A bug on the ocean waves (Heteroptera, Gerridae, *Halobates* ESCHSCHOLTZ)[1]

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Abstract: Five species of *Halobates* are the only insects known to live on the open ocean. Here is a brief description of what they are, where to find them, some of their special adaptations and their origins.

Key words: Gerridae, *Halobates*, Heteroptera, marine, ocean.

Introduction

Insects are ubiquitous on land but they are commonly thought to be completely absent from the sea, which covers more than 70 % of the earth's surface. This is actually not quite true. A large variety of insects do occur in various marine environments (CHENG 1976). In fact, marine representatives can be found in at least 20 orders of the Insecta (CHENG 2003), the most important being the Collembola, Heteroptera, Coleoptera and Diptera (CHENG & FRANK 1993). Among the Gerromorpha (Heteroptera), marine species can be found in five of the six known families: Gerridae, Hebridae, Hermatobatidae, Mesoveliidae and Veliidae. Members of the Hydrometridae are known only from freshwater habitats (CHENG 2004). The most unusual marine insect is, undoubtedly, the bug that lives on the open ocean far away from land (CHENG 1985). What is this bug? Where do we find it? How do we catch it? How does it manage to live there? These are some of the questions I will try to address briefly in this article.

What kind of bug is it?

The bug that lives on the ocean waves belongs to the genus *Halobates*. It is a member of the Gerridae, one of the largest families of semi-aquatic Heteroptera (Gerromorpha) with 8 subfamilies and about 640 described species (ANDERSEN & WEIR 2004). Most of the known gerrid species are freshwater in habitat and can be found on ponds, lakes, streams, rivers, waterfalls and even temporary rain-filled pools. However, some 80 species are considered marine. These belong to 11 genera in 3 subfamilies: Trepobatinae, Rhagadotarsinae, and Halobatinae, to which *Halobates* belongs.

The genus *Halobates* was created in 1822 by ESCHSCHOLTZ for 3 insect species collected during a circumnavigation expedition. Many new species were added during the subsequent years, some from major ocean basins and others from various near-shore habitats. The taxonomy of the genus was in quite a mess until a monographic review was published by Jon HERRING (1961). He sorted out the systematic confusion, provided a key to 38 described species and carried out the first detailed study on the biology of a coastal species, *H. hawaiiensis* USINGER.

There are now 47 described species of *Halobates*; the most recent one was described from the Philippines by ZETTEL (2005). All but 2 species, *H. acherontis* POLHEMUS and *H. robinsoni* ANDERSEN & WEIR, are found in marine habitats. The marine species can be further divided into a coastal and an oceanic group, each with its own life history strategies, food requirements, behaviour, and environmental adaptations (ANDERSEN & CHENG 2004). The coastal group, with 39 species, can be found around tropi-

[1] This paper is dedicated to Ernst Heiss, an old friend and fellow heteropterist, on the occasion of his 70th birthday.

