

Observations From a Submersible Shed New Light on Crab Behavior

Any scientist who has conducted trawl surveys has firsthand knowledge that most organisms are not randomly distributed throughout their environments. This is especially true for crabs. Many tows produce few or no crabs at all, while some will plug the net with a "beetle-bomb"—thousands of crabs, typically of the same sex and size. Observations made near Kodiak, Alaska, using the submersible *Delta* (Fig. 1) in 1991-92 have provided us with new insights into the behavior causing aggregations of Tanner crabs (*Chionoecetes bairdi*).

From January through March, male and female crabs migrate into shallow (2-15 m) water to mate. There, male crabs grasp females in a mating embrace (Fig. 2) which may last up to 2 weeks. Prior to mating, the female (termed pubescent at this time) must undergo a maturity molt. The male protects her from predators and competing males, while the female sheds her old shell. Several hours after the female has molted, the male and female mate, after which the crabs separate. The female extrudes a clutch of bright orange eggs, usually within 24 hours after mating, and is then termed primiparous. Some males mate with multiple females (up to 10 in laboratory aquaria), but females probably do not mate again in the same season. After mating for the first time, female crabs migrate to deeper water. Females do not molt again after reaching maturity. Multipa-

rous crabs, which must remate in a hard-shell condition, are rarely observed in shallow water.

In 1991, I began to investigate the size relationships of mating Tanner crabs along with Jan Haaga and Eric Munk (National Marine Fisheries Service, Kodiak Laboratory) and Bill Donaldson (Alaska Department of Fish and Game). During 1991-92, we collected more than 120 pairs of crabs by scuba in shallow water (< 15 m). Virtually all were pubescent females paired with small (=107 mm width) males; the males, however, had relatively large chela (Fig. 3) and therefore were considered morphometrically mature. In order to determine what size males

mated with multiparous females, it was necessary to capture grasping pairs from deep water. Using the submersible *Delta* was considered to be the only method for doing this.

The *Delta* is a two-person, one-atmosphere sub, with a working depth of 400 m. It is equipped with a two-fingered mechanical arm which we modified by adding six extra fingers (the "grabber"). Crabs captured with the arm were placed into a plastic sampling basket from which they could not escape. An external video camera viewed and recorded a path slightly over a meter wide.

In late April 1991, we began searching Chiniak Bay with the *Delta* at depths of 100-150 m for the presence of grasping crabs. Crabs were distributed sparsely (0.05 crab/m²) over most of the bottom. After 4 days, we discovered a dense aggregation unlike any we had ever seen. Our first glimpses were of low mats of female crabs (Fig. 4) piled two or

