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PROJECT QUICK FIND: A MARINE MAMMAL SYSTEM FOR OBJECT RECOVERY

by
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Work on a sea lion object recovery system was initiated in October 1969 and was completed, including an operational test, in December 1970.

This report was reviewed for technical accuracy by B. A. Powell and H. O. Porter. Special acknowledgment is given here to Donald I. McSheehy for his many contributions, especially for the behavioral conditioning of the animals used during the project, and to Ronald L. Seiple for his unique approaches to a most difficult hardware development effort.

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13 ABSTRACT

Project Quick Find is a recovery system that consists of two men, a rubber boat, a reel of nylon line, a pinger receiver, a grabber device, and a California sea lion. It was developed to provide the Navy with an effective alternative to the use of divers and submersibles for the underwater recovery of small objects.

During training sessions four California sea lions demonstrated the ability to locate and recover pingered objects from a depth of 500 feet. In an actual system demonstration they recovered an inert depth charge from 180 feet of water. The depth charge was 6 feet long and weighed approximately 500 pounds, but the breakout force required to pull it out of the ocean bottom was greater than 500 pounds. Recovery hardware was designed and fabricated that can be used by the sea lion to recover objects weighing approximately 2 000 pounds.

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SUMMARY

Objective

Project Quick Find is a recovery system that consists of two men, a rubber boat, a reel of nylon line, a pinger receiver, a grabber device, and a California sea lion. It was developed to provide the Navy with an effective alternative to the use of divers and submersibles for the underwater recovery of small objects.

Results

During training sessions four California sea lions demonstrated the ability to locate and recover pingered objects from a depth of 500 feet. In an actual system demonstration they recovered an inert depth charge from 180 feet of water. The depth charge was 6 feet long and weighed approximately 500 pounds, but the breakout force required to pull it out of the ocean bottom was greater than 500 pounds. Recovery hardware was designed and fabricated that can be used by the sea lion to recover objects weighing approximately 2,000 pounds.

Recommendation

The sea lion recovery system should be used to augment existing recovery forces presently being used to recover experimental and test items.

CONTENTS

INTRODUCTION

General

The use of conditioned marine mammals in an object recovery role was identified early by researchers working with marine mammals as showing promise in adding a significant capability to naval recovery forces.

This report will deal with the development and test of Project Quick Find, a recovery system involving the California sea lion *(Zalophus californianus)*. Specifically it will describe (1) the NUC animal training facilities at Kaneohe Bay, (2) the procedures by which the animals were selected and trained, (3) the selection process used to determine the optimum recovery system concept, (4) the recovery system itself–its operating procedures, its advantages, and its disadvantages, (5) the system hardware, and (6) the test and evaluation program, which culminated in the successful recovery of an ASROC Mk 17 depth charge from 180 feet of water.

Background

Objects lost at sea can be divided into those for which there are recovery requirements and those for which there are not. The known or estimated locations of a large percentage of the objects that must be found enable recovery forces to concentrate their efforts in a small area. Lost objects in this category include (1) prototype and exercise mines, torpedoes, and air-to-surface missiles, (2) aircraft that crash near airports or while in company with other aircraft, (3) missiles that impact in a planned area or in an unplanned area near their launching sites, and (4) moored oceanographic instruments.

The major problem areas of recovery are surface weather, surface and subsurface navigation, the effects of current, bottom topography, the limitations of and difficulties experienced by divers, underwater visibility for all light sensors, and target classification.

Saturation diving systems, manned and unmanned submersibles, and recovery aids such as pingers and transponders are among the most current tools for finding and raising lost objects. The consensus of some 35 persons interviewed who are concerned with recovery operations is that about 90% of the money spent to recover a lost object is spent on finding the object, and only 10% is spent on raising the object once it is found. Pingers and transponders are frequently placed on objects that are susceptible to loss at sea because they significantly decrease the cost and the time required to find a lost object.

Marine mammals have been used previously to locate and mark pingered objects for recovery; however, divers were required to complete the actual recovery, and the system was limited to safe diver working depths. It became apparent that a more practical system could be developed by using California sea lions to attach the recovery device to the object to be recovered. These animals had already demonstrated an ability to dive to depths greater than 500 feet at the Marine Bio-Science Facility at Point Mugu, California (Ref. 1). In addition, sea lions are relatively inexpensive and readily transportable.

Accordingly NUC formulated a development program for a recovery system that utilized the California sea lion. Emphasis was placed on the recovery of practice, test, and experimental torpedoes and mines currently being recovered by diver personnel and submersibles.

TRAINING AND HOLDING FACILITIES

Basic training and holding facilities were constructed as part of the project (Fig. 1). The basic training was conducted in the fenced area on the pier platform and in the individual holding pens (Fig. 2). The advanced training was started in the large fenced water area, and after the animals became proficient the training was moved to the open bay. The basic training area contained a work and storage area for training equipment. It also had electricity available to power repair tools or training equipment.

Figure 2 shows the individual sea lion cage area where the animals could be separated. Each pen contained a 2x2x3-foot fiberglass swimming pool to help the animals maintain correct body temperature. The individual holding pens were 3x6 feet, and when the gates were open the animals had access to a 20x20-foot communal swimming area, which was used when the animals were not being trained.

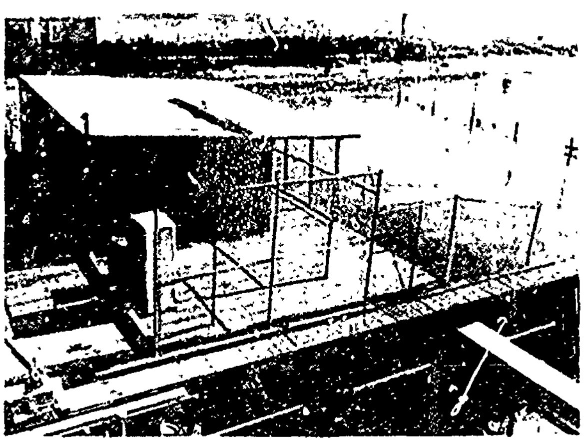


Figure 1. Training facilities.

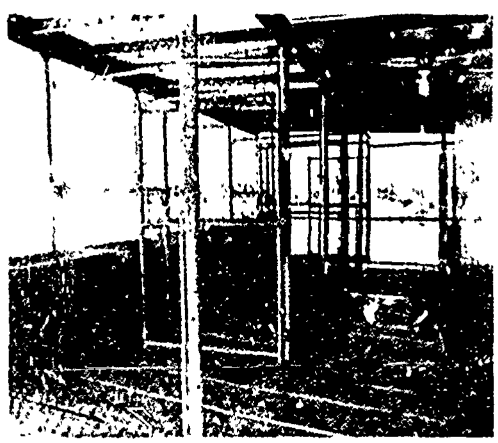


Figure 2. Individual holding pens.

ANIMAL SELECTION AND CONDITIONING

Selection

During the course of the project the animals listed in Table 1 were obtained through commercial sources or from NUC, Point Mugu. The initial goal of the project was to condition a minimum of four sea lions to perform recoveries. It was deemed advisable to procure at least six animals for training in order to provide some scope for selection and for the replacement of any animals rejected or lost through death or escape during untethered ocean work. Young animals were selected for the project because of the ease with which they can be captured, trained, and transported.

Table 1. Sea lions acquired by NUC.

No.	Name	Sex	Approximate Age, years	Weight, lb	Disposition
1	Akahi	male	2	67	Quick Find
2	Fatman	male	2	88	Quick Find
3	Sam	male	2	68	Quick Find (Lost animal)
4	Juneau	male	4	88	Quick Find (Died Dec. 1970)
5	Red	female	2	60	Rejected as hostile (University of Hawaii)
6	Al	male	2	65	Rejected as hostile (University of Hawaii)
7	Turk	female	3	95	Quick Find
8	Unknown	male	3	82	Rejected as unfit (University of Hawaii)
9	Unknown	male	3	69	Rejected as unfit (University of Hawaii)
10	Sniffer	male	1.5	45	Quick Find

The first shipment, in September 1969, consisted of animals numbered 1 through 9. During the adaptation to captivity phase of the training program, animals 5 and 6 proved excessively hostile, appeared to require intensive training before they could be handled, and consequently were rejected. Animals 8 and 9 showed very little progress during the hand taming and harnessing phase and they too were rejected. These four animals were given to the University of Hawaii for physiological research experiments in which a close animal-human relationship was not required. Another naive sea lion (number 10) was obtained from California in January 1970, and with this acquisition the project's full complement of six animals was obtained.

Conditioning

Standard operant conditioning techniques were used to train the sea lions during the project. The animal-conditioning program consisted of the following basic behaviors (required for any task the animals would be expected to perform under free-swimming, open-ocean conditions): (1) adaptation to captivity and hand taming, (2) harnessing and muzzling, (3) cage conditioning, and (4) recall training and open-water control. The recall behavior was started in the training enclosure with a waterproof, battery-powered aviator rescue strobe light. But the strobe light proved ineffective during the training conducted in the bay and was replaced with a buzzer.

The advanced system conditioning (primarily for recovery work and not necessarily required for other tasks) originally consisted of training the animal to (1) approach and touch an underwater object with a nose cup (target hit), (2) correctly trigger the grabber devices (target mark), (3) hit the target in a specific place (center hit and end hit), and (4) report the presence or absence of a 9-kHz or 37-kHz pinger (hear-tell). As the training program progressed, however, it was discovered that the animals could only detect the 37-kHz pinger at very short distances, so this behavior was eliminated from the program. Experience gained from the test and evaluation program indicated that night and foul weather conditioning should have been included.

