

QUEUING BEHAVIOR OF THE HAWAIIAN SPINY LOBSTER
PANULIRUS MARGINATUS

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Queuing behavior of spiny lobsters consists of highly stereotyped single file formations and is best known for the western Atlantic species *Panulirus argus* (Herrnkind and Cummings, 1964; Herrnkind, 1969; 1977; 1980; Herrnkind and McLean, 1971, Herrnkind et al., 1973; Herrnkind and Kanciruk, 1978; Berrill, 1975; Bill and Herrnkind, 1976; Kanciruk and Herrnkind, 1976; 1978; Davis and Dodrill, 1980). Queuing in *P. argus* generally is reported in the context of extensive linear formations of up to 65 individuals that assemble inshore during a seasonal migratory phase and which move offshore. Returning queues have not been reported. The queues are noncommunal, gregarious groups in which relationships between consecutive individuals are established continually as old ones are dropped and as group membership shifts (Herrnkind et al., 1973). However, *P. argus* also forms short, aseasonal queues of just a few individuals in situations such as when deprived of shelter (Herrnkind, 1969), and when two or more individuals encounter one another over open bottom during the day (Berrill, 1975). Although there are 49 extant species of spiny lobsters (Phillips et al., 1980), heretofore queuing is described only in one species. Here we record observations of queuing in a nonmigratory lobster species, *P. marginatus* (Quoy and Gaimard, 1825) in Hawaii.

TIME SPENT IN OBSERVATIONS

The apportionment of total diver-hours of observation by diel period and geographic location during 1977-1982 is summarized in Table 1. The majority of the diving time was expended in the conduct of research on the population biology of *P. marginatus* at Kure Atoll and at French Frigate Shoals, Northwestern Hawaiian Islands. Observations rarely were made at depths exceeding 20 m.

OBSERVATIONS OF QUEUING

Queuing of *P. marginatus* was observed on two occasions in the lagoon at Kure Atoll (28°25'N, 178°20'W) and on two occasions in Kaneohe Bay at Oahu (21°30'N, 158°W) (Table 2). Respectively, these islands are situated near the northern and southern ends of the Hawaiian Archipelago. Areas where the observations occurred are sheltered from the open ocean and consist of fringing and patch reefs separated by broad stretches of silty or sandy substratum. Refer to Gross et al. (1969), Dana (1971), and Smith et al. (1973) for detailed descriptions of these areas.

In each instance, the queue consisted of two adult lobsters arranged head-to-tail as depicted for *P. argus* by Herrnkind and Cummings (1964), Herrnkind (1969), and Berrill (1975) and was highly stereotyped. Tactile contact by the antennular rami and first pereopods of the second lobster with the extended abdomen of the lobster ahead apparently maintained queue formation. The lobsters did not feed while in the queue which appeared solely in the context of locomotion. Queues were observed once at dawn, early during the day twice, and once at night. At dawn and early during the day, lobsters were moving over open sandy bottom enroute to a patch reef when they were encountered by the diver.

Table 1. Apportionment of total diver-hours of observation (2,457 h) at different times and geographic locations in Hawaii

Diel Period	Location		
	Kure Atoll Lagoon	Kaneohe Bay, Oahu	Elsewhere in Hawaiian Archipelago*
Dawn	0	143	6
Day	1,161	279	522
Night	15	35	296

* Midway Islands, Pearl and Hermes Reef, Maro Reef, French Frigate Shoals, Necker Island, Nihoa, other locations at Oahu, Maui, and the island of Hawaii.

Upon arriving at the reef, the lobsters disengaged themselves from each other and separately acquired shelter. It was apparent, without disturbing the lobsters, that they were adults, based on their size, and that none were ovigerous females. At night, the lobsters were moving up the slope and across the top of a patch reef when encountered and captured by the diver. The leading individual was an ovigerous female of 8.5 cm carapace length and the other individual was a male of 9.5 cm carapace length. The chance encounter with each queue did not permit observation beyond about 10 min, and the duration of queuing was not determined. Although *P. marginatus* were observed in queues on only four occasions, it should be noted that the observations were made during summer, fall and spring seasons.