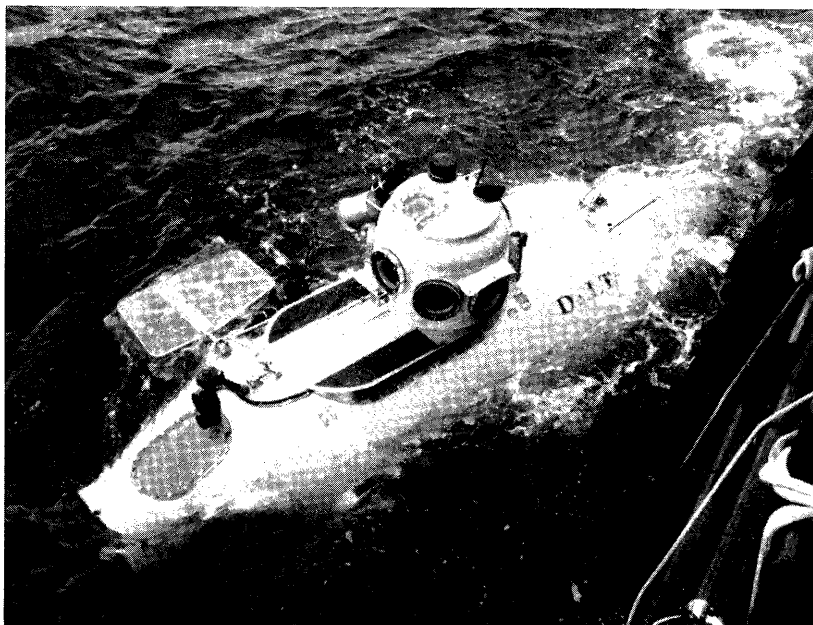


Figure 1. The two-person submersible *Delta* can dive to 400 m and collect a variety of information. The basket used for holding captured samples is on the starboard side of the vessel beneath the Plexiglas diving plane.

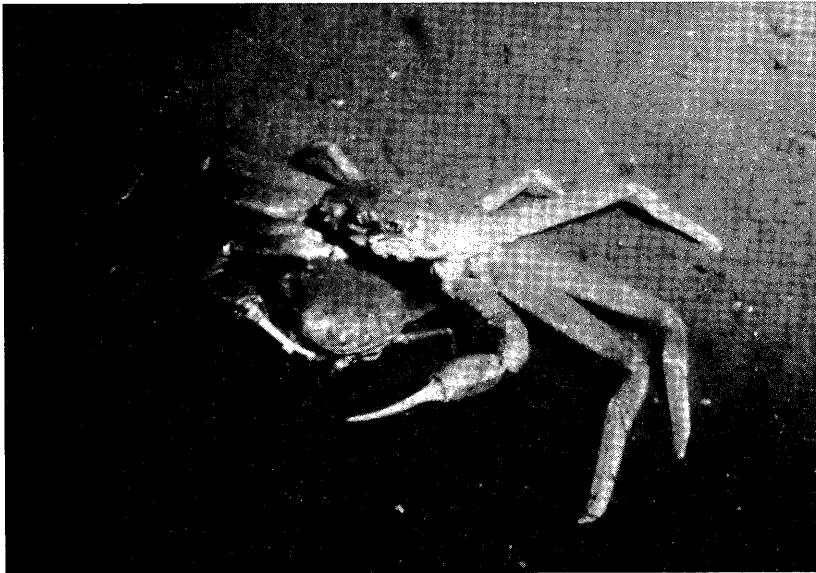


Figure 2. A mature male Tanner crab grasps a smaller female in a pre-mating embrace.

three deep over several square meters of bottom. After several more days of diving, we realized that such piles were only a small portion of a much larger aggregation covering an area approximately 150 m x 150 m (about 2.2 ha). In the center of the aggregation, females formed dome-shaped mounds (Fig. 5) about 1 m in diameter and 0.5-1.0 m high. The mounds were regularly spaced on the seafloor at intervals of 2-3 m and contained 100-400 crabs each. All crabs in the mounds appeared to be multiparous females with eyed eggs about to hatch. While examining the aggregation and searching for paired crabs, we literally plowed into mounds, stopping the *Delta* and scattering crabs over and around the vessel. Often, we turned away from one mound and immediately crashed into another, like a pinball bouncing off the bumpers. On one dive transect of 50-m length, 19 different mounds were encountered.

Males were present in low numbers (1-10 per 100 females) and were distributed mostly around the

outside of the aggregation, where they were mating with individual females. Using the grabber, we were able to capture 47 pairs from the aggregation. Males mating with multiparous females were larger (= 120 mm) than those we

had observed mating with pubescent females in shallow water. Although male crabs as small as 60 mm will mate with females in laboratory aquaria, our data show that only those crabs with large claws participated in mating in the ocean, the few exceptions mostly having regenerated claws. Crab counts obtained from the video recordings were averaged over 10-m intervals and mapped (Fig. 6), showing the size of the aggregation. Crab densities in the aggregation were 2-3 orders of magnitude greater than densities in the surrounding area. Summation of crab densities over the mapped area (0.25 km²) provided an estimate of 100,000 crabs.

