

Hand-Rearing of Twin Gray Seals (*Halichoerus grypus*) from Birth to Weaning*

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ABSTRACT: Captive-born twin gray seals *Halichoerus grypus* were hand-reared to weaning at 30 d postpartum. Two artificial formulas were used, starting on Days 1 and 11, respectively. Supplemental force-feeding with whole fish started on Day 9. The pups were trained to bottle-feed from the beginning, and regulated their own intake of formula. No suckling pattern was evident. Proximate analyses of the formulas and raw fish were performed, and the total daily energy requirements were calculated. Regression analysis of daily change in body weight on kilocaloric intake per metabolic body weight ($\text{kcal kg}^{-.75}$) yielded the equation

$$Y (\Delta \text{ body wt, kg}) = -0.464 + 0.00128X (\text{kcal kg}^{-.75})$$

in which $r^2 = 0.49$. Maintenance gross energy requirement ($Y = 0$) was 362 kcal kg^{-1} of metabolic weight, indicating a minimum need of $2775\text{--}3185 \text{ kcal d}^{-1}$. Total kilocalories consumed each day showed a bell-shaped pattern, being highest in the third week. Diarrhea was mild but chronic, which probably resulted in overestimation of the maintenance gross energy requirement. The rearing formulas were inadequate to promote normal growth, despite the addition of fish, and incremental weight gain was considerably less than in wild pups. Results indicate that environmental pressures may be more limiting than composition of the diet.

INTRODUCTION

Pinnipeds (true seals, fur seals, sea lions, and walruses) exist at the apex of oceanic food chains, yet their significance in marine ecosystems is poorly understood. Since the classic paper by Lindemann (1942) it has become accepted practice to view ecosystems in terms of energy flow. By monitoring the transfer of energy from one trophic level to another it is possible to assess the role of a population and estimate its impact. The principles of ecological energetics are useful adjuncts in wildlife biology. In their study of neonatal growth of northwest Atlantic harp seals (*Phoca groenlandicus*), Stewart and Lavigne (1980) wrote: 'For exploited populations in particular, productivity, or rate of biomass (energy) must be known in order to formulate appropriate management programs.' Any such analysis must ultimately consider the

physiological energetics of individual animals. As Stewart and Lavigne pointed out, growth of the neonate is a function of energy stored in the milk, which in turn represents a significant percentage of the annual production energy of adult females.

The captive rearing of marine organisms is an indispensable tool of marine ecologists. In the case of pinnipeds, efforts to date have not always led to reproducible techniques. However, quantitative descriptions of rearing methods are necessary preludes to more exacting studies, including those involving energetics. One serious obstacle has been the lack of a suitable substitute for seal milk, one that promotes normal growth. The availability of such a formulation would greatly augment research in pinniped energetics. The birth, and subsequent rejection by the mother, of twin gray seal (*Halichoerus grypus*) pups at Mystic Marinelife Aquarium (Mystic, Connecticut, USA) provided an opportunity to hand-rear the animals to weaning and record their progress. In doing so, we gained a rudimentary understanding of their energy requirements.

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METHODS

Parturition. The gray seals at Mystic Marinelife Aquarium came from the Canadian population. The pups described in this report were dizygotic twins born to a primiparous female that had conceived in the exhibit. Pregnancy had been confirmed in October 1980 using an ultrasound scanner*. Only one fetus was seen at that time, and the birth of the second pup was unexpected. The female was moved indoors on the evening of 28 December 1980 and placed in a small enclosure that includes a pool. The pool was drained at 1630 h the next day and the animal was left lying on the bottom. At 1730 h dilation of the vagina was observed. Ordinarily, gray seal pups are delivered rapidly (Burton et al., 1975). When parturition still had not occurred by 2033 h, 60 I.U. (3 cm^3) of oxytocin** were administered intramuscularly to induce labor. The dosage had no apparent effect, and a second injection of 80 I.U. (4 cm^3) was administered 10 min later. The first pup (female) was born at 2139 h and parturition took 35 min. The second pup (male) was born at 0610 h the next day (30 December), 10 min after labor began. Weights and standard lengths (nose to tail) were taken at 0945 h. The female was 94 cm and 14.7 kg; the male 87.6 cm and 13.6 kg. The weights of both pups were within the normal range for newborn gray seals from the Canadian population (Mansfield, 1977); no values for standard length are available. Some weight loss may have occurred, because neither animal had suckled.