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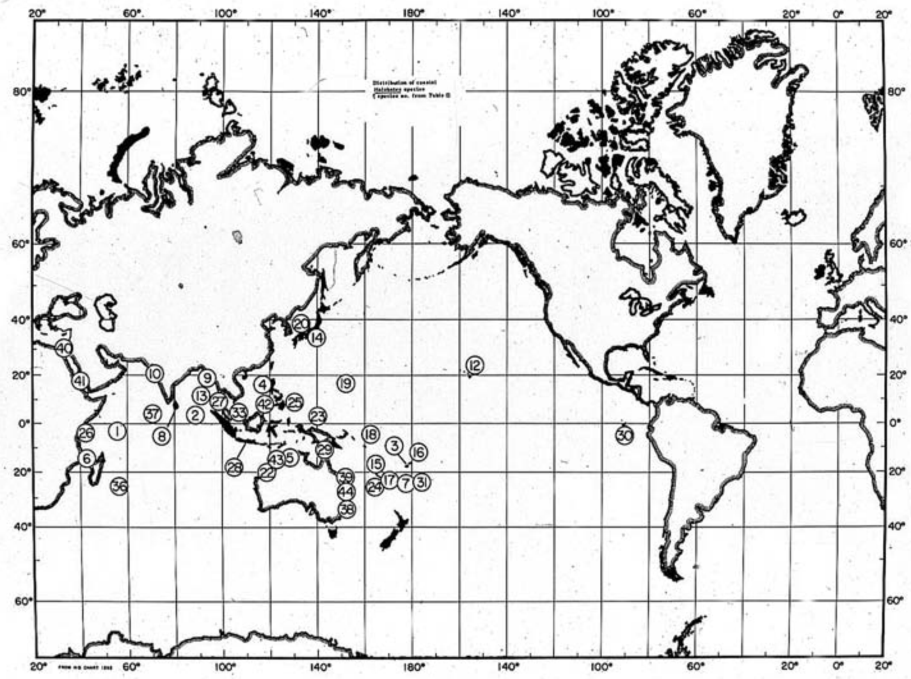
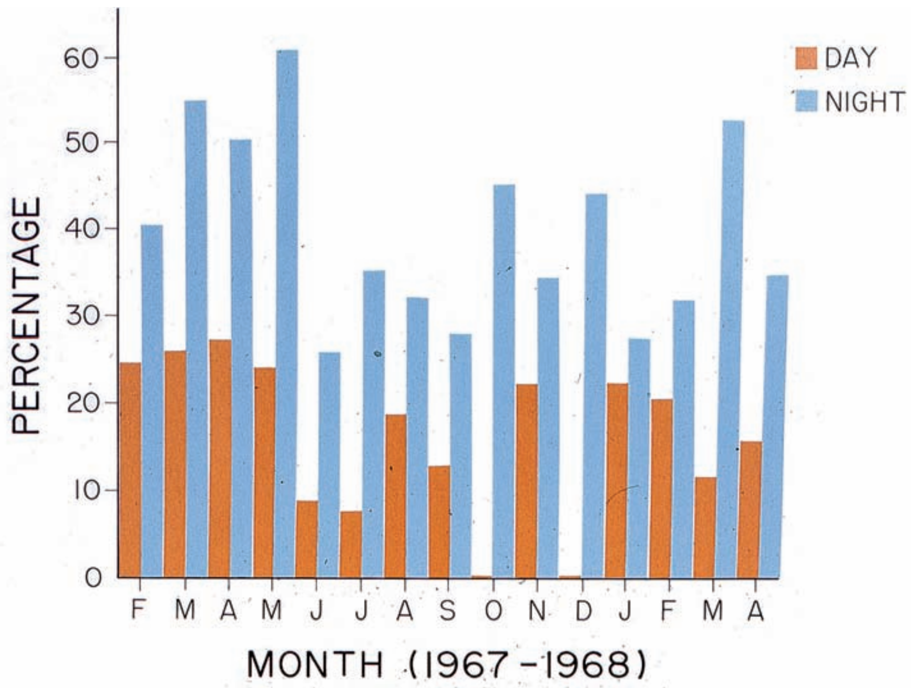


Fig. 1: Type locations of coastal *Halobates* species. (Reprinted with permission from the Annual Review of Entomology, Vol. **30**, 1985).

Fig. 2: Comparison of monthly day and night samples with *Halobates* spp. (Modified from CHENG 1973a).



cal island shores, and many are endemic to islands or island groups. The majority were described from the Indo-Pacific region (Fig. 1). The open-ocean group, with five species (*H. micans* ESCHSCHOLTZ, *H. sericeus* ESCHSCHOLTZ, *H. germanus* WHITE, *H. sobrinus* WHITE and *H. splendens* WITLACZIL), is widely distributed in the Pacific, Indian and Atlantic Oceans. They are rather small, the largest adults measuring only about 6 mm in body length. Although winged morphs may be common in some freshwater gerrids, no winged forms are known for any *Halobates* species. The rest of this article will be devoted solely to these five oceanic *Halobates* spp.

Where do we find oceanic *Halobates*?

Oceanic *Halobates* are confined to the sea-air interface. They are widely distributed on the three major oceans between latitudes 40°N and 40°S (Fig. 9). All five species can be found in the Pacific Ocean, each with a rather well defined distributional range (CHENG 1989, 1997). Two species (*H. micans* and *H. sericeus*) are found in the Indian Ocean, but only one (*H. micans*) in the Atlantic Ocean. They generally occur only in warm waters, where even in winter the water temperatures are above 20°C. Although a few specimens have been caught in colder waters they are usually absent in areas where the water temperature is below 18°C. In the eastern tropical Pacific Ocean off the coasts of north, central, and south America we can find four of the five species (all except *H. germanus*). Although their ranges may overlap, each species tends to have its own preferred range (CHENG & SHULENBERGER 1980). The highest abundances (up to 10,000/km^2) occur in areas with temperatures between 24 and 28°C. We do not know what other environmental or physical factors determine their distribution. We may encounter no insects at all over some large expanses of the ocean, or find high aggregations comprising hundreds or thousands of individuals in other areas. We may find many individuals in one area during certain seasons but few at other times (CHENG et al. 1990).

