

DESCRIPTION OF STAGE II ZOEAE OF
SNOW CRAB, *CHIONOECETES BAIRDI*,
(OXYRHYNCHA, MAJIDAE) FROM PLANKTON
OF LOWER COOK INLET, ALASKA

Chionoecetes bairdi Rathbun 1924 (subfamily Oregoniinae) is the only species of snow crab (genus *Chionoecetes*) that occurs in Cook Inlet, Alaska, and contributes about 20% of the total value of the commercial fisheries harvest of the area (Trasky et al. 1977). The larval stages of *C. bairdi* consist of one prezoaeal, two zoeal, and one megalopal stage. The zoeae are readily distinguished from known zoeae of other genera of the subfamily Oregoniinae (*Hyas* and *Oregonia*) by size (the zoeae of *C. bairdi* are nearly twice as large as zoeae of *Hyas* and *Oregonia*) and by slight differences in morphology, especially setation of the antennule and length of the posterior lateral spines (Haynes 1973). The prezoaeae, Stage I zoeae, and megalopa of *C. bairdi* have been described from known parentage (Haynes 1973; Jewett and Haight 1977). In this report, I describe the Stage II zoeae from plankton and compare them with other known Oregoniinae zoeae from the North Pacific Ocean.

Methods

Stage II zoeae of *C. bairdi* were collected in lower Cook Inlet in 1976 during a joint survey by

the National Marine Fisheries Service and the Alaska Department of Fish and Game. The *C. bairdi* zoeae were collected near the southwestern tip of the Kenai Peninsula (Figure 1) in water 37-141 m deep. Collections were made with two 61 cm bongo nets fished side by side from near bottom to surface. The nets had 0.333 mm mesh, and cod end jars 0.571 mm mesh. The zoeae were captured by lowering the nets to about 1 m from the bottom and then retrieving them vertically at a velocity of slightly <1 m/s. After retrieval, zoeae were washed from the nets and preserved in a 5% solution of formaldehyde and seawater.

Drawings of the Stage II zoeae (Figure 2) were made from preserved specimens. The terminology, methods of measurement, techniques of illustration, and nomenclature of appendages are Haynes' (1973). Total body length includes telsonic furcations. Setation formulae refer to setae numbered from the distal to the proximal portion of the appendage. Comparison of morphological features was aided by first clearing the zoeae in 10% KOH. For clarity, setules on setae are usually omitted but spinulose setae are shown. Any variation in setal counts is noted in text.

Description of Stage II Zoeae

General shape characteristic of Stage II zoeae of *Chionoecetes* is shown in Figure 2A, B. Dorsal and rostral spines long, tapering, essentially