Initial feeding. By noon on 30 December (Day 1) it was evident that the female had rejected both pups. At 1220 h they subsequently were force-fed 60 ml of artificial milk (Formula A, Table 1) through a stomach tube. The intubation apparatus consisted of 60 cm of clear polyethylene tubing (0.79 cm outside diameter, 0.16 cm wall thickness)*** and a 60-ml syringe. The end of the tubing was flamed to round off any rough edges that might have damaged the esophageal mucosa. The tubing was inserted in the esophagus to a depth equal to the distance from the tip of the nose to the position of the foreflippers, or ~38 cm. Intubation was repeated at 1335 h (150 ml) and 1952 h (90 ml). Bottle-training commenced at 1753 h on Day 1, using standard bottles and nipples manufactured for human babies and filled with Formula A. The nipples were inserted in holes in four different mate-

rials in succession to determine which provided the best tactile stimulus to induce suckling.

Formula preparation. Formulas A and B were prepared by the same method. All ingredients except whipping cream were mixed to a uniform homogenate in a commercial blender, then strained through a fine-mesh net to remove pieces of bones and scales that clogged the nipples. Whipping cream was stirred in by hand and the mixture was diluted to volume (3 l) with tap water. Each batch was transferred to a plastic pail, which was floated in a larger pail of hot water to keep the temperature at ~30 °C. Material not used after 4 h was discarded.

Table 1. Ingredients in Formulas A and B

Ingredients	Formula	Vol or wt
¹ Amino acid mix	A, B	250 ml
² Corn syrup	A, B	500 ml
Headless Atlantic herring	A, B	1.3 kg
³ Thiamine hydrochloride	A, B	200 mg
⁴ Tocopherol	A, B	200 mg
⁵ Heavy whipping cream	A, B	1.5 l
⁶ Casein (vitamin-free)	B	150 g
⁷ Safflower oil	B	350 ml
⁸ Lecithin	B	10 g
⁹ Tap water	A, B	~1.0 l

¹ AA 1000, Beecham Laboratories, Bristol, TN 37620, USA. Content per 100 ml: 1 g crystalline amino acids, 5 g dextrose, 180 mg B vitamins, 800 mg electrolytes

² Karo Light Corn Syrup, CPC International, Inc., Englewood Cliffs, NJ 07632, USA

³ Vitamin B₁, Chelsea Laboratories, Inc., Inwood, NY 11696, USA

⁴ Vitamin E, Solgar Co., Inc., Lynbrook, NY 11563, USA

⁵ 36% fat

⁶ Vitamin Free Test Casein, Teklad Test Diets, Madison, WI 53713, USA

⁷ Hollywood Pure Safflower Oil, Hollywood Health Foods, Los Angeles, CA 90061, USA

⁸ ALC Lecithin Granules, American Lecithin Co., Inc., Woodside, NY 11377, USA

⁹ To volume (3 l)

Later feeding. An attendant was on duty around the clock from Days 1 through 22, and formula was given on demand. From Days 23 through 29, formula was offered only between 0800 and 1630 h. Formula was withheld starting on Day 30. The formula was supplemented with force-fed whole Atlantic herring *Clupea harengus harengus* starting on Day 9 (Table 2), and Formula B (Table 1) was substituted for Formula A after 1645 h on Day 11. Force-feedings of fish were conducted 3 times daily. If a pup gagged while being force-fed, that particular feeding session was stopped. Individual fish averaged 20 cm and 69 g.

Data collected. Each seal was weighed daily at

* Toshiba SAL-20 Linear Array Real-Time Ultrasound Scanner, Toshiba Medical Systems, Carson, Calif. 70945, USA

** Oxytocin (20 I.U. cm^{-3}), Spencer Mead, Inc., Valley Stream, N.Y. 11582, USA

*** Nalgene 800 Nontoxic Autoclavable Lab/Food Tubing, Sybron/Nalge, Rochester, N.Y. 14602, USA

Table 2. Daily caloric intake kg^{-1} of body weight of artificial formula and force-fed whole fish for unweaned, twin gray seal pups during the first 29 d postpartum

