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Tens of thousands of genera of insects are known on land: there is only one on the sea—Halobates.

Notes on the Ecology of the Oceanic Insect *Halobates*

LANNA CHENG

INTRODUCTION

Members of the genus *Halobates* (Heteroptera:Gerridae) are the only known insects found in the oceans, yet they are among the least studied marine organisms. Although these insects have been known to marine biologists and oceanographers since the early 1800's, nothing much was added to our knowledge of these unique insects until the last 20 years (Cheng, 1972). We now know that there are 39 described species found in the world's oceans, seas, and lagoons (Herring, 1961, 1964).

DISTRIBUTION

Five *Halobates* species are commonly found in the open ocean (Figure 1). All five—*H. micans*, *H. sericeus*, *H. germanus*, *H. splendens*, and *H. sobrinus*—are found in the Pacific Ocean, but only the first two occur also in the Indian Ocean, and only *H. micans* is known from the Atlantic Ocean (Cheng, 1973a). In general they are found in tropical and subtropical waters, their ranges extending from lat. 40° N. to 40° S in the Atlantic (Cheng, 1973b) and the Pacific (Cheng, 1973a, 1973c) but being more restricted in the Indian Ocean (Cheng, 1971). Although the exact factors limiting the distribution of each species are not known, they are certainly related to surface properties of the ocean such as temperature, salinity, surface currents, and winds (Savilov, 1967).

GENERAL BIOLOGY

Our present knowledge of the biology of these oceanic insects is based mainly on casual observations at sea, since attempts to rear them in the laboratory have not been successful so far.

The adults are dark gray or black, with some pale markings on the head and prothorax, almost 5 mm in body length, with a leg spread of about 15 mm (Figure 2). The eggs are laid on any suitable or available floating object, the commonest substrates being pieces of wood, seabird feathers, and tar lumps. They are about 1 mm in length and look rather like miniature rice grains. The newly hatched nymphs, which are also about 1 mm in body length, are light brown in color with characteristic dark brown patterning. There are five nymphal stages before the insects become sexually mature. We do not know how long each stage takes, but laboratory data from rearing closely related freshwater gerrids (Cheng, 1966a) and a nearshore species, *H. hawaiiensis*, (Herring, 1961) suggest that 10-12 days is a reasonable period for each stage. Hence it would require a period of about 2 months for the eggs to develop into mature adults. The sexes are not distinguishable until the last nymphal stage.

These insects live exclusively on the surface of the ocean, as they are wingless and cannot fly. Although some earlier workers have reported that *Halobates* can dive, I have not been able to induce them to do so. However, when they are forced under water they can swim for as long as an hour or two. This ability to swim under water is presumably important for the survival of these insects, since in storms they are probably often submerged by waves or spray. Ultimately they must re-surface, before they become waterlogged and drown. For this reason they possess a very effective water-repellent coating of hairs on their body surface, the so-called "plastron" which also helps them to retain a supply of oxygen to enable them to respire when submerged (Cheng, 1973d).

The adults are attracted to light and may be dip-netted easily by using a light lure. When a light trap was used on a raft at the Hawaii Institute of Marine Biology, Coconut Island, in January 1973, the first specimens, all adult males, came to the light after about 10 minutes. The first nymph was caught at the light some 4½ hours after the trap was set up. Adult *Halobates* continued to come to light throughout the night, between 1930 and 0645 hours, at which time it just began to get light.

During a recent expedition to the north central Pacific (South Tow 13) on the R/V *Thomas Washington*, one of the Scripps Institution of Oceanography research fleet, we likewise found that *Halobates* adults arrived within 10 minutes after the ship had arrived on station and the light had

Lanna Cheng is a member of the Marine Life Research Group, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92037.

Halobates were observed to feed on one another when numbers were kept without food in an aquarium on board the R/V *Thomas Washington*.

The only definitive published record of predators of *Halobates* is one by Ashmole and Ashmole (1967), who carried out a very detailed study on the feeding ecology of seabirds of Christmas Island (a small tropical island in the central Pacific), and recorded these insects in the stomach contents of two (out of eight examined) species of surface-feeding seabirds, the blue-grey noddy, *Procelsterna cerulea*, and the Phoenix petrel, *Pterodroma alba*. Although fish and squid formed the main bulk of their food, *Halobates* was found to be quite an important component of their diet. In a total of 95 samples of regurgitated food from *Pt. alba*, *Halobates* was found in 11 samples, though it constituted less than 0.5 percent of the total volume of food. Among 34 *P. cerulea* samples studied, 23 contained remains of *Halobates*, which in this case constituted as much as 7 percent by volume.

