ADDITION TO TASK ORDER NO. 1

BASIC CONTRACT NO.

for

PROPOSED WORK DURING TEN MONTH PERIOD

23 April 1966 - 23 February 1967

INTRODUCTION

Our proposed plan for research and development for the next ten months is described below in five major task areas. However, the overall objective remains identical to last year's goal: that of being able to provide the client with rapid, flexible services in engineering, electronics, animal behavior, and operations analyses. New technical and biological developments will continue to be reviewed so that we can maintain a facility for answering and anticipating needs. In order to maximize the capability for meaningful response and planning, it is proposed that the practice of periodic contacts between the Technical Monitor and Task Leaders remain in effect, and increased where possible.

The five task areas are:

- ad hoc consulting on special problems
-
- animal capabilities
- animal guidance
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A DOSSIER ON PINNIPEDS (SEALS)

SUMMARY & CONCLUSIONS

A survey of pinnipeds (seals) was made to determine their ability to be trained. Information on their sensory abilities, physiology, and anatomy was also accumulated.

It was found that of all the kinds of pinnipeds, the sea lion (Zalophus californicus) and the common harbor sea (Phoca vitulina) were the ones most easily trained. Other types were rejected because of apparent lack of intelligence, large size, or scarcity of the species.

Data on their abilities indicate that Zalophus is superior to Phoca in size, locomotion rate, strength, and ability to perform certain circus-type tricks. Phoca, on the other hand, is superior to Zalophus in terms of ability to swim immediately upon being born, eats more omniverously (and less), and can probably swim faster. Phoca is reported to do a greater number of things because he is usually kept as a house pet while Zalophus usually performs more exacting routines in the circus or zoo. Both seem equally intelligent and seem to possess equal sensory abilities.

Both are readily available at the proper time of year. Zalophus costs about $100 (up) and Phoca $25 (up). Maintenance costs for Zalophus are correspondingly high.

WHAT IS A 'SEAL'?

A 'seal' is any of the suborder pinnipedia of the order carnivora. The seal is a flesh-eating animal that presumably returned to the sea and evolved into his current physical form. Sea cows, manatees and dugongs are not seals, but rather herbiverous animals who, as the whales, may have never initially left the sea environment. There are three families of pinnipeds:

Family 1: Otariidae (The eared seals)

The fur seal (Callorhinus alascansus)
The stellar sea lion (Eumetopias stelleri)
The sea lion (Zalophus californicus)

Family 2: Odobenidae (The walruses)

The arctic walrus (Odobenus)

Family 3: Phocidae (The 'true' seals)

The common harbor seal (Phoca vitulina)
The harp seal (Phoca groenlandica)
The hooded seal (Cystophora cristata)
The sea elephant (Macrorhinus leoninus)
The grey seal (Halichoerus grypus)

Thus, a 'seal' is either the sea lion (Zalophus) that we see performing in the circus, or it is the common harbor seal (Phocida) which also is commonly called the sand seal; or the grey seal (Halichoerus) which is sometimes called the Atlantic Seal. Other

seals (harp, hooded, hair, walruses, and the like) are less common because they inhabit remote arctic waters.

The only seals commonly trained have been:

1. The california sea lion (Zalophus californicus)
2. The harbor seal (Phoca vitulina)

The other seals are either hostile, very large, unintelligent, or will not live in temperate climates.

Following is a list of characteristics of the two types of seals which, for simplicity, I call Zalophus and Phoca.

Name	Length	Weight Male	Weight Female	Dentition
ZALOPHUS	10'	2,000	600	$I\frac{3}{2}, C\frac{1}{1}, P\frac{4}{4}, M\frac{1}{1}$
PHOCA	5'	50-60	50-60	$I\frac{3}{2}, C\frac{1}{1}, P\frac{4}{4}, M\frac{1}{1}$

FOOD AND FEEDING

Young seals are difficult to feed. Transition from liquid to solid food is difficult and should be accomplished as early as possible. Enteritis common and usually fatal - anti-biotics helpful.

Feed seal pups 50% cows milk, 50% animal oil of any sort, add 3 tsps cod liver oil per feeding, emulsify with tragacanthus gum. Feed via bottle or intubation (Tube cannot enter lung accidentally). Fill animal to overflowing. Animal will burp, groan, roll over and appear dead but is only sleeping. Add vitamin 'B' complex (B_1 critical) to diet. May be taught to catch own food but not recommended. Adult animals will eat dog food, cat food, agricultural fish meal (fertilizer), vegetables, soups, etc. Very omniverous. Starving animal will swallow stones, occasionally when not starved; will regurgitate them voluntarily.

