were collected for the BLM survey in an area of the Gulf further east and south than those collected in 1976 and 1977 (Figs. 1, 2). Unfortunately, we were unable to obtain the complete series for the present study; however, the samples available provide useful comparative data. In 1972, seven samples were available, all collected in August and all containing large numbers of *Halobates* (average 218 insects per tow). There were many adults (61%), but first-instar nymphs were conspicuously absent and less than 1% were second-instar nymphs (Table 7). In 1973 samples were available for March and June. *Halobates* was absent in all five of the March tows. Although they were present in all four of the June tows, the numbers were very low (14 insects/tow). First- and second-instars were both absent in the June samples, where the majority of insects were in the final-instar (69%).

Although the samples from 1972 and 1973 came from a much wider area than those from 1976 and 1977, and we have no complete series for our study, we can, nevertheless, conclude that adults of *Halobates* appear to be absent from the Gulf of Mexico in the colder winter and spring months. A few specimens appeared in March, many in their earliest developmental stages. Numbers increased steadily towards summer and fall, and disappeared by October or November. Whether the insects are able to complete one or more generations during this period is not known. In the winter months they may either overwinter in the egg stage or move further south.

SERIES 4. A total of 215 samples from the Caribbean were available for our study. The stations sampled covered the entire Caribbean (Fig. 2). The cruises took place between 1966–1969 and 1972–1975. The numbers of samples collected, the duration of each cruise and the season of sampling varied from year to year. There were samples for all months except August (Table 8), and *Halobates* was found in all months except February, June and July. About 22% of the tows caught *Halobates* but the number per tow was generally low, averaging about 3.7 insects. An interesting feature is the apparent absence of *Halobates* from the east-central part of the Caribbean (Fig. 2), possibly an artifact of our inadequate seasonal coverage. Stoner and Humphris (1985) reported some *Halobates* from this area, but the densities were much lower than in surrounding areas.

Table 7. Cruise, station position and population composition of *Halobates micans* samples, Gulf of Mexico (First two digits of cruise number indicate year) (Series 3)

Cruise-station No.	Position		Total No. insects	Developmental stages (%)					
	Latitude °N	Longitude °W		I	II	III	IV	V	Adults
72-A-13/25	23°21.4′	96°52.4′	35	0	3	46	29	3	20
34	26°24.9′	94°47.7′	288	0	0	8	23	20	49
40	27°25.5′	94°09.7′	56	0	2	70	7	4	18
50	27°38.3′	94°51.0′	301	0	1	11	7	6	75
60	27°54.0′	94°55.4′	232	0	0	25	7	8	60
54C	27°22.8′	94°55.2′	305	0	0	17	10	10	63
54D	27°24.0′	94°55.2′	277	0	1	10	10	10	69
73 -A- 4/2	26°43.0′	94°53.8′	0						
3-1	26°01.1′	93°56.6′	0						
3-2	26°04.5′	93°35.0′	0						
4	24°55.4′	93°01.7′	0						
6	25°57.0′	89°49.0′	0						
73-A-10/8	23°48.0′	92°15.3′	16	0	0	6	12	48	34
11	23°35.7′	92°32.5′	21	0	0	29	5	48	19
12	24°03.3′	92°39.0′	2	0	0	0	100	0	
18	26°58.7′	92°59.4′	4	0	0	0	0	50	50

Although the distribution of *Halobates* appears to be affected largely by surface seawater temperatures, we do not know why they were absent from our June and July samples when the average seawater temperature was 28° to 29°, a range found to be favored by the sea-skaters in the Atlantic (Cheng and Schulz-Baldes, 1981; John, 1982) as well as the Pacific (Cheng and Schulenberger, 1980) Oceans. In other studies, the highest densities were found on waters at these temperatures (John, 1982; Andrews and John, 1984).

Table 8. Cruise and area of sampling of Caribbean neuston tows and population composition of *Halobates micans* (First two digits of cruise number indicate year) (Series 4)