I recently obtained from the Smithsonian Institution 20 samples of stomachs belonging to three species of surface-feeding seabirds, the white tern *Gygis alba*, *Procelsterna cerulea*, and *Pterodroma alba*, all collected during the Smithsonian Pacific Ocean Biological Survey Program in 1966 (Table 1). The samples came from a rather wide area of the Pacific Ocean, extending roughly between lat. 25°N to 20°S and long. 150°W to 180°W, well within the distribution range of at least three oceanic species of *Halobates* (Figure 3). Most of the stomachs were found to be almost empty or contained only a few unidentified fragments of partially digested food. However, *Halobates* was found in five samples of *P. cerulea*, corroborating the earlier report by Ashmole and Ashmole (1967). Four of the stomach samples came from birds collected in an area several hundred miles northwest of the Hawaiian Islands, and the remaining one came from Enderbury Island, together with one sample of *Gygis alba* which contained no recognizable *Halobates* remains. Two of these stomachs contained only well digested *Halobates* remains, but the heavily cuticularized legs are easily recognizable by their black color. In two other samples, the insects' bodies, too, were still recognizable, while in the fifth sample some of the *Halobates* specimens were still intact. (Since the sample size was so small no attempt was made to estimate the proportional volume of insects in the food of these seabirds.)

Dissections of adult *Halobates*, collected alive, have shown that their body cavity is often filled with orange-colored lipids, suggesting that they may be a rich source of food for surface-feeding fishes. However, the stomachs of several fishes (*Centrobrachus brevirostris*, *C. choerocephalus*, and *Cymbolophorus* sp.), caught in neuston nets together with *Halobates* in the North Pacific Gyre (lat. 28°N, long. 155°W), contained no insect remains. *Halobates* remains have been found in a young Pacific anchovy (Dr. A. S. Loukashkin, California Academy of Sciences, San Francisco; personal communication) and also in the stomach of a *Sardinella siim* collected in Jakarta Bay (Dr. M. Hutomo, Institute of Marine Research, Jakarta; personal communication). In both cases they were initially considered to be aerial contaminants. I hope that in the future more of our colleagues will report any insects which they may find in fish stomachs, so that we may learn more about *Halobates'* predators.

PREY

Halobates have been reported to associate with pelagic coelenterates such as the Portugese man-of-war, *Physalia;* the by-the-wind-sailor, *Velella;* and the jellyfish, *Porpita*, presumably feeding on these common surface marine animals. It seems unlikely that they could live by feeding exclusively on these animals, which consist of about 90 percent seawater. On a recent expedition to the North Pacific, various organisms collected in the neuston tows or dip-netted from the surface water were offered to the *Halobates* kept in an aquarium on board the ship. These insects were never seen to feed on *Physalia*, *Velella*, or *Porpita*. They were, however, observed to feed on pontellid copepods, hyperiid amphipods, euphausiids, and myctophid larvae trapped on the surface film. How often such animals become caught in this way is not known, but I found many small animals could be caught by simply pouring the contents of a plankton haul from one beaker to another, and presumably surf and spray could have the same effect in nature. It is also very likely that *Halobates* could feed on floating fish eggs, which, during some seasons, are found in great abundance in tropical and subtropical waters. Unfortunately, suitable fish eggs were not available for feeding experiments during the recent expedition. The insects

Table 1.—Collecting data on seabird stomach samples.

