

May 9, 2005

Lacking a decent meal, killer whales reach for the popcorn

By [Françoise Chanut](#)

A study comparing the nutritional demands of killer whales with the caloric content of their prey has startling implications for the potential impact of these large predators on populations of other marine mammals.

The study also raises issues relevant to the establishment of marine reserves and efforts to reintroduce large predators into terrestrial ecosystems, said Terrie Williams, professor of ecology and evolutionary biology.

Williams and her coauthors at UCSC and the University of Alaska published their findings in the December issue of the journal *Ecology*.

Their analysis suggests that as few as 40 killer whales preying on Steller sea lions along the coast of the Aleutian Islands could have caused the fivefold decline that has been recorded in that population since the early 1980s. Similarly, the more recent tenfold drop in sea otter numbers in the same area could be the feat of just one pod of four or five killer whales specializing in sea otter hunting.

"Our main finding is the magnitude of the appetite of the killer whales," Williams said. "Predators with such a large body size and high metabolic rate have high nutritional demands."

This study bolsters a hypothesis put forth by the authors in earlier papers that linked declining marine mammal populations in the Pacific Northeast to the decimation of the great whales by industrial whaling.

The story begins more than a decade ago when Williams's coauthor James Estes, adjunct professor of ecology and evolutionary biology at UCSC, was trying to understand the rapid disappearance of sea otters in parts of the Aleutian Islands, a 1,200-mile archipelago west of the Alaska Peninsula. The first eyewitness reports of killer whale attacks on sea otters came in the 1990s, a time when the Aleutian sea otter population was declining by 25 percent each year. But in protected bays that were inaccessible to killer whales, Estes found the sea otter populations to be stable. He concluded that killer whale predation was driving the disappearance of the sea otters.

At the same time, researchers had been puzzling over the precipitous decline of Steller sea lions and harbor seals in the same region. They had first blamed overfishing by commercial fisheries, which would deprive seals and sea lions of their staple food. But they couldn't find evidence that the animals were dying of starvation, nor for that matter of any illness.

"After having seen what killer whales did to sea otters, it wasn't hard to imagine that they could do the same thing to seals and sea lions," Estes said.



The skull of a killer whale in relation to a sea otter skull emphasizes the size difference. Recent studies indicate that killer whales have been preying on sea otters in areas of the Aleutian Islands where the sea otter population has collapsed.

Photo: T. M. Williams

Looking at records of marine mammal counts dating back to the 1950s, coauthor Alan Springer of the University of Alaska in Fairbanks observed successive waves of population collapses. The sea otters' nosedive that began in the early 1990s came after similar trends had affected Steller sea lions in the late 1980s and harbor seals in the late 1970s. Before these declines, the 1960s had seen the decimation of the North Pacific great whales by commercial whaling.

The team proposed that killer whales had once fed primarily on great whales, until those large prey became too scarce to provide a steady food supply. The killer whales then redirected their hunting to progressively smaller animals.

But did the numbers add up? That is the question the researchers set out to answer in their latest paper.

It is difficult to evaluate the nutritional requirements of large predators, Williams said. Scientists know how much killer whales eat in captivity, but not when they are swimming and hunting in the open ocean. Direct measurements of killer whale diets in the wild were not feasible, but Williams and others have done extensive research on the physiology and nutritional needs of smaller marine mammals, such as dolphins and seals.

Williams extrapolated from this work to estimate the caloric intake of the much larger killer whales. She calculated that an adult female, weighing approximately two tons, would need more than 190,000 kilocalories per day; a 4.5-ton male would need 290,000 kilocalories per day.

Adult sea otters weigh between 50 and 75 pounds, which represents, on average, 50,000 kilocalories. Depending on its size and the size of its prey, an adult killer whale could satisfy its appetite by gobbling up between 3 and 7 sea otters a day--or 1,095 to 2,555 otters per year.

