
by Fred Wendell, Christine Pattison, and Michael Harris

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Fred Wendell, Christine Pattison, and Michael Harris
Marine Resources Division
California Department of Fish and Game
213 Beach Street
Morro Bay, California 93442

Abstract

Limiting sea otter geographic distribution in California (containment management) has long been recognized as being necessary to preserve human recreational and commercial uses of shellfish resources. However, passage of federal legislation that focused preferentially on marine mammal protection and the 1977 listing of the California sea otter population as "threatened" effectively precluded any range-limiting management program.

Research, however, that evaluated various non-lethal means of influencing sea otter movements and distribution was encouraged. Our research suggests that herding and acoustical devices may not have any real potential use in this context. Based on research-related capture success rates, capture and relocation techniques may be useful in influencing sea otter geographical distribution.

The translocation of sea otters to San Nicolas Island provided the first opportunity to test the technical feasibility of maintaining a large area free of sea otters. Capture success rates were appreciably poorer than those achieved during research-related efforts. We identify several logistical and behavioral influences that contributed to the relatively poor success rate. Based on this evaluation, we discuss the factors likely to limit application of these techniques in the future.

We feel that capture techniques can be useful in a long-term management program, if used in conjunction with efforts to limit the sea otter population growth rate. Consequently, we feel future research should focus on assessing individual health effects from using chemical contraceptives and assessing the feasibility of their use to safely control population growth.
Introduction

Most recreational and commercial use of shellfish in California has stopped when those shellfish populations have also been subject to predation by sea otters (Ebert 1968, Wild and Anes 1974, Miller 1975, Wendell et al. 1986, Wendell 1994). As a consequence, sea otter range expansion in central California has concentrated existing human use of shellfish into areas not occupied by sea otters and has exacerbated problems associated with long-term management of shellfish fisheries.

Early recognition of this pattern of displacement of human shellfish use as well as a recognition of the sea otter as a prized member of California's marine fauna lead to the first consideration of means to resolve the resource conflict. In 1967, the California State Senate passed a Concurrent Resolution requesting the Department of Fish and Game (Department) to "determine the feasibility and possible means of confining sea otters ... or other means that will maintain the abalone and sea otter populations and will lessen the possibilities of resource conflict ... ."

The Department undertook studies in compliance with the requirements of the resolution. Although research continued on ways of limiting the distribution of sea otters, concern over the loss of shellfish fisheries became a secondary issue in 1972 with the passage of the federal Marine Mammal Protection Act (MMPA). The MMPA imposed a legislative mandate that focused primarily on marine mammal protection. The Act transferred management control for marine mammals from states to the federal government and created the Marine Mammal Commission to provide guidance. Sea otter management was assigned to the U.S. Fish and Wildlife Service (Service).

In 1977, the California sea otter population was listed as "threatened" under the Endangered Species Act (ESA), which imposed an additional barrier to resolving the resource conflict. The threatened listing limited sea otter management options by focusing first on actions designed to reduce the threat imposed by the possibility of a large-scale oil spill.

Establishing one or more geographically separate colonies was identified in a sea otter Recovery Plan as the preferred way to reduce this potential threat (USFWS 1982). Nevertheless, the adverse effects that "translocation" would have on commercial and recreational shellfisheries in the vicinity of the new colony were recognized.

To alleviate some of these concerns, the Marine Mammal Commission recommended in a letter to the Service that they recognize the ultimate need for "zonal management". That is, in meeting their legislative mandates, the Service should recognize that the sea otter need not be reestablished to each and every area it once inhabited. Such an approach required designation of "otter" and "non-otter" zones and required development of methods for maintaining otters in their zones and removing them from designated zones managed for shellfisheries.

The effectiveness, safety, selectivity, and cost-efficiency of techniques likely to influence the movements and distribution of sea otters were reviewed in a contract study for the Marine Mammal Commission (Packard 1982). The Packard report also suggested research priorities on these issues. The social science perspectives surrounding assigning priorities to protection of marine mammals and human uses of shellfish were also discussed during this period (Cicin-Sain et al. 1982).