Day	Female				Male				
	Formula		Fish		Formula		Fish		kcal kg^{-1} body wt
	(ml)	(kcal)	(kg)	(kcal)	(ml)	(kcal)	(kg)	(kcal)	
1	480	1,217			300	761			61
2	955	2,421			1,135	2,877			223
3	1,195	3,029			1,790	4,538			339
4	2,280	5,780			1,450	3,676			274
5	2,350	5,957			2,050	5,197			363
6	1,550	3,929			1,880	4,766			324
7	2,190	5,552			1,400	3,549			241
8	1,980	5,019			1,500	3,803			250
9	1,980	5,019	0.36	776	1,660	4,208	0.36	776	320
10	2,080	5,273	0.93	2,005	870	2,205	0.93	2,005	225
11	2,080	6,376	1.34	2,889	1,245	3,817	1.34	2,889	394
12	1,770	5,426	1.45	3,126	1,620	4,966	1.45	3,126	452
13	1,480	4,537	1.92	4,140	860	2,636	1.61	3,471	341
14	960	2,943	1.95	4,204	1,080	3,311	1.95	4,204	401
15	935	2,866	1.90	4,096	1,190	3,648	1.90	4,096	403
16	1,225	3,755	1.95	4,204	1,775	5,441	1.95	4,204	471
17	2,045	6,269	2.01	4,334	2,160	6,622	2.01	4,334	512
18	1,820	5,579	2.01	4,334	1,215	3,725	2.01	4,334	361
19	1,955	5,993	2.01	4,334	2,590	7,940	1.94	4,183	523
20	2,720	8,338	1.95	4,204	2,220	6,805	2.01	4,334	470
21	1,220	3,740	2.23	4,808	2,020	6,192	2.23	4,808	437
22	980	3,004	2.07	4,463	1,050	3,219	2.07	4,463	307
23	650	1,993	2.45	5,282	990	3,035	2.45	5,282	345
24	980	3,004	3.13	6,748	690	2,115	3.12	6,727	373
25	370	1,134	3.12	6,727	600	1,839	3.12	6,727	345
26	450	1,380	3.36	7,244	520	1,594	3.36	7,244	341
27	140	429	3.36	7,244	280	858	3.36	7,244	313
28	200	613	3.13	6,748	230	705	3.36	7,244	302
29	270	828	2.46	5,304	270	828	2.46	5,304	231

1000 h by placing it in a wooden box suspended from a hanging scale. This information and the time of each feeding, its duration, and volume of formula or fish ingested, was recorded in a daily log. Data from suckling sessions that occurred less than 10 min apart were combined. The nature of the stools, general health, and behavior also were recorded.

Conditions. The pups were kept indoors on a sheet of plywood ($244 \times 122 \times 0.6$ cm) laid flat on a concrete floor. The overhead fluorescent lights were left on continuously; air temperature averaged 15°C . The pups were washed and towel-dried as often as necessary to remove feces, urine, and formula from their hair.

Proximate analyses. The composition of the diet was determined as follows. *Dry Matter:* Duplicate samples (250 to 300 g each) of individual complete formulas were homogenized, shell-frozen, and lyophilized to complete dryness. Raw, whole Atlantic herring with heads removed were dried to constant weight at 48°C in a forced-air convection oven. Percent dry matter was calculated as the weight of the remaining solids and fat, relative to the weight of the

diluted, ready-to-feed formula or raw fish sample. All further analyses were performed on representative portions of the lyophilized or air-dried material. *Crude Protein:* Total nitrogen was determined in triplicate analyses by the Kjeldahl method (A.O.A.C., 1965). Crude protein was calculated as $\% \text{N} \times 6.25$. *Total Lipids:* Complete lipid determination was performed on duplicate, homogenized samples by repeated methanol-chloroform (2:1, v v⁻¹) extraction, followed by rotary evaporation at 30°C (Kates, 1972). *Ash:* Duplicate samples were dry-ashed at 600°C for 18 h (A.O.A.C., 1965). *Gross Energy:* Total energy values of duplicate samples of dried formulas or fish were determined by adiabatic oxygen bomb calorimetry (A.O.A.C., 1965).

RESULTS AND DISCUSSION

Geraci (1977) recommended inserting the nipple of a bottle through a strip of cotton cloth or neoprene to induce pinniped pups to bottle-feed. After the second intubation, the following materials were tried: a cotton



Fig. 1. *Halichoerus grypus*. Male pup at age 2 d, bottle-feeding through the sealskin surrogate

shirt, a piece of neoprene from a diving suit, and a strip of velour from a child's stuffed toy. None was successful. The female accepted a bottle with no such surrogate at 2234 h on Day 1, or 282 min after the third intubation. The male refused to bottle-feed for the remainder of Day 1 and the morning of the next day (Day 2). A fourth surrogate was made from a sealskin coat. The male nuzzled the hair of the coat and suckled successfully at 1210 h on Day 2 (Fig. 1), the first time the sealskin surrogate was tried. Thereafter, the sealskin was used when either pup acted hungry but was unable to locate the nipple of a bottle extended to it. The female required this procedure less often than the male.