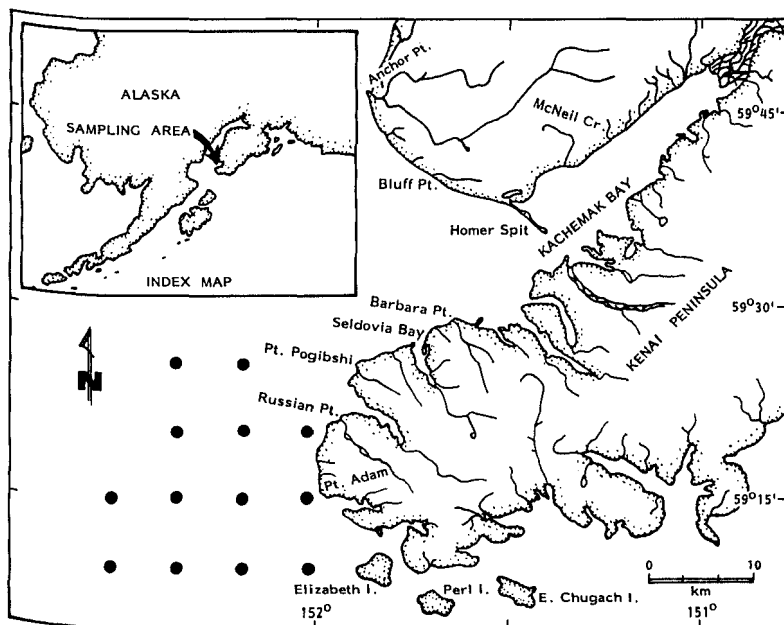
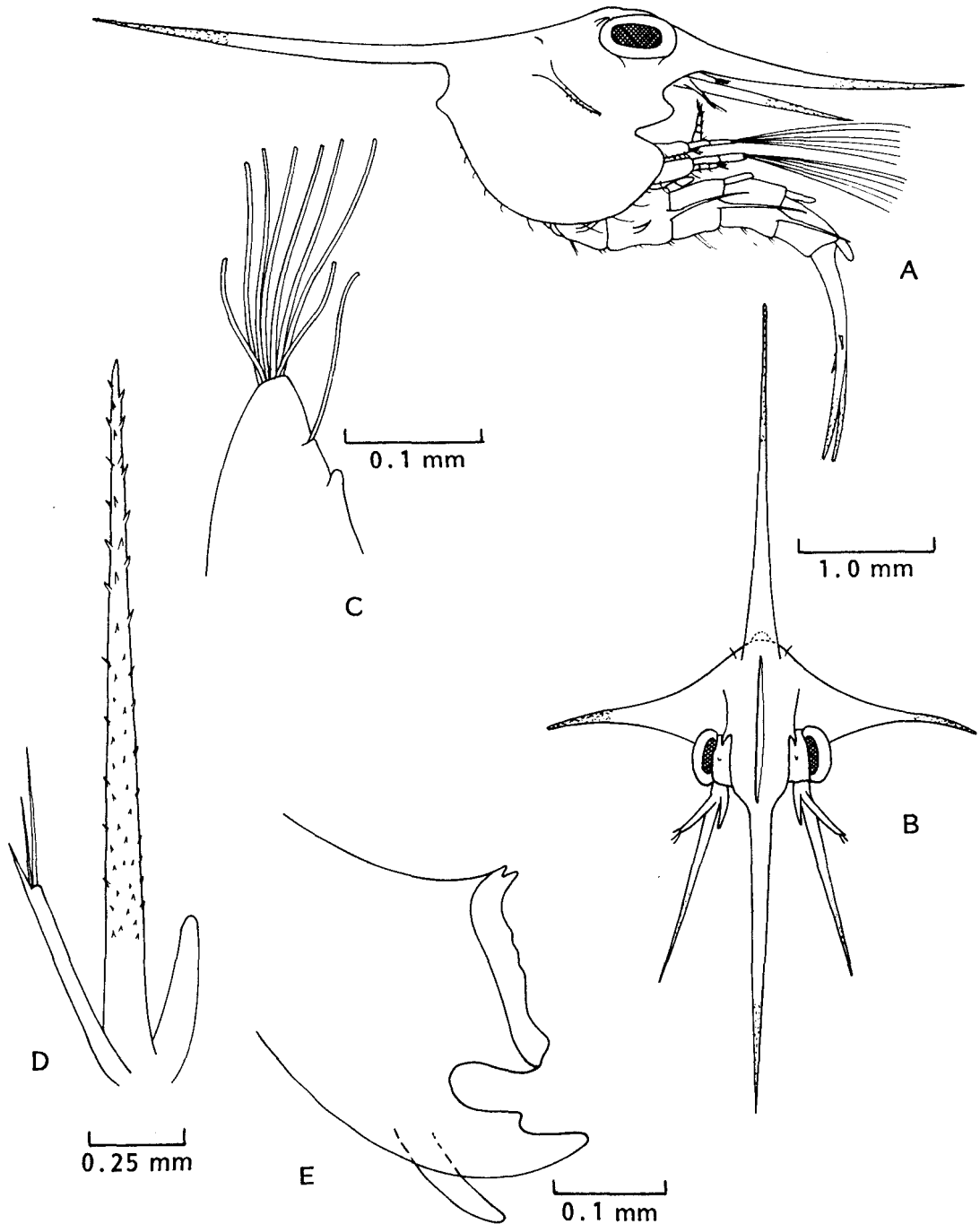


FIGURE 1.—Sampling locations in Cook Inlet, Alaska, where Stage II zoeae of *Chionoecetes bairdi* were captured in 1976.

straight; dorsal spine slightly longer than rostral; lateral spines long, at right angles to carapace, curving downward slightly. Distinct protuberance on carapace posterior to dorsal spine; minute hair on each side of carapace between lateral spine and base of dorsal spine; supraorbital spines

present, 11 or 12 setae along posterior edge; lateral margin of carapace strongly indented just posterior to eye. Eyestalks short, articulated, each bears minute protuberance about midway between eye and carapace.