A broadly supported plan (Translocation Plan) was eventually approved with the passage of federal Public Law 99-625 and the selection of an area around San Nicolas Island as the site for the colonization effort (translocation zone). The plan was broadly supported because it included provisions for limiting the adverse effects that "translocation" would have on commercial and recreational shellfisheries. This was achieved by authorizing the non-lethal capture and removal of all sea otters observed in a large area surrounding the translocation zone (management zone) and relocating them within the mainland range (Figures 1 and 2). Thus, implementation of the translocation plan in 1987 provided the first opportunity to test the technical feasibility of non-lethal containment management. Here, we report on aspects of the Department's early research into methods with potential for influencing sea otter spatial distribution. We also evaluate the effectiveness of the approach used in the first effort to maintain an area free of sea otters. Finally, we evaluate the potential for a successful, long-term resolution of the resource-use conflict and identify factors likely to limit the success of zonal management, and the potential for successfully surmounting them.
Acoustic Repellents

A test of sea otter sensitivity and behavioral reaction to the sound emitted by an underwater electronic acoustic device was conducted in the Monterey area (Figure 2). The nearshore habitat in this area is rocky bottom interspersed with sandy areas. The dominant canopy-forming kelp in the test area was the giant kelp, Macrocystis pyrifera.

The test device produced a randomized pulse from portions of the signal emitted by a sweep-signal generator. The signal was sent through a 1000-watt amplifier and then to a transducer in the water. The transducer was designed to operate within specific frequencies. The system produced a full load of power (sound) with a minimal buildup to and from the peak. The result was a sudden burst of loud noise sent at random intervals, for varying lengths of time, and at varying sound ranges (10-40 kHz).

The experimental subjects were individual resting otters, either females without dependent pups or males. The otter was approached slowly by boat. When a diving response was achieved, a prior random-choice determination established whether or not the device was activated.

The boat remained stationary once a diving response was elicited. The operator, after activating the sonic device, mapped the movements of the animal at 15-second intervals. Data were recorded on time of day, environmental conditions, and general appearance of the test animal (sex, approximate age, health, wet or dry).

Two observers located at the bow of the boat, unaware of whether the device was activated or not, independently recorded behavioral observations for a 2-minute period. Analysis of the recordings provided estimates of the time an otter spent underwater, the number of dives made, the amount of time spent on the surface with head submerged, time spent swimming, and estimated distance moved. The test ended with a subjective appraisal of whether the observations suggested a behavioral response to the signal.

Herding

A test of the sea otter’s response to herding was conducted in the Estero Bay area near Cayucos Point (Figure 2). The nearshore area includes both rocky and sandy substrate. The rocky substrate typically supports giant kelp.

Methods

Management-related research conducted by the Department’s sea otter project in the 1980’s focused on ways to control and/or influence sea otter distribution or movement. These efforts included testing the usefulness of an acoustic repellent device, herding with boats and noise makers, and capture techniques.
The study design incorporated a phased approach. That is, subsequent testing was dictated by the results of prior tests. The first phase tested the feasibility of herding otters ahead of a line of slowly moving boats. Eight boats ranging in size from 12 to 28 ft in length were used. Each boat also had some form of noise maker for startle effect.

The noise makers used have been employed by the Service as a noninjurious method of herding waterfowl (bird bombs, whistlers, and cracker shells) and by commercial salmon fishermen on the Columbia River to keep harbor seals away from gill nets (seal bombs). The devices create a loud report or flash and are propelled from a special pistol, shotgun or by hand. The greatest range obtainable is approximately 150 yards.

In the first herding effort, six boats approached the study area from the south in a line perpendicular to the shore. Although the boats were to maintain a line, the initiation and subsequent use of noise makers was unrestricted. The pace of movement was dictated by a lead vessel. Two additional vessels followed along to herd animals missed by the larger group of boats.

The area was surveyed before, during, and after the herding attempt to provide count data for evaluation purposes. A follow-up monitoring schedule was established to determine the length of time taken for otters to reoccupy the area. Monitoring was scheduled for 1, 3, 7, 14, and 28 days after the herding or until counts indicated that 50 percent of the preherding population had reoccupied the area.