Williams estimated that the decline of sea otter numbers in the 1990s in the Aleutian Islands corresponded to the loss of approximately 10,000 adults per year. An average pod of killer whales (one adult male and four to five adult females) with a single-minded appetite could easily eliminate that many otters.

Biologists recognize at least two different types of killer whales in the northeastern Pacific Ocean. They differ in behavior, social structure, genetics, and diet. Most killer whales eat fish, but a small proportion--perhaps 10 to 17 percent--feeds primarily on marine mammals. A conservative estimate places the number of marine mammal-eating killer whales at around 170 in the Aleutian Islands waters, according to Williams and her colleagues. While no killer whale may care for a diet consisting exclusively of sea otters, each one of those 170 orcas would only have to eat one or two sea otters a week to cause the observed decline.

Compared with the lean sea otters, blubber-padded seals and sea lions have a high caloric content, so fewer are needed to feed a killer whale. Williams estimated that an average adult killer whale would be satiated on two to three Steller sea lion pups every day or one adult every two to three days.

A predator population of 170 killer whales bent on a sea lion diet would remove 40,000 individuals from circulation each year, three times the number needed to drive the yearly rate of Steller sea lion decline observed since the 1980s.

By comparison, one great whale represents an enormous supply of calories. "You could feed 17 killer whales for a day on a single gray whale carcass," Williams said.

Williams noted that she probably underestimated the potential impact of killer whales, because she didn't factor in the greater caloric requirements of pregnant females and growing juveniles. Her calculations do not prove that killer whales are responsible for the disappearance of smaller marine mammals, but they show that it is a definite possibility.

"It's really a feasibility study," Estes said.

Over years of field observations in the Aleutian archipelago, Estes has found no evidence that sea lions or otters were starving, a common hypothesis to explain large population drops. On the other hand, there is a lot of historical and current evidence that killer whales attack and feed on large whales, he said. After the great whales declined, it would make sense for killer whales to turn to other kinds of prey.

In the Monterey Bay, reports of killer whale attacks on gray whales are common during the spring migration. The killer whales prey on juvenile gray whales as they migrate with their mothers from calving grounds in Baja California to feeding grounds in Alaska.

"What is remarkable is how quickly we could lose the sea otter population in the Monterey Bay if killer whales decided to change from hunting gray whale calves to feeding on otters. Theoretically, the otters would be gone in two months," Williams said.

Switches in predatory behaviors are well documented among land animals, Williams said. Lions, for instance, may prefer wildebeests, but they will hunt small antelopes in the absence of larger prey, she said.

"Many carnivores chose prey that make energetic sense," she said. "Rather than starve when preferred foods are gone, they may turn to the prey equivalent of rice cakes and popcorn."

Killer whales are resourceful, Estes said. Different groups of marine mammal-eating killer whales have different diets and hunting strategies, he said. Some specialize in seals, others in porpoises.

"A few animals learning to do something clever could have a lot of local impact," Estes said. "The implication for nature conservation is that whale populations should be allowed to recover. Gray whales may have completely recovered, but they are a very small part of the whole whale community."

The methods Williams and her colleagues used--demographic analyses and measurements of caloric value--have been around since the 1940s, she said. What's new is putting together physiology and demographics.

"It is amazing that we haven't made more use of these simple analyses," she said.

Knowing the nutritional requirements of killer whales has important implications for the design of marine reserves. Williams drew a parallel with the reintroduction of wolves in Yellowstone. "We would like to re-create a natural ecosystem, but we need to do it with a realistic idea of what predators are going to need to survive," she said.

She is currently applying her approach to estimate the ecological impact of terrestrial predators, such as coyotes and mountain lions, on local ecosystems.

Alaska Science Forum

December 10, 1998

Killer Whales Develop a Taste For Sea Otters Article #1418

by Ned Rozell

This column is provided as a public service by the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community. [Ned Rozell](#) is a science writer at the institute.