Species Field Number	Date	Locality	*Halobates*
Gygis alba			
5872	18 Feb 66	11°03'S 171°06'W Swain I.	—
5873	18 Feb 66	11°03'S 171°06'W Swain I.	—
5874	18 Feb 66	11°03'S 171°06'W Swain I.	—
5876	18 Feb 66	11°03'S 171°06'W Swain I.	—
0528	26 Apr 66	20°N 158°W Hawaiian Is.	—
6580	26 Jul 66	04°40'S 174°31'W Gardner I.	—
2387	6 Aug 66	02°29'S 162°30'W	—
6638	7 Aug 66	00°15'S 159°55'W Jarvis I.	—
6693	10 Sep 66	16°45'N 169°32'W Johnston I.	—
6726	16 Sep 66	03°08'S 171°05'W Enderbury I.	—
Procelsterna cerulea			
1794	26 Feb 66	02°39'S 175°21'W	—
2234	8 Jun 66	23°20'N 164°40'W	+
2236	8 Jun 66	23°21'N 164°43'W	+
2237	8 Jun 66	23°24'N 164°52'W	+
2238	8 Jun 66	23°28'N 164°59'W	+
6686	17 Aug 66	00°48'N 176°38'W Howland I.	—
6731	26 Sep 66	03°08'S 171°05'W Enderbury I.	+
6765	11 Oct 66	03°35'S 171°32'W Birnie I.	—
6766	11 Oct 66	03°35'S 171°32'W Birnie I.	—
Pterodroma alba			
2414	20 Aug 66	04°59'N 173°22'W	—

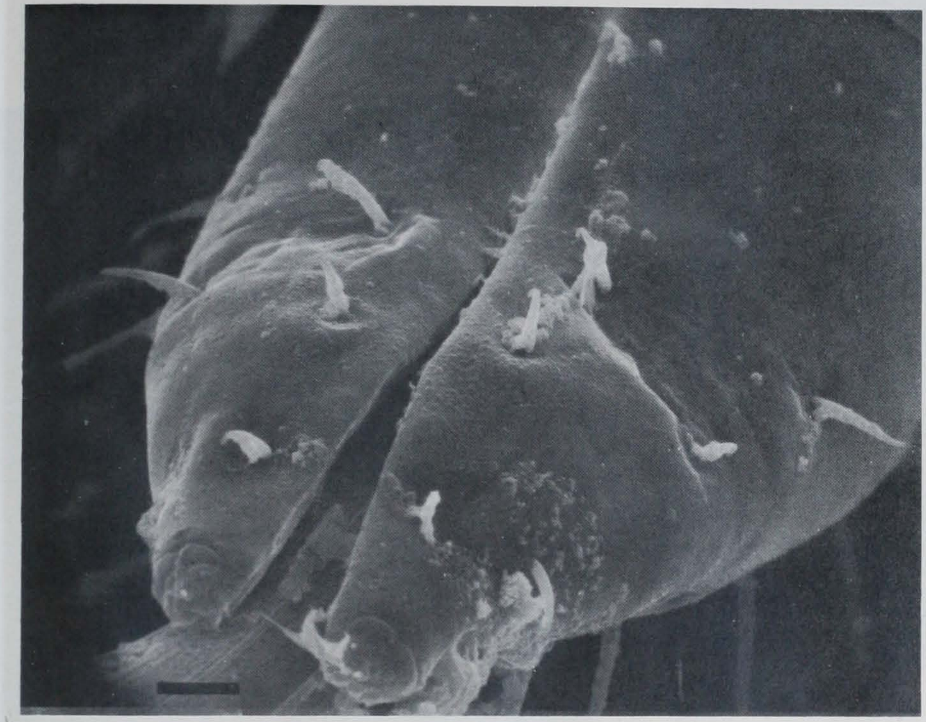


Figure 4.—Tip of rostrum (Scanning Electron Micrograph) (Scale = 10μ).

have not been observed to dive underwater to catch prey, even when potential prey was swimming directly underneath them.

The mouthparts of *Halobates* are of the classical hemipteran type. The rostrum or beak consists of a four-segmented sheath, enclosing a pair of serrated mandibles and a pair of long maxillae or stylets. It is usually held in a horizontal position, tucked under the head, but when the animal is feeding it is swung forward and held perpendicular to the longitudinal axis of the body. Its tip is equipped with sensory papillae and hairs (Figures 4 and 5) which are presumably responsible for locating suitable spots for penetrating the body of the prey. The mandibles, which are only slightly longer than the rostrum, flank the paired maxillae, and serve to pierce the body wall of the prey. The inner maxillary surfaces are lined with hairs which hold the edges of the two stylets together to form the feeding tube (Figures 6 and 7). The food is liquified by salivary enzymes injected into the prey via the salivary canal and then sucked up via the food canal, much in the same way as in other gerrids (Cheng, 1966b).

