FINAL REPORT

PHYSIOLOGICAL INVESTIGATIONS OF CAPTIVITY MORTALITY IN THE SEA OTTER (Enhydra lutris).

Amchitka Island.....February - March, 1954

Purdue University.....April - June, 1954

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We are also indebted to our colleagues on the staff of Purdue University for assistance in processing and evaluating the material brought back here for further study. Drs. L. P. Doyle, G. M. Neher, and R. M. Claflin of the Veterinary Science Department examined all of the histological material and assisted in the consideration of the pathological aspects of the problem. Dr. M. X. Zarrow of the Department of Biological Sciences made the final liver glycogen determinations and assisted in the consideration of the endocrinological aspects of the problem. Dr. R. M. Cable of the Department of Biological Sciences is examining the parasitological materials brought back.

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ABSTRACT

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Mortality in the Sea Otter (Enhydra lutris)

In February and March of 1954 a project was undertaken on Amchitka Island in the Aleutians by the U. S. Fish and Wildlife Service with collaboration by the Agricultural Experiment Station, Purdue University, for the purpose of studying the physiology of the sea otter (Enhydra lutris), with special attention to the problem of captivity mortality. Determinations were made of various blood components, organ weights, gastro-enteric activity, temperature control, and pathology of normal sea otters and compared with animals which had died in captivity.

The cause of captivity mortality was probably due mainly to the narrow range of temperature tolerance and the very high food intake requirement which the sea otters have. Shock or stress, resulting from temperatures outside the tolerable range, insufficient food, or adverse neurological stimuli, as the immediate cause of death is discussed.

Three otters were successfully maintained in captivity by proper management of the environment. A description of the habits, activities, and mannerisms of sea otters in captivity and suggestions for further study of the sea otter are given in the appendices.

Physiological Investigation of Captivity Mortality in the Sea Otter (Enhydra lutris)

INTRODUCTION

Although the sea otter (Enhydra lutris) was the object of man's attention because of its desirable pelt for two centuries prior to 1900, since then its near extinction resulting from this attention precluded any organized scientific investigations of it until the past few years. The remoteness and rugged character of the habitat in which it lives further hampered such studies. Consequently, except for a preliminary study of the parasitology[1] and numerous incomplete or sketchy field observations of its habits virtually nothing was known about the fundamental life processes of the sea otter prior to this investigation.

An attempt to transplant otters in 1951 from Amchitka Island in the Aleutians to other areas of its former range was met with failure because of the inability to keep the animals alive in captivity. Subsequent efforts along the same lines were equally unsuccessful. The causes of death in captivity was not immediately apparent, though in some respects the symtoms of this captivity mortality resembled those of animals dying naturally around Amchitka. Survival in captivity was relatively short, varying from a few hours to one instance in which an adult male lived for eleven days. The average survival period was three to four days. The only striking and constant symptom attending death was a severe gastroenteritis, often resulting in sloughing of the intestinal mucosa. Oddly enough the otters gave the outward appearance of accepting and adapting to captivity with relative ease, often accepting food within minutes after capture.

Extensive discussion and correspondence with Robt. D. Jones Jr., Refuge Manager, Aleutian Islands National Wildlife Refuge, who had made all previous attempts to keep the sea otters in captivity, led to the formation of a hypothesis concerning captivity mortality based upon his observations and experiences. According to this hypothesis, the otters suffered from an acute stress or shock reaction.

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[1] Rausch, Robert. Studies on the Helminth Fauna of Alaska. XIII Disease in the sea otter with special reference to Helminth parasites. Ecology 34:3. July 1953.

possibly neurogenic in nature, arising from the circumstances of their capture and confinement. Because nothing was known of the basic physiology of the sea otter, it was difficult to test this hypothesis with known facts.

During February and March, 1954, a project was undertaken at Amchitka Island by the U.S. Fish and Wildlife Service with collaboration by the Agricultural Experiment Station, Purdue University having the following objectives:

1. To determine if the cause of captivity mortality was primarily physiological in nature, and if so what processes were involved, i.e., to test the hypothesis that captivity mortality was due to a physiological stress or shock reaction.

2. To devise a technique for capturing and holding sea otters in captivity which would prevent captivity mortality.

3. To make fundamental physiological observations on the sea otters which would provide a basis for future investigations.

4. To collect such other basic scientific information about sea otters as time and circumstances would permit.

A detailed outline of experimental procedures was prepared (appendix 1), realizing that the limitations imposed by field conditions, and that other procedures indicated by the results of early experiments would necessarily modify this outline as the work progressed.

PROCEDURES

In order to get tissues and observations from as nearly normal animals as possible, six otters were shot in the wild and brought into the laboratory immediately. Five were killed instantly with a head shot from a .257 Roberts rifle. The sixth was shot through the thorax and died in less than three minutes. The otters were retrieved from the water by a man in a "frogman" suit, or in the dory, and transported by jeep to a temporary laboratory set up on the water front. All specimens arrived in the laboratory in less than ten minutes after the shot was fired, the average time being 6.5 minutes. The animals were observed, usually

feeding, for ten minutes to over an hour before being shot and were judged to be healthy.

Immediately upon arrival of the carcass at the laboratory the temperature was taken, the pituitary was excised and preserved, blood was drawn and either diluted directly for subsequent procedures or an anticoagulant added, and liver samples were taken for liver glycogen analysis. The temperature was taken by inserting a pre-warmed thermometer to a depth of about ten centimeters into the rectum for forty seconds and then to a depth of fifteen centimeters for twenty seconds longer and read. Blood was obtained by cardiac puncture from the left ventricle by inserting a 3 inch 17 gauge needle between the 5th and 6th ribs just left of the sternum. It was noted that in three of the animals the heart was still beating with sufficient strength to force blood through the needle at the time the blood was drawn four to five minutes after the animals were shot.

Following these initial procedures, the carcass was weighed and transported to the main laboratory. The gross necropsy was started immediately. Samples of brain, liver, diaphragm and leg muscle were first excised and weighed for the tissue moisture content procedure. All organs were critically examined and any signs of apparent abnormalities were noted. The thyroid, adrenals, kidneys, and liver were weighed. Samples of all major body organs, (brain, spinal cord, skelital muscle, heart, lung, spleen, liver, kidney, thyroid, pancreas, lymph node, stomach, duodenum, jejunum, ileum, colon, gonads, and bone) were preserved in A.F.A and/or Bouins fixative at this time. The gastro-intestinal tract was opened along its entire length and the contents, condition of the lining, and presence of parasites noted.

Live otters were captured in a dip net while sleeping on the beach or inshore rocks, or while swimming and feeding off shore. They were transported back to the base in an aluminum carrying cage or simply loose on the floor of the jeep or deck of the dory. In the case of anesthetized animals, (see below) they were transported in a canvas litter. Upon arrival at the base they were weighed and placed in confinement.

Some animals were held in a tank of salt sea water 30 inches deep and 10 feet in diameter which was provided with a rock "island" three feet square in the middle for the animals to haul out on. The water, pumped directly from the sea was freshened daily and remained at or a few degrees below sea temperature (39°F). A building located a few feet east of the tank afforded a wind break from this direction, but no other protection from the weather was provided.

Other animals were confined in cages 48 x 24 x 18 inches covered with 1 x 1 inch welded wire fabric. These cages were located in a large warehouse which gave some but not complete protection from the wind. At first no bedding was provided, but later dried grass was used as litter in the cages.

Subsequently a small unheated wooden building was remodeled for an animal house. The plank floor of this building was covered with 1/2 inch of sawdust overlaid with an inch or so of dried grass and provided an area about 15 x 20 feet in which the otters could move about freely. Windows in the east, north, and west walls admitted ample light, and although not open to the direct force of the wind, the walls and windows allowed some penetration of wind and driven rain so that a damp, draughty atmosphere prevailed. Grass filled cages, described above, were placed against one wall of this building and were available to the otters in the daytime and used to confine them at night. One otter was kept for eleven days as a "pet", having the run of the living and laboratory quarters most of the time when not confined in a grass filled cage.

Attempts were made to feed the otters as nearly a natural diet as possible, however, the extreme difficulty in securing the marine invertebrates, which are the main item in the wild otters' diet, precluded the use of more than token amount of this material. The bulk of the diet of the captive otters was made up of marine fish, mostly kelp greenling, which were caught in traps and on set lines and fed fresh. When fresh fish were not available in sufficient quantity goose and seal flesh including viscera and commercially frozen fish were offered to and accepted by some of the otters.

During the early part of the project, feeding was rather haphazard, but when a backlog of fish, kept alive in a large wooden tank, was achieved the otters were fed four times daily at 0700-0730, 1100-1200, 1600-1700 and 2100-2300. Depending upon the available supply, the amount given at each feeding varied from one-half to two pounds of fish per animal.

The entire fish was fed, usually chopped up into chunks roughly 1 inch cube. The bones of the head and vertebrae of larger fish were chopped finer. Occasionally marine invertebrates, primarily blue mussels, limpets, hermit crab, and octopus, were given in small amounts to supplement this diet. Every other day about 10 grams of a dehydrated milk-like product Terralac* was sprinkled on the food of each otter.

The otters showed very strong food prejudices and individual variation in preferences. Some would not eat commercial frozen filet of sole or fresh water Dolly Varden trout; another refused starfish which were readily accepted by the others.

Fresh water was provided the otters not held in the tank in tipproof, swimproof pans, or in the form of snowballs which they readily accepted. No conclusive attempt was made to determine the otters' preference or need for fresh as compared with sea water. Otters held in the tank were not provided with fresh water, although snow was often present on the rocks in the middle of the tank. Otters were never observed eating this snow, however.

Three otters were anesthetized with intraperitoneal injection of sodium pentobarbital (Nembutal) at the time of capture. The first received 40 mg/kilo, the other two received 20 mg/kilo. During the course of experimentation, one of the latter received intraperitoneal injections of glucose, phenobarbital and metrazol.

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* Teralac was supplied for this work by Charles Pfizer and Company, Inc., Brooklyn, New York.

Smaller animals could be handled with the use of heavy mittens, larger ones were restrained in a cord net. Sex was determined by observation or palpation for the baculum of the male. The animals were weighed in a sack or dip net. Attempts to draw blood from unanesthetized, living animals were unsuccessful because of the difficulty in restraining the animal, although the fleshy, vascular ear offered an excellent site for a shallow puncture. Body temperature of living animals was measured by inserting a laboratory thermometer 10-15 cm into the rectum.

Breathing rate was readily obtained by direct observation, particularly on sleeping or quiescent animals. The breathing pattern, including depth, was recorded on a chart ruled to represent 5 second intervals. Heart rate was determined by auscultation and by palpation of an artery in the tarsal region, probably the tibialus posterior on anesthetized or restrained animals. The heartbeat of otters sleeping in a supine position could readily be observed as a pulsation of the abdomen just below the sternum.

The passage of food through the alimentary tract was timed by feeding a meal containing blue mussels or other shelled molluscs to animals that had been receiving an exclusively fish diet for at least 48 hours. The occurrence of shells in the feces then gave the time of passage of the material through the gut. The frequency, character, and amount of the feces were noted.

The habits, mannerisms, and activities of the sea otters in captivity were noted and will be found in Appendix 2.