The necessity for and frequency of herding in subsequent phases of the test was based on the rate of reoccupation. Subsequent herding provided data to evaluate the potential for negative conditioning through harassment. Herding evaluations were limited by permit to no more than 10 attempts, but were to be terminated if proven ineffective at preventing reoccupation for 14 days.

Capture Techniques

Ongoing field testing and refinement of capture equipment and techniques focused primarily on the use of tangle net and diver-operated traps (Wilson trap).

Observations made during the herding experiments suggested that herding otters into tangle nets might be feasible in isolated kelp beds, particularly those that were used by large rafts of otters. A channel was cleared of kelp, tangle nets were set within the channel, and each net was anchored at both ends to maintain proper orientation. A small skiff equipped with a kelp-cutting knife to facilitate slow travel through the surface kelp canopy was used to coax otters toward the net.

A trap system has also been developed to capture sea otters. Development and early use of the diver-operated trap was described by Wild and Ames (1974). The trap is maneuvered up and around the otter from beneath while they are resting on the surface. The initial use of a diver propulsion vehicles to propel the trap was described by Ames, Hardy, and Wendell (1986).

For the subsequent changes in the trap, in the use of diver propulsion vehicles (DPVs) and, in the diver’s breathing equipment. Field testing of prototype capture systems was conducted as circumstance allowed and evaluations were largely subjective in nature.

Changes in the diver’s breathing equipment involved converting from conventional SCUBA to oxygen rebreathers. A contract with the U.S. Navy provided a SEAL Team equipped with rebreathers to allow the Department to evaluate whether use of this bubbleless equipment would improve capture efficiency. The test was inconclusive because the Team lacked familiarity with sea otters and the underwater trap. However, the time spent directly under resting otters without disturbing them suggested that the elimination of the diver’s exhalent bubbles had the potential for greatly improving capture efficiency.

We obtained training in the use of oxygen rebreathers from the Navy. Additional self-paced training with the rebreathers incrementally incorporated the use of the diver propulsion vehicles and traps and progressed from protected shallow waters to unprotected open-water areas.

Results

Acoustic Repellents

The underwater acoustic device was tested on 10 individuals (five test and five control) in the Monterey area in September 1983. An average of 2.1 dives per otter were made during the test period with a range from one to five dives (Table 1). Test animals made significantly more dives (Wilcoxon test \( U = 3, P = 0.028 \)). The proportion of surface time spent with the head submerged was also greater for test animals.
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(U = 5.5, P = 0.047). The cumulative amount of time spent underwater ranged from 2 to 83 seconds and averaged 32.3 seconds. There was no statistically significant difference between test and control animals in the amount of time spent underwater (U = 11.5, P = 0.460). There was also no difference in the amount of time spent swimming at the surface (U = 8, P = 0.210) or in the distance moved (U = 13, P = 0.580).

The on-site (blind) observer assessment of whether the otter was being exposed to the acoustic device’s signal was completely accurate. The otter’s behavior, primarily the amount of time spent on the surface with the head submerged, made it apparent when the device was activated or not. However, the signal did not elicit a startle or directional response.

To aid us in understanding the nature of the otter’s response, two observers in snorkel gear subsequently entered the water and slowly approached the boat while the acoustic device was operated. The signal was obvious from a considerable distance (200 m). However, the divers were able to approach to within touching distance of the transducer without discomfort.

Herding

Counts in the area the day before the herding experiment in July 1984 ranged from 102 to 110 individuals and included females, pups, and a large raft of males.