In the wild they eat crustacea, fish and squid.

Zoo Diet: Zalophus (600 # male): 96 pounds/week

Butterfish - 48#
Mackerel - 24#
Smelts - 24#

Phoca (70 # female): 28 pounds/week

Mackerel - 28#

HEARING

The auditory acuity of both Phoca and Zalophus seems to be quite acute in air. Little is known about their hearing ability in water although it is reported that they emit sounds (clicks) which might be used for proximal echo-ranging. Zalophus calls were short bursts of clicks at rates up to 50/sec with frequencies ranging from 600 to over 1,000 cy/sec. These clicks were also recorded in the 'bark' that Zalophus makes in the air. Phoca's signals (clicks) were of less intensity than Zalophus' and each of the subspecies of Phoca had a major component near 12 kcy/sec. The fact that both Phoca and Zalophus respond to the human voice indicates sensitivity in the 325 to 2500 cy/sec. range. Although active echoranging might be of minimal effectiveness it is generally agreed that all pinnipeds possess excellent passive listening capabilities.

LOCOMOTION (LAND)

Phoca travels poorly on land - 10% flipper action and 90% bumping on his rig cage. Fatigues easily and can go about ½ mile in 8 hours. Zalophus, with forward-facing flippers can hurry along for several miles at about 1-3 mph. Greater rates seem possible. Phoca has been clocked going uphill at 1.5 mph and 4-5 mph downhill for very short distances. Presumably Zalophus could carry a load faster and farther than Phoca. Mobility is determined by the nature of the surface over which the animal has to travel.

LOCOMOTION (SEA)

Phoca can swim 15-20 mph and stay submerged 10-12 min. Zalophus can remain submerged for about 15 minutes and can swim 10 mph and possibly faster under duress. Again it seems likely that Zalophus would beat Phoca in load-carrying ability in the water, but mainly due to his greater physical size. Both have been taught to pull a small boat and retrieve objects. Both swim well in either salt or fresh water.

VISION

Both Phoca and Zalophus seems to have the same visual capabilities and anatomy, so the single description following will serve for both.

Cornea is flatish and serves well both in water and air. There is the possibility that there is also some muscular adaptation which also helps vision in both water and air environments. Reportedly can see color. Can detect hand waving handkerchief 120 yards away. Can follow trajectory through the air of a stone 1" in diameter thrown 40 feet through an arc 20 feet high. Vision not necessary to survival because blind healthy seals have been captured. No ducts to remove tears to nasal passages, so eyes overfow with tears that run down their cheeks and may influence vision.

ON DIVING

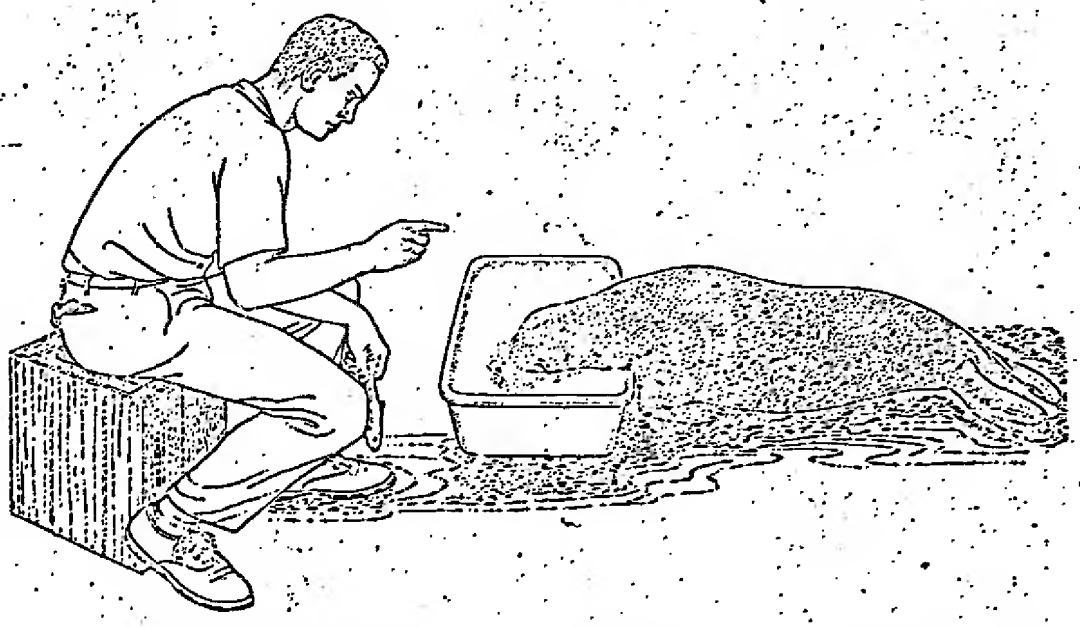
Seals will dive to different depths depending upon whether they are sleeping, playing, or fishing. The seal usually plays in shallow water near the shore and likes to dive in waves. The sleeping seal usually seeks quiet water and will sleep in 0 - 15 feet of water. The 'sleeping' seal will come to the surface, take several breaths (10-20), and sink to the bottom again without opening his eyes. The sleeping seal remains on the bottom between 5 to 10 minutes before repeating the respiration cycle. Afloat they breathe more regularly.