In early May 1992, we revisited the same site with the *Delta*, with the goal of capturing females, counting piles, and determining the number of crabs present. Unfortunately, we discovered during our first dives that nearly all the crabs had mated and dispersed,

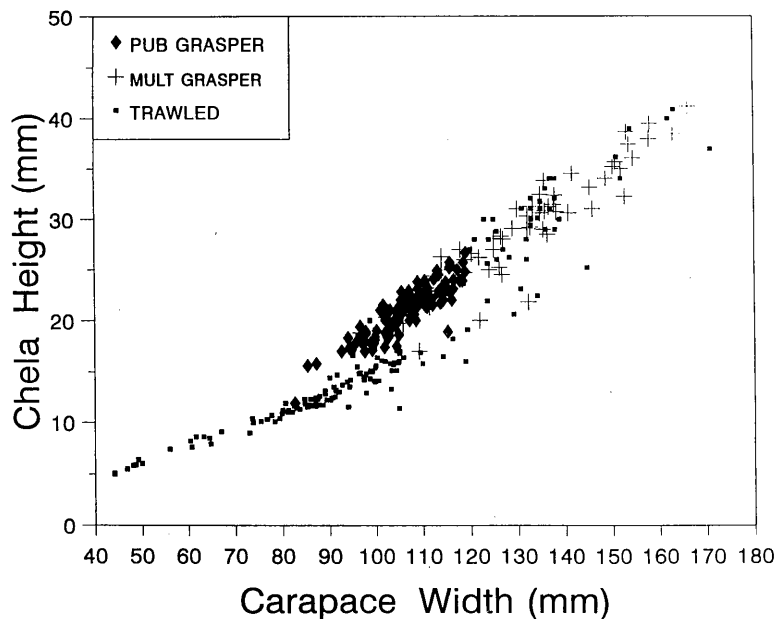


Figure 3. Relationship of chela height to carapace width for male Tanner crabs by pairing status. Pub grasper = male grasping pubescent female (collected by scuba). Mult grasper = male grasping multiparous female (collected by submersible). Pairing status of trawled crabs is unknown.

probably due to warmer (5.4°C vs. 3.6°C) water. The highest crab density observed was only 2.2/m² (vs. 100/m² in 1991): Over 85% of the females were buried in the mud, and of those, 88% had extruded new clutches. But some females remained active on the surface, and 75% of those had not remated. This activity pattern reversed at night, when 71% of females were surface-active. Thus, after mating, females resumed a diel rhythm of nocturnal foraging alternating with diurnal burial. In 1992, crabs were spread out over a much larger area (25 ha) at lower densities (0.3/m²) than in 1991, but a similar number (75,000) were present. The large number present in 1991 was probably drawn from a relatively small local area. We also observed dead mature crabs of both sexes in the area of highest density, suggesting that some mortality occurred after mating, perhaps as a result of the combined effects of exhaustion, starvation, and senescence.

These observations have led to a complete reexamination of our existing paradigm of mating in *Chionoecetes* and other genera of the family Majidae. (In a serendipitous event, we also discovered nearby two similar aggregations of the closely related lyre crab, *Hyas lyratus*. Although we had long suspected that crabs were semi-gregarious, especially when mating, we had no idea of the intensity or scale of such aggregations. An extensive literature search turned up anecdotal observations of aggregative behavior in seven other species of Majid crabs, suggesting that rather than being unusual, such behavior may be characteristic of the family. Our observations are the first directed study of such behavior.