The otters’ response to the herding experiment was not unidirectional. At least seven otters moved

<table>
<thead>
<tr>
<th>Otter no.</th>
<th>Group</th>
<th>Behavior</th>
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<tr>
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</tr>
<tr>
<td>2</td>
<td>Test</td>
<td>5 51 26 0.377 17 25</td>
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<td>Test</td>
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<td>5</td>
<td>Control</td>
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<tr>
<td>7</td>
<td>Test</td>
<td>2 18 21 0.206 35 20</td>
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<tr>
<td>9</td>
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<tr>
<td>10</td>
<td>Test</td>
<td>1 10 16 0.146 0 15</td>
</tr>
</tbody>
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Mean Control 1.4 30.2 12.4 0.140 12.2 26.0
S.E. 0.4 13.9 4.8 0.044 8.2 7.3
Mean Test 2.8 34.4 32.6 0.396 22.2 24.0
S.E. 0.7 11.1 11.2 0.116 6.7 2.9

Behavior description

1 Number of dives
2 Time (seconds) spent underwater
3 Time (seconds) at surface with head submerged
4 Proportion of total surface time with head submerged
5 Time (seconds) spent swimming at surface
6 Estimated distance moved (meters)
behind the line of boats and swam south. Twenty-six otters were observed in very shallow inshore water displaying normal resting and feeding behavior after the herding effort had started. Otters that moved into open water dove and swam in various directions. Some animals simply refused to move more than a few feet to avoid approaching boats. Individuals that refused to move out of the kelp bed were mostly young (dark-headed) animals. These animals tended to swim short distances on their bellies while occasionally looking down into the water.

Whistlers were largely ignored by all individuals. Cracker shells elicited a startle response if they were fired near the water; they were ignored if they exploded high in the air.

Census efforts the day after the first herding experiment yielded a count of 103 otters. Since there was no obvious decline in the density of otters, the second herding attempt was modified to determine if a concentrated effort could move all otters out of a single large isolated kelp bed.

Counts in the selected kelp bed ranged from 41 to 46 individuals within 1 hour of the herding attempt. Seven boats approached the bed in much closer formation and stopped before entering the bed. A barrage of noise makers started the slower-paced movement through the bed. The largest group of otters in the bed broke away from the approaching boats after that barrage. At least five otters never left the bed despite a good deal of effort focused in their direction. All boats were beyond the kelp bed after 1 hour. The number of otters observed in the kelp bed subsequently increased to 12 within 15 minutes. Twenty individuals were observed in the bed within 30 minutes. Thirty-eight otters were counted in the bed within 1 1/2 hours after the end of the herding experiment.

The herding experiment was not successful and was stopped after the two attempts. However, the effort suggested that individual otters could be coaxed to move in a selected direction within a bed through the slow and careful movement of a skiff. This observation coupled with the otter’s general reluctance to leave the kelp bed suggested a modification to capture techniques that has subsequently proven successful.

Capture Techniques

Use of the tangle nets proved most productive in areas with poor water clarity and within kelp beds used by large rafts of male otters. Repeated capture attempts were made possible by the otters’ tendency to remain together and their reluctance to leave the confines of the kelp canopy. With these behavioral characteristics, otters could be coaxed to move toward the net by slowly moving the capture boat toward the otters from the side opposite the net. The otter’s reluctance to leave the bed allowed the boat to approach the group from the other side of the net for another pass. This sequence could be repeated and had the advantage that otters, once caught, spent relatively little time in the net compared to passive tangle net operations.

This capture technique proved to be labor intensive. Many hours were spent cleaning kelp and debris from the net and mending holes created by cutting the net to expedite removal of captured animals. However, it also proved very effective when conditions precluded use of other capture techniques. The peak capture rate by a single crew, 11 otters in a day’s effort, was similar to rates achieved using other capture techniques.

Much of the Department’s current containment research has focused on refining our capture capability using the diver-operated Wilson trap. Maneuvering through thick kelp was improved by using thinner gauge tubing to reduce drag weight. The trap’s pursing system was modified by rerouting the pursing line to allow complete closure of the net bag with a shorter pull. This provided for faster pursing and made securing the net bag easier.