Sea otters are getting harder to find along the western part of the Aleutian chain. Their population has dropped from about 53,000 animals in the early 1990s to only 6,000 today. Some biologists think the missing otters of western Alaska have disappeared to an unlikely place--the bellies of killer whales. Researchers say the actions of people may have caused this unusual switch in the diet of killer whales.

Jim Estes, a wildlife research biologist who works for the U.S. Geological Survey at the University of California, has watched sea otters in Alaska since the 1970s. On his 1990s cruises to the Aleutians, he and other biologists noticed a 25 percent decline in sea otters each year. At first, Estes didn't consider killer whales as a reason for the sea otter decline. Killer whales mostly eat sea lions, seals, and other marine mammals that spend most of their time far offshore, away from sea otters.

When he was on a cruise from Attu to Dutch Harbor in the early 1990s, Estes and his colleagues saw killer whales where they hadn't before, observations that later became a clue to the disappearance of the sea otters. "We were seeing killer whales near the beach all the time," Estes said during a phone interview from his office in Santa Cruz, California. "All of us commented on how peculiar that was."

The whale sightings in shallow waters frequented by sea otters coincided with a nosedive in the population of harbor seals and Steller sea lions, but Estes said he was skeptical about the killer whale-sea otter connection. One reason for his doubt was that in several decades of going to sea and observing otters, he had never actually seen a killer whale eat a sea otter.

No one had published a scientific paper on killer whale predation on sea otters until Brian Hatfield, also of the U.S.G.S. in California, gathered anecdotes for a paper

published in the October 1998 *Marine Mammal Science*. Researchers doing wildlife surveys following the Exxon Valdez oil spill and biologists studying otters in the Aleutians witnessed killer whales attacking sea otters.

One method the whales used was to breach near floating otters and land on top of them, presumably eating the stunned otters underwater because the animals never returned to the surface. Hatfield concluded that the lack of reports of killer whales eating sea otters may be due to the fact that killer whales have only recently shifted their diets to include sea otters, possibly because of the decline of Steller sea lions and harbor seals.

Estes said he wasn't convinced killer whales were eating sea otters until he and Tim Tinker, also from Santa Cruz, did a study in which they compared two populations of sea otters at Adak Island. The number of sea otters in Clam Lagoon remained stable from 1993 to 1997, while sea otters in nearby Kuluk Bay disappeared at a rate five times greater. Clam Lagoon is an area uniquely protected from killer whales by a narrow channel only three or four feet deep, while Kuluk Bay is open coastline that offers otters no protection from killer whales.

One killer whale with a taste for sea otters could eat more than 1,800 sea otters a year, Estes said. Why the killer whales changed their diet is still a matter of speculation, but people may be the culprits. In a recent Anchorage Daily News article, director Andy Rosenberg of the National Marine Fisheries Service said a link may exist between overfishing of pollock and the decline of the Steller sea lion, a killer whale prey species that has declined more than 70 percent since the 1960s. Estes said the cause of the killer whales' change in menu may also be a natural warming of the ocean or some other change in ocean ecology.

Alaska Science Forum

March 24, 2005

Glacier Bay hot real estate for sea otters

Article #1743

by Ned Rozell

This column is provided as a public service by the Geophysical Institute, University of Alaska Fairbanks, in cooperation with the UAF research community. [Ned Rozell](#) is a science writer at the institute.

Sea otters have had a rough time since Vitus Bering's journey to Alaska: They were hunted almost to extinction in the 1700s and 1800s, made a comeback in the 1900s, then declined again in the last few decades. Though sea otter numbers are dropping in the Aleutians and elsewhere in Alaska, the animals are increasing in Glacier Bay.