The results of our investigations have led to many more ques-

tions about the aggregative behavior of crabs. What is the purpose of aggregation? Does mound-forming concentrate an odor trail which attracts males, thereby in-

creasing mating opportunities? Do females form mounds to delay mating or to prevent multiple matings? Does mound-forming provide the larvae access to better

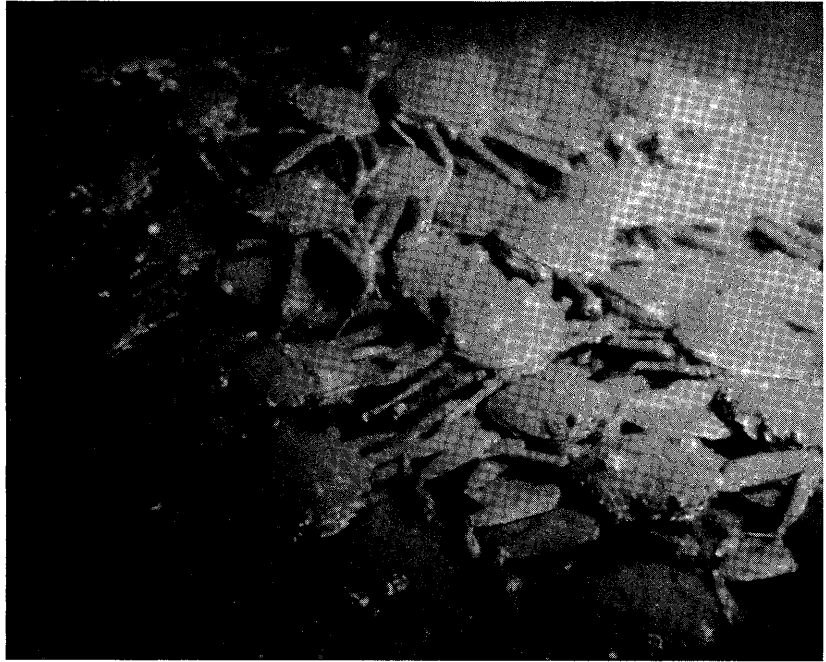


Figure 4. Early stage of mound formation consists of a mat of female crabs in one to two layers.

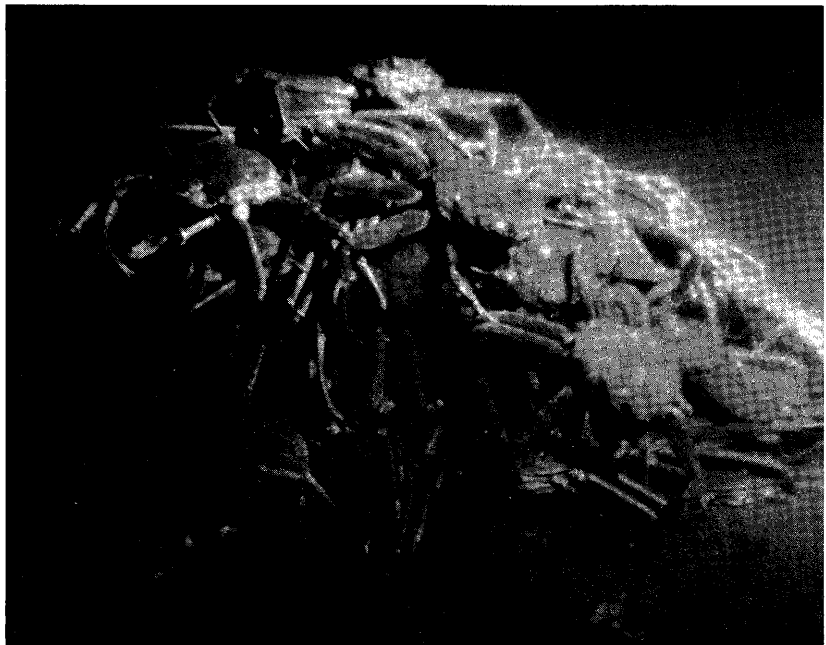


Figure 5. Typical pyramidal mound of female Tanner crabs with cloud of suspended sediment particles trailing off to right. Note that barnacles indicate advanced shell age.