Halobates are most easily observed during calm days when they can be seen skating over the sea surface. Although they may appear silvery in the sunshine, they are actually dark blue or black when alive. They can move at speeds of up to 1 m sec^{-1}, so they can be rather difficult to catch. For some unknown reason they are attracted to artificial lights. If a non-directional bright light is shone on the sea surface at night they will come towards the light and may skate around it. It is then possible to scoop them up with a dip net, if one is quick.

Ocean-skaters almost never come near a coast except when blown by strong onshore winds. They can then be found in rather dense aggregates in bays or lagoons near shore, and can even become trapped among strands of seaweeds after a storm. I have found numerous specimens, mixed in with debris, on a sandy beach in Fiji (CHENG 1981). Such stranded insects can be easily shaken free from sand and debris, but their movements are awkward on land. They will almost certainly be doomed unless they can somehow return to the sea, perhaps being carried by waves as the direction of the wind changes.

Fig. 3: *Halobates* eggs on seabird feather. Scale in mm. (Copyright L. Cheng).

What do we know about them?

Since few entomologists go to sea, and almost no oceanographers are interested in insects, little biological information on open-ocean *Halobates* was available in the early literature. Studies on the oceanic species remained sparse until I joined the Scripps Institution of Oceanography in 1970 and had opportunities to participate in ocean-going research expeditions.

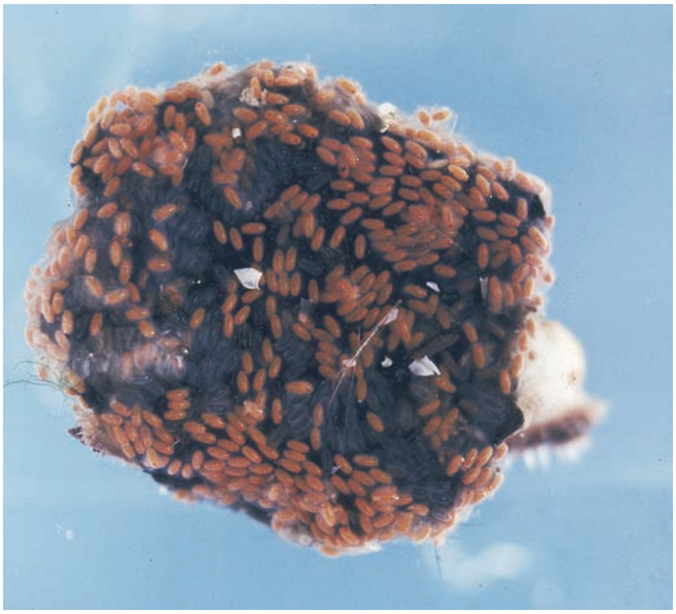


Fig. 4: *Halobates* eggs on tar lump, top view. Scale in mm. (Reprinted with permission from Oceanography and Marine Biology, An Annual Review, Vol. **42**, 2004).

How do we catch them and keep them alive?

Since these insects live at the sea-air interface they are rarely caught in conventional plankton nets which are towed under water. Instead, a surface neuston net or a Manta net must be used to capture them (BROWN & CHENG 1981). Such nets have rectangular openings and are buoyed up by flotation devices so that when in operation the lower rim remains mostly below the water surface (Fig. 13). They are usually towed over the sea surface away from the bow wave at a speed of about 4 knots (~7.4 km/hour). If living specimens are needed for experimental studies we normally tow such nets for 30 min or less. If the nets are towed for longer periods the continuous surge of the water tends to drown or kill the insects.