Average measurements: carapace length 1.04



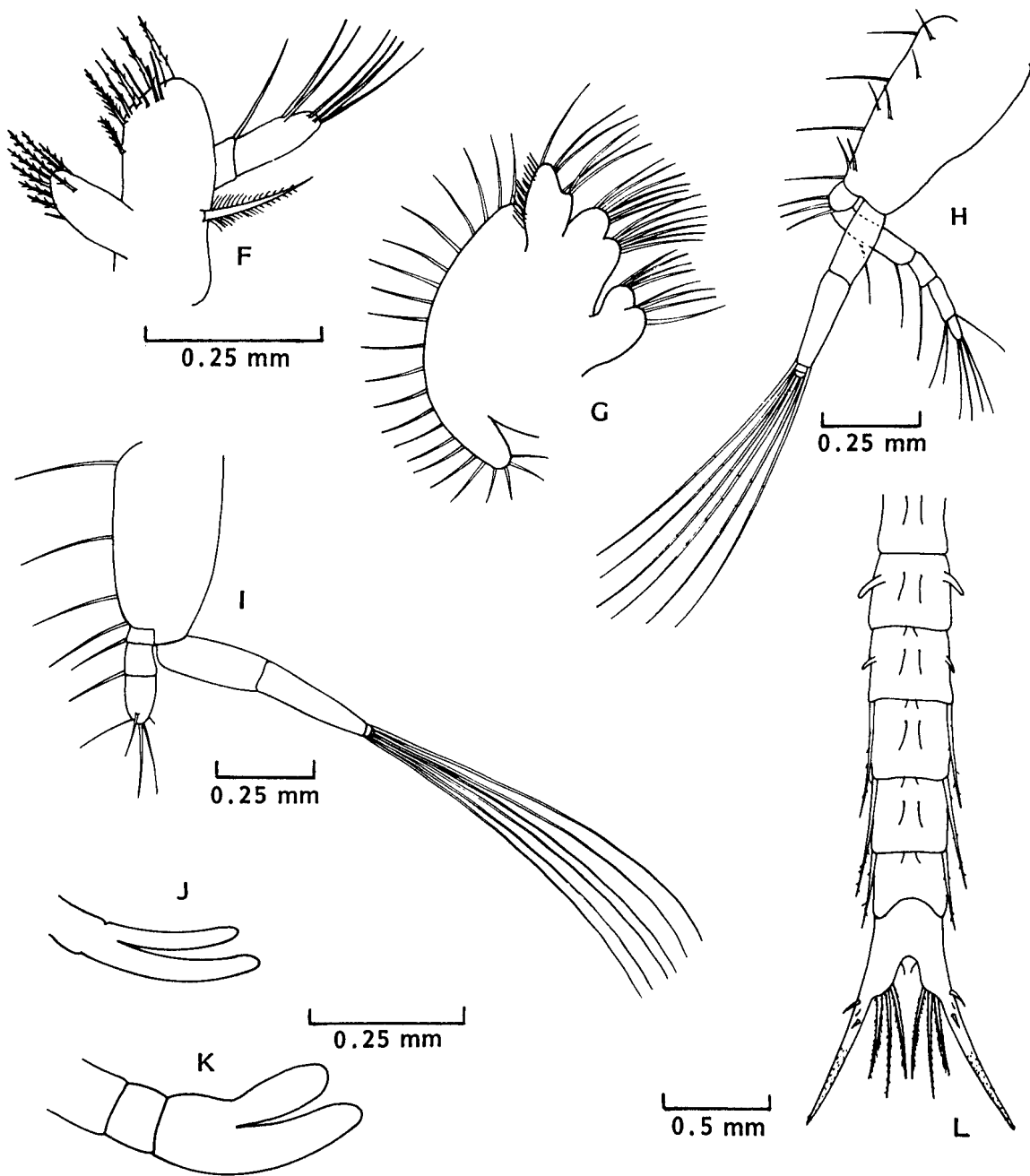


FIGURE 2. — Stage II zoea of *Chionoecetes bairdi*: (A) whole animal, right side; (B) whole animal, frontal; (C) antennule, dorsal; (D) antenna, dorsal; (E) left mandible, posterior; (F) maxillule, ventral; (G) maxilla, dorsal; (H) first maxilliped, lateral; (I) second maxilliped, lateral; (J) third maxilliped, lateral; (K) first pereopod, lateral; (L) abdomen, dorsal.