Once bottle-trained, the pups regulated their own intake of formula. Formula consumed during the first 22 d is shown in Figs. 2 and 3. No pattern is evident. Suckling frequency (n) in each 24-h period was variable, as was the amount of formula consumed during each suckling. From Days 23 through 29, when formula was offered only during working hours, the number of sucklings and amount of formula ingested declined. The female suckled twice on Day 24 and the male twice on Days 23 and 24; otherwise, both pups suckled only once a day. The suckling pattern of wild gray seal pups is unknown, making comparisons impossible.

The total quantities of formula, force-fed fish, and kilocalories ingested each day, and the number of

kilocalories ingested each 24-h period per kilogram of body weight (based on proximate analysis), are presented in Table 2, and depicted graphically in Fig. 4. Daily caloric intake showed a general bell-shaped pattern, being highest in the third week. During the pre-weaning period, the individual daily caloric intake was 61 to 523 kcal kg⁻¹ of body weight, with an average value of 341. This is higher than the average daily energy intake of yearling gray seals (98.7 kcal kg⁻¹ of body weight), as reported by Van Dyke and Ridgway (1977). However, the energy requirements of newborn mammals typically are higher than in older conspecifics (Kleiber, 1961).

Regression analysis of daily change in body weight (kg) on kilocaloric intake per metabolic body weight (kcal kg^{-0.75}) yielded the following relationship:

$$Y_{(\Delta \text{ body wt. kg})} = -0.464 + 0.00128X (\text{kcal kg}^{-0.75})$$

where $r^2 = 0.49$. Thus the maintenance gross energy requirement ($Y = 0$) of these 2 pups was 362 kcal kg⁻¹ of metabolic body weight (Fig. 5). Considerable variation is evident in this relationship. However, moderate but consistent diarrhea may have contributed to the noticeable variation in efficiency of nutrient (energy) utilization, as measured by body weight gain. According to our data, unweaned gray seals weighing 15 to 18 kg would have a minimum energy requirement of 2775 to 3185 kcal d⁻¹, which is high but comparable with