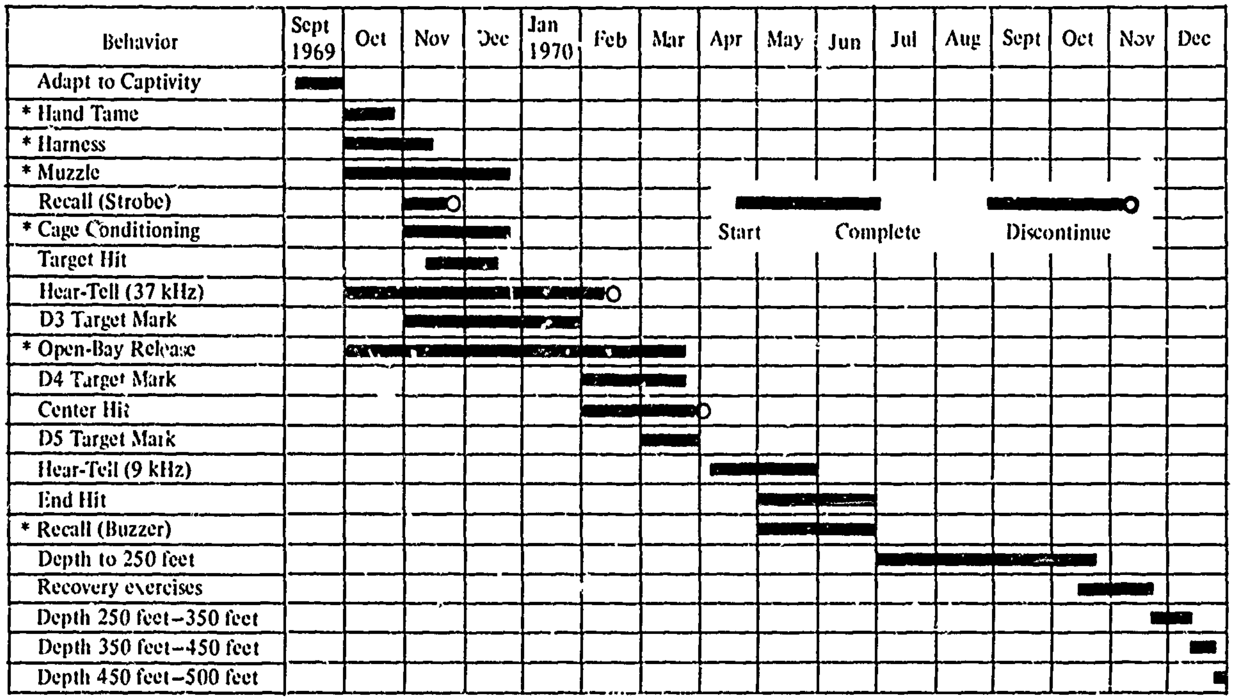
A summary of the training schedule of all behaviors is presented in Table 2. Certain behaviors required progressively more difficult training devices (grabbers) to be manipulated by the animals. These grabbers are indicated in the table as D3, D4, and D5. Table 3 shows the criteria used in measuring animal performance; the actual time devoted to each behavior is shown in Table 4.

Basic Behavior Training. Six California sea lions arrived from Point Mugu, California, on 6 September 1969. Five of the six animals were wild (untrained) when acquired. The sixth animal, a male, approximately 4 years old, had been conditioned in a series of deep dive studies conducted at Point Mugu and had made dives of approximately 550 feet before coming to Hawaii. Four other naive young animals arrived at later times. Of the ten animals, four were to be selected for studies conducted by the University of Hawaii. Formal training did not begin until 25 September when the construction of training facilities was completed. Prior to this time the animals were allowed to adapt to their new environment and were given free access to the fenced swimming areas. During this period of adaptation the daily diets consisted of 7 to 10 pounds of smelt with a routine vitamin supplement (2 multivitamins, 100 mg thiamine, and 100 I.V. vitamin E).

The training of the naive animals began with a hand taming sequence, which is a necessary step before the harnessing behavior. Hand taming allowed the trainer to rub the animal and established physical contact between the trainer and the animal. This behavior was acquired by holding a fish in one hand to distract the animal while gently placing the other hand on the animal's back. After several trials the period of holding the animals was increased, and the fish reward was given to the animals as

Table 2. Training schedule of animal behaviors.

Average times are indicated.



*Denotes basic behaviors.

Table 3. Training criteria.

BEHAVIOR	Criterion	Achievement Time
Hand Tame	Allow trainer to touch and handle for 30 seconds without trying to bite.	3 to 21 days after arrival (two animals rejected after failure to reach criterion after 38 and 89 days).
Harness	Allow one trainer to harness and tighten straps.	1 to 32 days.
Muzzle	Wear muzzle for complete training session, usually 1.5 hours.	1 to 22 days.
Recall	Swim to and touch recall device. Start recall behavior within 10 seconds after device is placed in the water.	Average time: 10 days.
Cage Conditioning	Remain in cage, with door open, for at least 30 seconds.	2 to 8 training days.
Hear-Tell	Report the "on condition" of a 9-kHz pinger by pressing a rubber pad. 65% correct responses considered as minimum standard.	1 to 30 days after basic training was conducted with 37-kHz pingers in shallow water at close range (approximately 20 feet).
Open-water control	Work untethered in bay or ocean without wandering away from training area. Measured in conjunction with recall training	44 to 108 training days.
Target Mark	Wear final grabber design, swim to target, and correctly trigger grabber. 65% correct responses considered as minimum standard.	Average training time: 41 days. This behavior represents a series of approximations and a chain of behaviors.

Table 4. Training times from start to criterion.

Animal	Time[a]	* Hand Tame	* Harness	* Muzzle	Recall (Strobe)	* Cage Conditioning	Target Hit	Hear-Tell (37 kHz)	D3 Target Mark	* Open-Water Release	D4 Target Mark	Center Hit	D5 Target Hit	Hear-Tell (9 kHz)	End Hit	Recall (Buzzer)	Depth to 250 ft	Depth 250 to 500 ft[b]
No. 1 Akahi	hours	1:50	3:00	5:33	1:45	1:00	1:35	5:55	8:00	32:51	1:25	4:54	2:10	:43	7:50	:20	28:29	8:44
	calendar days	8	12	27	5	3	7	23	19	82	6	29	8	1	12	1	92	28
	training days	4	6	12	4	3	3	12	13	52	5	15	7	1	19	1	55	19
No. 2 Fatman	hours	2:50	14:45	4:12	:20	1:25	:20	12:36	:20	70:53	-	-	:20	2:50	8:02	1:30	25:29	12:00
	calendar days	21	105	161	1	9	1	122	1	152	-	-	5	3	21	3	92	28
	training days	7	32	22	1	7	1	33	1	108	-	-	2	3	14	3	55	19
No. 3 Sam	hours	1:15	2:40	3:30	2:30	:40	:60	6:0[illegible]	7:10	41:03	2:00	4:48	4:00	:30	-	1:20	-	-
	calendar days	12	19	28	11	2	3	25	59	104	34	28	16	1	-	6	-	-
	training days	5	5	14	6	2	2	13	16	64	7	14	11	1	-	4	-	-
No. 4 Juneau	hours	-	-	-	1:40	-	2:10	5:54	:25	43:18	-	-	5:20	-	8:50	5:50	27:04	1:50
	calendar days	-	-	-	2	-	10	13	1	68	-	-	52	-	26	40	92	8
	training days	-[c]	-[c]	-[c]	2	-	4	12	1	40	-	-	10	-	17	11	53	6
No. 7 Turk	hours	0:35	-	:12	-	1:52	2	11:42	1	17:00	4:30	7:36	2:00	1	8:50	2:30	26:40	6:50
	calendar days	3	-	1	-	10	4	69	4	90	18	30	10	2	25	5	92	16
	training days	3	-	1	-	8	3	20	3	48	4	16	6	2	11	4	50	12
No. 10 Sniffer	hours	-	:20	1	-	1	:30	9:54	:30	29:50	:40	-	3:45	:15	13:50	7:20	33:30	8:57
	calendar days	-	1	5	-	2	1	47	1	72	2	-	14	1	36	50	92	26
	training days	-	1	3	-	2	1	29	1	44	2	-	11	1	27	18	52	17

* Denotes basic behaviors.

[a] Hours: Total time spent training from start of behavior to criterion.
Calendar Days: Total elapsed time from start to criterion.
Training days: Total number of days on which training took place

[b] Animal No. 4 deepest dive: 300 feet
Animal No. 7 deepest dive: 330 feet
Animal No. 10 deepest dive: 420 feet

[c] Behaviors previously conditioned at Point Mugu.

the rubbing stopped. Three naive animals of the original group of six responded well to this taming procedure: two animals remained hostile and eventually were rejected from the training and replaced by two other naive animals from the University group. Before the animals were rejected, however, an experiment was conducted in an attempt to reduce their hostility. On two separate occasions the project veterinarian orally administered a tranquilizer (librium); first he gave them 175 mg (slightly less than 3 mg per pound of sea lion body weight) and then 125 mg (slightly more than 2 mg per pound). Although the tranquilizer reduced the animals' viciousness, it made them groggy and prevented any training from being conducted. The sixth of the original group of animals was trained to wear a harness at Point Mugu so that this training was not necessary in Hawaii. Advantage was taken of these conditioned behaviors by using this animal in the hardware development studies which were required as the project progressed.