To keep these insects alive they must be freed from other organisms and allowed to dry themselves. They can then be kept in aquaria filled with clean seawater, where they may soon begin to preen and resume active skating over the water. If they are not

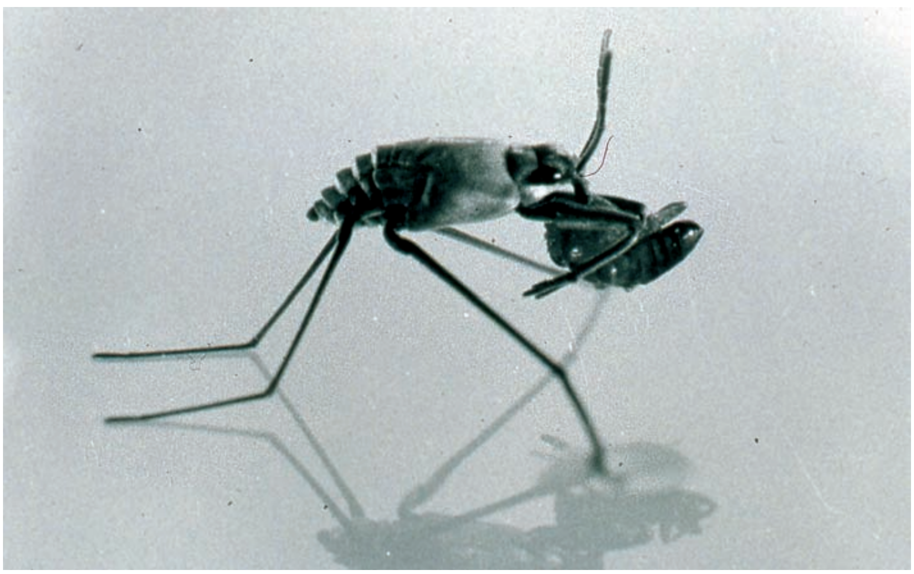


Fig. 5: *Halobates sericeus* ESCHSCHOLTZ female feeding on fly. (Copyright L. Cheng).

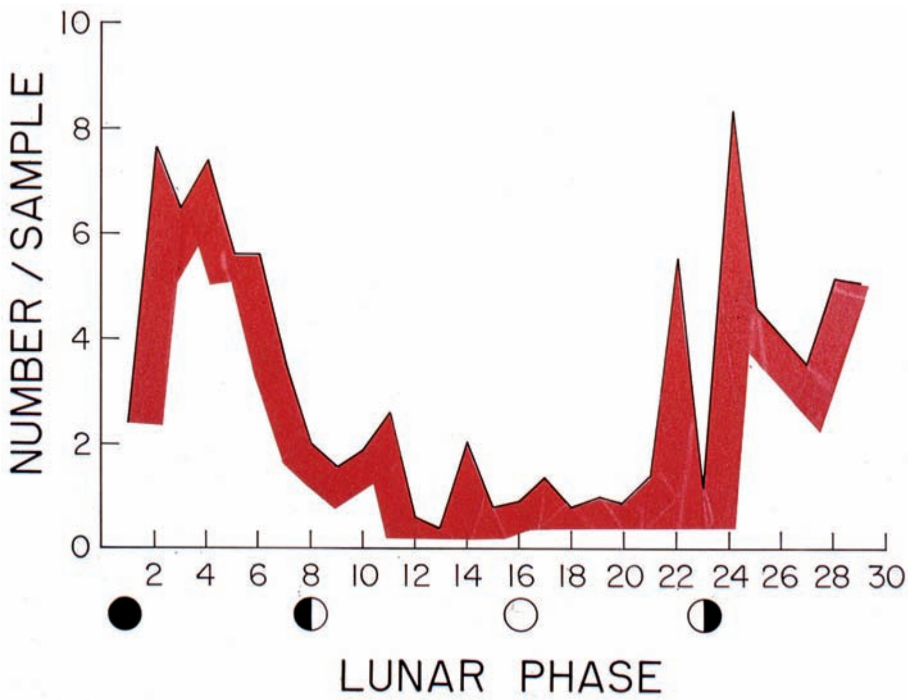


Fig. 6: Average numbers of *Halobates* spp. caught by moon phase. (Modified from CHENG & ENRIGHT 1973).

Fig. 7: Mating pairs of *Halobates robustus* BARBER. (Reprinted with permission from Oceanography and Marine Biology, An Annual Review, Vol. **42**, 2004).

allowed to dry themselves they soon become waterlogged and sink. They are also greatly affected by contaminants at the surface film. If it is oily or dusty they tend to get stuck on the film and are then unable to move freely. In order to keep them alive long enough for experimental purposes they need to be held in a large container. Since there are no solid physical barriers in their natural habitat, they apparently do not know what a wall is, so when confined to a small aquarium they may continue to hit themselves against the sides until they die.