When *Halobates* is feeding it holds its prey with its front legs. If the prey is relatively small it is held well above the water surface, the insect assuming a rigid "standing" position during the entire feeding period (see cover), which may last from 5 to 20 minutes. If the prey is relatively large, such as a fish larva 1-2 cm long, the insect merely grasps it; in such cases, more than one insect may feed simultaneously on the same victim. The "standing" feeding position is presumably an adaptation for avoiding competition, since these insects may detect food by the surface ripples created by a struggling organism in the same way as their freshwater relatives (Murphy, 1971), and lifting it off the sea surface eliminates such ripples. This standing position, with the antennae held in an upright position and the body supported on the tips of the mid- and hind tarsi, is very different from the usual "resting" position of these insects, in which

Figure 5.—Tip of rostrum, showing sensory hairs and papillae (SEM) (Scale = 2μ).

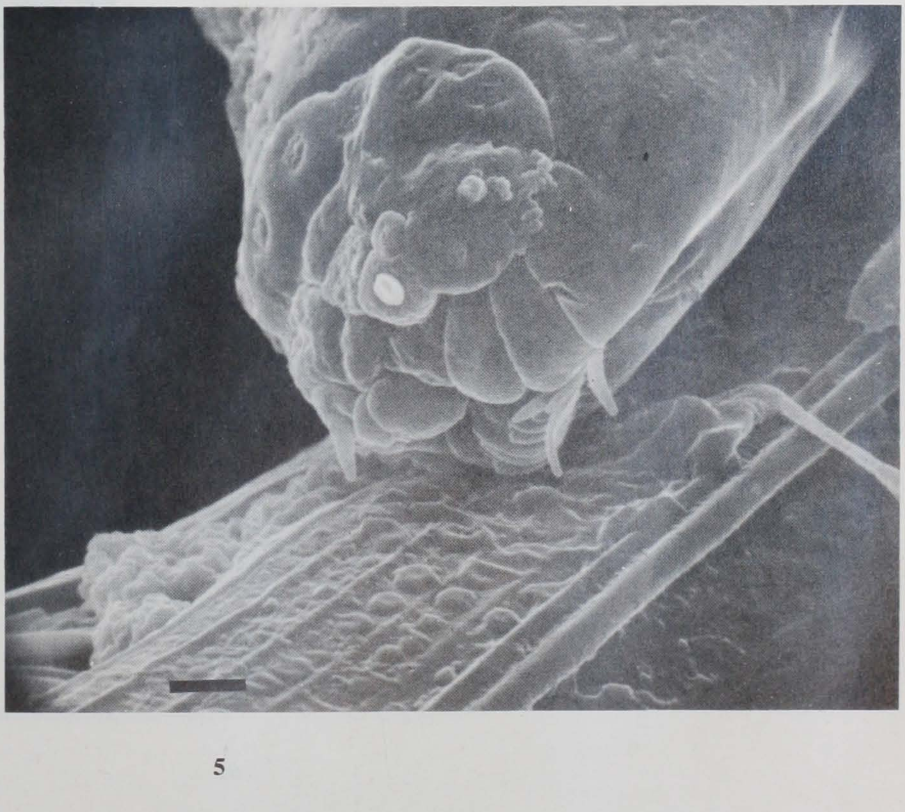


Figure 6.—Third and fourth segment of rostrum ensheathing maxillary stylets (SEM) (Scale = 50μ).

Figure 7.—Hairs on inner surface of maxillary stylet (SEM) (Scale = 5μ).