mm (range 0.98-1.12 mm, 10 specimens); dorsal-rostral length 6.15 mm (range 5.95-6.37 mm, 5 specimens); width between tips of lateral spines of carapace 2.89 mm (range 2.66-3.22 mm, 3

specimens); total body length 5.20 mm (range 4.55-5.95 mm, 9 specimens); rostral spine length 2.24 mm (all 4 specimens); dorsal spine length 2.45 mm (all 4 specimens).

ANTENNULE (Figure 2C). — First antenna, or antennule, conical and uniramous; bears eight terminal aesthetascs (six long and two of intermediate length); small budlike projection and single aesthetasc subterminally.

ANTENNA (Figure 2D). — Protopodite (spinous process) of antenna elongate, about two-thirds length of rostral spine, armed with numerous sharp spinules that increase in size distally; exopodite slender, less than one-half length of protopodite, two setae near sharp tip, each seta with two rows of many fine setules; endopodite naked, about two-thirds length of exopodite.

MANDIBLES (Figure 2E). — Right and left mandibles nearly identical; palps unjointed and naked; incisor composed of two large, rounded processes.

MAXILLULE (Figure 2F). — First maxilla, or maxillule, bears coxal and basial endites and an endopodite. Proximal lobe (coxopodite) bears nine spinulose spines, eight terminally and one subterminally. Median lobe (basipodite) bears nine spines distally: two setose spines, three simple spines, four spinous spines (especially stout) plus a large setose seta proximally. Endopodite two-segmented, originates from lateral margin of basipodite, bears seven setae (six on distal segment, one on distal margin of proximal segment).

MAXILLA (Figure 2G). — Bears platelike exopodite (scaphognathite) with 21-23 plumose setae along outer margin; no long, thick seta at proximal end. Endopodite unsegmented, bears six setae distally and fine hairs along outer margin. Basipodite bilobed; each lobe bears six setae. Bilobed coxopodite bears eight setae, four on each lobe.

FIRST MAXILLIPED (Figure 2H). — Exopodite completely segmented; bears six heavily plumose (natatory) setae on distal end. Endopodite five-segmented; setation formula 4, 3, 1, 2, 3. Basipodite bears 10 setae along posterior edge, all setae except natatory setae sparsely plumose.

SECOND MAXILLIPED (Figure 2I). — Exopodite completely segmented, bears six long, heavily plumose (natatory) setae terminally. Endopodite three-segmented, setation formula 5, 1, 1. Basipodite bears four setae along posterior margin, all except natatory setae, sparsely plumose.

THIRD MAXILLIPED (Figure 2J). — Not fully developed, unsegmented, bilobed.

FIRST PEREOPOD (Figure 2K). — Chela segmented from carpopodite, bilobed but not functional.

SECOND TO FIFTH PEREOPODS. — Small, uniramous, not segmented or bilobed.

ABDOMEN AND TELSON (Figure 2A, L). — Abdomen consists of six somites and telson. Somites 1-5 bear pair of simple setae middorsally; somites 2-5 also bear pair of simple setae near dorsal posterior margin. Second and third somites both bear pair of curved lateral processes; length of pair on second somite about half the height (Figure 2A) of second somite; pair on third somite about half the length of pair on second somite. Pair of long well-developed spines on posterior lateral margins of third, fourth, and fifth somites; those on third and fourth somites extend beyond posterior margin of adjacent somites to about midpoint of fifth and sixth somites, respectively. Spines on fifth somite extend to level of anus; lateral spines usually bear a few minute spinules. Undeveloped pleopods (Figure 2A) present on abdominal somites 2-5; length of pleopods about three-fourths height of abdominal somites. Telson bifurcate; furcations long, slender, finely spinulate, tips upcurved. Each furcation bears three articulated telsonic setae and one simple seta on mesial margin, a prominent spine laterally on outer margin, a smaller dorsal spine posterior to telsonic setae, and minute spinule about midway between the lateral and dorsal spines; lateral and dorsal spines on furcations minutely spinulate. Each telsonic seta, except pair of simple setae, bears two rows of spinules. Uropods (Figure 2A) on somite 6 undeveloped, length about four-tenths height of sixth somite.