About five sea otters lived in Glacier Bay in 1995, but today more than 1,800 live there. Jim Bodkin and his colleagues at the USGS Alaska Science Center in Alaska have studied the sea otter's recent emergence in Glacier Bay. A biologist, Bodkin started the study in 1993, two years before otters showed up in the bay. He and other researchers knew otters were nearby at the time and would probably soon move in. Glacier Bay National Park,



located in Southeast

A sea otter in Glacier Bay, one of the few places in Alaska with a growing sea otter population. Jim Bodkin photo

Alaska, has been in existence for about 250 years, when huge glaciers at the mouth of the bay began retreating.

The Russians and later the Americans almost wiped out Alaska's sea otters because the otter's fur is among the thickest in the animal world, with more hairs per square centimeter than the total on any person's head, according to otternet.com. Males can be nearly five feet long and can weigh more than 100 pounds. They dive to the sea floor to hunt and eat while floating on their backs, using their forepaws to eat sea urchins, clams, mussels, crabs, and octopus.

Starting in 1965, the Alaska Department of Fish and Game captured otters on Amchitka Island in the Aleutians and some in Prince William Sound, releasing 412 off the coast of Southeast Alaska, a few of those off Cape Spencer near Glacier Bay. In the mid-1990s, some otters found their way into Glacier Bay. Bodkin and his coworkers counted five otters during an aircraft survey of Glacier Bay in 1995. They counted 39 in 1996 and 21 in 1997, but since then the yearly counts have showed more and more otters. From 2000 to 2001, sea otter numbers more than doubled, from 554 to 1,238.

At the same time, sea otters in the Aleutians and other areas of Alaska have been decreasing. Some scientists think the population crash is due to killer whales eating more sea otters in the Aleutians, possibly because traditional killer whale prey, such as large whales and sea lions, have also dwindled in the Aleutians. Terrie Williams of the University of California and Jim Estes of USGS authored a recent study in the journal *Ecology* showing that male sea otters contained almost 62,000 calories when eaten whole, a decent percentage of the 243,000 calories an average male killer whale needs to survive each day.

Killer whales also hunt in Glacier Bay, but they don't seem to be slowing down the otters. People have seen killer whales eat otters in Southeast Alaska, but other marine mammals that killer whales eat are not as rare in Southeast as they are in the Aleutians and that perhaps takes the pressure off the otters, Bodkin said.

While the possible otter/killer whale connection in the Aleutians is intriguing, Bodkin and his colleagues are more interested in looking at the sea otter as a predator and how its sudden emergence in Glacier Bay will affect other living things. Clams in Glacier Bay might be fewer and smaller after a few years, and the distribution of sea birds, fish and some other mammals could change there with the sea otter feasting on local crabs, sea urchins and other shellfish.

Because scientists began the study before otters were in Glacier Bay and sea otters haven't yet occupied the entire bay, the researchers have been able to document the plants and animals of the bay before otters. While other scientists study the otters in the Aleutians as victims of changes that began with the 1741 passage of Bering's ship, the *St. Peter*, Bodkin will look at Glacier Bay otters as agents of change in a young ecosystem.



Sea Otter
Photo © PhotoDisc

Sea Otter

Enhydra lutris

Sea Otters are playful animals that spend almost all their time in the sea. They eat, sleep, and even have their babies in the water. In the daytime sea otters float on their backs eating Abalone, their favorite food. To open the Abalone shell they place a small rock on their chest and smash the shell against it. Sea otters are one of the few mammals, beside humans, that use tools. They will use strands of kelp to tie themselves into the kelp beds for a secure night's sleep. They love to frolic with other otters and seals. Unlike seals and walrus, sea otters have no blubber to keep them warm in the cold arctic waters. Air trapped in their fur keeps them warm and bouyant. Oil spills can damage this fine fur and cause the otter to get very cold and die. That is why volunteers cleaned the sea otters so carefully after the oil spills in Alaska.