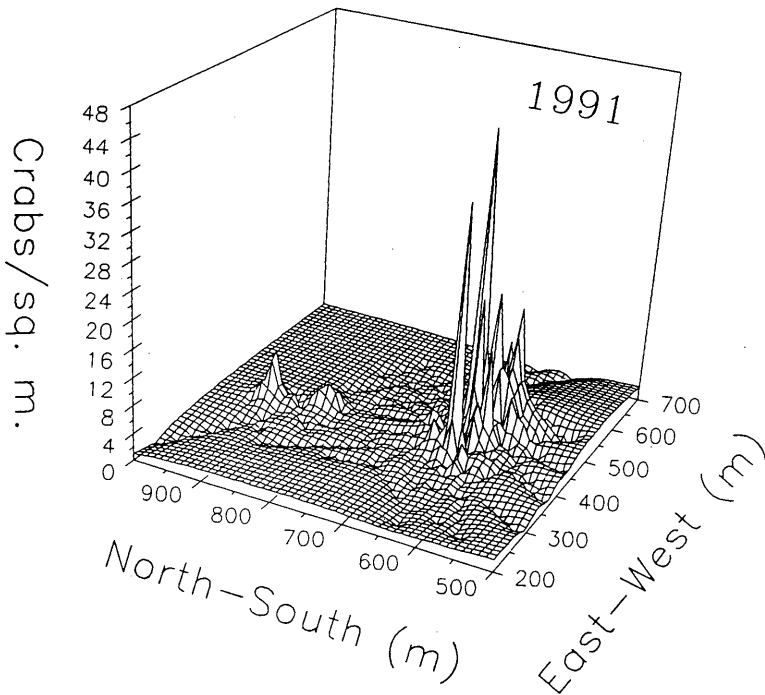


Figure 6. Density of aggregated Tanner crabs in 1991. X and Y values are distances in meters from an arbitrary origin. Z values are distance-weighted mean crabs m^{-2} , averaged over intervals of 10 m. Large peaks represent areas with multiple mounds. A secondary aggregation to the north consisted of one mound (leftmost peak) and a region of single-layer "mats."

quality water, or does aggregation concentrate larvae to reduce predation? (Aggregation does not seem related to predation on adult crabs since few large predators were observed). Why don't pubescent females aggregate? Do they release a strong pheromone prior to molting, which multiparous females do not? How do the females form the aggregations? Why are mounds so regular in size, and why don't all the mounds coalesce into one large mound? Are females in mounds at different reproductive stages than those outside of mounds? With such a low male-to-female ratio, do all the females mate? How long do the females remain in one area? What is

the distribution of aggregations? What controls the timing of aggregative behavior? When does it begin and how long does it last? In order to answer some of these questions, we hope to revisit and resample the Chiniak Bay aggregation by remotely operated vehicle (ROV) and submersible in the next few years.

Despite the many unknowns which remain about crab behavior, our recent observations shed new light on some important issues relevant to fisheries management. Aggregation creates a large source of variability in trawl surveys designed to assess the abundance of crabs; our new knowledge explains one cause of

this variability. It also raises the question "Are crab aggregations vulnerable to disruption or capture by groundfish trawls (with high subsequent mortalities)?" If so, a compelling argument exists for closure of trawling in times and areas where aggregative mating occurs, provided such times and areas could be defined.

If fisheries management is going to continue to progress, use of modern technology is needed in the future. Our wealth of knowledge about crab behavior gained over the past 2 years has been possible only by use of the submersible. Use of *in situ* technology has allowed us to determine spatial relationships of individual organisms, to collect specimens for examination, and to observe behaviors that are only hinted at by other means of sampling. In the future, surveys could be conducted with other types of technically advanced equipment such as side-scan sonar, ROVs, or laser scanning systems to determine the size and distribution of crab aggregations in the Bering Sea. Assessment could then be done by video transect, targeting those areas where aggregations occur. Such stratification might lead to improved estimates of abundance. Eventually, use of *in situ* methods to assess benthic resources could become as routine and indispensable as hydroacoustic assessment is for pelagic fish populations.

This article was written by DR. BRADLEY STEVENS of the Resource Assessment and Conservation Engineering Division's Kodiak Laboratory.