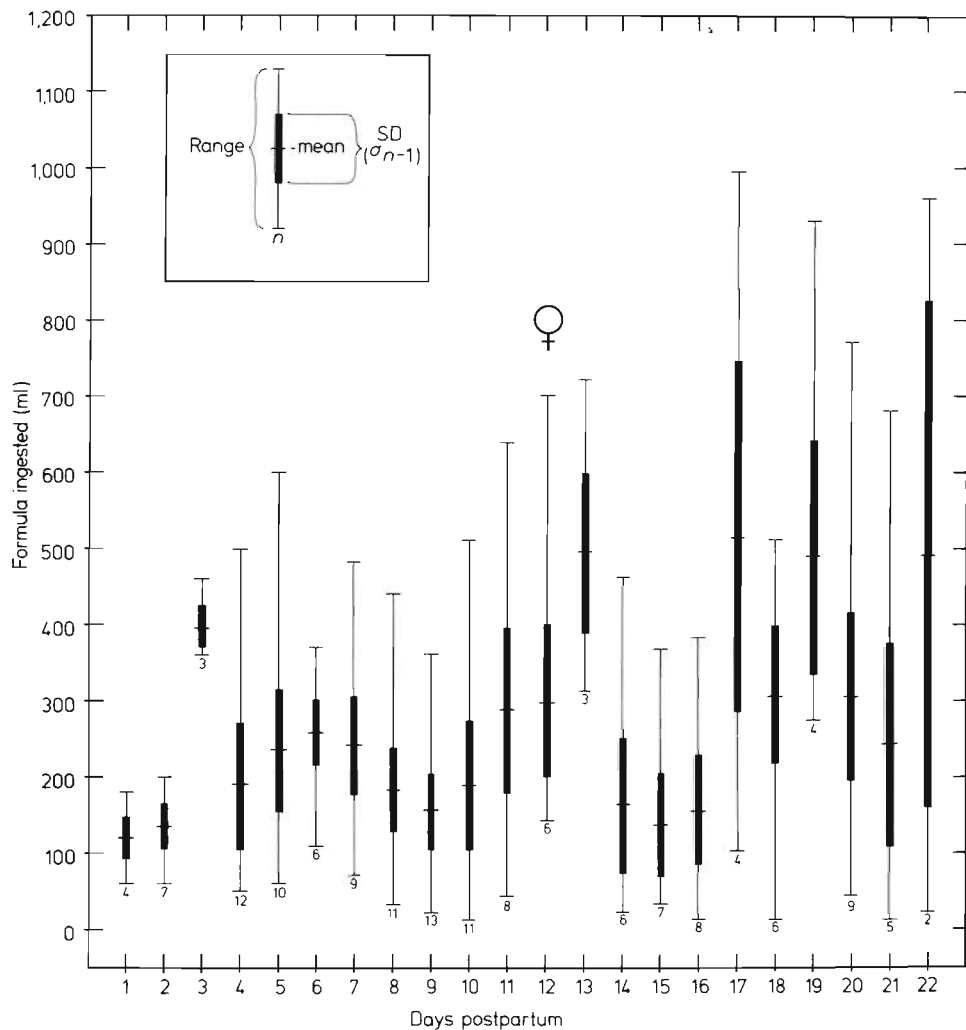


Fig. 2. *Halichoerus grypus*. Suckling pattern of female pup and volume of formula ingested for the first 29 d postpartum; n = number of sucklings in each 24-h period

the maintenance energy estimates for other young mammals (Kleiber, 1961; Wooden et al., 1970; N.R.C., 1974, 1978).

Proximate analyses of the 2 formulas and raw herring are presented in Table 3. The addition of casein, safflower oil, and lecithin (a fat emulsifier) to Formula A to produce Formula B increased the concentration of total solids. The caloric content of Formula B thus exceeded that of Formula A, but the percentage of fat was less. Casein and vegetable (safflower) oil are satisfactory, if marginal, protein and energy supplements for artificial formulas containing raw fish and cream.

Growth was linear, as illustrated in Fig. 6. Both pups continued to gain weight until weaning. Unweaned, wild gray seal pups grow rapidly, often doubling or tripling the birth weight during the brief suckling period. Mansfield (1977) weighed 8 pups of known age on Sable Island, Nova Scotia, at regular intervals for their first 14 d of life. The mean of these weights is plotted in Fig. 6. One animal grew from a birth weight of 18 kg to 59 kg during this period, or an average of

2.9 kg d⁻¹. Birth weight doubled and tripled in 6 and 12 d, respectively. The average weight of the 8 pups increased from 17 to 46 kg, or a near-tripling of birth weight in the 14-d period. Average growth was 2.1 kg d⁻¹. By comparison, our seals gained less than 0.5 kg d⁻¹. At 14 d they weighed only 20.5 (female) and 18.8 kg (male), less than half the average weight of 2-week-old pups born in the wild.

The combined nutritional value in the fish and formula obviously was inferior to gray seal milk, as shown by failure of the pups to gain weight normally, and as demonstrated by proximate analysis (Table 3). Surprisingly, a complete proximate analysis of gray seal milk still has not been published. A preliminary report by Amoroso and Mathews (1951) stated only that it contains approximately 52.2 % fat, 11.2 % protein, 2.6 % lactose, and 0.7 % ash. Compared with gray seal milk, both formulas contained insufficient fat and protein, and perhaps were deficient in other constituents as well, despite the addition of fish.