Early in the training the animals were conditioned to climb onto a training stand and to remain in the position indicated in Fig. 3. It is in this position that the muzzle and harnessing behaviors were introduced to the animals. Every day the animals' work began by being harnessed on the training stand. By climbing onto the stand, the sea lion was elevated to a more convenient level for harnessing by the trainer. The harnessing phase consisted of first having the animal allow a 10-inch-diameter rubber hose ring to be placed over his head and then around his neck. After several trials the hose ring was eventually replaced by the neck band of the harness, which was left on the animal for a short period of time. After this was accomplished successfully the snaps and belts were loosely coupled and, again after a period of adjustment, were tightened. The harnesses were left on overnight initially, but one animal became entangled in the fence of the communal swim area, and this practice was discontinued. The harnessing of the animal allowed the trainer to walk the animal as he would a dog (Fig. 4) and to thus lead him into unfamiliar areas if required. Also the open-ocean or open-bay training could be accelerated considerably by working the animal on a tether tied to the harness.

Figure 3. Harnessing position.

Figure 4. Harnessed sea lion with leash.

Muzzling was initiated at about the same time, but because it involved the more sensitive areas of the head, this training took considerably longer. Muzzling was required in order to restrict or retard the animal's tendency to hunt for fish while in the open ocean. Secondarily the muzzle also provided a convenient attachment place for the marker-grabber device. This behavior was obtained by placing the ring previously employed in the harnessing phase around the animal's neck while he wore his harness and then having the animal allow the trainer to first touch and then hold his nose. Once this procedure was accomplished, an elastic neoprene rubber ring was substituted for the hose ring. An empty paper coffee cup was then used in place of the hand. After the animal allowed the trainer to place the elastic ring and cup on his nose, the actual muzzle was substituted. The cup of the muzzle was placed on the animal's nose for short intervals, and then the animal was rewarded. The interval that the muzzle was left on was gradually lengthened until the animal was completely accustomed to wearing the muzzle without shaking it off. The muzzle, harness, and leash are shown in Fig. 5.

Recall training was started by using two aviator rescue strobe lights and having the animal swim from one to the other as they were turned on. The position of the recall lights was constantly varied in order to prevent the animals from acquiring a position pattern. Eventually a more practical, durable, and effective recall device was obtained–the buzzer section of an underwater communications unit.

The last of the basic training behaviors was cage conditioning, which was required because of the necessity of holding the animal in a cage while he was not being worked or trained. The holding cage could be modified for long-range transport by the addition of a waterproof liner (Fig. 6). The animal was baited into the cage by throwing fish inside. Once the animal entered the cage he was fed and then released. He first spent short intervals in the cage, then graduated into lengthy periods of time. The training now entered the more complex behaviors of target marking, hear-tell, and open-water release.

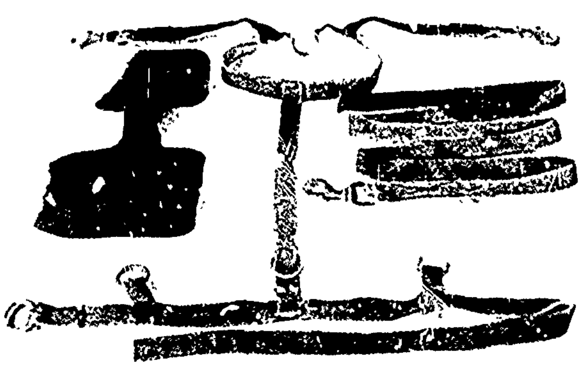


Figure 5. Typical harness muzzle and leash.

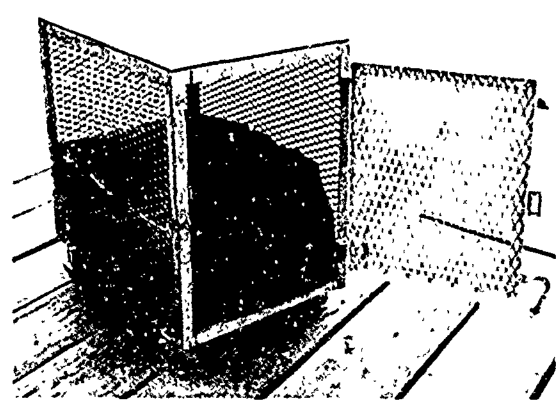


Figure 6. Holding cage configured for transport.

Complex Behavior Training. Conditioning for the target marking behavior began in late October by having the animal hit with his nose a small canister on the surface of the water. A 37-kHz pinger was placed inside the canister, and the animal was required to swim 20 feet, touch the canister, and then return to the trainer. The canister was then gradually submerged until it rested on the bottom of the training area. Next, a marking device was affixed to the muzzle, and the animal was required to carry the device to the canister, touch it, and return the nose piece to the trainer. The initial marking device was a lightweight cup whose primary function was to condition the animal to carry the marker to the pinger target and hit it. As the training progressed, the configuration of the marker changed to represent more complex and complete pieces of hardware.

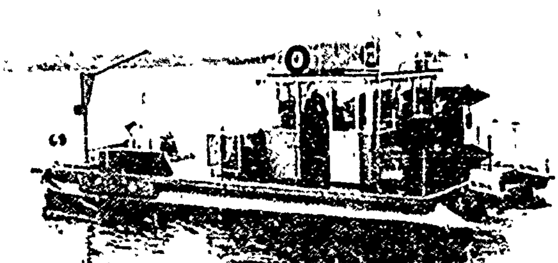
A lightweight marking device (D3) was used during the early training in order to keep the required hardware manipulation as simple as possible until the animal achieved the desired behavior.

After the required behavior was obtained at short distances, the target was randomly moved about the training area before each trial. It soon became apparent that the animals would locate the target by following the pinger control cables, which was easier than locating the target with any directional hearing ability. The training environment was changed so that the animal could not locate the target by following the cables; that is, the cables were laid in the water so that they approached the target from the direction opposite to that from which the sea lion was being worked.

At this same time the hear-tell behavior was started. During this behavior the animal entered the water, listened for a 37-kHz pinger, returned to the trainer, and reported a positive by hitting a large rubber pad on the side of the transport cage or a negative by entering the transport cage. This behavior was to be used as a contingency measure during the search portion of a recovery. The primary search would be conducted with a directional hydrophone (Burnett Electronic Model 512), but the animals would be used if there were an electronic equipment failure. The hear-tell behavior also strengthened the marker-grabber attachment behavior, since it conditioned the animal to the next required task in the behavior chain, following the pinger sound to the target and marking it.

Once the animals had reached the criterion for each of the required behaviors in the shallow-water enclosure, the behaviors were integrated into a chain of behaviors in the deeper water of Kaneohe Bay and then into the ocean. For ease of operation and efficiency during this phase, a 37-foot pontoon barge (Fig. 7) was converted so that all the personnel, animals, and hardware required during a day's training could be loaded aboard the craft, and the personnel could operate independently of the training pier.

Figure 7. Training barge.



Several different areas within Kaneohe Bay were used as training sites; the water depth was approximately 15 feet deep at these areas. A typical shallow-water training site is shown in Fig. 8, where a hard-line control to the pinger and a feedback system were used to monitor animal performance. The bay and the ocean training procedures were similar, but since the more advanced hardware was available for the ocean work only, the ocean training will be described here.

The weather during the ocean training period of July to December was normally calm and presented no problems; however the training personnel were able to work on several occasions when there were 25-mph winds, with gusts to 35 mph, and 6-to-8-foot waves.

The training session began by placing the target at the desired depth by rope. The target was lowered by hand to ensure that it would be upright on the bottom. Then the first animal to be worked, along with his trainer, a boat driver, and a line handler would get into the rubber work boat and drive a short distance away. After the animal was signaled into the water for hear-tell he then returned to the work boat to report. The pinger in the target could be remotely controlled from the barge, and the work boat driver served as radio operator in order to inform the trainer of the pinger's operating condition. After a positive report on the pinger the animal was again signaled to enter the water and to remain near the side of the work boat while the trainer placed the grabber on the animal's head. Figures 9, 10, and 11 show the animal leaving the work boat and placing the grabber on the target. Figure 12 shows a typical ocean training session with the relative positions of the boats.

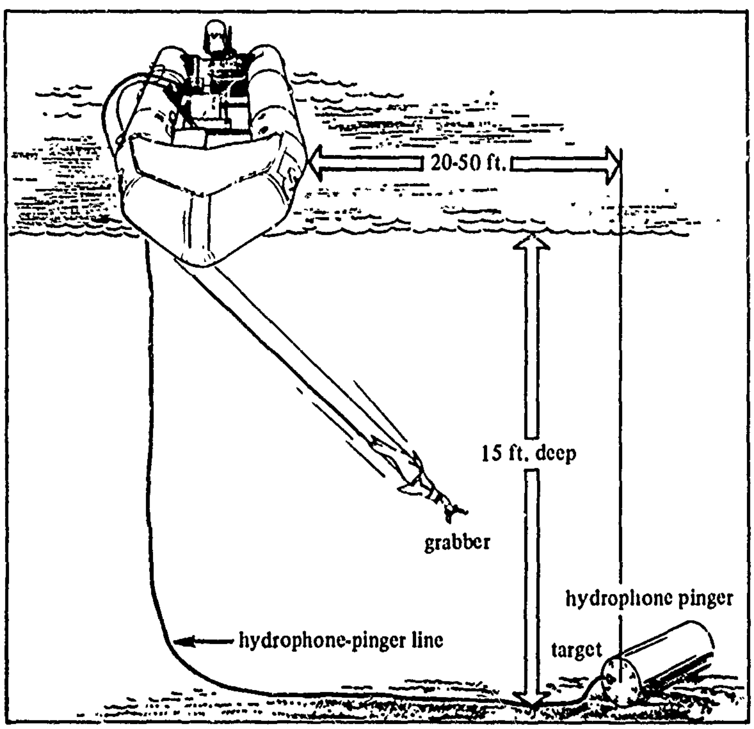


Figure 8. Typical shallow-water training operation.