While fishing the seal will follow food to great depths. Shrimp and other crustacea which are found in deep water lead seals to depths of approximately 1,000 feet. Seals have been caught in nets at 900 feet. Researchers have lowered seals to 1,000 feet with no apparent damage to the seals. It should be noted that the seal exhales before diving and calls upon a lower heart rate (10 beats/ minute) and oxygen reserves in the blood and other tissues to sustain itself up to one-half hour in extreme cases. Other physiological mechanisms such as low lactic acid formation also help the seal endure asphyxiation.

There is evidence that deep dives for long duration result in

nitrogen narcosis and embolism in the seal.

The Weddell seal has been tracked to about 800 feet in his quest for food. It seems likely that depths in excess of 1,000' would be neither safe or common for the seal.



VOLUNTARY DIVING eliminates any possibility that restraint affects the seal's responses. This harbor seal (*Phoca vitulina*) is being trained to keep its nose under water until the experimenter lowers his warning finger and instead displays the reward, a fish.

From: Scholander, P.F. The master switch of life. Scientific American, December, 1963

MEMORY AND LEARNING

Both Zalophus and Phoca seem to have excellent learning ability and memory. Zalophus has been used in public demonstrating balancing, musical, and other abilities. Phoca perhaps has more written about him as an intelligent pet who can be housebroken, learn commands, and perform a few useful acts.

Phoca has been reported to respond to 35 words such as basket, here, in, out, ball, sing, swim, mouth organ, stick, trumpet, plate, mackintosh, and others. He would stay in a boat, go overboard, swim forward, abeam, or aft on command. Would get the mail and carry it home. Also carried and unpacked a picnic basket. List of clever behavior long.

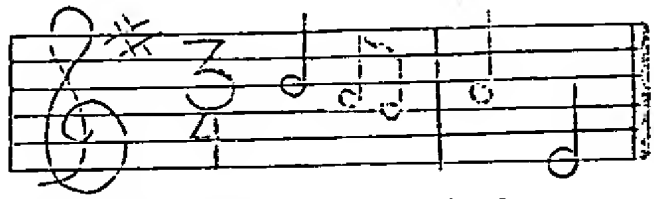
Has a fair time sense in that he can predict events that occur twice per week. Remembers geographical locations after a period of two years. Also remembers locations of holes in ice which implies navigational memory.

In general Zalophus and Phoca both seem to learn readily and will retain habits for a great length of time.

SEAL TALK AND SONG

Seals seem to able to communicate and express themselves in terms sufficient to establish territorial boundries and to indicate pleasure. They can emit a bark, click, or roar and have been able to "sing" according to some experts. (See section on hearing for details on frequencies of 'clicks'). They have a large range of vocal ability. Their 'singing' has been recorded (see song below), and history is available of times when seals were called and sung to by fisherman and indeed the seals responded by approaching the singer and even falling asleep.

Ability for seals to play musical instruments indicates at least sensitivity to a great range of sounds and also a certain degree of adiance toward these sounds. However few of the sounds seals make(other than roars of rage) seem to carry much information.



Note: The 'musical ability' of pinnipeds should not be considered unusual when we take the complex but repetitious songs of birds so much for granted.