Comparison of North Pacific Zoeae of the Subfamily Oregoniinae

The subfamily Oregoniinae comprises three genera, *Chionoecetes*, *Hyas*, and *Oregonia* (Garth 1958). Zoeae of the subfamily have been described, at least in part, for *C. opilio*, *C. japonicus*, *H. coarctatus alutaceus*, *H. lyratus*, and *Oregonia gracilis* (Hart 1960; Kurata 1963; Yamauro 1968; Haynes 1973; Motoh 1973). Based on these descriptions, Stage I and II zoeae of the Oregoniinae are readily separable from each other (Table 1). Stage I zoeae are characterized by sessile eyes, four natatory setae on the first and second maxillipeds, absence of pleopods, and three pair of setae on the inner margin of the telsonic furcations. Stage II zoeae bear stalked eyes, six natatory setae on the first and second maxillipeds, pleopods, and four pair of setae on the inner mar-

TABLE 1.—Morphological characteristics for distinguishing between Stage I and II zoeae of the subfamily Oregoniinae.

Characteristic	Stage	
	I	II
Supraorbital spines	absent	present
Eyes	sessile	stalked
Natatory setae:		
First maxilliped	4	6
Second maxilliped	4	6
Pleopods	absent	present
Pairs of setae on inner margin of telsonic furcations	3	4

gin of the telsonic furcations. In addition, the Stage II zoeae bear supraorbital spines which are lacking in the Stage I zoeae.

Hart (1960) reared and described the larvae of *H. lyratus* and *O. gracilis* from ovigerous females collected in British Columbia waters. Based on Hart's brief description, Stage II zoeae *H. lyratus* and *O. gracilis* are similar morphologically to Stage II zoeae of *C. bairdi*, but markedly smaller. Dorsal-rostral length of Stage II *H. lyratus* and *O. gracilis* averages 4.0 mm and 4.5 mm, respectively, compared with 6.5 mm for Stage II zoeae of *C. bairdi*.

Kurata (1963) described larvae collected off Hokkaido that he provisionally identified as *H. coarctatus alutaceus*. They can be distinguished from Stage II zoeae of *C. bairdi* by their smaller size (dorsal-rostral length averages 4.4 mm) and the lack of a distinct protuberance posterior to the dorsal spine.

Stephensen (1935) described zoeae from the collection of the Zoological Museum of Copenhagen previously identified by C.N. Rudolph and subsequently believed by Stephensen to be zoeae of *C. opilio*. Because of the numerous (14) natatory setae on the exopodites of the maxillipeds, Stephensen's zoeae are obviously not zoeae of the genus *Chionoecetes* nor even of the Oxyrhyncha. Stephensen's zoeae undoubtedly belong to the Brachyrhyncha and likely the families Atelecycloidea or Cancridae.

Kurata (1963) described Stage I zoeae of *C. opilio elongatus* (= *C. opilio*¹) reared in the laboratory from known parentage and the remaining larval stages from plankton of the Hok-

¹Rathbun (1924) designated *C. opilio* in the Sea of Japan as *C. opilio elongatus* based on the length/width relation of the second merus. According to Tohshi Kon, Fukui Prefecture Fishery Experimental Station, Tsuruga-shi, Fukui-Prefecture, Japan (pers. commun. November 1978), Kamita's (1941) findings invalidate Rathbun's subspecific designation.

kaido area. Motoh (1973) described the zoeal and megalopal stages of *C. opilio* reared in the laboratory from an ovigerous female caught in the Sea of Japan. I confirmed Kurata's and Motoh's brief descriptions of Stage I and II zoeae by comparing their descriptions with specimens from the Sea of Japan sent to me by Tohshi Kon (see footnote 1). For both stages, zoeae of *C. bairdi* are morphologically identical with zoeae of *C. opilio* from Hokkaido and the Sea of Japan, except for length of the curved lateral processes on the third abdominal somite. In Stage I and II zoeae of *C. opilio* from Hokkaido and the Sea of Japan, the curved lateral processes reach the posterior margin of the third abdominal somite, but, in Stage I and II zoeae of *C. bairdi*, they are markedly shorter (Figure 2A, L).