Figure 9. Ocean training session.

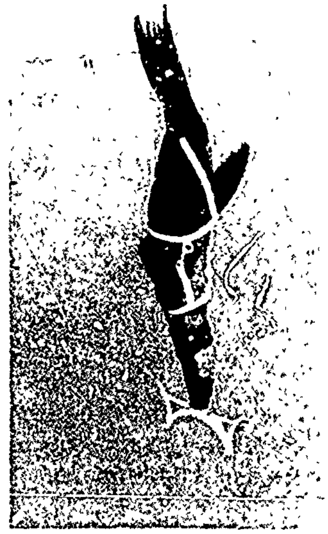


Figure 10.
Sea lion diving with training grabber.

Figure 11. Sea lion attaching grabber to target.

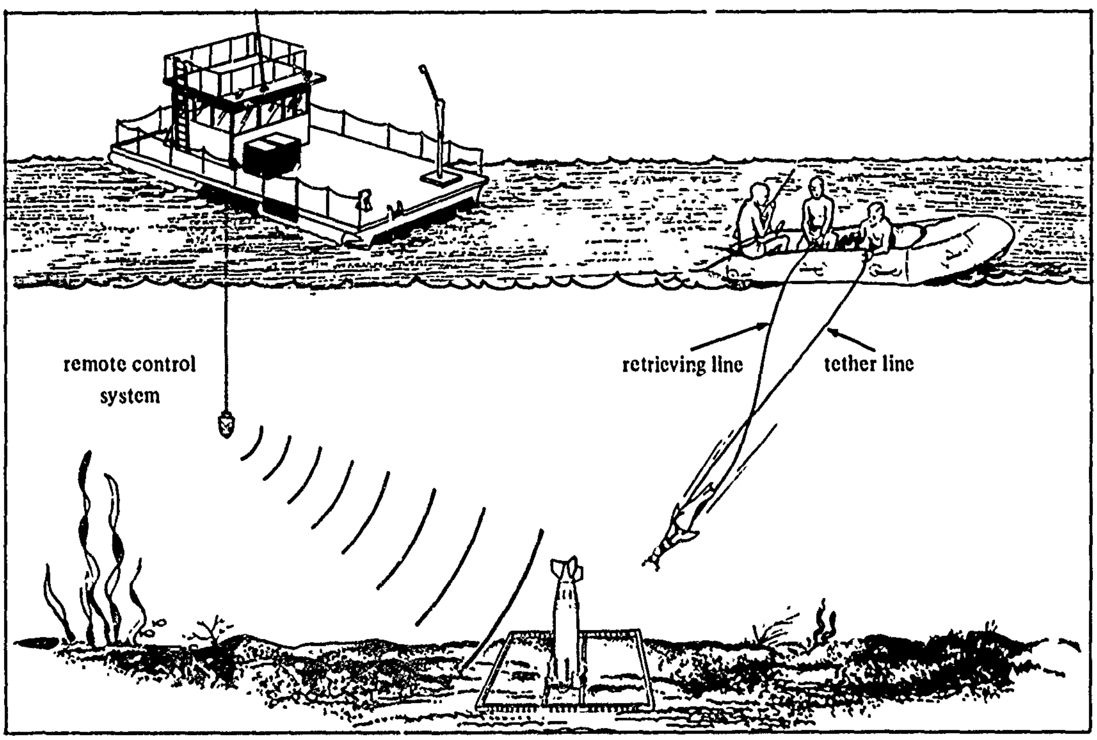


Figure 12. Typical ocean training operation.

RECOVERY SYSTEM CONCEPTS

The target capture device and the capture method used by the animal to retrieve a pingered object on the ocean floor played a vital role in several aspects of the object recovery mission. These included:

1. Animal conditioning.

2. Design and use of the system work boat from which the handler and animal work.

3. Tasks performed by recovery personnel between the time the grabber is actuated and the time the object is safely aboard the recovery vessel.

It was important to formulate and compare alternative concepts for the target capture device and capture method so that the best concepts could be selected for design and development.

Twenty-two concepts were generated by project and contractor personnel (Ref. 2). A preliminary rating of these concepts revealed that three were worthy of additional investigation. The five factors used to evaluate the concepts were:

1. Animal Safety: What were the chances of the animal drowning or being injured by becoming entangled in lines or trapped if a release did not work?
2. Animal Training: How difficult was it to train the animals to perform tasks associated with the concept? Also, what were the requirements for reorienting the training from the current approach?
3. Hardware Reliability: How likely was it that all the mechanisms would operate properly, including releases working, lines not tangling, reels not catching, etc?
4. Strength Required: How much weight could the animal carry each way and how much drag must he overcome? Also what lengths and sizes of lines would be required?
5. Engineering Time and Complexity: How much engineering would be required? How much time would be needed to get the devices designed, built, and tested.

A line towing study was conducted, and the results indicated that the Project sea lions could tow a line that would be capable of lifting an ASROC. A brief description follows of the recovery concept selected and developed. Selection was made on the basis of the system's simplicity and the reduced hardware design requirements.

Description

The sea lion pulls the free end of the recovery line to the target. The bitter end of the line and the stationary reel are on the boat. The free end of the line is fastened to the grabber. The force of the animal swimming toward the target causes the line to pay out from the reel on the boat. Grabber actuation establishes the connection between the boat and the target (Fig. 13).

Advantages

1. The animal works to pull the line only on the descent leg of the round trip.

2. Since the reel is on the boat, the animal's carrying load is lighter than if he were carrying the reel; also, the hydrodynamic drag of the reel is eliminated.

3. Fastening the free end of the line to the grabber eliminates the hazard to the animal that could occur if the free end of the line were attached to the harness and grabber actuation failed to detach the free end of the line from the harness.

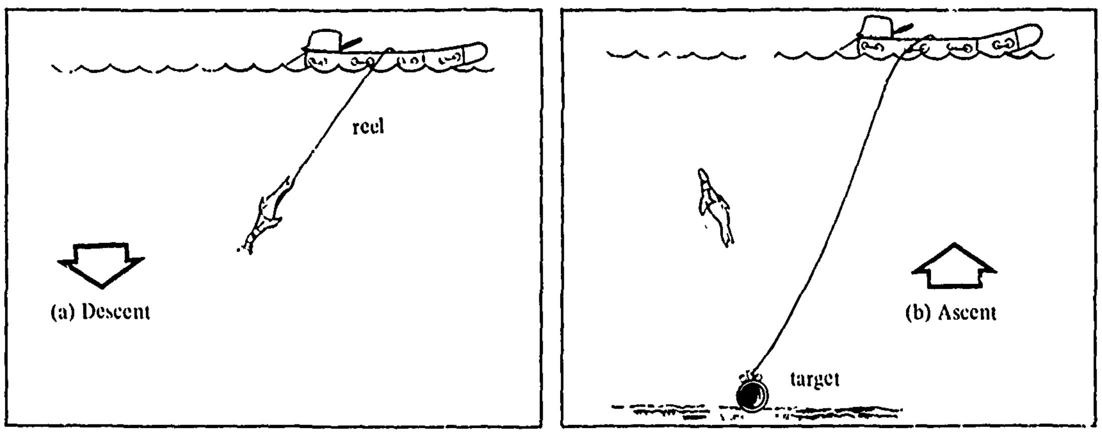


Figure 13. Illustration of recovery method.

Disadvantages

1. There may be a hazard to the animal if he becomes tangled in the line as he descends to the target.

2. Fastening the free end of the line to the grabber concentrates the pulling load at the animal's mouth instead of distributing it over his body.

DESCRIPTION OF HARDWARE

The hardware developed for the Quick Find recovery system consisted of both simple training aids and complex pieces of equipment. Only brief accounts of the hardware will be given here; for a more complete discussion of the engineering design and fabrication see Ref. 3.

Harness, Leash, and Muzzle

There are several advantages in being able to work with an animal that is capable of being conditioned to wear a harness and muzzle. Initially the harness is used in conjunction with a tether line which allows open-ocean training to be conducted before complete reliability is reached in the recall behavior. The muzzle's primary function is to restrict the animal in such a way as to reduce his natural behavior to hunt for fish while working in the ocean.

The original harnesses obtained from the Marine Bio-Science Facility at Point Mugu were constructed of a flat nylon strap material that had rough serrated edges. This material caused sores on the animal after he wore the harness for any length of time—two hours or longer. A new harness utilizing a tubular nylon strap with brass snaps and rings was designed by project personnel. This harness has been used with no bad effects.

There is a ring attached to the harness at the back of the neck strap, and it is at this point that the leash is connected. The sea lion can thus be walked as one would walk a dog. This method of moving the animals simplifies the overall logistic requirements.