Use of diver propulsion vehicles (DPV) allowed both team members to operate a trap on a dive. We replaced the longer Farallon model DPV with a shorter Tekna model to tighten the turning radius. We improved the diver’s ability to monitor depth and compass direction by attaching an instrument panel to the vehicle (Figure 3). The greatest increase in efficiency came when we eliminated the diver’s exhalent bubbles by converting from conventional SCUBA to oxygen rebreathers. Captures were made in much more turbid conditions than were typically productive using conventional SCUBA; the capture of more than one otter during a dive was more common and the number of unsuccessful dives decreased significantly. The maximum number of otters caught in a day’s effort by a capture team doubled (7 to 14) and selectivity was greatly improved. Divers were often able to target animals, based on size or tags, because they could stay under the otters longer without the otters being aware of their presence.
Discussion

Research
The field tests of the acoustic device and herding techniques suggested that these would be unsuccessful in influencing the movements and distribution of sea otters in a containment management scheme. Capture techniques, on the other hand, have been developed and refined to the point where they are useful for some aspects of containment management.

The number of otters captured within the mainland range in one day by a three-person team using the Wilson trap and rebreathers ranged from seven to 14 animals. Thus, any effort that relies solely on these techniques will be labor intensive.

Implementation
The practical application of capture and relocation as a management tool was tested in conjunction with the sea otter translocation effort. The law authorizing the translocation (P.L. 99-625) established a no-otter management zone around the translocation area and required the non-lethal removal of all otters found there.

The Service established, through regulation, the approach to be taken in implementing the containment management effort. A Memorandum of Understanding was developed that defined the respective roles and responsibilities of the Service and the Department in conducting containment activities. The Service agreed to provide the necessary funding and personnel to implement, enforce, and carry out the program. The Department agreed to provide trained personnel and capture equipment to assist in the containment efforts.

Capture and relocation was identified through proposed regulation as the preferred method for maintaining the management zone free of sea otters (50 CFR Ch. 1 (10-1-87 Edition)). The regulations required verification of sightings before a capture effort was mobilized. The verification initially proposed was the confirmed sightings of two otters together for more than 2 weeks.

The Department expressed the concern that the response had to be rapid to be effective. Verification and a capture attempt should occur virtually simultaneously. Anything less would hamper implementation by imposing unnecessary delays. The final federal rulemaking required confirmed sightings of one or more otters before initiating a capture effort.

Implementation was hampered by the verification requirement. During the first 2 years of effort, the Service received reports of 56 sightings within the management zone of which 23 were verified. Both misidentification and otter movement probably influenced the number of sightings that could be verified. However, only three capture efforts occurred during this period. Three otters (two adults and one dependent pup) were captured and relocated in two of those attempts. Thus, the operation was relatively successful when a team responded quickly.

The relative lack of success in getting a team to the otters was due to delays caused by the verification requirement and the need to subsequently coordinate with the Department to organize a capture attempt. Coordination with the Department was necessary because of the Service's lack of an independent rebreather-equipped capture capability. The Service did not have all of the equipment necessary to operate independently during the first 2 years of the implementation effort. Personnel changes within the Service and the subsequent need for training necessitated cooperative capture efforts for another 3 years.
Funding subsequently became a problem. By May 1992, the Department was expressing concern over the effect that the Service’s chronic funding problems was having on the cooperative containment effort. The Service’s renewed commitment to provide funding at that time resulted in the removal of 10 otters from San Miguel Island in six trips made through February 1993.

No containment efforts have occurred since February 1993. Although not immediately apparent, the Service’s distribution of funds among other activities had resulted in the loss of funding for containment.

The Service indicated that containment efforts were being stopped early in 1993 while they evaluated whether the death of an otter after a release constituted a form of lethal take rather than the non-lethal approach required by law. The results of that evaluation were never distributed. However, the Service had already provided a formal biological opinion, in the EIS on the translocation, that acknowledged that deaths were likely during a capture and relocation effort (USFWS 1987).

On the positive side, the program was adaptable in that the verification requirement was eventually dropped in areas where sightings were frequent. The implementation approach was modified by conducting visual scans from shore in areas where sightings were frequent while simultaneously being prepared to capture. This approach showed potential, but, was not fully tested before the observation of a large group of otters (10-14) at San Miguel Island changed the focus of the containment program. Almost all subsequent effort was directed toward the capture and relocation of that group.