Apparently larvae of *C. japonicus* are known; but, except for a brief comparison of their morphology with larvae of *C. opilio* by Yamauro (1968), I am unaware of their description in the literature. Based on Yamauro's comparison, Stage I and II zoeae of *C. japonicus* are distinguished from Stage I and II zoeae of *C. bairdi* by length of the posterior lateral spines on the third, fourth, and fifth abdominal somites. In *C. japonicus* zoeae the posterior lateral spines barely reach the posterior margin of the somite, but in *C. bairdi* zoeae they extend beyond the margin.

The following key is provided for distinguishing Stage II zoeae of *C. bairdi* from Stage II zoeae of *C. opilio*, *C. japonicus*, and the genera *Hyas* and *Oregonia*. In the key, length of the lateral processes on the third abdominal somite of *C. opilio* zoeae is based on specimens from the western Pacific Ocean. Stage II zoeae of *C. opilio* from the eastern Pacific Ocean have not been identified, and it is not known whether they can be distinguished from Stage II zoeae of *C. bairdi* by length of their lateral processes.

Key for Distinguishing Stage II Zoeae *C. bairdi*

- 1a. Dorsal-rostral length 4.0-4.6 mm *Hyas, Oregonia*
- 1b. Dorsal-rostral length 6.0-6.9 mm 2
- 2a. Lateral processes on third abdominal somite reach posterior margin of somite *C. opilio*
- 2b. Lateral processes on third abdominal somite do not reach posterior margin of somite 3
- 3a. Posterior lateral spines on abdominal

- somites 3, 4, and 5 barely reach margin of somite *C. japonicus*
 3b. Posterior lateral spines on abdominal somites 3, 4, and 5 extend beyond margin of somite *C. bairdi*

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FEEDING RATE OF CAPTIVE ADULT FEMALE NORTHERN FUR SEALS, *CALLORHINUS URSINUS*¹

Overexploitation of fishery stocks in the North Pacific and Bering Sea is thought by some to be contributing to a small but perceptible decline in the northern fur seal population (Gentry et al.²). To manage both fishery and fur seal resources intelligently it is necessary to know how much a northern fur seal eats and to identify the factors that affect its food intake. Our data show that feeding rate of captive adult females is variable and influenced by season of the year and body mass of the individual.

Methods

Ten adult northern fur seals (two males and eight females) were captured on St. Paul Island, Pribilof Islands, Alaska, in mid-October 1977.³ The ages of the females were estimated at 5+ yr, based on the color of the vibrissae, which were completely white (Scheffer 1962). After a short observation period all seals were shipped by air freight to Mystic Marinelife Aquarium in Mystic, Conn. On arrival, the females were tagged with monel metal cattle ear tags⁴ identical to those used in the National Marine Fisheries Service's Pribilof Fur Seal Program. One tag was placed on each seal's left foreflipper above the fur line. Numbers assigned were XCu01 through XCu08. Once acclimated, all seals were kept together in a large outdoor exhibit. Husbandry requirements, including feeding rate, were studied for the next 2 yr. This report deals only with the females.

Feeding rate was recorded daily for 356 days of 1978 (5 January through 27 December). Data are summarized in Table 1. The year was divided arbitrarily into three periods, each starting the day after the animals were weighed. Weights were taken 4 January (Period 1 = 5 January through 7 March), 7 March (Period 2 = 8 March through 25 September), and 25 September (Period 3 =

¹Contribution No. 16, Sea Research Foundation, Inc.

²Gentry, R. L., J. H. Johnson, and J. Holt. 1977. Behavior and biology, Pribilof Islands. In *Marine Mammals Division, Fur seal investigations, 1976*, p. 26-39. *Northwest Fish. Cent. Processed Rep.*

³Permit No. 178, applied for under the *Fur Seal Act of 1966* and issued 2 May 1977 by the National Marine Fisheries Service.

⁴NASCO, 901 Janesville Avenue, Fort Atkinson, WI 53538. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Feeding rate and body mass data for eight adult female northern fur seals from the Pribilof Islands, Alaska, 1977-78.