Marker-Grabber

Simulated grabbers were constructed while the final grabber design was being perfected. This allowed the trainers and sea lions an opportunity to work with the device and provide feedback to the engineers on its probable advantages and disadvantages. These simulated grabbers had about the same surface area, weight, and configuration as the real grabber. Figure 14 shows two of the training models. The model on the left is a copy of the final grabber; the one on the right is an earlier version that has "wrap around" grabbers. The one on the left simulates a telescoping model. These models were used as training aids because, since they did not require the fine tolerances of the recovery grabbers, they were much cheaper and quicker to fabricate.

Figure 14. Training grabbers.

Recovery Grabber

The present ASROC recovery grabber (Fig. 15, 16, and 17) has two telescoping arms that lock around the target after being triggered. The target is recovered by means of the stainless steel cable, and no mechanical strain is applied to the grabber arms. The cross-sectional area of the grabber can thus be held to a minimum because the moving parts are not required to lift any weight. This grabber can be used on targets with diameters up to 12 inches and weights up to 2,000 pounds. Figure 18 shows how the grabber is placed on the animal's head. The two round spools on the grabber are spring-drive units used to close the arms after triggering.

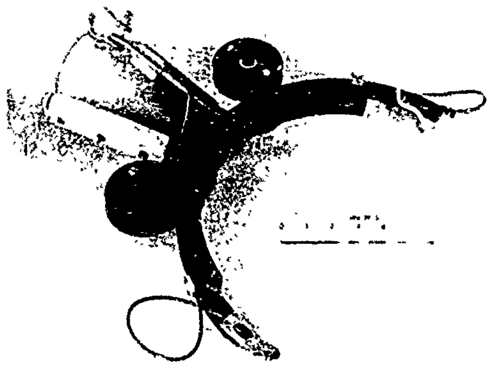


Figure 15. Recovery grabber.

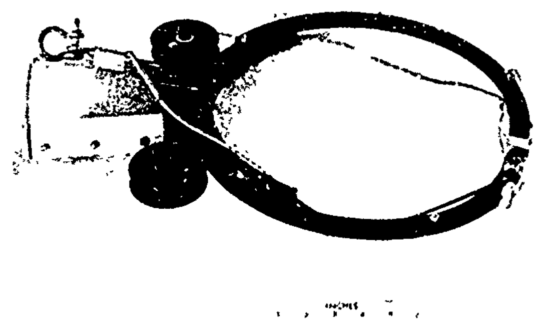


Figure 16. Recovery grabber (triggered).

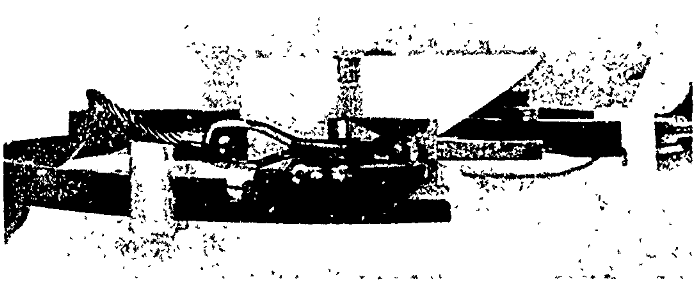


Figure 17. Detail of grabber locking device.

Figure 18. Sea lion with recovery grabber.

Klunk Detectors

During the training process the animal handler must be constantly aware of the sea lion's performance in order to reward him for only correct responses. During the basic behaviors the trainer is able to observe the animal's actions and act accordingly. But once the more advanced training phases are reached personal observations become impossible because of distance, depth, and turbid waters.

A feedback system consisting of a hydrophone, cable, audio amplifier, and speaker was built in order to monitor the animal's performance. The animal was trained to attach a grabber device to the underwater target, and when he did this correctly the trainer could hear a sharp, loud "klunk" over the speaker. Incorrect trials would produce little or no noise because these areas were isolated from the hydrophone. This system was used while a more advanced one was being manufactured.

A system that would eliminate the cables and also permit the pingers to be switched on or off and to release a float and retrieving line was manufactured by InterOcean Systems, Inc., of San Diego, California. This unit consisted of a klunk detection hydrophone and a transponder system which remotely controlled 9-kHz and 37-kHz pingers. When the animal correctly hit the target the klunk detection hydrophone would sense the shock and turn the pingers off. In this way the trainer could monitor the animal's performance with immediate feedback and reward the animal accordingly.

The surface unit consisted of three parts: the command transmitter, the overside transducer, and a receiving hydrophone. Within the command transmitter were a programmed code generator, a high-power audio frequency amplifier, a nickel cadmium rechargeable battery pack, a current meter, and a set of headphones.

The subsurface electronics unit consisted of a waterproof pressure housing containing a crystal acoustic receiver, eight detector filters, logic circuitry for RELEASE, PINGER ON, and PINGER OFF functions, and a rechargeable nickel cadmium battery pack. A motor-driven release mechanism was connected to the electronics unit by cable. Four other similar cables on the housing were used for two hydrophones and two pingers. One hydrophone was used for klunk detection, and the other hydrophone received the coded command signals.

The acoustic control system served as a monitor of the animal's underwater behavior. When the animal hit the machine while the pinger was on, the initial impact or the impact of the arms of the grabber on the target caused the pinger to shut off. The termination of the pinger could be monitored on board the training barge, both visually (via the current meter) and acoustically (via the headphones). This information was then relayed by radio to the trainer on the work boat, and he would reinforce the animal accordingly.

The subsurface unit theoretically has an operating depth of 5,000 feet, but during a critical period of ocean testing, several external acoustic cable breakdowns were experienced at 240 to 300 feet. As a result of these breakdowns the subsurface electronics unit was not available for the deep ocean work.

After the animals had completed the learning process and were conditioned to the required tasks, there remained the need for a confirmation of a successful dive. Since the klunk detector was inoperable the critical area of the target was painted with a heavy grease, and when the grabber was retrieved by the trainers a telltale sign of grease would be on the grabber after a positive clamp. This method proved to be adequate, but did not provide the immediate feedback that would have been required during the training phase.

Recovery Float

Historically, trained sea lions have proven to be easily distracted by fish that may swim into the work area and will chase them if not prevented. In an attempt to dampen their desire to chase fish, the animal was muzzled. As another precaution a sea lion recovery float was attached to the animal's harness (Ref. 4). This recovery system originally consisted of a rubber balloon that contained calcium carbide and water separated by an external salt washer. As the animal swam, the washer was slowly eroded away and the water and calcium carbide were eventually allowed to mix, generating acetylene gas that inflated the balloon. The animal was then marked on the surface by a large colored balloon and could be easily spotted and caught by boat if he did not return.

There were several disadvantages to this system:

1. Unreliable washers–the indicated dissolving time was not accurate and would cause premature or late inflation of the balloon.

2. The calcium carbide would start to generate gas if the least amount of water leaked around the washer, again causing a premature inflation.

3. Inconvenience in the daily preparation and assembly of the required number of floats.

In an attempt to improve this system, a new float was designed which consisted of a balloon, carbon dioxide cartridge, firing pin, and magnesium washer. The washer retained the firing pin until it eroded to a certain point, and then the pin fired into the cartridge and the balloon was inflated by the carbon dioxide gas. This was a much more predictable system and required less maintenance and fewer assembly problems.

However, after one animal (No. 3) was lost while being worked in the open ocean, the float was replaced by a tether line, a thin nylon line attached to the harness and wound on a 4/0 salt water fishing reel. A "weak link" that would break loose if the animal became tangled on any object while diving was built into the harness. Under normal swimming conditions, however, the animal was prevented from wandering off and becoming lost. The animal that was lost at sea may have been frightened by large sharks that were sighted in the work area, or it may have been prematurely released before the recall behavior was sufficiently strong.

Recall Device

A recall device is usually a sound source that is actuated when an animal is to be recalled to a pen or boat. The first recall device used during this project was an aviator's distress strobe light. The strobe light produced a broad band high-frequency noise with an accompanying bright flash which was an effective homing device in the shallow, clear water of the training area. This worked well in the confines of the fenced training area, but when the training progressed to the open turbid waters of Kaneohe Bay, a more effective device was required. The tone alert section of the yack-yack diver communication unit provided a waterproof broad band sound source that is a rugged piece of equipment, with most of the output energy ranging from 5 kHz to 12 kHz, which takes advantage of the sea lion's best hearing range.

Cage

The purpose of the cage was to provide a holding space for the animal while it was not being worked and, with the addition of a waterproof nylon liner, to serve as a long-range transport conveyance. It was constructed of aluminum angle and expanded metal and would conveniently fit into any commercial airliner, as demonstrated during the ASROC recovery exercise. The ocean work boat was outfitted so that five cages could be conveniently bolted to the deck. The sea lions were individually worked in the ocean and returned to the holding cage when their training session was completed.

Inflatable Work Boat

In line with the original concept of keeping the recovery system as uncomplicated and as mobile as possible, an inflatable rubber boat was procured. This boat was 13 feet long and 4 feet wide, weighed 75 pounds, and was powered by a 20-hp Johnson outboard motor. Figure 19 shows the boat with the recovery and tether line reels in place. Figure 9 shows the usual work positions during a training or recovery operation. The sea lion and trainer rode in the bow and worked off the starboard side. The assistant trainer rode in the center and handled the lines to prevent backlash or fouling lines. (This position could possibly be eliminated with additional hardware development.) The third person drove the boat and maintained radio contact with the training barge to receive feedback from the target klunk detector and to provide the data recorder with training information. During the actual recovery operations, communication was maintained between the work boat and the recovery ship.