Sea otters also faced great dangers from hunters who wanted their valuable coats. They were hunted so heavily in the 18-19th Centuries that they had to be placed on the U.S. government endangered species list. Now the populations have come back to a large extent, but conservationists would like to continue to protect them. Fishermen would like them off the endangered species list in order to protect the abalone harvest.

19th Century Naturalist

Edward Nelson Recounts:

"In 1760-65 when Bering and his party first explored the Aleutian Islands, they found the Sea Otters so numerous that the Aleuts wore long mantles made of their skins and a scrap of old iron was enough to secure the finest skin. In 1840 Veniaminov wrote that the Sea Otters in these islands are distinguished above everything on account of their great value and small numbers. There was a time when they were killed in thousands, now only by hundreds. There are plenty of places where before there were great numbers of Sea Otters; now not one is to be seen or found. The reason for this is most evident; every year hunted without rest they have fled to places unknown and without danger.

When the Fur Seal Islands were discovered the sea otters there were very numerous, and two sailors killed five thousand there the first year. The next year less than one thousand were killed, and from the end of the next six years to the present day the Sea Otter has been unknown there. From the Aleutian Islands south to Oregon the Russians found these otters so numerous that they were obtained in numbers running from two to three thousand kills per year. This great increase in the

catch during the later years is entirely due to the greater vigor with which the animal has been hunted, and the introduction of fine long-range rifles. Good rifles now replace to a great extent, the primitive spears.

There is little doubt that in the course of a few years under the present regulations and mode of hunting, this valuable animal will be exterminated, and in place of affording the Aleuts a livelihood will leave them dependent upon the Government."



Sea otter, eating abalone, Point Lobos, CA
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The Otter Enigma

Sea otter populations explode in Southeast and crash in the Aleutians, triggering chain reactions that will alter the ecosystem and the economy.

By Doug Schneider

Thirty. Sixty. One Hundred Feet. Sea Otter No. 23 Quickly Disappeared

into the blue-green depths of Cross Sound, a remote waterway along Southeast Alaska's Icy Strait.

At the surface, Brendan Kelly watched his laptop computer to see how deep the otter was diving. A transmitter attached to the 97-pound male's flipper relayed the depth.

At 300 feet, the otter finally leveled off. "He's hit bottom," said Kelly, a marine mammal scientist at the University of Alaska Fairbanks.

No. 23 was probably looking for lunch, a task that is becoming increasingly competitive as sea otters repopulate areas of Southeast for the first time since Russian and American fur traders hunted them to extinction 150 years ago.

These days, an estimated 10,000 to 15,000 sea otters populate Southeast waters, about as many as probably existed when Vitus Bering stumbled onto the region's rocky coast in 1741 and claimed it for Russia.

The resurgence of sea otters in Southeast is a mixed blessing for the region's residents. Fishermen worry sea otters, which are voracious shellfish predators, will eat too many Dungeness crabs -- a favorite prey and the mainstay of the region's multimillion-dollar commercial fishery. Natives who depend on clam beds for subsistence also worry about the sea otter's impact.

Yet tourists love them, and in a region increasingly dependent on tourism, more sea otters is good news.

"After whales, I'd say the sea otter is the one animal that most impresses visitors," said Jim Hammond, operations manager for Auk-Nu Tours, a sightseeing company based in Juneau. "We have nice viewing out in Icy Strait, where they hang out in the kelp forests. They are an important part of our business."

But while Southeast is swimming in sea otters, populations in the Aleutian Islands have plummeted nearly 80 percent in the last seven years. Scientists say the two circumstances are not related. In Southeast, abundant prey has fueled the sea otters' dramatic population increase, while predation is responsible for the decline in the Aleutians.

More interesting, say scientists, is what will happen to these two ecosystems as the sea otter populations change.

"Sea otters are a keystone species," said Jim Bodkin, a sea otter researcher with the U.S. Geological Survey. "By definition, that means their presence or absence will trigger a host of significant changes to the ecosystem."