Animals which died in captivity or were found dead in good condition on the beach were necropsied as soon as they were discovered. Only one captive animal was sacrificed (shot with a .22 caliber bullet in the occipital region) because it was considered moribund. All others died in the early morning hours, having shown no recognizable signs of impending morbidity, even though they were usually observed as late as 2100 the evening before. If the animal had been dead less than three hours (as judged by body temperature and onset of rigor mortis) blood was drawn

immediately by cardiac puncture. Except that the pituitary was weighed and preserved for histological examination and no liver sample for liver glycogen analysis was taken, the necropsy was carried out exactly as indicated above for animals shot. If the animal was judged to have been dead longer than three hours no blood determinations were made.

The following laboratory procedures were completed on Amchitka:

1. Tissue moisture content. Tissue samples of brain, liver, diaphragm, and leg muscle weighing approximately 0.5 gm were excised, placed on glass slides and weighed to the nearest miligram. They were then placed on a shelf above the stove to dry and re-weighed at 24 hour intervals until two weights within three milligrams were obtained. The difference between the original and terminal weight was divided by the original weight to give the percentage of water in the tissue.

2. Organ weights. The pituitary, thyroid, and adrenal glands were excised, freed of connective tissue and weighed to the nearest milligram. The kidneys and liver were weighed to the nearest 1/2 oz and the weights converted to grams.

3. Blood cell counts. Oxalated blood (0.1 ml. 10% potassium oxalate per 10 ml. blood) was diluted in appropriate pipettes with Hayem's solution for RBC counts, Turk's solution for WBC counts, and phloxine-sodium carbonate-propylene glycol stain for eosinophil counts. Counting was done on a Spencer Bright Line hemocytometer and results expressed as number of cells per mm^3 blood.

4. Blood hemoglobin determination. Blood hemoglobin was determined on oxalated blood by the Sahli hemometer method and the results expressed as grams of hemoglobin per 100 ml of blood.

5. Blood sugar determination. Unoxalated, fresh blood was used to determine the blood sugar content with the LaMotte Blood Sugar Outfit which uses a modification of Folin's Method. Results, determined by color comparison with standards, are expressed in milligrams of blood sugar per 100 ml. of blood. This method is reasonably accurate within a range of $\pm$ 7 mg%.

The following laboratory procedures were started on Amchitka and completed at Purdue.

1. Histological. Tissues for histological examinations were collected and fixed in either or both A.F.A. and Bouin's fixatives. The tissues in A.F.A. were changed to 70% ethyl alcohol after 48 hours. Tissues were carried back to Purdue in either 70% Alchol or Bouin's where they were imbedded in paraffin, sectioned, mounted, stained with Mayer's hematoxylin and eosin, and examined.

2. Liver glycogen determination. Two liver samples of about 1 gm in weight were collected from animals at the time of death and weighed to the nearest milligram. One piece was preserved in fixative (9 parts absolute ethyl alcohol and 1 part neutral formaldehyde) and returned to Purdue for histo-chemical examination. The other piece was disintegrated in hot 30% potassium hydroxide, the glycogen precipitated with 95% ethyl alcohol, centrifuged and the supernatant fluid discarded. The precipitate was returned to Purdue, broken down to glucose by acid hydrolysis, and the amount of sugar measured.

3. Pituitary ACTH content. Pituitaries were removed from animals as soon as possible within ten minutes of the time an animal was killed. They were immediately preserved in neutral acetone and returned to Purdue. This procedure will be completed at a later date.

The presence of parasites in the gastrointestinal tract was noted. Parasites and scrapings from the lining of the gut (duodenum, jejunum, and ileum and gall bladder of 15 animals were preserved in A.F.A., changed to 70% alcohol and returned to Purdue. This material will be examined at a later date.

Measurements of the gonads of 11 animals were made and testis smears from six males were examined. The complete urogenital tract of six males and five females were preserved and will be described morphologically at a later date.

RESULTS

The animals used in this study are divided into three groups. The first group

will be referred to as "normal" and includes one adult and two subadult males and three adult females which were shot in the wild, as well as one subadult male which was killed immediately after capture by a lethal dose of nembutal. These animals ranged in weight from 11.3 Kg to 37.2 Kg. The weight of individual animals will be found in Table 1.

The second group, referred to as "pathological" is made up of one adult and eight subadult males and one adult female which died after 12 hours to 7 days in captivity. Also included are two subadult males and one subadult female found dead on the beach. These animals ranged in weight from 9.9 Kg to 31.8 Kg at the time of capture, and from 8.6 Kg to 30.8 Kg at death. The circumstances of their capture and confinement, including capture and death weights and weight loss will be found in Table II.

The third group, consisting of one subadult male and two subadult females, lived for more than three months in captivity and were still alive when these observations were concluded.

Necropsy. At necropsy, the seven normal animals appeared to be in good physical condition as indicated by the presence of considerable amounts of subcutaneous and visceral fat. The adult male (17-54) was extremely fat, the greatest concentration of fat was found in the subcutaneous inguinal region and about the kidneys. With the exception of the lower gut, the organs of these animals appeared quite normal. In all but one (27-54) there were indications of a mild inflammation of the jejunum and ileum in the form of local, mild hyperemia and petechiae of the mucosa. In no case was there blood found in the lumen of the gut. The gut was very long; in one 30 Kg animal it measured slightly more than 40 feet in length. Very little fluid was noticed in the body cavities. (See Table I).

The pathological group revealed a somewhat different picture, (Table II). Two animals of this group were devoid of fat and two others showed markedly less fat than was observed in the normal animals; however, three of them were quite fat.

Table I Weight, Death, and Gross Necropsy Examination Data for Normal Sea Otters.

Animal Sex	Body wt. Kgs.	How killed	Necropsy gastro-intest. enteritis* Stom.	duo.	jej.	il.	content	Other organs; remarks
17-54 m	37.2	shot head	-	-	x	x	food	Very fat; appeared in good shape.
51-54 m	16.3	shot head	-	-	-	xx	food	normal
50-54 m	12.6	shot chest	-	-	x	x	food	normal. Not killed instantly, died within 3 Minutes
3-54 m	11.3	nembutal	-	-	x	x	food	normal except for some cardiac decomp.; vasodil. splanchnic area.
6-54 f	22.7	shot head	-	-	x	x	food	normal, quite fat.
22-54 f	19.5	shot head	-	-	-	x	food	normal
29-54 f	17.5	shot head	-	-	-	-	food	normal

* - Normal epithelium, no enteritis
x Mild enteritis, few isolated lesions
xx Moderate enteritis, less than 50% involved
xxx Severe enteritis, more than 50% involved

NOTES: [1] Actual (Kg) and % total body weight lost during captivity
[2] - Normal epithelium, no enteritis
x Mild enteritis, few isolated lesions
xx Moderate enteritis, less than 50% involved
xxx Severe enteritis, more than 50% involved.

Death cause	wt. Kg.	loss[1] %	Necropsy enteritis[2] gastro-intest. stom.	duo.	jej.	il.	content	other organs; remarks
capt. mort.	30.8	1 3%	-	x	xx	x	food & mucus	Lungs 20% congested; serum & blood pedk, serous fluid in body cavity; mod. subcut. & visc. fat.
hyper therm	15.0	0	x	xx	xx	xx	gas & mucus	Lungs nearly black with blood; wh cysts on spleen; massive vasodil. all organs, brain.
shot capt.	13.2	1.8 12%	-	-	-	xx	meat & blood	Lymphatics engourged.
found dead	12.2		xxx	-	xxx	xxx	mucus	Decompensated heart; subcut. edem
capt. mort.	11.3	1.3 10%	-	xx	xxx	xx	blood mucus	Lungs very hemorrhagic; water in lungs; quite fat.
capt. mort.	10.8	.2 2%	x	xxx	xxx	xxx	blood mucus	Lungs OK; fluid and bubbles (frot in body cavity.
capt. mort.	10.8	.2 2%	-	-	x	x	food mucus	Lungs very black with blood; deco pensated heart; visceral veins en gourged.
found dead	10.3		xxx	xx	xxx	xxx	much blood	Lungs OK; little subcut. fat.
hyper therm	9.9	1.4 13%	-	-	xxx	xxx	blood	Lungs extensively hemorrhagic; liver "white & washed out"; good subcut. and visceral fat.
capt. mort.	7.2	2.7 27%	x	-	xxx	xxx	blood mucus	Lungs OK; very thin and emaciated no fat.
capt. mort.	19.9	1.8 8%	xx	xxx	xxx	xxx	meat & blood	Lungs OK: some subcut. fat, littl visceral fat.
found dead	8.6		-	x	x	x	blood mucus	Lungs OK; very thin, no fat.

Table II Weights, Capture, Captivity, Death, and Gross Necropsy Data for Pathological Sea Otters

Animal Sex	Capture wt. Kg.	Capture how taken	how held	duration	Captivity food	remarks
1-54 m	31.8	net on beach	tank	36 hrs.	1# invertebrates	24 hrs in cage in snow drift; rough handling in attempt to draw blood.
5-54 m	15.0	net on beach	cage in bldg.	6 hrs.	none	hyperthermia following nembutal anesthesia
7-54 m	15.0	net on beach	tank	46 hrs.	3# fish, seal & goose	nervous, excitable; took no food first 24 hrs; in & out of water often.
31-54 m	Found dead on beach					
9-54 m	12.6	hand, beach	tank	36 hrs	none	nervous, excitable; in & out of water often.
15-54 m	11.0	hand, beach	cage, bare	12 hrs	6 Oz. fish	Became very weak 4 hrs. after capture; fed & revived
18-54 m	11.0	net on beach	cage, bare	12 hrs	1# fish	No signs of morbidity up to few hrs of death; looked good!
23-54 m	Found dead on beach.					
4-54 m	11.3	net on beach	floor in bldg.	38 hrs.	8 oz. liver	Severe hypothermia after nembutal anesthesia; revived; weakness, hyperthermia
27-54 m	9.9	net in water	cage & straw	7 days	2½ # fish/day	Seemed well adapted to captivity; no warning signs of impending morbidity.
8-54 f	21.7	net on beach	tank	36 hrs	7# fish, seal, goose	Appeared thin, emaciated but strong; shivering; ate very well
14-54 f	Found dead on beach					

Nearly half of these animals had marked pulmonary congestion. In three instances, the lungs were nearly black and filled with blood. Cardiac decompensation, as indicated by engourgement of the large veins and right side of the heart was observed in over half of these animals. The abdominal and thoracic cavities usually contained several hundred cc of a pinkish or brownish serous fluid which was frothy in some instances.

Gross examination of the abdominal organs showed few abnormalities except in the gastro-intestinal tract. The organs were usually darker colored, indicating vasodilation, but specific lesions were noted in only two instances. Cysts were observed on the spleen of one animal (5-54) and the liver was pale in another (4-54). Only two of the thirteen animals in this group showed mild enteritis. In all others, gastro-enteritis was moderate to severe. In some instances the gut was so inflamed that externally it appeared an angry purplish-red color along its entire length. The condition of the lining varied from isolated areas of hyperemia and petechiae to a continuous severe ecchymossis with erosions and sloughing of the mucosa. The lumen usually contained blood. No perforating ulcers were found.

Histological: The histological structure of the sea otter closely resembles that of other mammals. The tissues are quite vascular and even in the normal animals there was a condition which might be construed as hyperemia in some organs, particularly lung and kidney. The secretory epithelium of the gastro-intestinal tract is well developed. An indication of the high level of activity of these organs is indicated by the branching of the gastric pits, crypts of Lieberkühn, and the villae. Most of the specimens, both normal and pathological, showed numerous old scars in the enteric mucosa, submucosa and muscularis, indicating some old damage to the mucosa--the result of mechanical injury or infection. This was true of juvenile as well as adult animals.