Figure 19. Inflatable work boat.

Training Target

The initial training target selected was one similar in size and shape to a general class of U.S. Navy mines. It was the project's original intent to demonstrate the recovery system during one of the drill mine exercises routinely conducted off the Southern California coast. The drill mine was selected as the initial target because of the convenience offered by having several exercises conducted each year and the ease with which the demonstration could be coordinated. Several facts discovered as the project progressed, however, required a change in the type of target selected for demonstration:

1. Practice or drill mines normally contain 37-kHz continuous wave pingers. This frequency is at or outside the sea lion's normal hearing threshold.

2. Drill mines are normally laid in 60 to 80 feet of water and their recovery presents little problem to Navy divers.

3. The recovery difficulties encountered during a mine exercise were not as critical as those that would be encountered at greater depths–for example, during an ASROC recovery.

4. The design of a grabber that could be carried and manipulated by a sea lion and be strong enough to recover a 1500-pound drill mine presented a difficult engineering task. To make the problem even more difficult, there was no part of the mine that was consistently exposed, such as the tapered tail section of an ASROC, for a grabber attachment. The animal would have to hit the top center section of a mine, and the clamp would have to wrap around the circumference of the target. It is easy to visualize the problems that would be encountered.

For these reasons the class of target was changed, in May 1970, from a drill mine to an ASROC depth charge.

The training target was a lightweight simulated ASROC depth charge mounted on a base frame at a 45-degree angle (Fig. 20). (The ASROC normally penetrates the ocean bottom after firing and is usually found in an upright position by the recovery divers.) The animals were then trained to approach this target, align the grabber perpendicular to the tail fin, and clamp the target. At this time the 9-kHz and 37-kHz internal pingers were turned off by the correct clamping action and could be both visually and acoustically monitored aboard the ocean barge. If the animal

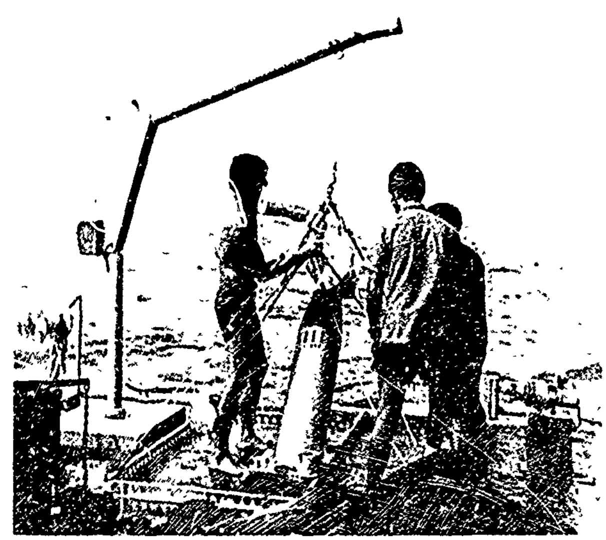


Figure 20. Training target.

incorrectly hit the target, the pingers would not be shut off The information, whether of correct or incorrect clamping, was relayed to the inflatable work boat, and the trainer could then take the appropriate action.

There were two major recurring problems with the acoustic control part of the target. First, the sensitivity adjustment that shut the pinger off after a correct hit was extremely difficult to regulate so as to ensure 100% reliable feedback. In addition, there was an isolation problem with the receiving hydrophone: on occasion an incorrect hit would and a correct hit would not turn the pingers off. In order to gain additional feedback, the trainers coated the correct target area with a heavy black grease; if the grabber had a tell-tale sign of grease, the animal was rewarded. Because of the time required to retrieve the grabber, however, there was a disadvantageous time delay between the animal's return and verification of a correct hit.

Second, as the training proceeded to deeper and deeper waters, the external cables would fail, the pingers would stop, and the target would have to be pulled up and repaired, sometimes in the middle of a training sequence. Most of these failures, which occurred around 250 feet, were corrected by the purchase of better cables.

TEST AND EVALUATION

A test and evaluation program was developed to provide information required primarily for the design of hardware in the early phase of the project. The lead time required for the fabrication of hardware imposed a requirement of early closure on the hardware designs in order to meet delivery dates for the system demonstration.

The physical capabilities of the sea lion and a measurement of his "horsepower" were of prime interest to the project engineers. The animal-hardware interface presented many problems, among which were: (1) formulation of a recovery concept within the animal's capabilities, (2) design of the animal-manipulated grabber, (3) development of a system to minimize interference to the animal's hearing, sight, or natural swimming ability, (4) development of a method of attaching lines to the animal with desired safety features.

The urgency with which the information was required precluded designing and conducting long, detailed investigations; instead quick and direct studies were conducted to provide the required data (Table 5).

One animal (No. 4) was procured specifically for use with innovative and experimental hardware and for training new behaviors. The use of this animal, which had been previously conditioned for open-ocean release at NUC Point Mugu, saved considerable time and redesign effort. As other animals became conditioned they too were used to provide feedback on hardware redesign.

Table 5. Test and evaluation studies.

Studies	Description
Grabber Configuration and Weight	Determine the sea lion's ability to swim with and to manipulate different grabber configurations and weights.
Line Towing	Determine the sea lion's ability to tow the recovery line through the water; observe the animal's performance.
Distance Hearing	Determine the sea lion's sound detection threshold as a function of horizontal distance from a 37-kHz pinger and a 9-kHz pinger.
Avoidance	Investigate the possibility of using an underwater strobe light as a means of marking a located target in order to avoid unnecessary relocation and duplication of effort in multiple-target situations.
Deep Diving	Determine the depth to which sea lions could tow the recovery line and then successfully attach the recovery grabber.
System Demonstration	Demonstrate the system's capabilities during an operational deployment and recovery with the Fleet.

Grabber Configuration and Weight

One of the first questions asked by design engineers was how large a package could the animal carry and manipulate. The size and weight of the class of targets to be recovered was known, but there was no information available on the animal's ability. Two tests were conducted to determine the animal's ability to maneuver with different grabber weights and shapes.

In the first test six 1-inch-by-3-inch boards varying in length from 10 inches to 38 inches and in weight from 3 pounds to 5 pounds were fitted to crude nosecups, and the animal was conditioned to wear the nosecup and to swim to a pingered target 50 feet away and to hit the target with the board. The animal's swimming behavior was observed, along with the degree of difficulty with which he manipulated the boards.

When the length of the board was greater than 15 inches the animal had some difficulty in swimming in a straight line, and there appeared to be a "rudder effect" that exaggerated the slightest head movement. The boards were replaced by pieces of 1-inch polyvinyl chloride plastic water pipe, and the animals could swim with a 15-inch piece of pipe without any difficulty.

Lead weights were then added to the pieces of pipe, and the animal was able to manipulate a weight of about 4 pounds without difficulty.

The orientation of the boards and pipes during the first test were in a horizontal position while being carried. It was also desirable to investigate a vertical mode to see if there was any difference in the animal's ability.

During the second test the same boards and pipes were used, but the animal varied his swimming pattern so that he could hold the board completely out of the water and thereby eliminate all drag. However, when he tried to dive to the target he exhibited the results of a "rudder effect" even with the short boards; the pieces of pipe did not produce this effect. Because of the animal's tendency to swim with his head held high out of the water instead of diving, the vertical orientation was rejected.

From these tests it became apparent that the surface area of the grabber had to be kept to a minimum and the lifting had to be achieved by other means. The solution, as demonstrated in the current grabber design, was to make the cable the stress member.

Line Towing

Two of the most practical sea lion recovery concepts required the animal to tow lines to the target, and one of these required the animal to make a round trip towing the line. Before a decision could be made as to which recovery concept to adopt, information was required on the animal's ability to swim with large lines. A 3/8-inch nylon line with a 2,000-pound tensile strength was selected because it would provide a 4 to 1 safety factor for lifting the ASROC depth charge and sufficient break-out strength if the depth charge was partially buried. The sea lion was conditioned to tow the line between two boats, and then the distance between the boats was increased.

The animal was easily able to swim to a boat 500 feet distant. Because this was a horizontal distance and much more difficult than a vertical dive of equal distance, in which the line would also be sinking, the recovery concept described was within the sea lion's capabilities. The simplicity of this concept lent itself to the general Quick Find Project and was therefore developed.

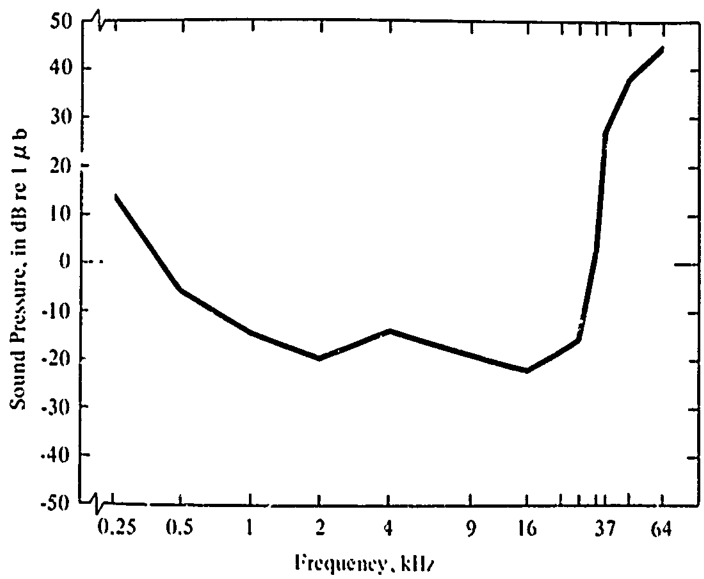
Distance Hearing

A contingency search plan required the sea lions to report the presence or absence of a pingered object; however, in order to design an effective search procedure the distance at which the animal could detect a 37-kHz or a 9-kHz pinger had to be determined. The animal was therefore conditioned to report if a pinger was on or off by hitting a rubber pad at the trainer's station. The pinger was randomly turned on or off and moved gradually away from the sea lion and trainer's station.