In Southeast, scientists want to know if too many sea otters will wipe out commercial crab stocks and decimate shellfish beds. In the Aleutians, they wonder if too few will erode the very foundation of the region's coastal marine food chain.

Largest of the Weasels

The sea otter is the largest of the mustelid family, which includes the mink, river otter, weasel and wolverine. But it's also the smallest marine mammal; adults weigh 60-100 pounds.

They've inhabited the North Pacific since the late Pleistocene era about 20,000 years ago, and Native peoples have harvested them almost that long, using their dense fur and thick hides for clothing and handicrafts. The sea otter still holds an important place in the cultures of Southeast Natives and the Aleuts of the Aleutians

Long and sleek, with large, leathery flippers, sea otters are most comfortable in the water. But they generally stick close to shore and rarely venture more than a few miles from land. That may help explain why Alaska's sea otters went undiscovered by Europeans for so long.

But once discovered, news of abundant sea otters and fur seals led to their exploitation. Russian traders arrived in the mid-1700s, followed by Americans beginning in the late 1700s. Russians aren't entirely to blame for the otters' demise, according to Bob DeArmond, longtime Southeast resident and historian who has written on Alaska's history and who now lives in the Anchorage Pioneers' Home.

"Natives did the hunting and the killing," DeArmond said. "They mostly sold their pelts to the Americans. There were probably 50 American trading vessels here from 1790 to around 1840. By that time there weren't enough sea otters left for it to be worthwhile."

Seventy-one years later, in 1911, Congress adopted the fur seal treaty, ending legal hunting of sea otters. By then they were considered extinct in Southeast and rare throughout the rest of the state.

Skyrocketing in Southeast

Today it's hard to imagine sea otters were ever missing from Southeast. They can be found in nearly every harbor, floating on their backs while grooming their fur or tending to pups.

From the mid-1800s to the 1960s, there were no sea otters in Southeast. In the late 1960s, federal biologists relocated 412 to Southeast waters from healthy colonies in Prince William Sound and the Aleutians; nearly half went to Kachemak Bay. At first, the otter population grew slowly. Then, beginning in the late 1980s, the numbers skyrocketed.

"They're now increasing at a rate of about 20 percent a year in Southeast," said Tom Shirley, a marine ecologist at the University of Alaska Fairbanks. "That's a better return than much of the stock market."

Today, about 10,000 sea otters live in Southeast. Without accounting for natural mortality and hunting (which is restricted to Alaska Natives), Shirley said that number is expected to double about every five years.

Ironically, Southeast sea otters owe their recovery to their nearly 150-year absence from the region. During that time, Dungeness crabs, urchins, clams, and abalone stocks grew -- becoming easy prey for today's otters.

"The predator niche filled by the sea otter was left empty for a long time after the sea otter was exterminated," Kelly said. "So the prey base was able to expand."

Crashing in the Aleutians

While life is good for Southeast sea otters, the good times have vanished for their Aleutian brethren. Along this remote 3,500-mile archipelago, sea otter numbers had recovered from the hunting of a century before. Yet in just the last few years, some 45,000 animals -- about 80 percent of the region's population -- have disappeared.

Jim Estes, a marine biologist with the U.S. Geological Survey in Santa Cruz, Calif., has visited the now-abandoned Navy station on Adak Island the last eight summers, studying sea otters. During that time, he's watched the population around the island tumble from 2,500 animals to about 300.

In addition, aerial surveys done in 1965 and again in 1992 show that sea otter numbers were lower at 26 of the 27 major islands in the Aleutian chain.

"That was a pretty clear signature in my mind that something fundamental was going on here -- and on a wide scale," Estes said.

Estes and his colleagues conducted studies on the likely culprits -- disease, starvation, pollution and other causes. They ruled out each one.

Another possibility was that something was eating the otters. But what could eat so many over such a large area in so little time? In an article published last October in the journal *Science*, Estes and his co-authors put forth an unexpected answer: killer whales.