Queuing on shallow substrates is apparently infrequent in *P. marginatus*, judging by the few observations of queuing relative to the total number of diver-hours expended (Table 1). But queuing in this species might occur more frequently in the early evening and at dawn as lobsters leave and return to shelter while foraging at night; fewest of our diver-hours of observation were made at those times.

DISCUSSION

Our observations of queuing in *P. marginatus* raise several questions that pertain to the adaptiveness and evolution of queuing in the Palinuridae. Queuing in spiny lobsters is thought to serve an anti-predation function (Herrnkind, 1969; Kanciruk, 1980) and to conserve energy by reducing drag during group movements (Bill and Herrnkind, 1976). Additionally, queues possibly provide a mechanism assuring appropriate orientation of the entire population during seasonal migration (Herrnkind et al., 1973; Herrnkind and Kanciruk, 1978). The results of tagging studies at Kure Atoll and French Frigate Shoals (MacDonald, unpublished data) and at Oahu (Morris, 1968) indicate that *P. marginatus* does not migrate. Instead, patterns of movement consist of home ranging behavior (*sensu* Brown and Orians, 1970) and nomadism (*sensu* Herrnkind, 1980). Since *P. marginatus* does not migrate at any of these locations, and since the hydrodynamic efficiency associated with queues of two individuals hardly differs from that of a single individual (Bill and Herrnkind, 1976), it remains that predation might be an important factor selecting for queuing in *P. marginatus*. Although the type of predator is a consideration, the greatest theoretical gain in reducing an individual's risk of predation should occur when two animals form a group (Bertram, 1978). Even in *P. argus*, queues of two individuals occur most frequently (Herrnkind et al., 1973).

The evolution of the Palinuridae has been postulated based on external morphology (George and Main, 1967), and the two species, *P. marginatus* and *P. argus*, are considered to be directly descended from a common ancestor; queuing in these species evidently is a homologous behavior. However, there appears to

Table 2. Summary information on queuing behavior of *Panulirus marginatus*

Location	Lobsters/Queue	Depth (m)	Date	Time (h)
Kure Atoll lagoon	2	5	2 June 1979	0920
Kure Atoll lagoon	2	12	11 Sept 1980	0945
Kaneohe Bay, Oahu	2	10	18 April 1978	0630
Kaneohe Bay, Oahu	2	2	5 Mar 1982	2230

be a basic difference in queuing between the two species. Whereas queuing might be adaptive as a strategy to lower the individual risk of predation in both species, it is adaptive in migration, where it affords individuals a measurable advantage in hydrodynamic efficiency, apparently only in *P. argus*. Could the apparent difference in queuing between these species thus be caused by factors that selected for migration in *P. argus* but not in *P. marginatus*?

Herrnkind (1977; 1980) suggests that the autumnal mass migration by *P. argus* in the Western Atlantic probably represented a necessary seasonal exodus, out of rapidly cooling shallows during periodic glaciations and colder periods, from which it is now emancipated, and queuing subserves a rapid, efficient exodus. In this regard, it may be significant that the large shift in the path of Gulf Stream waters caused the Atlantic in the northern hemisphere to have the highest sea-surface temperature anomaly in the world ocean between periods of extensive glaciation and the present (CLIMAP, 1976). In contrast, sea-surface temperature in Hawaii at the time that continental glaciers reached their maximum extent was calculated to differ little from the present (CLIMAP, 1976). Under these circumstances, mass queuing probably would not confer a significant selective advantage on *P. marginatus* during periodic glaciations as it may have for *P. argus*.

A better understanding of the evolution of queuing in the Palinuridae requires further observations or study of *P. marginatus* behavior. But the tendency for both *P. marginatus* and *P. argus* to form short queues when encountering other individuals over open bottom during daylight is indicated as a possible preadaptation which could have led to the evolution of the elaborate queues that function in the seasonal mass migration of *P. argus*.

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