I have been somewhat successful in bringing living specimens back to the laboratory by keeping them in containers lined with moistened paper towels instead of on water. Most then survived a 14-hour trans-Pacific flight. They can be fed with laboratory-reared fruit flies (*Drosophila*), and readily pounce on live or freshly killed prey. However, they do not adapt well to laboratory life. I have not been able to keep any oceanic *Halobates* alive in the laboratory for more than a month. Thus almost all our knowledge on the biology and behaviour of ocean-skaters has been obtained either from short-term studies at sea or from analyses of preserved samples.

What are their special adaptations to an oceanic life?

Oceanic *Halobates* have well-developed eyes which help them to find prey, locate mates and presumably also avoid being captured (Fig. 11). Analyses of some 1,600 day and night samples collected over a period of 14 months during the EASTROPAC expedition revealed that they were caught in about 40 % of the night tows but only 16 % of the day tows (Fig. 2; CHENG 1973a). This suggests that during the day they are able to see approaching nets and avoid being captured. Furthermore, the number of positive tows was much lower during full-moon (24 %) than on new-moon nights (38 %) (Fig. 6; CHENG & ENRIGHT 1973), indicating that their eyes must be adapted for acuity even in moonlight. Whether this night vision helps in prey avoidance is doubtful since their most important predators are sea birds which feed during the day (CHENG & HARRISON 1983). When taken by birds their cuticles may remain undigested for some hours. Many samples from seabird stomachs contained fragments that could be identified to species (Fig. 10).

Life on the open sea means these insects are totally exposed to solar insolation since apart from clouds there is nothing there to provide shade. They are evidently able to avoid UV damage by having cuticles which absorb harmful wavelengths (Fig. 14; CHENG et al. 1978). The exact nature of the UV-absorbing substance is unknown, but it has been shown to contain microsporin-like amino acids (Krantz & Cheng unpubl.). (Perhaps we could develop a super sun-

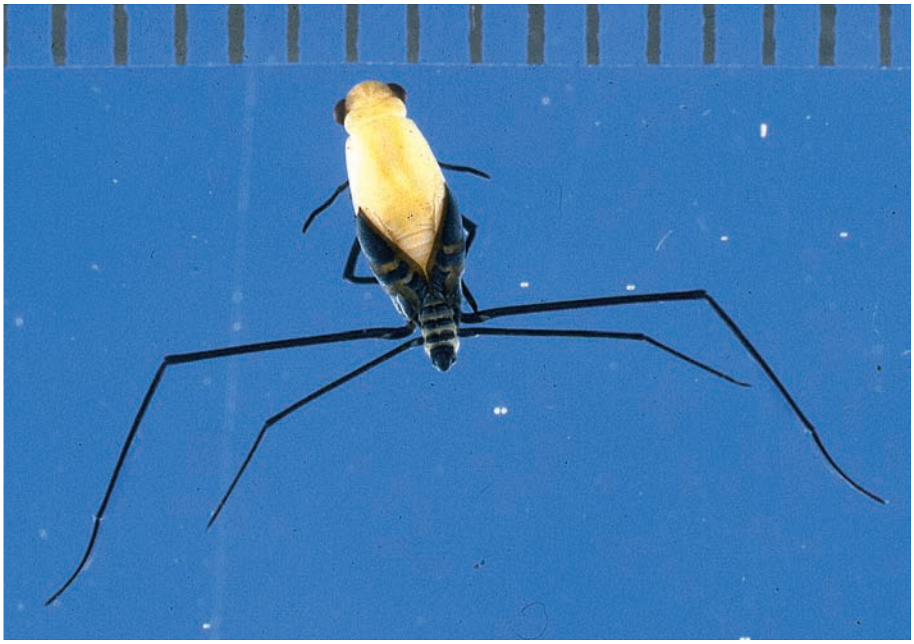


Fig. 8: *Halobates* nymph moulting. Scale in mm. (Copyright L. Cheng).

blocker for ourselves if we know more about the chemical composition of this material.)