The spleen is highly trabeculated, with numerous, thick-walled blood vessels, which might indicate that the sea otter's spleen functions primarily as a blood

reservoir.

The adrenal gland is somewhat unusual. It is irregular in shape, usually with several lobes. The capsule and various zones of the cortex are easily recognizable, but the medulla has no distinct definition. The group or cord arrangement of the cells usually seen in the adrenal medulla is nearly absent. In the center of the gland is a large sinus which is usually filled with blood.

In general the tissues of the pathological animals were more hyperemic than those of the normals. This was particularly true of the lungs which in some instances showed extravasated blood.

The most remarkable difference between the normal and pathological animals was found in the gut. Extensive necrosis and erosion were found in many pathological animals. In some instances this included sloughing of the mucosa. Severe hyperemia and extravasation of blood to form large sinuses were often observed in the submucosa and muscularis.

In several pathological animals the liver showed some abnormality also. The hepatic sinusoids had lost definition and the lobules were indistinct. In a few cases the pyramidal cells of the central nervous system seemed to be slightly shrunken, usually an indication that the animal had been subjected to stress prior to death. There was also some indication of increased thyroid activity (diminution of colloid, increased heighth of epithelial cells) in one or two of the pathological animals.

Organ Weights: The weights of the pituitary, adrenal, thyroid, liver, and kidney, and their percentage of total body weight are given in Table III for normal animals, Table IV for pathological animals, and summarized and averaged in Table V. The figures for the six animals which were shot may be slightly low because of the blood lost at the time of death; however, this cannot account for the total difference between these figures and those for the pathological animals.

Tissue Moisture: The percentage of water in leg muscle, diaphragm, liver, and

brain tissues of normal animals are given in Table III, for pathological animals in Table IV, and are summarized and averaged in Table V. All of these figures may be slightly low because of inadequate facilities for completely drying tissues. The figures for normals may be still lower because of fluid lost at the time of death; however this loss cannot account for the total differences between the normal and pathological groups.

Blood Studies: RBC, WBC, and eosinophil counts and hemoglobin and sugar concentrations of the blood are given for normal animals in Table III for pathological animals in Table IV, and are summarized and averaged in Table V, some inaccuracy may exist in these figures for animals from which the blood was not drawn at the time of death; however, the similarity between these figures and the figures for animals from which the blood was drawn at the time of death would seem to indicate that such inaccuracies were slight.

In two instances figures are available from the same animal at the time of capture as well as after death. In the first (5-54) there was a very slight increase in the R.B.C's, and a decrease in the W.B.C's, eosinophils, and blood sugar. This animal lived only six hours in captivity; it became hyperthermic following Nembutal anesthesia. In the second (4-54), an animal which lived 38 hours in captivity and was also anesthetized, there was a marked increase in the R.B.C's and hemoglobin concentration, with a marked decrease in W.B.C's, eosinophils, and blood sugar. The observations obtained from these two animals will be discussed in more detail later.

Liver Glycogen: Liver glycogen content for normal animals ranged from 3.3 to 8.5 gm% and averaged 5.4 gm% (Table III). Liver glycogen determination made on one pathological animal (7-54), was found to be 14.1 gm%.

Body Temperature and Temperature Control: The deep rectal temperatures of six normal animals taken a few minutes after they were shot were: 95.0, 96.5, 99.5, 99.5, 100.0, and 100.5°F, average 98.5°F. The deep rectal temperature of animals shortly

Table IV Blood and Tissue Moisture Values and Body and Organ Weight of Pathological Sea Otters

Animal sex	Blood time drawn	R B C /mm^3	W B C /mm^3	Eosinophyl /mm^3	Hb. gm%	Sugar mg%	Tissues: % Moisture Content leg musc.	dia. musc.	liver	brain
1-54 M							73%	66%	70%	72%
5-54 M	capture death	5,920,000 5,928,700	5,680 4,403	211 88	14.0	137 112	74%	73%	70%	81%
7-54 M	death	5,605,000	4,767	(?)33	16.5	167	73%	71%	68%	
31-54 M										
9-54 M							55%	89%	82%	78%
15-54 M	1.6 hr. p-mort.	4,888,400	2,505	11	13.5	<50	75%	77%	75%	78%
18-54 M							75%	75%	65%	78%
23-54 M										
4-54 M	capture 2 hrs p-mort.	5,930,000 9,494,000	7,440 1,520	183 (?)0	17.0 21.0	112 75	75%	77%	73%	76%
27-54 M	3 hrs p-mort.	4,090,500	3,798	17	10.5	<50	76%	75%	74%	75%
8-54 f							74%	73%	68%	72%
14-54 f										

Body and Organ Weights

body Kgs	pit. mgs	%[1]	adrenal (gms) r/l	adrenal (gms) total	%[1]	thyroid(r) gms	%[1]	Kidney gms r/l	Kidney gms total	%[2]	liver gms	%[2]
30.8	152	0.5	1.648 1.796	3.444	11	1.547	5	255 284	539	1.8	1,785	5.8
15.0	142	0.9	2.618 2.760	5.378	36	2.369	16	142 142	284	1.9	1,120	7.5
13.2			1.006 1.099	2.105	16	.605	5	113 99	212	1.5	624	4.8
12.2			.892 .920	1.812	15							
11.3	135	1.2	.782 .632	1.414	13	1.975	17	99 99	198	1.7	652	5.8
10.8	132	1.2	1.065 1.083	2.148	19	.697	6	99 99	198	1.8	510	4.7
10.8	126	1.2	.830 .815	1.645	15	.720	7	113 100	213	2.0	709	6.6
10.3	119	1.2	.505 .524	1.029	9			105 100	205	2.0	709	6.9
9.9	101	1.0	1.093 1.055	2.148	22	.655	7	113 114	227	2.3	764	7.5
7.2	145	2.0	1.000 .947	1.947	27	.716	10	85 85	170	2.4	397	5.5
19.9	176	.8	1.963 1.784	3.711	19	.798	4	170 170	340	1.7	1,162	5.8
8.6			.950 .905	1.855	22			113 85	198	2.4	595	6.9

1. mg. % of body weight

2. gm % of body weight

Table III Blood, Liver Glycogen, and Tissue Moisture Values and Body and Organ Weights of Normal Sea Otters

Animal Sex	time drawn	Blood R B C /mm^3	Blood W B C /mm^3	Blood Eosinophyl /mm^3	Blood Hb. gm%	Blood Sugar mg%	Liver Glycogen[1]	Tissues:% Moisture Content leg musc	dia. musc.	liver	brain
17-54 m	death	5,474,200	4,040	283	15.5	112	7.0	71%	70%	67%	68%
51-54 m	death	4,949,000	3,272	100	14.5	125	--	74%	69%	67%	71%
50-54 m	death	5,151,000	4,120	106	14.0	112	3.3	74%	73%	67%	77%
3-54 m	1.6 hr p-mort	4,696,500	4,686	106	13.0	137	--	75%	74%	72%	--
6-54 f	death	4,008,690	2,302	107	12.0	87	8.5	74%	74%	68%	66%
22-54 f	death	5,524,700	3,273	146	15.5	100	3.9	71%	73%	64%	
29-54 f	death	4,625,800	2,706	44	15.0	112	4.3	71%	72%	67%	77%

[1]gm% of liver weight

Body and Organ Weights

body Kgs.	pituitary mgs	%2	adrenal (gms) r/l	total	%2	Thyroid (r) gms	%2	kidney (gms) r/l	total	%3	liver gms	%3
37.2			1.345 1.685	3.030	8	2.423	7	511 566	1077	2.9	1,589	4.3
16.3			1.090 1.060	2.150	13			142 156	298	1.8	908	5.6
12.6	117	0.9	.700 .780	1.480	12	.848	7	113 114	227	1.8	653	5.2
11.3	152	1.3		2.189	19						823	7.1
22.7			1.042 1.425	2.467	11	1.413	6	170 170	340	1.5	1,021	4.5
19.5			1.455 1.212	2.667	14	1.790	9	170 142	312	1.6	992	5.1
17.5	156	0.9	1.328 1.298	2.626	15	1.510	9	142 156	298	1.7	807	4.0

2 mg.% total body weight.

3 gm % total body weight

Table V Summarization of Tables III and IV.

		Normal Animals			Pathological Animals		
		No. of Animals	Range	Av.	No. of Animals	Range	Av.
Tissue H_2O %	leg muscle	7	71-75	73	9	55-76	73
	diaphragm	7	69-74	72	9	66-89	75
	liver	7	64-72	67	9	65-82	70
	brain	5	66-77	72	8	72-81	76
Body wt (kgm)		7	37.2-11.3	19.6	12	7.2-30.8	13.3
Organ Weights	Pituitary (mg)	3	117-156	142	9	101-176	136
	mg% body wt		0.9-1.3	1.0		0.5-2.0	1.1
	adrenal (gm)	7	3.030-1.480	2.373	12	1.029-5.377	2.387
	mg% body wt		8-19	13		9-36	19.0
	thyroid (gm)	5	2.423-0.848	1.597	9	.605-2.369	1.120
	mg% body wt		6-9	7.6		4-17	8.6
	Kidney (gm)	6	1,077-227	414	11	170-539	244
	%body wt		1.5-2.9	1.9		1.5-2.4	2.0
	liver (gm)	7	1,589-653	970	11	397-1785	821
	%body wt		4.0-7.1	5.1		4.7-7.5	6.2
Blood	RBC/mm^3	7	5,524,700-4,008,690	4,918,700	5	9,494,000-4,090,500	6,001,320
	WBC/mm^3	7	4,686-2,302	.3399	5	1,520-4,767	3,339
	Eosinophyls/mm^3	7	283-44	127	3	11-88	39
	Hemoglobin gm%	7	15.5-12.0	14.2	4	135-21.0	15.4
	Sugar mg%	7	87-137	112	5	50-167	87

after the onset of Nembutal anesthesia were 100.0 and 100.5°F. The sea otter apparently does not have good temperature control. In captivity, particularly if insufficient food is available, it suffers greatly from temperature changes. Shivering was noted on numerous occasions in the animals kept in the tank and in others regularly kept in a dry environment but given a swim. In one case, three animals that had been kept in cages for several days were placed in the water tank for less than one minute. Two of these animals shivered excessively and did not recover full strength for at least twelve hours after the experience. Wetting of the fur always precipitated much rubbing and preening, possibly in an attempt to dry it (see Appendix 2).

In another instance, an animal (4-54) that had recovered from anesthesia was placed on the bare damp floor of an unheated shack over night. In the morning (0700) it was comatose and the body temperature was 79° F. Successive baths in water 105° F, and intraperitoneal injection of 10cc of 15% sterile glucose and 1.8 cc of 5% metrazol effected a temporary recovery of this animal with a return of body temperature to 98° F. at 1100. The animal accepted food at this time. At 1800, eight hours after recovery the animal began to scream, and though it was still weak it appeared normal. At 2400 its body temperature was 102.5° F and it had become restless. At 0120 the next day it was given a subcutaneous injection of 50 mg/kilo phenobarbital to quiet it. At 0245 it was sleeping, breathing regularly, and its temperature was 104° F. The animal was dead at 0715. It was noted subsequently that the fur "slipped" on the hide of this animal which may indicate the hyperthermic condition at the time of death.