The rapid growth of wild gray seal pups may be an

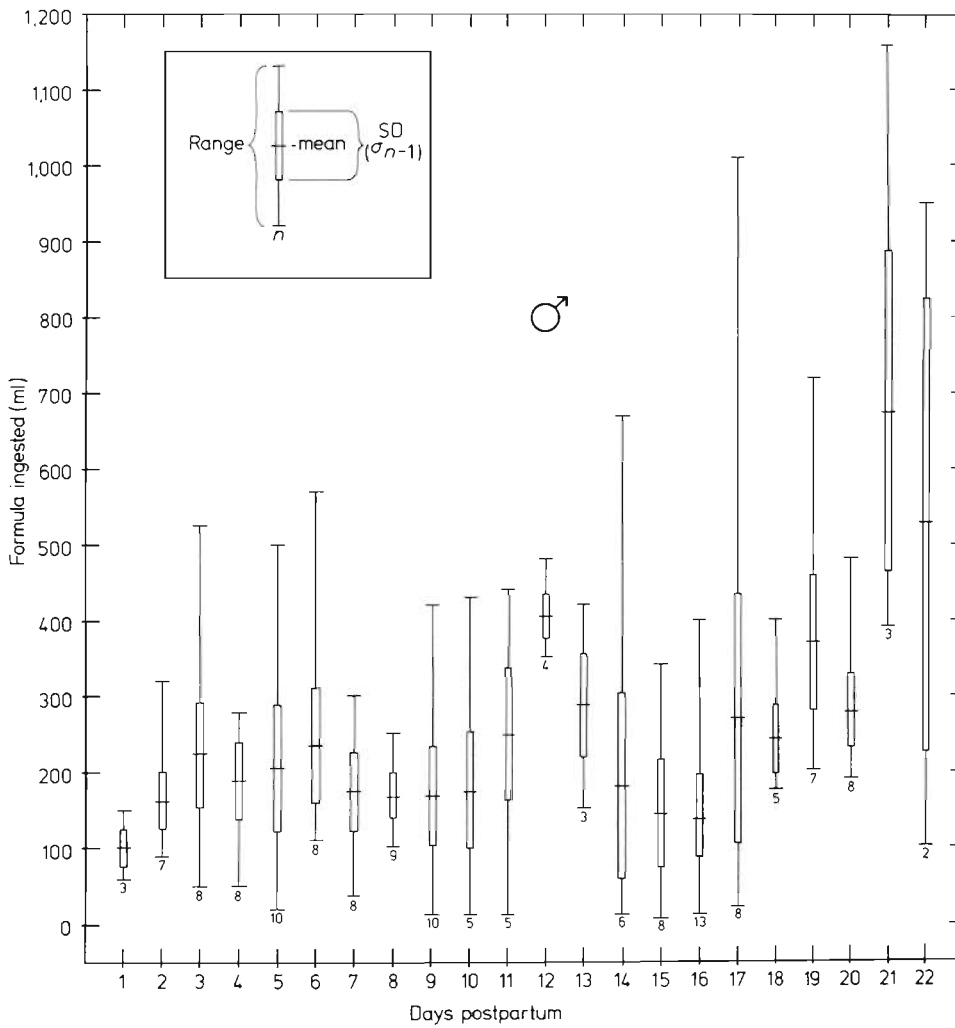


Fig. 3. *Halichoerus grypus*. Suckling pattern of male pup and volume of formula ingested for the first 29 d postpartum; n = number of sucklings in each 24-h period

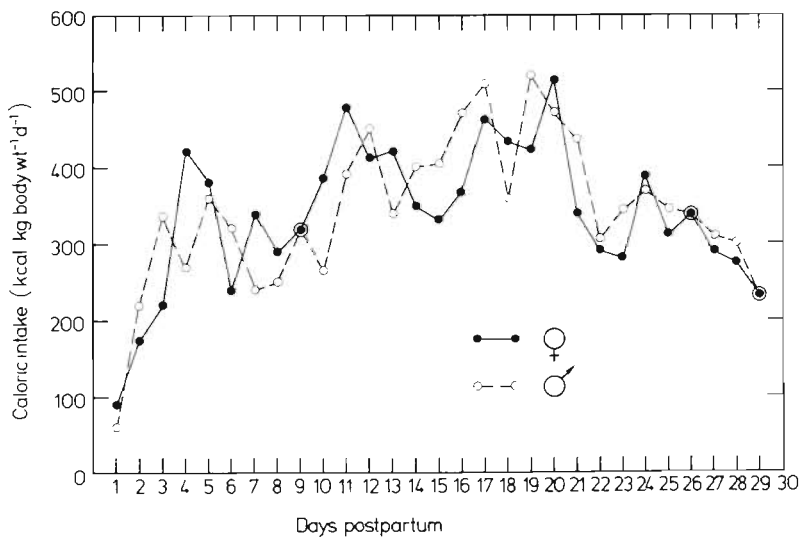


Fig. 4. *Halichoerus grypus*. Daily caloric intake of twin gray seal pups for the entire preweaning period of 29 d, plotted from data in Table 2

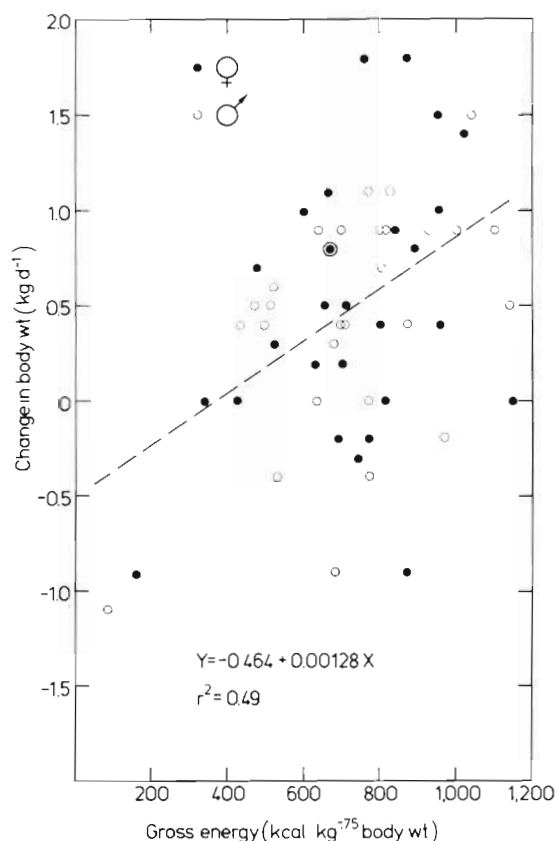


Fig. 5. *Halichoerus grypus*. Linear regression of body weight gain on gross energy intake (kcal kg^{-1} of metabolic body weight) of pups for the first 29 d postpartum