Tag no.	Acclimation (9 Oct.-4 Jan.)			Period 1 (5 Jan.-7 Mar.)			Period 2 (8 Mar.-25 Sept.)			Period 3 (26 Sept.-27 Dec.)			Final mass 28 Dec.
	Mass ¹ (kg)	Feeding rate (% body mass/d)	Mass change (%/d)	Mass (kg)	Feeding rate (% body mass/d)	Mass change (%/d)	Mass (kg)	Feeding rate (% body mass/d)	Mass change (%/d)	Mass (kg)	Feeding rate (% body mass/d)	Mass change (%/d)	
XCu01	38.8	7.3	+0.17	44.6	9.4	-0.062	43.8	5.1	(²)	(²)	(²)	(²)	42.8
XCu02	30.4	8.4	+0.57	45.5	12.2	+0.31	50.0	4.5	-0.07	42.9	5.6	+0.07	45.5
XCu03	36.6	5.8	+0.08	39.3	11.6	+0.25	42.4	5.5	-0.026	40.2	6.1	+0.037	41.5
XCu04	39.7	6.6	+0.23	47.8	10.4	+0.15	50.0	4.3	-0.13	37.5	7.4	+0.36	49.6
XCu05	31.3	7.1	+0.18	36.2	12.5	0	36.2	6.3	+0.031	38.4	5.4	+0.01	38.8
XCu06	34.8	9.2	+0.059	36.6	13.1	+0.19	38.8	7.1	-0.092	37.1	7.0	-0.01	36.6
XCu07	36.2	7.1	+0.53	52.7	6.7	-0.18	49.6	4.1	-0.56	35.7	7.2	+0.52	52.2
XCu08	44.2	5.3	+0.15	50.0	7.9	-0.28	45.5	4.9	+0.31	52.7	4.7	+0.057	55.4

¹Initial mass recorded within 3 h of capture.

²Nursing a pup—no data collected.

26 September through 27 December). A final weight was recorded on 28 December, making a total of four weighing sessions in 1978. Air and water temperatures for the three periods are summarized in Table 2. Data collected during acclimation (9 October 1977 through 3 January 1978) were omitted from the calculations because the seals either were not feeding consistently, or were consuming abnormally large quantities of food. According to our experience, such behavior is not unusual.

Seals were fed individually. The food for each seal was weighed and the amount left over after a feeding was subtracted. All animals were fed to satiation and none ate to obesity. Feedings were at 0900, 1330, and 1530 h daily. Food fishes used primarily were Atlantic herring, *Clupea h. harengus*, and Atlantic mackerel, *Scomber scombrus*, purchased frozen and thawed shortly before feeding.

The animals were not fed on the morning they were weighed. Weighing sessions started at about 1000 h, after the pool was drained, and were finished shortly before noon. Seals were herded into individual cages and weighed on a hanging scale (± 0.4 kg). Little food was present in the intestines at that point. Miller⁵ showed that digestion in northern fur seals takes about 8 h.

Results

Multiple linear regression was performed using water temperature and animal mass as independent variables, and feeding rate as the dependent variable (Tables 1, 2), for all three periods combined. The equation obtained was

TABLE 2.—Mean monthly values for air and water temperatures during the feeding observations on captive northern fur seals.

Period	Month	Temperature (° C)		Period	Month	Temperature (° C)	
		Air	Water			Air	Water
1	Jan.	-1.9	9.6	2	Aug.	22.7	19.4
	Feb.	-2.4	8.3		Sept.	17.6	18.1
	Mar.	2.7	9.8		Mean	17.0	15.8
	Mean	-1.9	8.8		3	Oct.	12.3
2	Apr.	9.4	11.5	Nov.		7.7	13.1
	May	15.7	14.5	Dec.		3.2	11.1
	June	20.7	16.8	Mean		8.3	13.8
	July	22.5	19.1				

$$F = -0.782 T_w - 0.096 M + 25.77$$

where F is feeding rate (as percentage of body mass per day), T_w is water temperature (degrees Celsius), and M is body mass (kilograms). The coefficient of multiple correlation (r) was 0.927 and the standard error of estimate 1.05. An attempt to relate the same data with air temperature resulted in poorer correlation ($r = 0.879$, $s_{y.x} = 1.34$).