Panting of sea otters was noted on several occasions following the exertion attending capture on the beach; however, this activity was never sustained for more than a minute or two at a time. The mouth was only slightly agape and the tongue was not extended.

Panting was not observed in an animal (5-54) which died when the body temperature was 106° F following Nembutal anesthesia. The body temperature at the time of capture and anesthetization was 100° F. At four hours, the animal began to recover righting reflexes; the body temperature was then 103° F. The animal was placed on a cool (30° F.), damp floor. It showed no further signs of recovery and the breathing had become dyspneic and the heart beat was irregular 6 hours 40 minutes after anesthetization with a body temperature of 105° F. Ten minutes later the body temperature had risen to 106° F., breathing stopped, the heart fibrillated, and the animal died.

Captive otters were observed to be rather restless and to seek the coolest area in a heated room. They avoided spots of direct sunlight which warmed their dark fur very rapidly.

Heart Rate: The heart beat of otters that seemed to be in reasonably good condition was strong and regular. The resting rates for three subadult animals that had been in captivity for two to three weeks are given in Table VI. Heart rates of two animals immediately after capture and injection with Nembutal, but before anesthesia was complete were both 168 beats per minute. In deep anesthesia, a heart rate of 188 beats per minute was recorded. In two animals which were comatose and in which the body temperature had begun to fall, but which subsequently recovered temporarily, the heart beat was very weak and irregular. During recovery the strength of the beat was recovered appreciably sooner than a constant rhythm was established. At the point of hyperthermic death, the heart went into fibrillation.

Breathing Rate: The resting breathing rates of three subadult otters after two to three weeks captivity are given in Table VI. Figure 1 shows the breathing pattern of these three animals. It was noted that there are two distinct breathing movements; the more frequent shallow breath is mainly thoracic while the deeper

Table VI Heart and Breathing Rates of Resting or Sleeping Captive Sub-Adult Sea Otters

Animals	Heart Rate/Minute			Breathing Rate/Minute		
No. & Sex	No. of observations	Range	av.	No. of observations	range	ave.
10-54 f	3	144-148	146.7	12	9-16.5	12.2
16-54 f	3	122-136	129.7	9	8-14	10.6
28-54 m	1	121	121	8	12-15	13.6
average			132.4			12.1

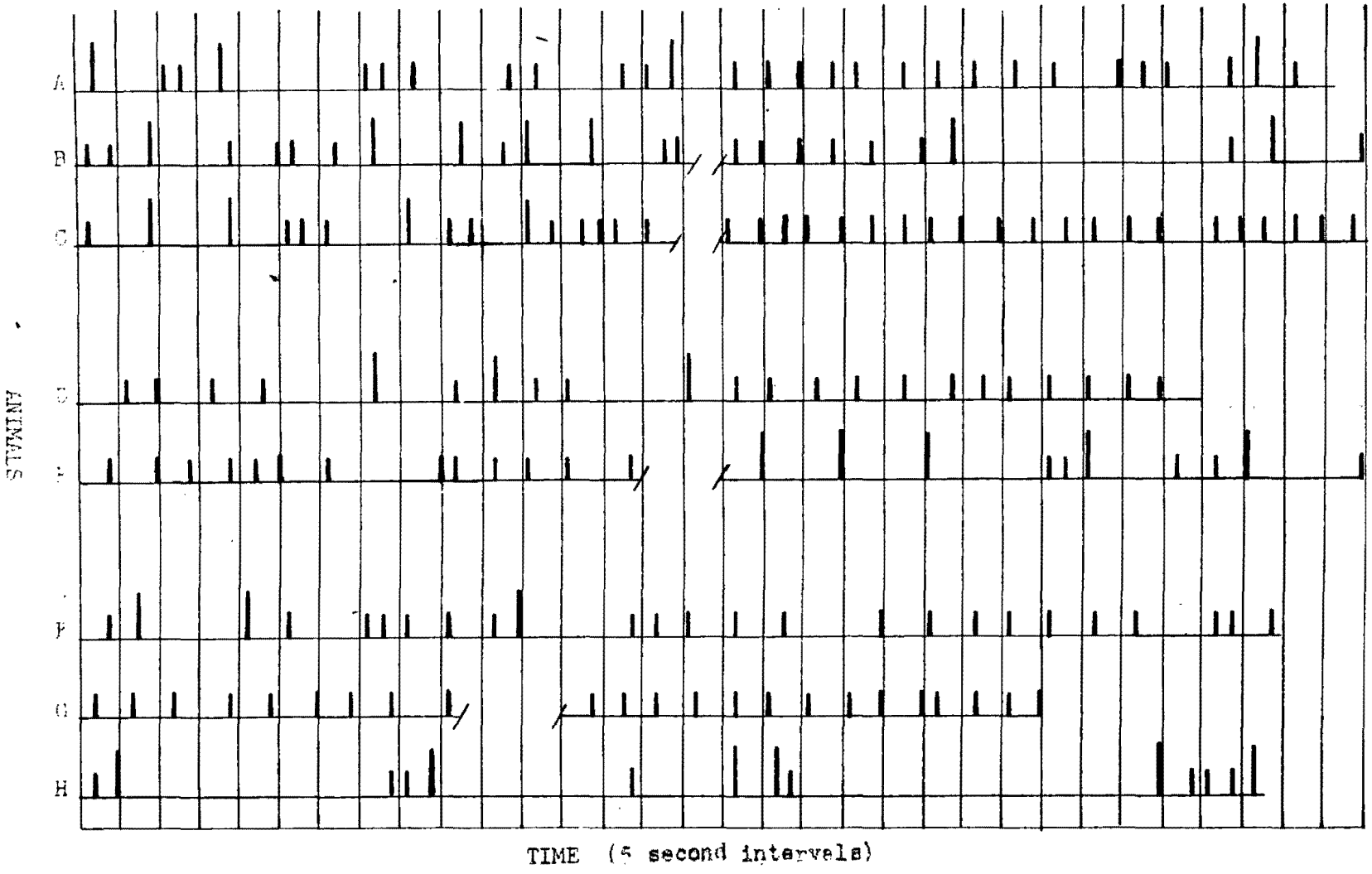

Figure 1. Breathing Pattern of Sleeping and Resting Captive, Sub-Adult Sea Otters.

ventilation is more abdominal in nature. It was also noted that the rhythm is not regular. The intervals between shallow breaths varied from 1 second to 15 seconds in the same animal during the same period (several minutes) of observation. This irregular rate was seen in animals both asleep and awake.

Breathing rates of 16/min and 22/min were recorded on animals shortly after capture. Several otters were observed to pant for short intervals at the time of capture.

Passage of Food and Digestion: The sea otter masticates its food very thoroughly Most bones and pieces of skin are completely ground up before swallowing. The shells of smaller mollusks are also ground up and swallowed, but larger shells may be cracked and discarded. (See Appendix 2). The shells of mollusks included in the food of the sea otters appeared in the feces within 4 hours after ingestion. In a timed experiment one otter passed shells in 2 hrs. 45 min, a second in 2 hrs. 50 min., and a third in less than 3 hrs. 15 min. after ingestion.

The feces of otters on a diet entirely composed of fish were not formed but were quite watery. Only a small percentage of the total bone ingested appeared in the feces, these being mostly head bones, ribs, and fin rays. All other parts of the fish were completely digested. The shells and chiton of invertebrates did not appear to be digested at all, and the feces of animals receiving this type of food were semi-formed and less watery.

When goose and seal flesh were included in the captive otters' diet, considerable amounts appeared in the feces apparently completely undigested. This was particularly true if this food was provided in chunks, though even when the meat was ground it could be recognized in the feces. When fish and meat were ground together, the fish was never recognizable in the feces, but the meat often was.

In one instance, three otters receiving about 21 lbs of fish in a 24 hour period produced about three and 1/4 lbs of fecal material during the same period. When the otters received insufficient food or were fed at intervals exceeding 10 hours, the

feces became black and tarry (blood). Unless adequate food was provided immediately death usually followed in a matter of hours.

Anesthesia: The first attempt to anesthetize an otter with sodium pentobarbital (Nembutal) was fatal. A dose of 40 mg/kilo injected intraperitoneally (the anesthetic dose for dogs) resulted in death of the animal in less than 30 minutes. Two other attempts, using a dosage of 20 mg/kilo gave good anesthesia. Undesirable after effects, as noted above, probably due in part at least to the anesthetic, contraindicated further use of anesthesia in light of the limited number of animals which could be handled.

Survival in Captivity: Three animals were successfully maintained in captivity. For the first ten days these animals lost weight and frequently appeared listless and in a weakened condition. During this time they were housed in the animal house, protected from the weather, and denied the use of water except for drinking. They were fed approximately 2¼ lbs of fish and meat per animal per day (12% - 15% of body weight). On several occasions they passed black tarry feces indicating that they were probably suffering from enteritis. One animal became very weak on two occasions refusing food once (he was finally induced to eat by "teasing" with small bits of chopped fish which he reluctantly swallowed), and showing acute respiratory distress (coughing, dyspnea, as in pulmonary conjestion) another time.

After ten days the rations of these animals were stepped up to about seven pounds of fish per animal per day (25% - 35% of body weight). The animals immediately pepped up and no further signs of enteritis were noted. They began to gain weight, were more active, and seemed to have more strength as they moved about. They successfully withstood captivity, steadily improving, for three and a half months, including 6,000 miles of transportation by ship and air.

They finally died in the National Zoo, in Washington, D. C., but beyond the fact that they had "hemorrhagic enteritis" no details concerning their deaths or the environmental conditions in which they were being held immediately prior to their

deaths have been received. A week prior to their deaths they were judged by competent observers to have been "in the best condition."

DISCUSSION

In many respects the sea otter represents an interesting intermediate stage in the adaptation of terrestrial mammals to an aquatic existence. This adaptation falls far short of that seen in true marine mammals such as Cetacea and Sirenia which not only have no requirement to leave the water, but are so highly specialized that they are unable to do so. Most Pinnipedia, though they are capable of going ashore, and do so, often for relatively long periods, to rest and bear their young, show marked specialization to an aquatic environment. Their morphological and physiological adaptations are much more pronounced than those seen in the sea otter.

On the other hand the sea otter has largely lost the ability to survive on land in the natural state. It is unable to travel any distance or procure food out of the water as most semi-aquatic mammals, such as the land otter and beaver are able to do. Morphologically the sea otter resembles these semi-aquatic animals more closely than it does the true marine mammals.

Because of the lack of adequate information about the life history, habits, and physiology of the sea otter it is difficult, if not impossible, to clearly understand its requirements and stage of adaptation between a terrestrial and aquatic existence. It is fairly certain that this adaptation is not complete and the evolutionary changes which are in progress have left the animal with a very narrow range of enviornmental tolerance. This would explain the slow recovery of the species from near annihilation even with complete protection for over 40 years, and the difficulties encountered in working with individuals in captivity.

On the basis of the work reported here, the causes for captivity mortality in sea otters stem from a combination of inadequate feeding and environmental stress. The lack of food does not usually result in a total energy deficiency as seen in chronic starvation, since many animals which died were quite fat, few, in

fact, having no fat reserves. It is rather a case of acute starvation in which the mere absence of food from the digestive tract brings about changes in these organs which are intolerable to the sea otter. It is also possible that the sea otter is unable to mobilize stored energy resources (fat) rapidly enough to entirely satisfy its immediate needs under stress.