adaptation to environmental pressures, primarily low air temperature. The positive correlation between increase in body weight and survival is well established. Mortality in British pups is highest among those that do not triple their birth weights by weaning (Coulson and Hickling, 1964). Most of the weight acquired in this short time is attributable to blubber. Mansfield (1977) showed that the sculp weight (blubber and skin combined) of Sable Island pups constitutes 50 % of total body weight at 21 d, compared with only 25 % 2 d after birth. Baker et al. (1980) discussed pathological findings obtained from 68 pups found dead on several

Table 3. Proximate analysis of artificial formulas A and B, and whole, headless Atlantic herring

Contents	Formulas and fish, as-fed basis		
	A	B	Herring
Gross energy, kcal g^{-1}	2.535	3.066	2.156
Crude protein, %	3.91	4.63	18.35
Fat, %	20.0	17.95	16.50
Ash, %	0.23	0.54	4.30
Dry matter, %	39.5	39.9	42.2

British rookeries. Nearly all were grossly underweight, either from starvation or disease.

Canadian gray seals breed in January and February, or during the coldest time of the year. Most births occur in 2 locations: on sea ice in the Gulf of St. Lawrence, and on snow-covered beaches of Sable Island. In the Gulf of St. Lawrence air temperatures between 0 and -20°C are typical, and wind velocity often is within the range of 2 to 5 m s^{-1} (Blix et al., 1979). From the moment of birth a seal may be exposed to a windchill of 0.9 to 2.1 kW m^{-2} (Blix et al., 1979). The birth coat (lanugo) offers little protection. It has poor insulative properties because it lacks an oily texture and is easily wetted (Ling and Button, 1975). Survival thus depends on how quickly a newborn seal can acquire a thick layer of subcutaneous fat.

Both pups experienced a mild, intermittent eye disorder characterized by redness around the entire circumference of the eyelid, and accompanied by a viscous exudate that crusted when dry. Hair loss occurred around the eyes. The condition was diagnosed as periorcular alopecia. Signs were first recorded on Days 12 and 13 in the male and female, respectively. During that time both animals were examined for possible respiratory infections. This was done because Gallacher and Waters (1964) had demonstrated a relationship between 'septic' eyes and pneumonia in unweaned, wild gray seals in Britain. However, the respiratory tracts of these 2 pups were clinically normal. The condition was therefore treated topically by washing the eyes periodically with a warm saline or boric acid solution.

Both pups suffered from moderate diarrhea throughout the pre-weaning period. Reduction in frequency or degree was not affected by either Formula B or the force-feeding of raw fish. This loss of digestive and absorptive efficiency may have caused, in part, the subnormal growth rate and the high maintenance energy estimate. Formulas used to rear unweaned pinnipeds of other species typically induce enteritis and diarrhea (Poulter et al., 1965; Picken, 1975; Klös, 1979), and electrolyte imbalances, bowel stasis, and tissue dehydration (Poulter et al., 1965). Some of these factors may have been responsible for the chronic diarrhea and occasional behavioral signs of gastric distress that we observed.

According to Ling and Button (1975), molting of Canadian gray seal pups lasts slightly longer than 1 wk and does not commence until after weaning. The suckling period lasts 14 to 15 d (Mansfield, 1977), compared with 16 to 21 d for British gray seals (Bonner, 1972). The pups described here started losing the lanugo on Day 12. The molting pattern followed the topographical sequence described in detail by Ling and Button (1975). The female finished molting on Day