Cruise No.	Month	Lat °N	Long °W	Total number of tows	Percent positive tows	Total No. insects	Developmental stages					
							I	II	III	IV	V	Adults
6701	Jan	15–23	69–84	12	0	—	—	—	—	—	—	—
	Feb	11–13	66–78	8	0	0	0	0	0	0	0	0
7401	Jan	25°39′	70°51′	21	5	10	0	0	0	20	30	50
7502	Mar	23°30′	84°00′	1	100	(1)	—	—	1cs	—	—	—
6803	Apr	16–28	79–88	25	24	26	0	0	0	31	38	31
6904	Apr	15–24	71–86	20	20	12	0	0	0	13	33	58
6705	May	11–18	60–65	13	31	38	0	3	13	18	13	53
7309	May	25°38′	79°49′	12	8	1	0	0	0	0	0	100
6606	June	11–23	75–82	8	0	0	—	—	—	—	—	—
	July	9–11	76–78	4	0	0	—	—	—	—	—	—
6805	June	14–21	70–86	8	0	0	—	—	—	—	—	—
7206	Sep	25°39′	79°49′	21	38	11	0	0	9	9	36	45
	Oct	25°39′	79°49′	13	46	7	0	0	14	0	29	57
6911	Oct	16–18	61–67	9	0	0	—	—	—	—	—	—
	Nov	16-21	65–74	8	13	1	0	0	0	0	0	100
7317	Oct	25°38′	79°49′	12	25	9	0	0	11	0	44	44
6811	Nov	8–23	78–86	20	50	59	0	3	27	25	15	29
6722	Nov	17–18	64	3	0	0	—	—	—	—	—	—
	Dec	11–17	59–62	7	43	3	0	0	0	0	0	100
Total				215	22	177						

Whereas a number of sampling stations in this series were in the vicinity of the Gulf of Mexico, very few yielded *Halobates* (Fig. 1). There were in fact only three positive stations along the eastern edge of the Gulf, and all those insects were collected in April, 1968.

Discussion

Members of the genus *Halobates* are the only known insects living on the open ocean. Their unique habitat at the sea-air interface makes them interesting organisms to study. However, the habitat tends to preclude direct field observations on their biology or behavior. Much of what we now know about these ocean insects has been gathered through analyses of surface plankton tows collected at various times by various institutions. Nevertheless, we have now accumulated quite a lot of information on the biology, distribution, occurrence and abundance of ocean-skaters (Cheng, 1985), although many aspects of *Halobates* biology still remain obscure.

Among the basic biological questions for which we still need answers are: 1) is there any breeding seasonality, and 2) are there separate populations of *Halobates* in different parts of the oceans?

Since *Halobates micans* is cosmopolitan, and is the only known species in the Atlantic, it would be interesting to find out whether there are discrete populations in the Gulf of Mexico, distinct from those in the Caribbean or the Atlantic Ocean proper, and, if so, to what extent they occasionally exchange genes with the larger gene pool. These restricted populations might be genetically better adapted to local climatic variations or environmental conditions. Data from the present study indicate that there is a sizable, actively breeding population of *H. micans* in the Gulf of Mexico, as evidenced by the sometimes large and persistent presence of first-instar nymphs throughout the warmer months of the year. It is possible that the local population overwinters as eggs on flotsam, not sampled in our study.

The densities of *Halobates micans* in various parts of the Atlantic appear to vary with latitude or, rather, the temperature of the surface seawater at the time of sampling (Table 9). The highest density recorded so far has been 210×10^3 km^{-2} in the south equatorial Atlantic. The density calculated for our study area at 27°N (Series 1) was 39×10^3 km^{-2}, about 10 times higher than those recorded from comparable latitudes in the Atlantic Ocean ($0.1–3.8 \times 10^3$ km^{-2}; John, 1982). The warmer water temperatures in the Gulf could perhaps account for this higher density of *Halobates*. The occurrence and abundance of *Halobates* elsewhere have been found to be correlated with sea-surface temperatures (Cheng and Schulenberger, 1980; Cheng and Schulz-Baldes, 1981; Cheng et al., 1986). We found a high proportion of first-instar nymphs in our 1976 and 1977 samples from the Gulf of Mexico, and very few adults (absent from 1977 samples). The low number of adults could be a result of migration into more open waters since adults of even coastal species are known to prefer open to nearshore habitats (Birch et al., 1979; Cheng, 1985). This behavior could also account for the presence of large numbers of adults in the August 1972 samples which were collected much further away from shore (Table 1).

Monthly population compositions of *H. micans* nymphs from the Atlantic Ocean, the Caribbean and the Gulf of Mexico, from the present study as well as from several other sources, are presented in Table 10. It can be seen that the proportion of nymphs varies from month to month and from region to region. However, for a given month, there appears to be less variation among samples collected from the same region than among those collected from different regions

Table 9. Estimated mean densities of *Halobates micans* from different regions of the Atlantic Ocean and the Gulf of Mexico