The animals were able to respond to the 37-kHz pinger distances of about 20 feet (90%) and at distances of about 30 feet (80%), but at 60 feet their response was at chance level (50%). Animal behavior indicated that 37 kHz was at the high frequency end of the animals' hearing threshold. This fact was verified by conversations with Ridgway (Ref. 5) and was later confirmed by Schusterman (Ref. 6 and Fig. 21).

The animals responded correctly (greater than 65%) to the 9-kHz pinger at 1800 feet, which exceeded the animals' diving capability and would be at a reasonable slant range to establish a search pattern.

Figure 21. Underwater audiogram for California sea lion.



Avoidance

The recovery demonstration was originally to be conducted with mine recovery forces in test exercises. During these exercises there were usually two dozen or more pingered mines planted and recovered, and there was the possibility that an animal could re-mark an already located target before the recovery forces had an opportunity to remove the target from the water. In an attempt to develop alternative tactics, the possibilities were investigated of having the grabber change the target's appearance to the animal after placement. In this way the sea lion could differentiate between targets and not repeat a marking. Consequently a modified aviator strobe light was attached to the target to emit a visual cue. One animal was used in this study and was conditioned to mark any one of three pingered targets on the first trial. As the animal hit the target, the strobe light was actuated. The animal was then required to hit one of the other targets on the next trial, and that target would be similarly strobe lighted. On the third trial the animal was required to hit the remaining target.

The animal was performing at about a 97% correct response rate when the class of target to be recovered was changed to a single depth charge, and the avoidance behavior became unnecessary for the system recovery demonstration. However, future use of such behavior may be necessary for multiple-pinger situations.

Deep Diving

Before the system demonstration the animals were worked at 250 feet; after the demonstration it was desirable to determine the maximum depth at which the animals could recover objects using the present system.

The development effort was scheduled to be completed on December 31, 1970, so only 6 weeks were available for deep dive studies. During this period two animals were able to make successful simulated recoveries at 500 feet, and one animal was able to do so at 420 feet. An animal was eliminated from the diving program if on two successive days he was unable to reach a deeper depth. This restriction was imposed because of the limited time available for the project's completion, and the amount of time involved in placing the target in deep water precluded placing the target at several different depths each day. The diving results for the individual animals are shown in Fig. 22, 23, 24, 25, and 26, and the average dive time at various depths for all the animals is shown in Fig. 27. Figure 27 seems to indicate that a maximum working depth had not been reached. In deep dive experiments conducted at Point Mugu sea lions were conditioned to dive to 520 feet using the method described by Evans and Harmon in Ref. 1.

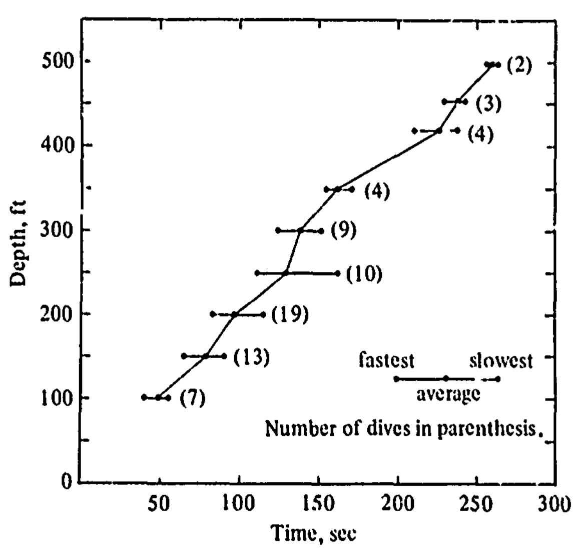


Figure 22. Dive record for animal No. 1 (Akahi).

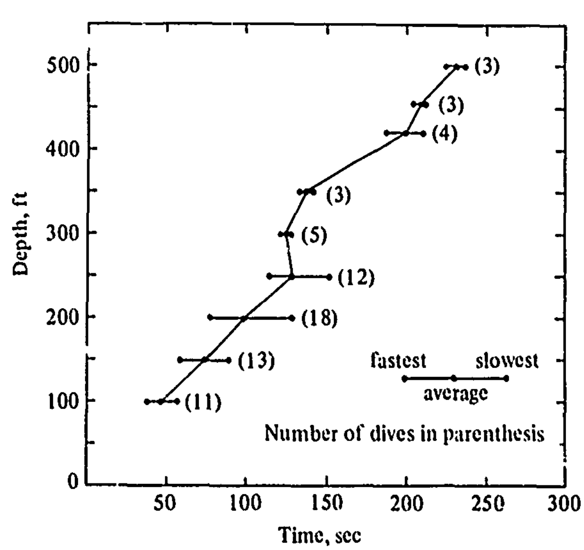


Figure 23. Dive record for animal No. 2 (Fatman).

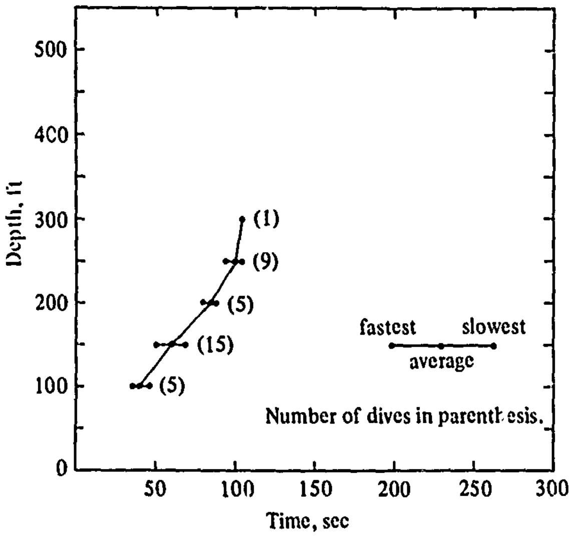


Figure 24. Dive record for animal No. 4 (Juneau).

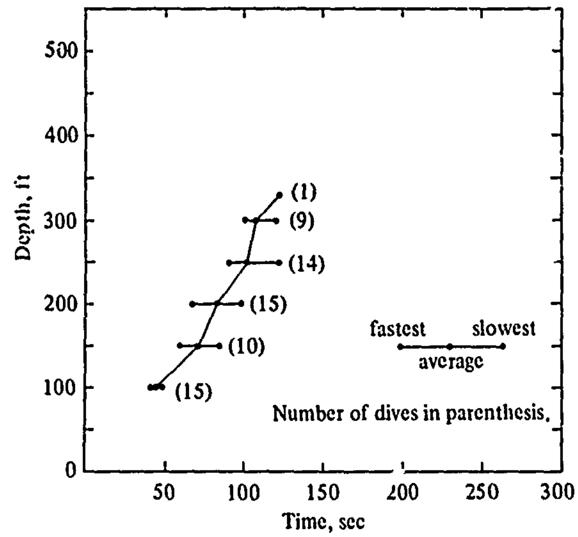


Figure 25. Dive record for animal No. 7 (Turk).

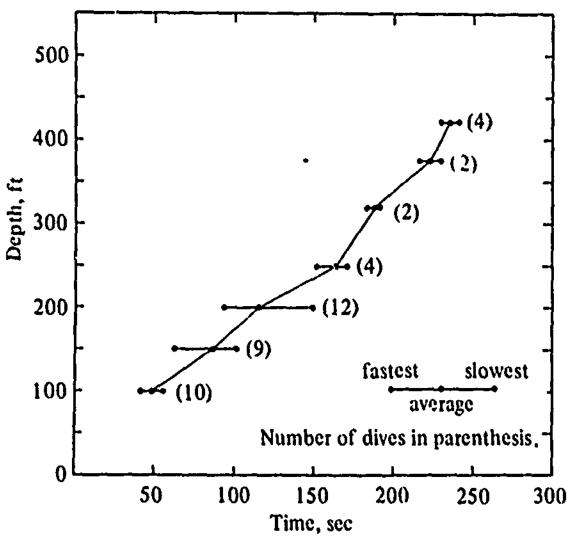


Figure 26. Dive record for animal No. 10 (Sniffer).

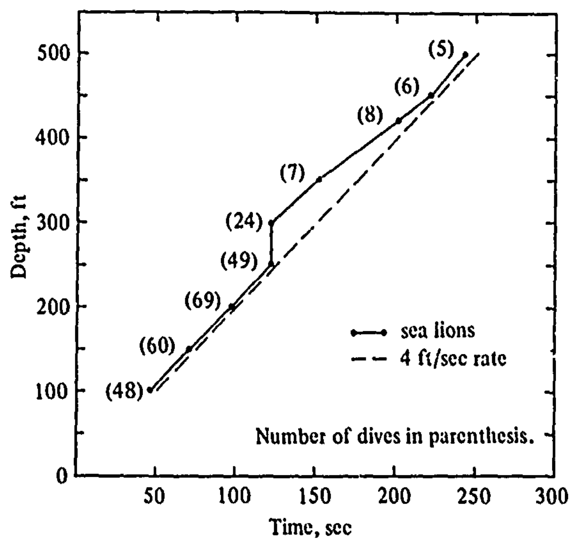


Figure 27. Average dive time to depth and return.