Feeding rate and initial body mass are strongly related, as is the feeding rate for all seals combined when considered seasonally. This is evident from data in Table 1 and the linear regressions of Figure 1. Large seals required a smaller percentage of body mass per day in all three periods. The steepest slope is in Period 1, in which differences between body and ambient temperature were greatest. Analysis of covariance demonstrated that Periods 1, 2, and 3 cannot be pooled for purposes of regression. Taken separately, regression produced correlation coefficients indicating high significance ($P \leq 0.01$ for Periods 1 and 2, and $P \leq 0.05$ for Period 3).

Discussion

Bigg et al. (1978) and Bigg⁶ showed that the fluctuation in body mass of adult females in

⁵Miller, L. K. 1978. Energetics of the northern fur seal in relation to climate and food resources of the Bering Sea. Rep. MMC-75/08, U.S. Mar. Mam. Comm., Wash., D.C., 27 p. Available Natl. Tech. Inf. Serv., Springfield, Va., as PB-275 296.

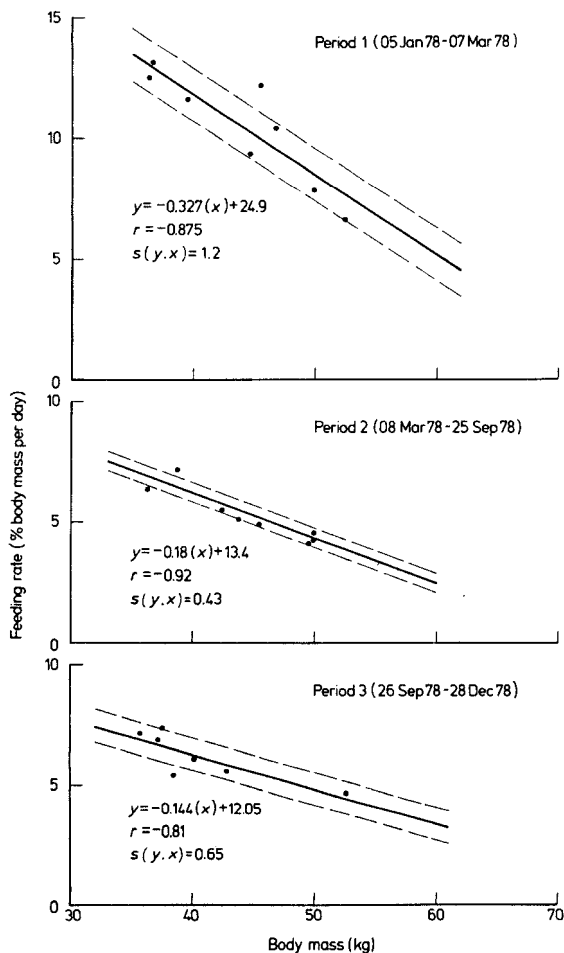


FIGURE 1.—Feeding rate versus individual body mass for eight adult female northern fur seals for Periods 1-3. Standard error of estimate ($s_{y,x}$) is indicated by the broken lines.

captivity follows a predictable pattern, implying a precise mechanism for weight control that is seasonally synchronized. Our findings are further confirmation of this. Food intake (and therefore body mass) was greatest from late autumn to late spring. Changes in mass reflected variations in blubber thickness, because all animals were fully mature.

Changes in water temperature probably account for the seasonal variation in food consumption shown by our seals, although individual differences in metabolism probably were important.

In Period 1, when water temperature averaged 8.8°C , the smaller seals required a greater percentage ration than the larger animals, as shown by the slope of the line in Figure 1 (-0.327). In Periods 2 and 3, when water temperatures were similar, the variation in feeding rate versus body mass was less, and the slopes of the lines also were similar, as shown in Figure 1 (-0.18 and -0.144 , respectively).

The above equation allows the feeding rate of captive adult females to be predicted with reasonable accuracy, given water temperature and body mass. The artifact introduced by captivity was to allow the seals to enter and leave the water at will. Future studies should be made using adult females that are confined to the water and not allowed to haul out for a length of time (and at a water temperature) that simulates the pelagic phase of the life cycle.

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