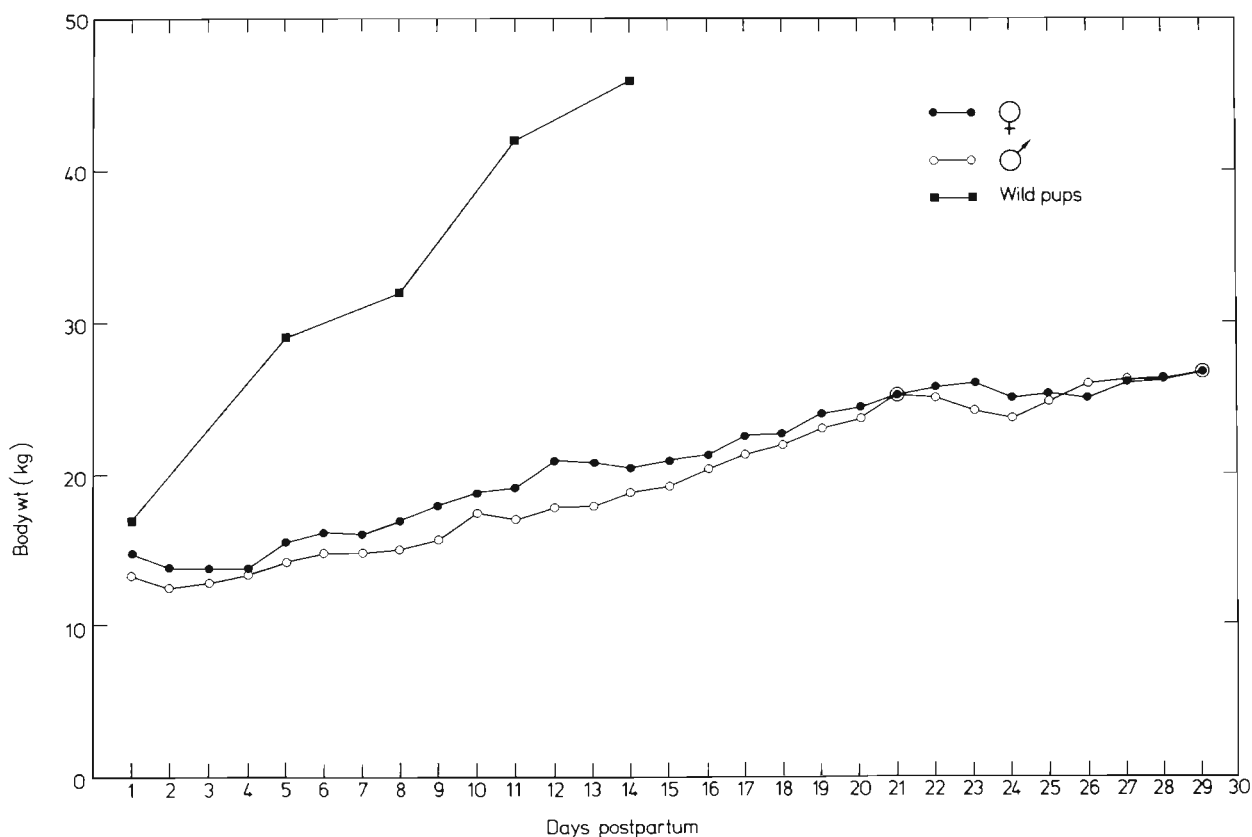


Fig. 6. *Halichoerus grypus*. Growth of the 2 captive-reared pups, compared with that of wild pups on Sable Island, Nova Scotia. The points on the curve for the wild pups are mean values for 8 individuals, plotted from data in Mansfield (1977)

23 and the male on Day 25. Thus the timing, duration, and pattern of molt were normal, compared with wild, Canadian gray seal pups, despite the abnormal environmental and nutritional conditions under which the animals were reared.

CONCLUSIONS

Unweaned pinnipeds reared artificially seldom gain weight in normal increments (Neugebauer, 1967; Mar. Mamm. Biol. Lab., 1970; Blix et al., 1973; Picken, 1975; Klös, 1979). This is convincing evidence that the rearing formulas used to date are nutritionally inadequate. The minimum energy requirement of 2775 to 3185 kcal d⁻¹ for suckling gray seals needs confirmation. An obvious error may have been introduced by studying pups with chronic diarrhea. Future reports on hand-rearing of pinniped pups should include a measure of digestible energy.

Our results suggest that environmental factors are more limiting than composition of the diet. The rapid deposition of blubber is less important when pups are hand-reared, provided that air temperature is main-

hand-reared, provided that air temperature is maintained above freezing, the pelage is kept clean and dry, and wind chill is eliminated. The practice of keeping pups on wooden surfaces, rather than on concrete, appears to have merit as a means of reducing the unnecessary expenditure of calories. The thermal conductivity of wood and concrete are 0.062 and 0.54 cal s⁻¹ cm⁻¹ C⁻¹, respectively (Perry, 1950). Concrete thus conducts heat 8.7 times faster when both materials are at the same ambient temperature.

The length of time we allowed the pups to suckle (29 d) was chosen arbitrarily. In thin animals weaning is an added stress, because several days may elapse before fish is accepted as a substitute for formula. In pups that demonstrate linear growth, weaning probably can be started between 2 and 3 wk of age, or earlier than we report here.

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