When the digestive tract remains empty for more than a few hours very rapid degenerative changes occur. Whether these changes result from the mere mechanical absence of material in the gut, a chemical attack on the lining of the gut, or the presence of some bacterial or viral organism is not clear. The rapidity of food passage through the gut, which is long for an animal of this type, and the histological evidence that the gut is very active, indicates that it is geared to handle large quantities of food material almost constantly. When this material is not available there is apparently no mechanism by which it can be slowed down. A severe gastro-enteritis then develops which leads to fatal shock or circulatory collapse.

The destruction of tissue (gastro-intestinal mucosa) and loss of blood usually seen in this condition is adequate stimulus for the shock syndrome. In a few instances the enteritic condition did not seem sufficiently severe to have been the sole causative factor of shock. However, the excitement and stress of capture and early confinement is in itself a strong neurological shock producing stimulus and would tend to aggravate the situation.

There is considerable evidence in the results from pathological animals to support this shock theory:

1. A hyperemic condition, indicating vaso-dilatation, was observed at necropsy on both gross and histological examination.

2. A slightly higher moisture content of the tissues, congestion in the lungs, and free fluid in the body cavity indicated loss of fluid from the blood and edema of tissues.

3. Higher R.B.C. and hemoglobin values are an index of hemo-concentration.

4. Eosinopenia is a well recognized symptom of acute stress.

5. The animals died very suddenly, showing few or no symptoms of morbidity up to a few hours of death, which always occurred in the early morning hours. The natural stimulations of human activity during the day and evening would have a sympathomimetic effect on the animals, blocking the shock syndrome temporarily. When this stimulation was removed the animals would succumb to shock rapidly.

In addition, it is possible that the entire otter population has a latent, as yet undetected, infection of a bacterial or viral organism which causes enteritis. When the animals are subjected to environmental stress or are unable to get adequate food supplies, an exacerbation of this infection might occur, and if it subsides, leave the scar tissue found in the gut of all animals, both normal and pathological, that were examined. Such a disease, and the toxins produced by it, might explain all of the symptoms noted.

However, repeated sublethal environmental stress and the inability to procure sufficient food during very rough weather might explain this scarring alone, since gastroenteritis is a recognized symptom of stress. It is fairly certain, judging from the condition of the animals and occurrence of blood in the feces, that the animals successfully held in captivity suffered attacks of enteritis during the early part of their confinement from which they recovered.

The rapidity with which food material travels through the gut of the sea otter is probably the reason why certain foods such as seal and goose flesh are not completely digested. These substances are much tougher than fish and offer more resistance to mastication. The digestive fluids would not have an opportunity to mix with and attack this type of food as readily as the more thoroughly macerated fish flesh, which contains less connective tissue, in the short time it remains in the gut.

The metabolic rate of the sea otter was not determined. The high caloric intake

of the otter per day would seem to indicate that it might be high; however, observation of the habits of animals kept in captivity did not bear this out. They display none of the nervous activity frequently seen in captive animals of other species. They did not pace and rarely moved about except at feeding time, spending most of their time sleeping or resting. Much of the time they were not even alert to their surroundings, being undisturbed by human activity, including carpentry, in their immediate vicinity. A high metabolic rate may be necessary to maintain body temperature, but it is difficult to assume that their heat loss is excessive through the fur that they possess, even if wet. The captive animals, kept dry most of the time, showed no decrease in food requirements, even when the environmental temperature rose.

The sea otter has a rather narrow range of temperature tolerance and is sensitive to abrupt changes in temperature. Captive animals held in a tank of water only one or two degrees below the temperature of the sea from which they had been taken shivered excessively and screamed their discomfort. The inadequacy of the diet provided these animals probably accentuated their inability to cope with this condition; however, they all had considerable fat reserves at the time of death.

Animals held successfully for more than a week in a dry environment, which were then placed in water, shivered intensely and were seriously weakened by only a few minutes exposure, taking 12 to 24 hours to recover from the experience. It is difficult to understand this reaction in animals which spend their lives in and out of the sea. It is quite possible that the artificial environment of captivity results in loss of insulation and waterproofness of the pelt which may become dirty and matted.

The temperature of the sea in the winter is probably at or near the lower limit that the otters can tolerate, and even a drop of two or three degrees, particularly if they are not in the best physical condition, causes a severe stress reaction or shock.

The obvious discomfort and distress of otters subjected to environmental temperatures higher than 50° F, or when subjected to direct sunlight for more than a few minutes, indicate that they cannot withstand excessive heat any better than cold. The lack of panting, except following strenuous exercise, when it is very brief and apparently ineffective, would seem to indicate that this usual method of controlling body temperature is not well developed in the otter. Another indication of the lack of an adequate temperature control mechanism is the uncontrolled rise of body temperature in captive otters following anesthesia.

One of the first effects of high environmental temperature in most animals is a loss of appetite and refusal to eat. In the sea otter this is very serious and may result in the gastro-enteritic lesions discussed above.

The narrow range of environmental temperature tolerance of the sea otter is not hard to understand in light of its natural habitat. The sea temperature has an annual fluctuation of only about 9° F (38° F to 47° F) while the air temperature varies only about 40° F (15° F to 55° F). Individual animals may be subjected to much less variation than this, depending upon their immediate surroundings. The changes within these ranges are slow and would give the animal ample time to make the slight seasonal adjustment necessary. In captivity these changes are more abrupt and often outside the natural range, and therefore constitute a potential stress-provoking stimulus.

Not enough data of a comparative nature were obtained in this study to definitely show how the blood sugar and liver glycogen effect, or are effected by, captivity mortality. There seems to be a decrease in the blood sugar with captivity mortality, but whether this is associated with the causes of captivity mortality or merely a side effect is not established. The value for the blood sugar and liver glycogen of normal sea otters falls within the range of other mammals.

The values obtained for the organ weights and their percentage of body weight are difficult to evaluate because of the wide range of size and age groups of sea

otters worked with. The apparent increase in size of the adrenal gland of pathological animals supports the theory that stress or shock is a causative factor in captivity mortality, since this gland is responsible for the body's defense against these conditions. The slight increase in the pathological animals of percentage of total body weight of the other organs measured is probably a reflection of the body weight loss during captivity. Much of this information which seems to be of little or questionable significance will probably become useful in light of the results of further investigations.

The heart rate observed in the sea otters is comparable to that of other mammals of similar size. The irregular characteristics of the breathing rate of the sea otter is similar to that observed by other investigators in seals and elephant seals and is apparently an adaptation to an aquatic existence.

Success in keeping sea otters in captivity depends largely upon adequate feeding and environmental temperature control. The importance of keeping the gut filled with food is obvious. Because of the rapid passage of food through the gut this cannot be done with one or two feedings per day, but requires four meals per day, spaced in such a way that no interval of more than ten hours elapses between feedings. The ideal situation would appear to be four meals spaced at six hour intervals, although an interval of eight hours at night does not seem to have a deleterious effect.

The quantity of food is also important. Enough must be given at each meal so that the stomach contains sufficient food material to be passed into the intestine over a period of hours following each meal. The total daily intake of food necessary to maintain body weight of the sea otter is probably in excess of 25% of the body weight of the animal. The food should be of a type that is readily digestible.

Maintainance of the animals in a dry environment was essential in the experiments reported here. However, if adequate food supplies were available, it would

probably be possible to allow the animals at least limited access to water for bathing, particularly if they are protected from the weather. Air temperatures within a range of 30 to 45° F. appear to be satisfactory. How much lower the air temperature may be allowed to drop before it has an adverse effect is not known, but higher temperatures definitely cause distress. Water temperature should not be below 40° F.

The possibility of environmental stress occurring in wild animals has already been pointed out, along with the evidence that this does occur. When animals already suffering from such stresses are subjected to the additional stress of capture and captivity their chances of survival are greatly diminished. Since there is as yet no way of recognizing stress in wild animals, it is to be expected that some animals in this condition will be taken captive and subsequently die, regardless of the care given them.

Individual variations in temperament may also be a source of failure of animals to survive in captivity. Some animals, although they outwardly appear to accept captivity gracefully remain nervous and uneasy. If they persist in this attitude, refuse food, or stop eating after a few days, they are doomed. Excessive handling, abrupt temperature changes, change of diet, isolation, and unusual, persistent stimulations (e.g., vibrations and movements of the cage during ship or air travel) should all be considered potential neurological stress-provoking stimuli capable of directly or indirectly precipitating captivity mortality.

This work is admittedly incomplete and should be considered as primarily an exploratory investigation. Any conclusions that might be drawn at this time, beyond the establishment of certain normal values for a few aspects of the sea otter's physiology, would unquestionably be vulnerable to criticism. The results do, however, provide a basis for, and indicate the direction which future investigations might take. Appendix 3 presents suggestions for further studies of the sea otter.

Appendix I

Sea Otter Project — Amchitka Island — February-March, 1951

Proposed Procedures and Experiments

Introduction

Information presently available indicates the distinct possibility that captivity mortality in sea otters is due to a stress or shock reaction precipitated by capture, handling, and confinement. The picture is probably complicated by the presence of certain parasites which are in themselves pathogenic.

The procedures and experiments contained herein are designed primarily to establish or disprove the theory that stress or shock is an important or the deciding factor in captivity mortality of sea otters. Some of the procedures will be carried out only so far as is necessary to preserve the materials for transportation back to the laboratory where they may be completed under more favorable circumstances. Others will necessarily be completed on the spot. Any reasonable line of investigation not mentioned here, which presents itself during the course of the investigation, will be explored as far as possible or noted for future consideration.

Animals to be used for normal observations, (Master Procedure I), should be carefully selected as completely normal on the basis of close observation in their natural habitat. They should be killed instantly with a head or neck shot before they become aware of any unnatural disturbance and before any alarm reactions can occur in the animal.

So far as possible, only normal healthy animals should be used for captivity experiments with living animals. In any event, a careful estimation of the general health and condition of the animal at the beginning of an experiment should be made.

Animals should not be allowed to die in captivity but should be sacrificed after they become definitely moribund and handled according to Master Procedure I.

Master Procedure - See Other Project

I. For Specimens Shot (for normal observations) or Sacrificed (unanesthetized).

Materials: (to be ready when animal is killed)
dissecting instruments
thermometer
vial of preserving acetone
hot KOH soln.
0.1 ml. blood pipette
blood sugar tube with 10 ml blood sugar reagent A
10 ml syringe with 18 gauge needle
testtube with oxalate or citrate
large scale (100 lb.)
microtortion balance
glass slides for blood smears

Procedure: Always record elapsed time from death until this phase of procedure complete. If time limit has expired, skip and go to next procedure.	Time Limit (from death) optimum	maximum
1. Gross weight of animal	immediately	
2. Insert thermometer in rectum (should be near body temp.). Go on to next procedure, but read thermometer and record within 2-3 min.	within 5 min.	10 min.
3. Expose pituitary (saw off top of cranium, "roll back" frontal lobes of brain). Excise pituitary and drop in acetone.	within 5 min.	20 min.
4. Expose liver. Excise 2 samples (about 2 gm. ea.), weigh and drop one in hot KOH sol'n. and the other in liver glycogen fixative. (see Procedure: Liver Glycogen)	within 5 min.	20 min.
5. Collect 0.1 ml blood and mix with 10 ml LaMotte's Reagent A (see Procedure: Blood Sugar Determination)	within 5 min.	20 min.
6. Expose large blood vessel or heart. Draw as much blood as possible(up to ten ml) into syringe. Discharge blood into testtube, oxalate or citrate and cool. (see Procedures: RBC, WBC, Eosinophil, Hemoglobin, Hematocrit, and specific gravity).	within 5min.	20 min.
7. Collect 1 drop of blood on glass slide (see Procedure: Blood Smears)	within 5min.	30 min.
8. Continue with Master Procedure II.	immediately	1 hr.