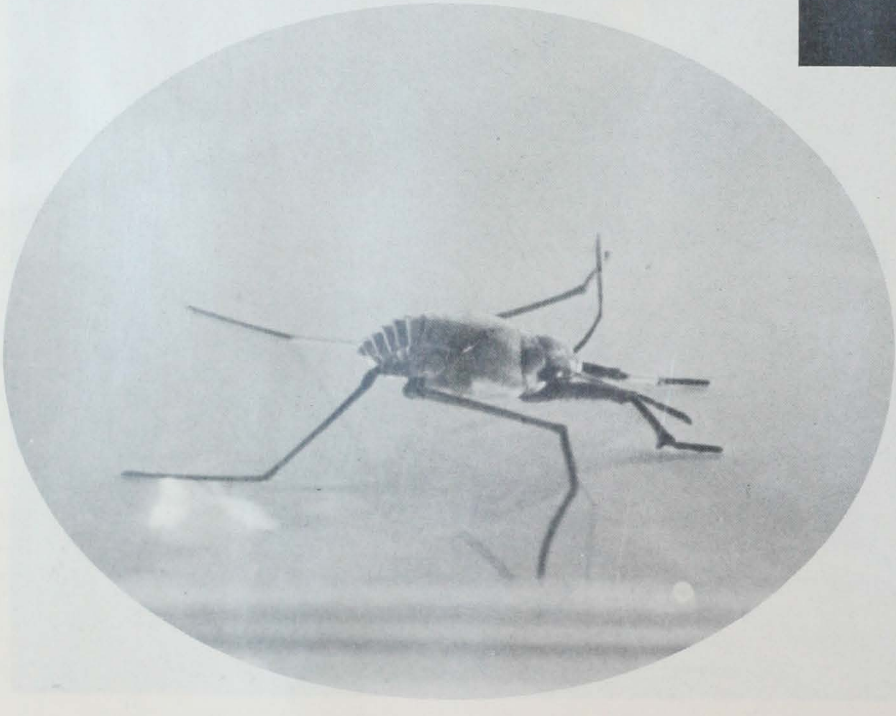
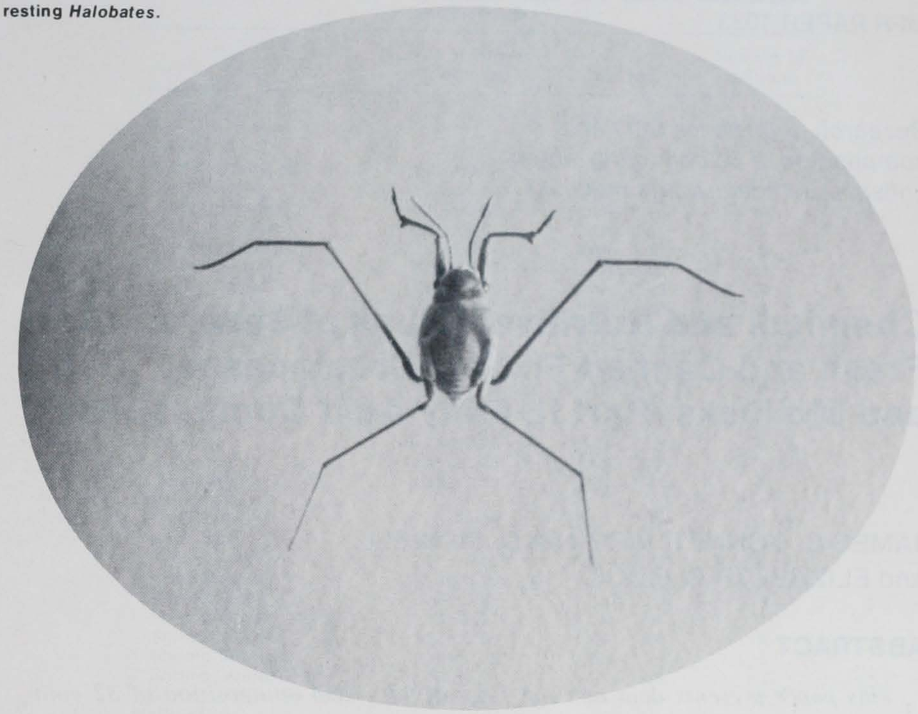


Figure 8.—*Halobates* in resting position.

Figure 9.—Top view of resting *Halobates*.



the antennae are held in front of the head and the legs are well spread out (Figures 8 and 9).

CONCLUSION

Organisms of the ocean surface have received very little attention in marine biological studies. Even the taxonomy of such common animals as *Physalia* and *Velella* has yet to be resolved (Savilov, 1968). Our knowledge of the biology of animals occupying this special stratum of the ocean and of their roles in the food web is still only fragmentary. Eggs and larvae of several species of fish are found exclusively in this layer. This is also where air-borne pollutants and other contaminants first come into contact with the ocean. Since the surface of the ocean is thus potentially of considerable economic and ecological importance, it is essential for us to study and understand better the animals living in this stratum, including, as one of the top predators of this ecosystem, that enigmatic insect, *Halobates*.

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Research determines fatty acid composition of 32 commonly eaten finfish, crustaceans, and mollusks.