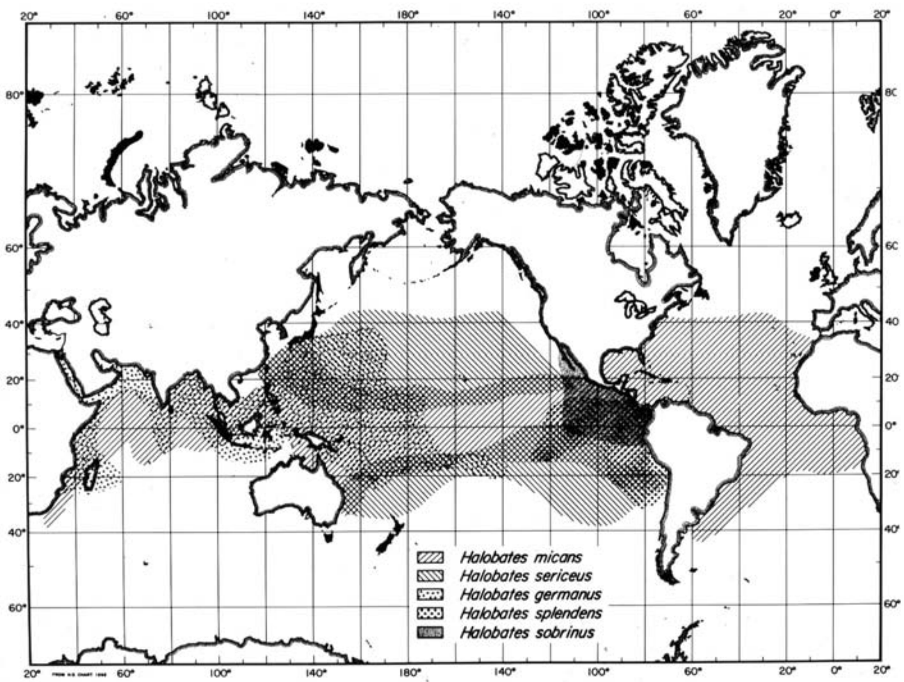
Rain and storms are unavoidable at sea. *Halobates* are air-breathing insects and are unable to survive under water for any length of time, so it is essential for them to have some ability to withstand drowning. This is provided by a thin layer of tiny velvety water-repellent hairs covering their body (Fig. 12). These hairs, or microtrichia, are about 1µm high and are spaced about 1µm apart. This allows air to be trapped but does not admit water (CHENG 1973b). Thus the insects are more or less enclosed in an air bubble. When they are pushed under water by waves they can normally regain their position above water within a few seconds.

Ocean-skaters are predators and feed by sucking body fluids of their prey. They are opportunistic feeders, and catch any zooplankton trapped at the sea-air interface (CHENG 1985). They detect their prey either by sight or by ripples generated by the struggling animal. If the prey is small they hold it in their front legs, lifting it off the sea surface so that it generates no further ripples that could be detected by their kin (Fig. 5). If the prey, such as a small fish, is too heavy to lift, more than one insect may feed on it at the same time. While nearshore *Halobates* can usually depend on aerial insects blown offshore from coastal vegetation to rain down, food availability on the open ocean must be more sporadic and harder to come by. Oceanic *Halobates* differ from their nearshore cousins in their ability to store excess food in the form of triglycerides, which can be metabolized in times of famine (LEE & CHENG 1974).

Nearshore sea-skaters lay their eggs attached to coastal rocks or vegetation. Since such substrates do not exist in the open sea, ocean-skaters lay their eggs on any floating material they can find, e.g. seeds, pieces of plastic, seabird feathers, empty mollusk shells, pumice and even bits of tar (Figs 3, 4). In some parts of the ocean where suitable flotsam for oviposition is in short supply, one might find one substrate used by more than one female. During an expedition at sea we encountered an empty plastic milk jug bearing more than 70,000 eggs (CHENG & PITMAN 2002). Since each female matures and lays an average of only 10 eggs at a time, we estimated that this substrate must have been used by more than 7,000 adult females.

Although nobody has been able to rear any oceanic *Halobates* from egg to adult, development and hatching have been observed in the field. The eggs take about 10 days to hatch at 25°C, and up to a month at lower temperatures. The newly hatched nymphs measure less than 1 mm in body length. What they feed on in nature is unknown. They go through five moults (Fig. 8)

Fig. 9: Ranges of distribution of the five oceanic *Halobates* spp. (Reprinted with permission from the Annual Review of Entomology, Vol. **30**, 1985).