Master Procedure -- Sea Otter Project

II. For Specimens Found Dead or Following Master Procedure I.

Materials:
dissecting instruments
specimen containers
fixatives
glass slides(for dehydration of tissue)
micro torsion balance
scale (gms)

Procedure: Always record elapsed time from death until this phase of procedure completes. If time limit has expired skip and go on to next procedure.	Time limit (from death) optimum	maximum
1. Weigh animal if not already taken.		
2. Collect samples and proceed immediately with determination of tissue moisture (see specific procedure)	within 20 min.	2 hrs.
3. Expose, excise, weigh, and fix pituitary, adrenals, liver, and kidney.	within 30 min.	12 hrs.
4. Careful gross examination of all organs and tissues noting apparent abnormalities. While doing this continue with next two procedures.	within 1 hr.	48 hrs.
5. Collect tissue samples of all major body organs, except reproductive and fix (see specific procedure).	within 1 hr.	12 hrs.
6. Collect tissue samples of liver, intestine, lung, spleen, and kidney and lyophilize (see specific procedure).	within 1 hr.	12 hrs.
7. Carefully examine reproductive organs taking necessary wts. and measurements, and preserve (see specific instructions).	within 2 hrs.	48 hrs.
8. Examine gastro intestinal tract for parasites. Preserve specimens and scrapings (see specific procedures).	within 4 hrs.	48 hrs.
9. Collect fecal samples from colon of at least six specimens and seal in plastic or rubber container for fungus determination.	within 4 hrs.	48 hrs.

Tentative Procedures -- Experiments with Living Sea Otters.

Note: The following are merely suggestions for procedures which may yield valuable information about the basic physiology of the sea otter or possibly prolong survival in captivity. The immediate circumstances, facilities, tractability of the animals, and the ingenuity and judgment of the investigators will necessarily determine what and how much can be done.

I. General

A. Breathing Rate: If possible, determine the breathing rate of undisturbed, resting, free living animals (Observation of the "breath" (fog) on a cold day, slight movement of chest or abdominal hair, movement of vibrisse, distension and contraction of nares). Observe and record breathing rate in captive animals whenever convenient, always noting conditions at time of observation (e.g., struggling, anaesthesia, sedation, etc.)

B. Heart Rate: Using stethoscope count the heart rate of captive animals whenever they are being handled (and convenient). Note strength (force, amplitude) as well as rate. Record conditions at time of observation.

C. Nervous Reactions: Note and record nervous reactions of free-living and captive animals whenever possible. Particular attention should be paid to apparent abnormal reactions such as hypertonicity, paralysis, convulsive contractions, etc. Test the pupilary light reflex and corneal reflex of freshly captured animals as well as those being held in captivity.

D. Body Temperature: Measure and record deep rectal temperature of captive animals whenever possible. The bulb and lower third of the thermometer should be near body temperature before insertion to prevent excessive local cooling of tissues. Record conditions at time of reading.

E. Feeding: Record the type and approximate amount of food each sea otter eats every [illegible]. Note apparent appetite, food preferences, etc. Record occurrence and character of fecal passages.

II. Anaesthesia, Sedation, and Immobilization.

The purpose of these experiments is to determine if protection of the sea otter from excessive fright and/or physical injury resulting from handling, transportation, and confinement immediately subsequent to capture may delay or prevent captivity mortality.

If it is determined that anaesthesia alone prolongs captivity survival, then it should be determined if a less drastic measure (sedation) will accomplish the same thing. If anaesthesia alone is ineffective or only partially effective, then it may be augmented by following it immediately with sedation. Sedation may be prolonged and slowly diminished over a period of several days or a week.

In the event that anaesthesia alone is effective then immobilization should be tried. Should immobilization be effective, it is strong evidence that captivity mortality is due to stress or shock resulting from physical trauma. If immobilization is ineffective while anaesthesia is effective it is equally good evidence that captivity mortality is due to stress or shock of neurogenic origin (fright, anxiety).

If none of these experiments are effective in prolonging captivity mortality it may indicate that stress or shock occurring during the actual capture (before treatment can take effect) is sufficient to cause captivity mortality, that the treatment itself is stress or shock-provoking, or that an entirely different mechanism or agent is involved.

Note: The following dosages have been estimated on the basis of known responses in other species and may be too great or too little for sea otters. As soon as proper dosages for sea otters have been determined, they should be substituted.

2. Tentative Procedures - Experiments with Living Sea Otters

A- Anaesthesia: Immediately upon capture of an animal, estimate weight (in this case it is much better to err on the light side!) and inject 45 mg. of nembutal per Kg of body weight intra peritoneally. Note progress of anaesthesia and time. (If anaesthesia is not complete or well advanced within 6 to 10 minutes give an additional dose of 10 mg/Kg.) When anaesthesia is complete weigh animal and record breathing rate, heart rate, and body temperature.

If breathing rate continues to fall below 1/3 of the normal, resting breathing rate or becomes Cheyne-Stokes in nature (periods of rapid breathing followed by no breathing), or gasping occurs, immediately inject Metrazol, 25 mg/Kg. If animal fails to show any sig of recovery in 5 minutes, repeat, and continue to repeat until definite signs of recovery are noted, or animal dies.

Record times of all injections and reactions of the animal.

When transporting animals under anaesthesia care must be taken not to cause injury to the body. It is suggested that the body be wrapped firmly in a roll of canvas, possibly with the addition of a rigid splint along the back. Protect the animal from undue chilli during anaesthesia.

B- Sedation: A 100 mg/Kg dose of phenobarbital is prepared in a gelatin capsule. This may be fed to the animal in meat or it may be necessary to restrain the animal and place the capsule well back in the mouth, massaging it down the throat externally. If neither method is feasible, an aqueous solution may be prepared (this may be difficult due to the relative insolubility of phenobarbital) and a dose of 75 mg/Kg injected intraperitoneally If sedation is to follow anaesthesia, do not administer phenobarbital until the animal has recovered head reflexes and before righting reflex or the ability to stand is regained following anaesthesia.

Phenobarbital is a long-acting barbiturate and should be effective for 12 to 24 hours The proper level of hypnosis (sedation) is achieved when the animal is quiet or sleeps mo of the time, but is capable of being awakened, can move about, and even eat.

If sedation becomes too deep (depressed breathing) it may be counteracted with metraz 25 mg/Kg. Since metrazol is much more rapid in its action and the effects shorter lived than phenobarbital, it will probably be necessary to repeat metrazol treatment at interva as needed.

C- Immobilization: Inject 0.5 mg/Kg of Flaxedil intramuscularly. Observe animal close and record reactions. Recovery from this drug is quite rapid and it must be repeated in 15 to 20 minutes for prolonged immobility. Do not repeat dose until animal shows definit signs of recovery since effects of repeated injections may be cumulative.

If breathing is depressed too greatly or stops (this may happen very rapidly) as a re of an over dose, the specific antidote Tensilon should be administered immediately at the rate of 0.5 mg/Kg every 10 to 15 minutes until muscle tone is regained. If Tensilon is not available or its use undesirable, an animal may be kept alive for as long as 15 to 30 minutes by simple artificial respiration until the effects of the drug wear off.

Note: Flaxedil is not an anaesthetic but rather a synthetic curare-like substance which mer blocks the myoneural junction. When subjected to Flaxedil an animal does not lose consci ness and is normally capable of feeling pain and experiencing fear. Therefore, care must be taken not to subject an animal to undue sensory stimulation (pain, fright) while im- mobilized in this way.

III. Hormone Treatment

A failure of the adrenal cortex has been postulated in some instances as the cause of death following certain types of stress or prolonged shock. It has also been shown that adrenal corticoids may have a beneficial effect in certain types of shock and that pre- treatment with these substances will help protect the organism. The purpose of the following experiments is to determine if these measures will be effective in combatting captivity mortality in the sea otter.

-3- Treatment Procedures - Experiments with Sea Otters

A- DOCA: 4-pack long acting DOCA (Adrenosterone) [illegible] be the same given under "Drugs and Dosages". This material will replace the natural mineral corticoid activity. Note response to treatment and effect on captivity survival.

B- DOCA: Implant pellets of D.O.C.A. (according to directions given under "Drugs and Dosages"). This is a synthetically produced form of the adrenal corticoid hormone to supplement the animals own adrenal cortical production. Note response to treatment and effect on captivity survival.

C- Cortisone: Inject cortisone (cortone) suspension or implant cortisone pellets (according to directions given under "Drugs and Dosages"). This is another available adrenal corticoid hormone which supplements that produced by the animal's own adrenal gland. Note response to treatment and effect on captivity survival.

IV. Glucose Administration.

It has been shown that squirrels and [illegible] suffering from shock diseases can be helped by augmenting blood sugar. The purpose of this experiment is to determine if it is true in captive sea otters.

A- Glucose Injection: Inject 10-15 cc of a 10-15% solution of glucose intraperitoneally whenever it appears that this may be beneficial (e.g., labored blood urea, apparent muscular weakness). Closely observe animal. If injection has apparent beneficial effect, continue to repeat as long as desirable results are exhibited.

Directions for Filling Out Data Sheets
Sea Otter Project.

The success of this project depends upon the quality of the information recorded on the Data Sheet. No matter how well the work is done, its value still depends upon the amount and accuracy of the recorded data. If the space available is insufficient, make additional notes, referring to the Data Sheet and number of the animals, on blank pages. Vivid impressions received at the time the work is done are dimmed, contorted, or forgotten in time. This is a particularly important consideration in this project since it will be weeks, and perhaps months, before all the data can be analyzed.

Time and Date: The time of death is most important since results of some of the procedures must be interpreted with regard to elapsed post mortem time. Record to the nearest minute.

How killed: Tell exactly what killed the animal. If shot, give the path of the bullet through the body and amount of tissue destruction.

General condition or health: Give best subjective evaluation of the animal possible, ranging from apparently normal to descriptive of specific abnormalities in the living or freshly killed animal. This should be the impression gained before doing the physiological procedures.

Procedure: The procedures listed on the data sheet generally follow the outlined Master Procedures I and II; however, they do not correspond numerically.

Time: (post mortem) This should be recorded as the elapsed time between death of the animal and beginning the specified procedure. It should be given in minutes and hours, not time of day. Stars in this column indicate critical times.

Results: Entries in this column are usually obvious. In some cases, e.g., pituitary, ACTH, liver, glycogen, results will not be determined until a later date, so leave space blank. However, be sure to record time.

Remarks: This column is to be used to qualify or enlarge upon results. Under number 5, Blood Collected, state the type and amount of anticoagulant used, if any. Under number 8, Autopsy, a-p, note the type fixatives used for each tissue. Under number 9, Lyophilization or Sublimation, record the time it took to complete the process. In the event that any procedures are not performed, explain why. Such notations may be valuable in setting up experimental procedures for future investigations. It is expected that additional blank pages will be necessary to include all pertinent remarks.

Study the sample data sheet and refer back to it when undecided how to record a particular item of data.