System Demonstration

The November ASROC Quality Assurance Service Test exercise conducted at San Nicolas Island (SNI) by the Naval Ammunition Depot (NAD) Oahu; the Pacific Missile Range (PMR), Point Mugu; and the USS *Orleck* provided an opportunity to demonstrate the Project Quick Find recovery system. Before the exercise, the Quick Find sea lions were trained daily at 250 feet in the open ocean outside of Kaneohe Bay. The ASROC was scheduled to be fired into approximately 180 feet of water. Involvement in a Fleet-conducted exercise was deemed an invaluable experience for project personnel and provided a realistic test for the proposed system.

The original test schedule for Project Quick Find called for two test exercises. Test One with the Mk 57 bomb was to be conducted at Maui, Hawaii, in September; Test Two with the Mk 17 ASROC depth charge was to be conducted at San Nicolas Island. Both pieces of ordnance were to be recovered by divers. The first test was planned as a preliminary system check-out; and if required, the second recovery would be attempted at San Nicolas in November with any required changes. The Maui exercise of the Mk57 encountered several delays and was not conducted. Consequently the San Nicolas Island ASROC test acquired more importance as a demonstration of the system as an easily transportable recovery system.

The sea lions were shipped from Hawaii to California via a commercial airline on 26 October. The animals were kept at the NUC Bio-Science Facility, Point Mugu, where excellent assistance was provided by facility personnel.

Plans were made to work at Point Mugu for a week prior to the ASROC shot, but the temporary shipping loss of training equipment and local storms allowed only three training days of questionable value.

Two meetings of the test participants were held at San Diego and Point Mugu, with project members in attendance. It was during these meetings that the required paint pattern on the ASROC was verified.

The day before the ASROC was fired, project equipment was shipped from Port Hueneme to SNI. Personnel and sea lions were flown to SNI along with the explosive ordnance disposal divers, representatives of NAD, NUC, Sandia Corp., and NUC and PMR photographic personnel who were documenting the test. The sea lions were quartered in the "fish house" at SNI, a small building used by island personnel to clean fish and abalone. It proved very handy in that it was easily cleaned and provided a sheltered compound for the "Hawaiianized" sea lions. The animals appeared to have lost weight soon after arriving in California; the weather and ocean water temperatures were much colder than conditions at Kaneohe.

The schedule for the day of the test was as follows:

0700-0730	YFU recovery boat to load personnel and sea lions
0800	Plant target buoy
0900	ASROC shot
1000-1100	Recovery and return to SNI

On the morning of 5 November SNI was in a fog bank and visibility was greatly reduced. The firing was delayed until after 1520 hours. At 1500 hours, the author suggested to the Recovery Officer that because of the adverse weather conditions and the impending darkness the shot be postponed and rescheduled for the following day. At about the same time, the NAD representative had suggested the same rescheduling while aboard the USS *Orleck.*

At 1522 hours the ASROC was fired and, in accordance with the test operation sequence, the hovering helicopter dropped a smoke flare and a dye marker at the impact point. The YFU recovery boat was directed to the general area by the USS *Orleck.* The YFU spent over an hour trying to locate the target buoy and the point of splash down in the fog. The ASROC was reported to be 500 yards off the target buoy. The sea lion inflatable boat, with project personnel, left the YFU and proceeded to home in on the ASROC's pingers. At approximately 1700 hours the pingers' location was marked by the search team, and the first sea lion left in the inflatable boat. After reaching the buoyed area, the animal was worked for four dives with negative results, although a dive of approximately 100 feet was recorded. The second and third animals were tried with the same negative results. After twelve dives were attempted during a 20-minute period it was decided to stop operations because of darkness. The only possible reason for the animals' refusal to dive and for so many aborted dives was the darkness. There was included in the project outline a period of night training as an optional task, if time permitted. In retrospect the training should have been mandatory.

The Recovery Officer refused to allow any divers to enter the water because of the darkness, and recovery operations were cancelled for the day. The YFU returned to SNI, where people and animals were off loaded. Because of the darkness, the beaching of the YFU was a difficult and hazardous operation, and people were advised to hurry and not to delay or extend the YFU's time on the beach. Although the caged sea lions were carried from a truck to the YFU during the morning loading operations, they were now walked ashore and the cages left on the boat overnight. A near tragedy occurred when one sea lion became overly excited by all the lights, tractors, running people, and confusion and appeared to go into a state of shock. Another animal snapped and bit a trainer's hand after being similarly excited and scared. All in all, a more controlled and casual exit was called for. The animals were again returned to the "fish house". The animal in shock quickly returned to normal after being removed from the stressful situation.

The following morning, 6 November, a 4-hour search was conducted in a dense fog for the ASROC's location. Neither the PMR nor the SNI radars could assist because of the operation's proximity to SNI. The buoy's location was finally located by taking references on landmarks from the previous day's search and steering into the fog.

At noon the sea lion boat left the YFU with the first animal to be worked. A much slower pace was suggested for the work to be done this day—a dive after an initial familiarization swim by the animal and extended rest periods between dives. The first animal dove to the bottom, pulling 200 feet or more of line to the target, and returned with the grabber untriggered. A dive of 45 seconds could be expected at this depth. The depth of dive was determined by the time that had elapsed during its performance. After a total of seven negative dives in 45 minutes, animals were exchanged.

At this time the NAD representative disclosed that the ASROC was painted incorrectly. The depth charge had orange stripes in addition to the lone black stripe that had been requested and that had been painted on the training model. The new paint pattern was in all likelihood confusing the animals. It was decided to try the Mk 57 grabber, which was larger and would fit on the incorrectly painted target if placed on one of the orange stripes.

The second animal was then worked with the large grabber and secured the target on the second dive. This was at 1310 hours, and at 1325 hours the grabber broke while the YFU was trying to pull the ASROC out of the sand bottom. At 1410 hours the sea lion boat radioed that a second grabber had been secured to the target. Divers were sent down to inspect the target and to attach a safety line in case of another grabber failure. The divers returned to the boat at 1445 hours and reported that the ASROC was almost vertical and that the sea lion had properly secured the grabber to the tail section. Nevertheless, the divers attached their safety line as an added precaution. At 1450 hours the ASROC was removed from the water by using *only* the sea lion grabber and rope to complete the recovery (Fig. 28). At 1505 hours the ASROC was on board and secured in its shipping container.

Figure 28. Recovered ASROC depth charge.

After the YFU returned to SNI the sea lions were caged, carried to a pick-up truck, and driven to an awaiting helicopter for return to Point Mugu. The following day the equipment was unloaded from the YFU and taken to Point Mugu for crating. The material was placed on a truck for shipment to Hawaii, and the project personnel and animals were taken to Los Angeles International Airport. United Airlines personnel in Los Angeles were able to fit the sea lion cages in the cargo hold of a DC-8, so commercial flights will not be limited to the Boeing 747 jumbo jets. (Incidentally, the air fare for a sea lion one way from Hawaii to California is $50.10.)

To sum up, the sea lions had not been trained during inclement weather or during darkness, which may explain the animal's reluctance to perform during the first day of the recovery. The ASROC had landed on the bottom in a near vertical position, whereas the training target was placed at a 45-degree angle and occasionally in a horizontal position. The vertical orientation of the ASROC presented a new situation to the animals, and they were forced to approach the target at a new angle in order to trigger the grabber effectively. The ASROC was painted differently from the training target, and again a new situation was presented to the animals. In spite of the accumulative effect of these differences, which furnished a few tense moments during the recovery, the system concept was successfully demonstrated.

CONCLUSIONS

1. Sea lions can be conveniently transported to remote operating areas by a variety of methods without harming the animal and without adversely affecting his behavior. During the course of the training program, the animals were routinely transported aboard small surface craft, and during test and evaluation exercises, they were subjected to several aircraft flights, truck rides, and four YFU beach landings without any harmful effects.

2. The sea lions have demonstrated an ability to tow a large enough nylon line to retrieve objects weighing 2000 pounds and to correctly manipulate a clamping device.

3. The sea lions have demonstrated an ability to search for and to locate underwater pingered objects.

4. The sea lions have demonstrated an ability to work in rough weather and in remote and unfamiliar areas.

5. A reliable recovery system which does not require divers or submersibles has been developed to augment existing recovery units.

6. No further additional engineering and development work is necessary for the recovery of ASROC depth charges or torpedoes. However, other classes of targets, such as mines or instrumented packages, may require grabber redesign.

RECOMMENDATIONS

1. The repetitive deep diving capability of the sea lion should be utilized to reduce the hazards and complex logistic problems that deep diving operations present to human divers and submersibles.

2. A recovery team should be established using sea lions to augment existing test range recovery capabilities. The recovery team should be available on call to respond to any urgent recovery or salvage problem. Such a team could consist of several sea lions and military diver-handlers.

3. The possibility should be investigated of using sea lions, with their very acute vision, to search for and to locate unpingered objects.

4. Additional training should include a variety of different target placement positions.

5. Any future programs should make training mandatory in night and inclement weather.

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