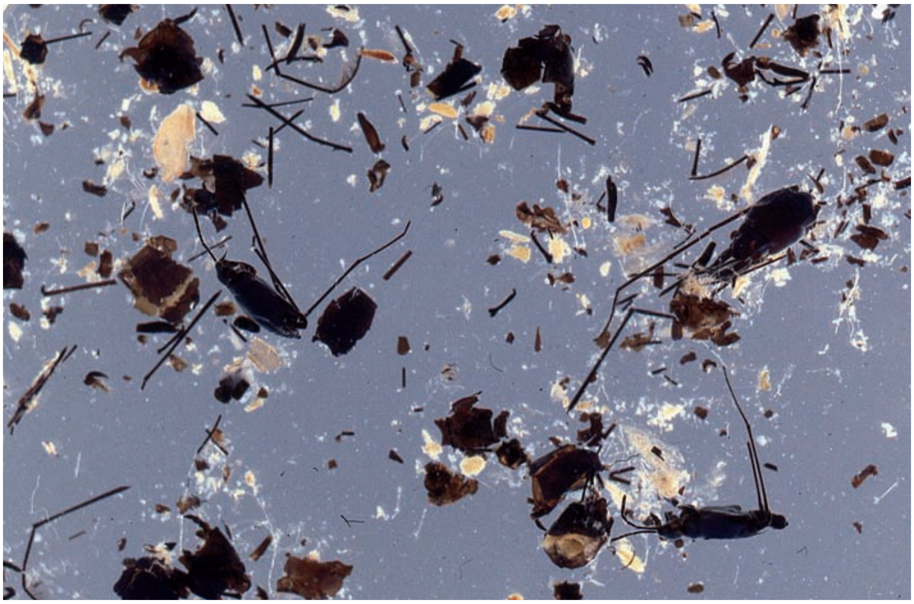


Fig. 10: *Halobates* remains from seabird stomach. (Copyright L. Cheng).

Fig. 11: SEM head of *Halobates sericeus*. (Copyright L. Cheng).

before reaching adulthood, each stadium taking 7-14 days. How long the adults live in nature is unknown, though they have been found to survive in the laboratory for up to a month. Mating occurs with the male riding on top of the female (Fig. 7) and the pair can remain in copula for several hours. How they find mates is another mystery. Although individuals could be brought within close proximity of others by ocean currents and/or surface winds, it is still necessary for them to encounter one another closely (IKAWA et al. 1998). A related coastal veliid (*Trochopus plumbeus* (UHLER)) has been found to use surface-active chemicals as sex attractants (CHENG & ROUSSIS 1998), but whether such semiochemicals are employed in mate location by ocean-skaters is still unknown (PETRAKIS et al. 2003).

Where do they come from?

Insects are believed to have evolved from swamp-dwelling ancestors some 400 million years ago. Throughout their evolutionary history most have tended to move away from wet, swampy areas towards a largely terrestrial or drier aerial existence. Among the attendant adaptations are waterproof cuticles, a tracheal breathing system, and wings for dispersal. Although a fair number of insects have returned to an aquatic life, relatively few have managed to find niches in marine environments, where crustaceans reign supreme.

Marine Gerridae probably evolved from freshwater ancestors, which became adapted to live on salty waters. The earliest known gerrid fossils are more than 50 Myr old (ANDERSEN et al. 1993). The only known fossil sea-skater, *Halobates ruffoi*, dated to about 45 Myr, was discovered in a middle-Eocene marine deposit in Verona, in northeastern Italy (ANDERSEN et al. 1994). It was remarkably similar in morphology to a modern day *Halobates*. However, no living *Halobates* has ever been found on the Mediterranean at the present time.

Oceanic *Halobates* most likely evolved in the Indo-Pacific from some nearshore relative that inhabited coastal mangrove swamps or estuaries. Ancestral *Halobates* were probably accidentally carried out to the open sea, where they were somehow able to find food and oviposition substrates, and so became established there (ANDERSEN & CHENG 2004). Phylogenetic studies using molecular data and morphological characters have revealed that the oceanic species belong to two independently derived groups: *H. germanus* and *H. sericeus* in one, and *H. sobrinus*, *H. micans* and *H. splendens* in the other (DAMGAARD et al. 2000). The discovery of two freshwater *Halobates* species in Australia (POLHEMUS 1982, ANDERSEN & WEIR 2003) has suggested that some sea-skaters were able to re-colonize freshwater habitats.