4. Liver glycogen *

5. Blood collected *

a. blood sugar

b. RBC's

c. WBC's

d. eosinophils

e. hemoglobin

f. hematocrit

g. specific grav.

h. blood smear

6. Tissue moisture *

a. leg muscle

b. diaphragm

c. liver

d. brain

e. other

7. Organ weights *

a. pituitary

b. adrenals

c. kidney

d. liver

a. brain	
b. heart	
c. lung	
d. spleen	
e. stomach	
f. duodenum	
g. ileum	
h. jejunum	
i. colon	
j. lymph node	
k. thyroid	
l. pancreas	
m. bone (rib or sternum)	
n. other	
7. Lyophilization or sublimation	*
a. blood	-
b. tissues	
8. Reproductive tract, weight,	*
a. testis/ovaries measurements,	
b. testis/ovary weight	
c. accessory organs	
d. fetus	

Appendix 2.

THE BEHAVIOR OF SEA OTTERS IN CAPTIVITY

Although the behavior of wild sea otters in their natural environment has been described* nothing has been published concerning their behavior in captivity, primarily because heretofore it has been impossible to keep them alive for more than a few days. During the course of this work more than twenty sea otters of both sexes and all ages were held in captivity for periods ranging in length from a few hours to more than three months. Because of their phlegmatic nature in captivity it is possible to observe them very intimately without disturbing them, and to describe certain activities which might be obscure to, or misinterpreted by a more remote observer. The subjects for most of these observations were three subadult, probably yearling, sea otters: two females (Hortense, 19 3/4 lbs, and Aggie, 24 lbs) and one male (Peter, 25 lbs).

Form and Appearance The length of the adult sea otter is four feet more or less and adult weights range from 35 to 80 pounds, the latter in extremely large males. Although at home in water, the body is pendulous and poorly supported on land by the relatively short, muscular limbs. The fore paws are pad-like with no separation of the digits although the terminal phalanges are movable and give great flexibility to the tips of the paws; short and slightly curved claws are normally retracted onto the back of the paw but may be extended forward beyond the tip of the paw. The hind foot is a broad, flipper-like structure, fully webbed, each digit with a nail-like claw above and terminal callouses below. Unlike the forepaw, the hind foot is furred on both sides and all phalanges are mobile. (In the following discussion the fore feet and hind feet will be referred to as paws and flippers respectively).

The musteline head is flat and blunt with a small dark eye and a small external ear which is fleshy, vascular, naked, and twisted upon itself. A blunt, black nose pad separates stiff, decurved but mobile vibrissae.

*Fisher, Edna M. 1939. Habits of the Southern Sea Otter. Jour.Mamm., 20(1), pp.21-36
*Jones, Robert D., Jr. 1951. Present Status of the Sea Otter in Alaska Trans. 16th N.A. Wildlife Conf., pp. 376-383.
*Murie, Olas J. 1940. Notes on the Sea Otter. Jour. Mamm., 21(2), pp. 119-131.

The body fur is dark, soft, and luxurious with fine dense guard hairs and under fur, but the head fur has a bristled appearance. In some individuals the head and neck is a contrasting buff color and grizzling of guard hair tips is common in older otters.

The skin are remarkably loose upon the body, even about the head, and is not underlain with blubber as in other marine animals. On the chest extending from one axilla to the other is a capacious fold of skin. A pouch for holding food is formed as needed by the otter's manipulation of this loose skin; however, it is not an enclosed structure like a marsupium.

Sleeping The usual position was on one side or supine, rarely prone. In any position the head and neck were usually turned to one side with the hind quarters curved or straight. The paws of the sleeping otter were held either rigid or relaxed, usually with the palms held together beneath the chin or pressed tightly over the ears. In the latter position the muzzle was thrust into the pouch region. At other times the head laid upon the palm of one paw, the other paw relaxed under the chin or extended outward or upward. The flippers were usually spread, plantar surface down, with the tail straight back, but commonly one or both of these flexible structures turned at nearly right angles to the long axis of the body. Occasionally when prone, the flippers were flexed forward under the abdomen. When supine an intermittent reflex raising, spreading, and outward rotation of the flipper was suggestive of sculling. (This reflex also occurred when the otters fed on their backs). Breathing movements, occurring at a rate of about 12 times per minute, were accompanied by slight nostril dilation and twitching of the vibrissae. Otters in sound sleep on a wooden floor apparently were not awakened by gentle walking or normal conversation a few feet from them.

Preening Preening was intensified when the fur was wet although the otters preened regardless of the condition of their fur; this activity might be considered a nervous reaction.

When preening any position was assumed. When supine the head was brought up and the nose was thrust into the fur of the chest or abdomen and rapidly rubbed from side to side with snorting and blowing while the paws rubbed sides, haunches, face, ears, or neck with rapid rotary and to and fro motions. Folds of the loose body skin were repeatedly gathered and "scrubbed" vigorously between the paws. The paw movements frequently were not synchronized; one might be rubbing the head while the other rubbed or even patted some other part. Hortense was very adept at rubbing the right elbow with the left paw while rubbing face with back of right paw. With arms folded before the chest, the paws rubbed opposite forelegs or shoulders simultaneously or the backs of the opposite paws alternately. In this action the digits of the paws frequently extended outward away from the palm. There was much snake-like wriggling on the straw, accompanied by pushing of the flippers against the floor and ear rubbing while the otters were on their backs, sides, or bellies; in the cage the wire was used for a rubbing surface for head, neck, and sides. When the fur was wet, vigorous shaking of the head and neck was done in nearly all positions, occasionally accompanied by a flipper scratching the shoulder region. Vigorous shaking in a half-reclining position swung the paws away from the body centrifugally, and even rotated the whole body to some extent.

Dried grass was used by the otters in preening. When permitted freedom of the "otter house", the otters sought the drier areas of straw for preening and sleeping although the warmer spots in direct sunlight were usually avoided. Wriggling in the straw has been noted above. When reclining the otters occasionally drew bunches of loose grass toward and over themselves, rubbing it between the paws and against the body. However, this behavior was not sustained very long at a time. When soiled, damp, and matted litter was exchanged for clean and dry grass, interest in grass increased and the otters frequently climbed into the box containing fresh bedding. Handfuls of grass dropped directly upon the animals were apparently enjoyed.

In any position the skin was moved to and fro, mainly in the abdominal and

lower back region, less about the shoulders. This is done by contraction of dermal muscles; it is not a rapid twitching as the fly-flicking of horses' skin, but a slower peristaltic-like wave easily followed by the eye. Its purpose may be to separate the water-matted fur by raising the guard hairs to an upright position, although the movement also occurred when the fur was dry or nearly so.

The tail was preened with either paws or flippers. From a supine position the otter flexed the head and upper trunk caudally between the flippers to grasp the tail with the paws. (The lower back region was also reached in this manner, with the chin resting on the base of the tail and the paws reaching over and past the tail to rub the back fur). The tail was worked over by the paws when body was in other positions. The dexterity of the flippers was demonstrated when the curved and tensed tail was held tightly and rubbed between the plantar surface of one and the dorsal surface of the other.

For a few hours after capture, especially when wet and/or nervous, the chest and less commonly the sides and haunches were vigorously slapped with the paws. This activity resulted in water flying from the fur and paws but it may have been primarily a nervous reaction since it was particularly noted immediately after capture. Depending upon conditions and size of the otter, the slapping sounds are audible for some distance.

Licking the fur was not common although the chest and belly perhaps were licked when the muzzle was held against these parts. The tongue was rarely seen as the muzzle moved about in the fur, and there was no sustained licking of one area as seen in dogs and cats. The tongue was not used to clean the face, lips, or paws although an artificial feed supplement stuck to the paws in quantity. Occasionally when preening it appeared that the fur of chest or forearms were nibbled or chewed.

Reaction to Handling From the first moment of capture, definite individuality of response was shown to handling as well as in other behavior. Generally the newly caught otter fought the net by twisting and rolling while biting at the net or any

other object within range of its teeth. Smaller animals of 18-25 pounds required little restraint and usually lay sullenly on their backs with head erect in the cage, tub, or bottom of boat. This was not cowering but an alert defensive position from which the otter could rear or lunge the full length of the body to snap at any offending object. Such attempts to bite were accompanied by hissing and rattling snarls but no sustained growls. The urge to escape dominated and new captives were not ordinarily aggressive unless forcibly restrained or provoked. As the otter reared to snap it often used one or both of its paws with surprising speed in an attempt to grasp the irritating object. A hand touching the neck or back of the head was easily grabbed by the upward reaching paws, and if not quickly withdrawn, was scratched or bitten.

Since the skin is extremely loose over the entire body, the otter can bite the hand holding it by the scruff. Small otters up to 25 pounds were momentarily restrained by grasping the neck from behind with both hands although the snapping jaws come close to the fingers on both sides. When held in this manner, the paws, and less commonly the flippers, are used with considerable force to dislodge the hands.

Bites usually resulted from carelessness or from deliberate handling when the bite was anticipated and prepared for. Injuries from bites are usually pinches which may or may not break the skin. Hortense was the most easily handled, probably because she received the most attention, but even after three weeks she objected to being touched. Preparatory to lifting her, she was first induced to bite and hold a mitten loosely covering the hand, and while thus preoccupied, she was then picked up and gently cradled in the arms. Apparently as soon as the otter's body was securely supported, the animal lost interest in biting and could be carried short distances or held for several minutes. Peter was less docile and Aggie resisted all handling violently.

Unless being handled, the otters usually ignored human presence, movements, and sounds after a few days in captivity. Flash bulbs, lantern light at night, and

unusual sounds (gunshot, carpentry, shouting, or whistling), elicited only passive interest. No signs of affection for man were noted. The close presence of people was tolerated, even to the extent of lying on the feet or resting against the legs of the person feeding them. Hortense, the most active and curious, climbed upon persons while exploring, but any other contact not self initiated, such as petting or that occasioned by some examination, was swiftly rejected.

Feeding In this activity also the otters showed great individuality. The remarkable fact that some wild sea otters accept food from human hands shortly after capture has been noted a number of times in the Narrative Reports of the Refuge Manager of the Aleutian Islands National Wildlife Refuge. Otters kept at first in the dry cages did not immediately come forward for food, remaining in a far corner on the defensive. They would eat, however, if food was thrown or offered to them on a stick. One newly caught otter, while swimming in the holding tank, approached the outstretched hand and took food in its mouth or paws, turning upon its back in the water to eat in the usual manner. Sea urchins and limpets tossed into the tank were speedily retrieved by the otter with an alertness and rapidity that belied its recent capture. The invertebrates were recovered in one or more quick dives, and the lot held with the aid of one arm and the loose pouch skin while the items were eaten one by one. Another otter on its first day of capture readily accepted pieces of goose and seal (including muscle, viscera, and bones) while resting on the rocks in the holding tank. Holding extra pieces of food beneath one arm it tried to secure additional morsels offered to two other otters in the tank. One of the latter, after refusing food for 24 hours while he was alone in the tank, began feeding as soon as two other otters were placed in the tank with him, though he remained quite shy. The third otter of this group was so fearful that it probably consumed no food before its death a day later.