Chemical and Nutritive Values of Several Fresh and Canned Finfish, Crustaceans, and Mollusks. Part II. Fatty Acid Composition

JAMES C. BONNET, VIRGINIA D. SIDWELL,
and ELIZABETH G. ZOOK

ABSTRACT

This paper presents data on total fat and fatty acid composition of 32 commonly eaten finfish, crustaceans, and mollusks. Among these are two canned finfish, salmon, tuna in oil and tuna in brine; the other samples were raw.

INTRODUCTION

Although there have been a number of studies carried out on the fatty acids in fish, very little has been done on the edible flesh of common market fish in the United States. Ackman (1967) has reported on some species of both freshwater and marine fish of North America; Krzeczkowski, Tenney, and Hayes (1972) have reported on some of the mollusks; and Stansby and Hall (1967) have also done some work in the area of commercially important fish in the United States. Much of the other fatty acid data available at present covers fish components which are not edible portions—liver, roe, milt, etc.

The object of this study was to provide total fat and the fatty acid composition of commonly marketed finfish, both fresh and canned, crustaceans, and mollusks. Since this report is an interim report for fatty acids, the values for some of the fatty acids may change somewhat as more data are added to the compilation.

James C. Bonnet, Virginia D. Sidwell, and Elizabeth G. Zook are members of the staff of the College Park Fishery Products Technology Laboratory, National Marine Fisheries Service, NOAA, College Park, MD 20740.

ANALYTICAL PROCEDURE

Samples

The sampling technique is described by Zook et al.[1]

Total Fat

The total fat was determined on edible muscle by the method developed by Smith, Ambrose, and Knobl (1964).

Preparation of Esters

Methyl esters were prepared using the method of Gauglitz and Lehman (1963). Amounts of reactants were scaled down for use with smaller sample size, about 0.5 gram. The esters were separated and identified using Gelman's[2] ITLC silica gel chromatography media and ultraviolet light, then extracted from the media with petroleum ether. The petroleum ether was removed by vacuum distillation and the esters were analyzed by GLC.

Table 1.—Common and scientific names of the fish and shellfish used in this study.

Common name	Scientific name
Finfish	
Catfish	*Ictalurus punctatus*
Cod	*Gadus morhua*
Flounder, yellowtail	*Limanda ferriginea*
Haddock	*Melanogrammus aeglefinus*
Hake	*Merluccius productus*
Halibut	*Hippoglossus stenolepis*
Perch	*Sebastes marinus*
Pollock	*Pollachius virens*
Rockfish	*Sebastes spp.*
Snapper	*Lutjanus campechanus*
Whiting	*Merluccius bilinearis*
Canned	
Salmon	*Oncorhynchus nerka*
Tuna	*Thunnus albacares*
Crustaceans	
Blue crab	*Callinectes sapidus*
King crab	*Paralithodes camschatica*
Lobster, spiny	*Panulirus argus*
Shrimp, brown	*Penaeus aztecus*
Shrimp, Maine	*Pandalus borealis*
Shrimp, Mexican	Mixed species
Shrimp, white	*Penaeus setiferus*
Mollusks	
Clam, hard	*Mercenaria mercenaria*
Clam, soft	*Mya arenaria*
Clam, surf	*Spisula solidissima*
Oyster	*Crassostrea virginica*
Scallop, bay	*Pecten sp.*
Scallop, calico	*Argopecten gibbus*
Scallop, sea	*Placopecten magellanicus*

Chromatographic Conditions

The Hewlett-Packard 810 GC used was equipped with dual flame ionization detectors and an 8 ft × ¼ in pyrex column packed with 5 percent diethylene-glycol succinate on $^{80}/_{100}$ mesh Chromosorb W (HP).

The helium carrier gas flow rate was 60 ml/min; hydrogen flow rate, 45 ml/min; air flow rate, 300 ml/min; column temperature programmed from 140°C to 210°C at 1° per minute; detector temperature, 235°C; and injection temperature 285°C.

RESULTS AND DISCUSSIONS

Table 1 lists the common and scientific names of the finfish, fresh and canned, mollusks and crustaceans.

All 13 species of the fresh finfish

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[1] Zook, E., J. Powell, B. Hackley, J. Emerson, J. Brooker, and G. M. Knobl, Jr. Survey for selected heavy metal content of consumer available fish. In preparation.

[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.