Density × 10^3 km^{-2}	Latitudes	Sea-surface temp. (°C)	Source of data
43	15°S–10°S	26	Cheng and Schultz-Baldes, 1981
137	10°S–5°S	28	Cheng and Schultz-Baldes, 1981
208	5°S–0°	28	Cheng and Schultz-Baldes, 1981
55	0°–5°N	28	Cheng and Schultz-Baldes, 1981
115	5°N–10°N	26	Cheng and Schultz-Baldes, 1981
11.1	10°N–14°N	>24	Andrews and John, 1984
6.7	10°N–22°N	22–24	Andrews and John, 1984
7.0	10°N–20°N	?	Stoner and Humphris, 1985
2.4	20°N–35°N	?	Stoner and Humphris, 1985
0.1–3.8	20°N–30°N	21–25	John, 1982
39	27°N	28	This paper

Table 10. Population composition of monthly *Halobates micans* samples from the Atlantic Ocean, Gulf of Mexico and Caribbean (1—Cheng, unpublished data; 2—This paper; 3—Cheng and Schulz-Baldes, 1981)

Month/Year	Geographic area	Total insects	% Adult	% Nymph	% Nymph of each instar I	II	III	IV	V	Source of data
Jan 74	Caribbean	10	50	50	0	0	0	20	30	2
Feb 67	Atlantic	711	71.2	28.8	0	0.5	32.2	36.1	31.2	1
Mar 67	Atlantic	2,799	22.1	77.9	2.2	11.1	26.6	34.3	25.9	2
Mar 76	Gulf of Mexico	672	0	100	57.1	23.8	19.0	0	0	2
Apr 71	Atlantic	1,872	155	84.5	32.4	22.1	17.9	16.3	11.3	3
Apr 77	Gulf of Mexico	117	0	100	1.7	4.3	3.4	54.7	35.9	2
Apr 68	Caribbean	26	30.8	69.2	0	0	0	44.4	55.6	2
Apr 69	Caribbean	12	58.3	41.7	0	0	0	20	80	2
May 66	Atlantic	120	10.8	89.2	4.7	15.9	39.3	21.5	18.7	1
May 68	Atlantic	246	40.2	59.8	6.8	39.5	32.0	10.2	11.6	1
May 77	Gulf of Mexico	100	0	100	12.0	52.0	14.0	6.0	16.0	2
May 67	Caribbean	38	52.6	47.4	0	5.6	27.8	38.9	27.8	2
June 68	Atlantic	2,641	24.3	75.7	10.3	30.1	30.6	20.5	8.6	1
June 73	Gulf of Mexico	55	20.0	80.0	0	0	18.1	22.7	59.1	2
June 76	Gulf of Mexico	2,488	3.2	96.8	18.9	20.6	15.0	42.9	2.7	2
July 68	Atlantic	70	31.4	68.6	14.6	18.8	25.0	22.9	18.8	1
July 76	Gulf of Mexico	688	0	100	72.1	9.3	18.6	0	0	2
July 77	Gulf of Mexico	91	0	100	20.9	18.7	46.2	12.1	2.2	2
Aug 72	Gulf of Mexico	524	42.6	57.4	69.4	11.0	8.6	3.0	8.0	2
Aug 72	Gulf of Mexico	1,517	60.1	39.9	0	0.7	43.1	30.1	26.1	2
Aug 76	Gulf of Mexico	1,616	5.9	94.1	8.4	23.2	10.5	37.9	20.0	2
Sep 76	Gulf of Mexico	2,972	2.2	97.8	47.3	10.8	14.4	19.6	7.9	2
Sep 77	Gulf of Mexico	182	0	100	83.0	17.0	0	0	0	2
Sep 72	Caribbean	11	45.5	54.5	0	0	16.7	16.7	66.7	2
Oct 76	Gulf of Mexico	394	8.1	91.9	24.9	22.1	21.0	18.2	13.8	2
Oct 72	Caribbean	7	57.1	42.9	0	0	33.3	0	66.7	2
Oct 73	Caribbean	9	44.4	55.6	0	0	20.0	0	80.0	2
Nov 76	Gulf of Mexico	16	0	100	0	100	0	0	0	2
Nov 77	Gulf of Mexico	16	0	100	0	100	0	0	0	2
Nov 68	Caribbean	59	28.8	71.1	0	4.8	38.1	35.7	21.4	2

(Table 10; April, May, Sept., Oct., Nov.). If the population we sampled in the Gulf of Mexico had been carried in from the Caribbean or the Atlantic Ocean proper we would expect the population compositions to be rather similar.

Thus, although we are limited by lack of direct evidence, data from our present study indicate that the Gulf of Mexico is likely to have an indigenous population of *Halobates micans*. This population probably overwinters in the egg stage, and may be able to complete two or three generations annually between March and November. Further evidence will have to await the collection of more seasonal samples from the same area over a period of 1 or more years.

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