The kind of food offered was determined mainly by availability although considerable effort was made in the case of several otters to present them with a

variety of foods in an attempt to find the most palatable and that which seemed to stimulate their appetites. Limpets, blue mussels, sea urchins, periwinkles, hermit crabs, and starfish were gathered in small amounts from the rocks at low tide. Kelp greenling was the only fish consistently caught in traps and on set lines. An occasional octopus was taken clinging to the fish traps. Of these foods the kelp greenling made up the bulk of the diet and was consistently palatable, at least with the three otters which were maintained long enough to establish preferences in their feeding habits. All of these otters were fond of limpets, blue mussels, and octopus, but one would not eat starfish which were relished by the other two. One otter was an indiscriminate eater, cleaning up fish skin and fins after others, and also stuffing on commercial filet of sole, which was rejected at first by the other two. Small amounts of Teralac*, a dried milk-like substance, were added to the diet periodically.

The kelp greenling were usually held in a live tank and fed fresh. The fish were cut into small chunks and the bones of the heads and vertebrae were chopped finer. On large fish the spiney-rayed fins were discarded. The viscera were usually pooled and divided equally among the otters in the interest of a complete diet.

The otters soon learned the meaning of the appearance of the bucket of fish and the hand axe used for chopping fish. Various begging attitudes were assumed, but for the first pieces the three animals would be directly underfoot or trying to climb up the leg of the person preparing to feed them. Chunks were grasped in the teeth (or in the paws if the otter was on its back) and the otter usually lay on its back to eat. Larger filets were held edgewise in the paws and strips of flesh pulled off with incisors. The molars were used to crush bones and to mash muscles from which the skin was then stripped. Small pieces of skin were thoroughly chewed and swallowed, but larger pieces were often cleaned of flesh and then discarded. The otters

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*Teralac was supplied for this work by Chas. Pfizer and Co., Inc., Brooklyn, New York.

masticate their food much more thoroughly than other carnivores; there was no gulping or "wolfing" of chunks.

Apparently any position the animal happened to fall into after receiving food was satisfactory for eating. Occasionally an otter lay on the belly with head and upper body twisted to either side. In this position straw frequently got into the mouth with the food, and although some was withdrawn by the paws, it was commonly ingested and found in the feces.

Mollusks were eaten with gusto. Smaller limpets, blue mussels, and snails were chewed up entire with loud crunching noises and then swallowed. Larger limpets were usually extracted from the shells by holding the mollusks' flesh against the lower canines and pulling downward on the shell with the paws. If this was not successful, the shell was held with the paws at the side of the mouth and cracked by the molars; the pieces were then cleaned in the same manner as the whole mollusk.

Octopus, available on a few occasions, was favored by the otters. All parts were eagerly accepted and eaten. When the tentacles were chopped into chunks or small lengths, the still functioning suckers sometimes clung to the otters' faces or more often their palates or pharynges. The latter difficulty was attended by attempts to scratch in the open mouth (similar to a dog's behavior with caramel or peanut butter in its mouth) or the tentacle was forcibly withdrawn with the paws; a morsel lodged further down caused much gagging and hawking until it was dislodged, retrieved and chewed again. The otters' persistent and successful efforts to swallow octopus tentacles indicated the high palatability of this mollusk.

Drinking When water was offered to captive otters kept in a dry environment, the animals attempted to get into the water as if to swim. The water in a bowl, pan, or bucket was usually tipped or pawed out, then rolled in. This made the use of small quantities of water for drinking impractical; however, snowballs provided acceptable substitutes. The snowballs were held in the paws like food and the otter bit off, chewed, and swallowed small pieces. Two snowballs of baseball size

were often consumed without stopping. Later a large tip-proof pan was provided with wooden guards to prevent the otters' crawling into the water. Water one-half inch deep was lapped with the tongue while the lower jaw rested on the pan bottom. There was no head motion, and although the nostrils were not submerged, considerable bubbling and slobbering were heard. When water was deeper in the pan, it was difficult to tell whether the water was lapped or sucked up because the head was dipped into the water and swished about while one paw swirled the water in the pan. It is not known whether wild otters require drinking water as such, but three captives held in a dry environment consumed about a gallon of fresh water daily. No conclusive observations were made to determine whether sea water would satisfy their water requirement.

Locomotion When walking the peculiar hobbling gait of the sea otter is not unlike that of land otters, though more clumsy. The shoulders are considerably lower than the hips with the lumbar region arched even higher; the head is held higher than the shoulders; the tail may drag or be held at an upward angle. Ordinarily the otters do not remain standing when not moving, but drop at once to their bellies, sides, or backs as soon as they stop.

At the usual slow gait the front and hind feet on opposite sides move alternately as in other fur-bearers. For short distances a laborious gallop is possible, with both fore feet hitting together alternating with both hind feet hitting together. At other times when in a hurry, there was no coordination as the short fore legs moved rapidly together or alternately and the hind legs moved more slowly. At a slow gait the flippers sometimes were placed outward about 30 degrees from line of forward motion and at other times the toes were directed straight forward.

One otter was adept at climbing upon anything offering a purchase but it was never seen to leap straight upward although jumping from a cot to a higher table about two feet away was attempted. It frequently made downward jumps of about two fe

Sociability For the most part the otters ignored each other. During the first

few days of captivity and after learning to take food from human hands there was some bickering and struggling for the same piece of food; but no fighting or mauling of a serious nature ever occurred. The competition for food was perhaps the result of extreme hunger. In some instances the larger animal stole from the smaller but rarely bullied. On one occasion Aggie crawled upon Peter's belly and lunged for fish in his paws which he quickly pulled back with a vocal "ha-ah-ah-ah." Another time after several unsuccessful attempts, Aggie grabbed the prize from Peter and he objected only with a low, explosive "oof" as the fish was jerked away. His other vocal objections to attempted thievery were a series of grunts "ugh-ugh-ugh." Hortense, the smallest, was usually led away from the others to prevent her being molested, and as long as more food seemed at hand for the others, she was seldom pursued and robbed. Hortense herself stole food from a weak captive she had seen but a few minutes before.

At a later time when the captives seemed in better physical condition as shown by gains in weight, bickering at feeding time was rare and little competition marred their docile behavior. When all otters had food to preoccupy them, they lay side by side or even leaned against one another while eating. Tidbits could be fed to one otter within inches of another's nose without interference. There was no indication that the otters either sought or avoided the immediate company of their pen mates. It was probably accidental that they sometimes rested against one another while preening or sleeping. No playing or any other signs of interest between otters was observed. However, when one otter was isolated or separated from the others it became very uneasy and upset, frequently voicing its displeasure with loud squeals or shrieks.

Voice The loudest vocal effort was a multi-syllabled shriek, variable among individuals, and phonetically rendered as "eeee-eeee-eh" or "eeee-uh" or "eeee-er". The first syllables always characterized by high pitch were uttered either with a quaver or as a clear, shrill shriek. The last syllable was a much lower tone of

short duration, like a grunt, and was inaudible at a distance of more than a few feet.

Captive otters in great distress, particularly moribund animals, uttered combinations of these sounds in high-pitched, ear-piercing screams. One young pup of four and one-quarter pounds probably less than a week old, cried continuously with a two syllabled "eee-ee", giving utterance about every two seconds. (This crying of the dependent pup was often heard from the wild animals, and at a distance resembled the mewing of a kitten). Hortense usually squealed with mouth open, the nose turning up with the last syllable. The otters squealed in any position and at any time except when sleeping. Restlessness while calling usually seemed to indicate that the otters wanted company or were hungry or thirsty.

A series of low, soft grunts "uh-uh-uh-uh" were uttered by otters feeding together. Other grunts of objection were given as described before as well as vigorous hawking in attempts to clear the throat. Other sounds made by the otters, in addition to the slapping noted before, included rumbling belches following eating and drinking, and audible flatus. Hiccupping commonly occurred but this was not accompanied by audible sound.

Elimination and Sanitation The otters showed no signs of establishing a midden or of any fastidiousness in their excretory habits. Fluid or semi-fluid feces were dropped spontaneously. Defecation usually occurred in a standing position, tail raised, rectum partially prolapsed, and was accompanied by urination. The animals ignored the scats, treading or avoiding them purely by accident.

Appendix 3.

SUGGESTIONS FOR FURTHER INVESTIGATIONS OF THE SEA OTTER

The results presented in this report represent only a bare introduction to a complete understanding of sea otter physiology. Much more must be learned before it can be hoped to successfully work with, and efficiently manage this animal in the field as well as in the laboratory. The following suggestions for further investigations, based upon the experience and results of the current project, would yield important additional information for a better understanding of the complete picture.

These suggested investigations are divided into three groups. The first, field observations of the sea otter and its environment, will help to explain some of the results which have been or will be obtained from captive animals. The second group are experiments on captive animals of a completely practical nature, the results of which should greatly improve the management of sea otters in captivity. Finally, we present suggestions for research of a primarily fundamental, physiological nature. These should not be overlooked since they will be a source of data, not only of interest from an academic standpoint, but will also serve to elucidate the results of the more practical research, and suggest additional areas for profitable investigation.

I. Field Observations:

A. Environment.

1. Measure the air temperature, humidity, and movement at or near sea level in the immediate vicinity of sea otter hauling grounds, including daily, seasonal, and yearly fluctuations. Find out exactly what conditions the otters are subjected to regardless of the general weather picture for the area.

2. Measure the water temperature at the surface and on the bottom, and the water movement (tides, currents, and wave action or mixing) in areas used by sea otters, including daily, seasonal, and yearly variations.

Water movement may be influenced by the presence of kelp or rock formations at certain seasons or in certain places. (Water movement might be determined by use of a sea-dye marker, noting the rate of dissolution and dissipation.)

B. Sea Otter Habits.

1. Determine the relative amounts of time spent by the otters in and out of the water, and the amount of time spent feeding, sleeping, etc., at various seasons of the year.

2. Determine if there are any seasonal movements of the otter population centers (even if only a few hundred yards) at various seasons of the year.

C. Correlate, if possible, the activities of the sea otters ("B" above) with the environmental fluctuations ("A" above), and establish environmental tolerance limits.

II Management of sea otters in captivity.

A. Environment.

1. Determine the high and low temperatures at which distress is noted in captive otters. Are these values influenced by humidity or air movement?

2. Determine whether captive otters can be maintained successfully if allowed limited or unlimited access to a water tank for swimming. (A dry, sheltered area should be provided for otters to haul out in.)

B. Feeding.

1. Determine the minimum quantity of food and the longest interval between feedings on which the sea otters can be maintained without loss of body weight.

2. Keep food continuously before the otters and note the frequency of feeding, quantity consumed, and whether or not they establish any pattern

or schedule of feeding on their own.

C. Water

1. Determine the amount of water consumed per otter per day.

2. Determine whether water requirements may be met with sea (salt) water.

3. Do the otters have any preference between fresh and sea (salt) water?

D. Pathological.

1. Seek to determine whether the otters have any latent infection of a bacterial or viral organism which might be the cause of gastro-enteritis.

2. Carefully examine all animals dying in captivity for evidence to corroborate or dispute the findings presented in this report.

III. Fundamental physiology.

A. Metabolism.

1. Determine the resting metabolic rate of the sea otter shortly after capture and after several weeks of captivity.

2. Determine the magnitude of effect of enviornmental temperature changes on the metabolic rate.

B. Temperature Control.

1. Study the temperature control mechanism in the sea otter.

2. Determine the insulation value of the sea otter pelt, both wet and dry.

C. Study water metabolism and excretion of the sea otter.

D. Pursue the endrocrinological studies of the sea otter, particularly regarding its defense against stress, as proposed in Appendix 1.