SOME GENERAL PHYSIOLOGY & ANATOMY

Composition of milk: (General)

Water	46.4 %	Protein	9.7%
Fat	42.0 %	Ash	0.85 %

Percent body weight: (Phoca)

Brain	0.63	Kidneys	0.70
Eyes	0.18	Adrenals	0.007
Heart	0.73	Liver	2.81
Lungs	1.85	Spleen	0.32
Thyroid	0.008		

Bones in body - 176 plus 7 (if not fused). (Phoca)

Breeding (Zalophus)

Puberty - about 3 years of age
Breeding season - June-July
Gestation period - 348 to 365 days
Litter size - 1
Estrous appears as isolated event in breeding season.

Composition of seal meat : Protein 19.1 % Fat 10.6 %
Carbohydrates 1.4 % Water 66.0 %
Other 2.9%
Calories per 100 g = 183

Minerals in seal meat : (mg / 100 g)

Fe 11.4 mg Niacin 4.9 mg
Riboflavin 0.09 mg
Thiamin 0.04 mg

Excreted Nitrogen: (Phoca)

Ammonia- N (2 - 7.5)
Urea - N (61-90)
Uric Acid - N (6- 11)
Combined Creatine - N and Creatinine - N (9.1 - 31)

BMR (Resting) : 540

BLOOD	pCO_2 mm Hg	pH	Temp.	tension ½ saturation
Zalophus				
Phoca(Smaller number)	40 - 44	----	37 - 38°C	28-40 mm Hg

ANATOMY & PHYSIOLOGY .... CONT.

Heart Rate (Phoca) : 100/ min (10-140/ min. 95% range)

Blood Pressure: (130 - 140 mm Hg 95% range)

Body Temperature: (36.8 - 39.8 ^{o}C range among species)

Sex Ratios : Percent Male - 51% (48 - 54 % 95% range)

NOTE: The 95% range indicates that 95% of all readings fall between indicated values.

Bile Acids: "Beta"-Phocaecholic Acid ($C_{24}H_{40}O_5$)

Hydroxyl groups 3,7,23(?)

Melting point 22.2 -22.3^{o} C

Specific Rotation + 27

UN-RECOMMENDED PINNIPEDS

NAME OF ANIMAL	REASON(S) WHY REJECTED
Grey Seal (Atlantic) (Halichoerus grypus)	Will grow up to 8' in length, weight 2,000 pounds (male); smells terribly normally and worse when sexually aroused. Pups need to learn to swim.
Stellar Sea Lion (Eumetopias jubata) (Eumetopias stellari)	Very large (males up to 7,000 pounds, females somewhat smaller).
Alaska Fur Seal (Callorhinus alascansus)	Does not survive well in warm climates. Hunted but protected. Not known for their intelligence.
The Walruses (Odobenus rosmarsu)	Excpetionally large (males 3,000 lbs, females 2,000 lbs.) Cannot survive in temperate zones comfortably. Not very intelligent.
Hooded Seal (Cystophora cristata)	Large (male 1,000 lbs / female 900lbs). Sunburns readily , even in Arctic.
Harp Seal (Phoca groelandica)	Another Arctic seal. Notably affectionate to humans and hence easy to slaughter -- and considered to lack intelligence.
Caspian Seal Seal Elephant Lesser Seals	All of these are relatively rare (fresh water species) or reduced in number by hunting and hence are relatively unavailable.

RECOMMENDATIONS
(MISC. DO'S & DON'T'S)

To anyone wishing to train a pinniped it is recommended that:

1. All those who will be handling the animal should work with it from the day it is captured as a pup.
2. Use only females.
3. Get animal eating dead fish as soon as possible.
4. Never under any circumstances punish the animal. Use only rewards to reinforce desired behavior.
5. Train in the physical environment where animal will be used most, e.g. ocean, lake, pool.
6. For training in water do not use tanks immediately (use schnorkle and mask).
7. Provide bed for animal (soft surface). Treat all open wounds with tincture of benzoin if animal to go in water.
8. Eliminate any animal that bites.
9. See attached information and study selected references.

MISCELLANEOUS

Following is a list of miscellaneous information on pinnipeds:

1. Pinnipeds (Zalophus and Phoca) will live well in either salt or fresh water. Both dry rapidly upon leaving the water.
2. Zalophus migrates farther, but both travel well and have excellent homing sense.
3. Sense of smell useless under water but quite acute in air. Female can smell human if he has touched her pup.
4. Males generally more difficult to handle than females.
5. Phoca becomes immediately attached to any human who handles it during first few weeks of life. Dislikes of people may also manifest themselves rapidly --- but rarely.
6. Behavior will be influenced by sexual maturity unless steps are taken to prevent it (surgically or chemically).

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