The island's remote location presented unique challenges for a capture and relocation effort. Since the capture boats were too small to provide overnight accommodations, a modification of the typical approach was required. Two modifications were considered; either work from a slightly larger vessel with limited overnight accommodations such as those used by the commercial diving fleet or charter a much larger vessel to provide living accommodations. The commercial diving industry operates at San Miguel Island from fast boats with limited overnight support capability. Thus, they are prepared to move rapidly to take advantage of optimal conditions and are prepared to stay the few days typical of a good weather window.

The Service chose to provide the overnight support by chartering a larger vessel. The decision to operate from a charter boat rather than purchase a vessel similar to that used by the abalone fleet was neither cost-efficient nor effective. The charters were expensive, required scheduling. Consequently, the capture team worked under a range of weather conditions including some when a capture effort would not normally have occurred.

Capture opportunities were also affected by the decision to fly captured otters to the capture-range release site. Capture operations had to cease at an early time of day to allow sufficient time to transfer otters to a plane at Santa Rosa Island during daylight hours. The Service did not consider holding sea otters overnight or providing boat transport to the mainland to be viable options.

Capturing otters at San Miguel Island was particularly difficult because of the site used by the otters and their particular sensitivity to the presence of boats. The most common rafting site was located near Point Bennett in a portion of the foul area where large reef systems funnelled and refracted the force of oceanic wave trains. The otters became active at any sighting of a boat, perhaps because of their relative isolation in a food rich area. Consequently, it was particularly difficult to get near enough to resting otters to stage a capture run.

Through trial and error, a system was developed that was effective in capturing otters. Capture runs were initiated on otters that apparently could not see the boat and were based on directions from a shore-based observation team. Course corrections were relayed to the divers from the capture boat using flag signals. The number and frequency of captures increased through time suggesting that these modifications were successful. All but two otters were removed from the Island before the Service’s funding stopped completely.

The experience gained in implementing the containment provisions of the Translocation Plan suggests that capture and relocation can be a useful tool in a long-term management program. The experience has also suggested modifications in approach that would enhance its effectiveness. However, it will likely remain labor intensive and costly.

Long-Term Feasibility

There is potential for substantially reducing containment costs through streamlining the imple-
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ment process and by keeping the number of no-otter zones to a minimum. Capture and relocation techniques would never stand alone in a long-term management plan. Eventually, a successful capture and relocation effort coupled with natural population growth would force localized otter populations beyond carrying capacity. Both individual and population health would be compromised. To manage a sea otter population for maximum health and resilience, a long-term management plan may also have to consider measures to limit population growth. Without some method for controlling population growth within occupied habitat, whether statewide or within otter zones, sea otters will generally have poorer health profiles and the amplitude of die-offs will be greater.

Chemical contraceptives and surgical procedures could potentially be useful in regulating sea otter reproduction (CDFG 1987). Potentially useful antifertility agents, reproductive inhibitors, and administration methods have been identified. However, no steps have been taken to test health effects on individual animals or to develop models to evaluated their effectiveness in controlling population growth.

These steps should be taken. Active management of sea otters is not a universally appealing idea. However, further study into the feasibility of controlling sea otter distribution will aid in reaching a decision on a future course of action.

We believe that an optimal population size would be one that provides resiliency and is resistant to large-scale fluctuations. A population size that is appreciably below carrying capacity would be one that is most likely to demonstrate these characteristics. If one recognizes this as a reasonable assertion, then long-term management plans would entail limiting sea otter numbers even if the loss of shellfish for human use was not an issue.

We also believe that, if left unchecked, sea otter range expansion will result in the loss of most recreational and commercial shellfish fisheries along the north Pacific rim. Given the potential magnitude of these losses and the likelihood that sea otter numbers will eventually be managed to avoid population crashes, it would seem that zonal management provides a balanced compromise for conflicting resource uses. Conceptually, this may seem so. However, the costs associated with zonal management will be substantial. Otter-free zones will have to be very large to provide enough shellfish resource to justify the cost while supporting the needs of a growing human population.

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Literature Cited