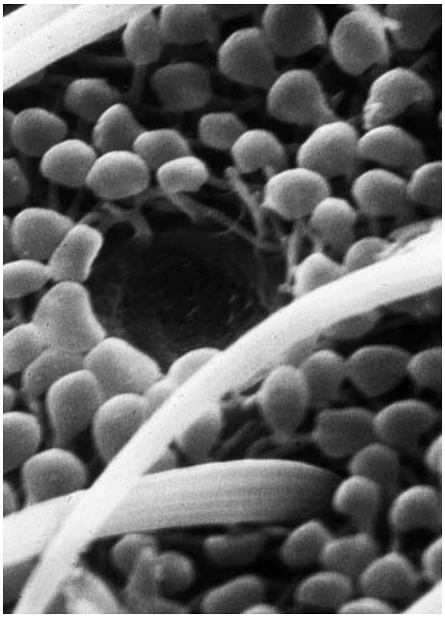


Fig. 12: SEM *Halobates proavus* WHITE cuticle showing hairs and microtrichia. (Copyright L. Cheng).

Fig. 13: Neuston net being towed in calm sea. (Copyright L. Cheng).

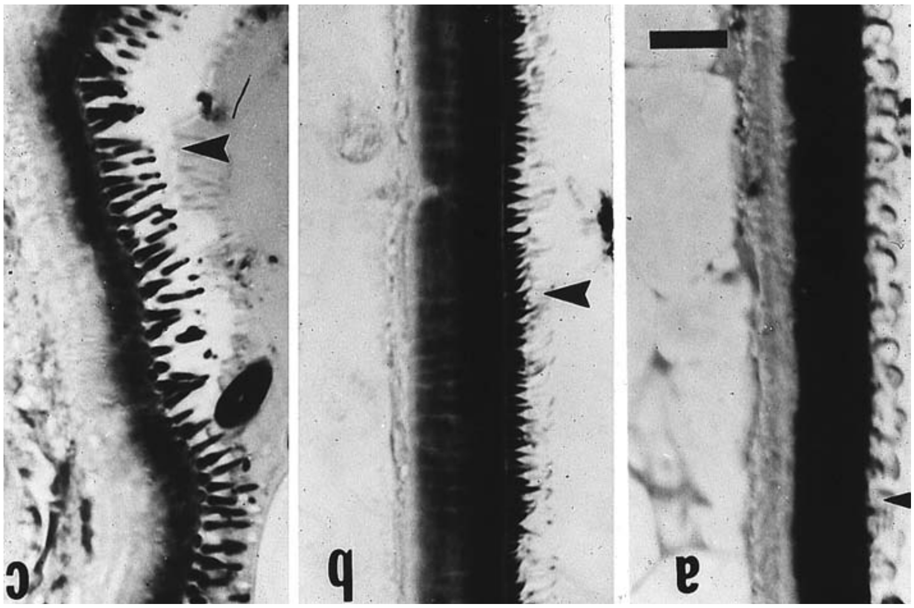


Fig. 14: Sections of gerrid cuticles showing UV absorbing layer (**a**) *Halobates sericeus* ESCHSCHOLTZ (marine) (**b**) *Rheumatobates aestuarius* POLHEMUS (brackish) (**c**) *Gerris remigis* SAY (freshwater). (Reprinted with permission from Limnology and Oceanography, Vol. **23**, 1978).

Concluding remarks

Only five species of *Halobates* have succeeded in surviving and reproducing on the ocean waves where no other insects are able to live. Although we now know where to find them, how to catch them and keep them alive, how they manage to live on the ocean waves, what they eat and what eats them, there are still a lot of fundamental questions about their lives on which we know nothing. So there is still plenty of scope for further research by any heteropterist who likes to go to sea.

Zusammenfassung

Fünf Arten der Gattung *Halobates* sind die einzigen bekannten Insekten, die am offenen Ozean leben. Dieser Beitrag gibt eine kurze Beschreibung wer sie sind, wo man sie findet, einige ihrer speziellen Anpassungen und ihrer Herkunft.

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