"Even we thought that killer whales being responsible was the most outlandish thing," Estes said. "They don't normally feed on sea otters much, since otters don't offer much in the way of nutritional reward. They are bony, furry creatures without much meat or fat."

But then he and his colleagues began witnessing killer whale attacks on sea otters in 1991. They found further evidence when they compared two sites: Clam Lagoon, a place where sea otters gather that is too shallow for killer whales, and Karluk Bay, an area frequented by both killer whales and sea otters that's just a few miles away.

Between 1993 and 1997, the Clam Lagoon otter population remained stable while the population on the exposed coast of Karluk Bay declined 76 percent.

Based on killer whale attacks observed at Karluk Bay, Estes estimated that whales could be responsible for the loss of 45,000 sea otters in an area from Kiska Island to Seguam Island, a span of about 300 miles

"That really perked us up," Estes said.

Diet studies showed that sea otters could sustain a killer whale, but it takes a lot of sea otters to replace their normal diet of sea lions and seals.

"We calculated that a single killer whale could consume around 1,800 sea otters in one year," Estes said. "So with that figure, four killer whales could be responsible over several years. That's assuming they were eating nothing but sea otters."

Estes said the killer whale theory is the only one put forth so far that can explain the disappearance of so many otters. But he says it's unlikely that as few as four whales are to blame. He believes more killer whales are eating sea otters. He's not sure exactly how many, but a science cruise in the Pribilof Islands north of the Aleutians last summer counted more than 400 killer whales.

Why killer whales would target sea otters in the Aleutians is a mystery, too. Estes and others suggest that the short supply of such traditional prey as Steller sea lions and seals is a factor.

"Learning more about why this is happening is the next step," Estes said.

Otter declines change kelp forest

In the Aleutians, rapidly disappearing sea otters have triggered a host of changes to the marine environment -- all of them linked to each other and, ultimately, to a crucial habitat called the kelp forest.

Kelp forests are large jumbles of seaweed, kelp and algae. Some species, like laminaria, anchor themselves to the seafloor. Others float with the currents. Either way, kelp forests harbor an oasis of sea life.

"Kelp forests are the foundation of the coastal ecosystem," Estes said.

Crabs, starfishes, sea cucumbers and urchins live at the base of the forest canopy. Farther up, numerous fish and shellfish find refuge in the kelps' endless green-and-brown tangles as well as easy prey. Species such as herring spawn by laying their eggs on kelp.

The benefits of kelp forests even extend to airborne creatures. Sea birds can find easy prey there.

Kelp forests have just one mortal enemy: sea urchins. These spiny, round animals don't just eat kelp, they chow down on it.

Because otters love to eat urchins, they help kelp forests flourish. But without otters, urchins can quickly decimate a kelp forest.

"When otters aren't present . . . sea urchins come in and go hog wild eating the kelp," said Brenda Konar, a kelp forest ecologist at the University of Alaska Fairbanks. "When urchins clean out a kelp forest we call it 'barren ground' because there's literally nothing left."

Unfortunately, that may be happening in the Aleutians. With so many sea otters gone, kelp is taking a beating, scientists say.

"As we went through the forests a couple of years ago, we saw thousands of urchins eating the kelp," Konar said. "There was literally nothing left but stumps. It was interesting to witness because you saw the marine community structure changing right there in front of you."

Without kelp, a variety of species could be in for a tough time, Estes said.

"As an example, halibut, which aren't a kelp bed species per se, do come in and feed in shallow water and consume . . . species that feed on the kelp," Estes said. There could be impacts on the region's commercial fisheries if too much kelp is lost."

Southeast shellfish stocks suffer

While Aleutian otters continue to decline, Southeast Alaska's booming population has hit shellfish stocks hard. Some scientists believe the government's reintroduction of sea otters may have worked too well.

"Typically, sea otters come into a new area and exploit the best prey first," said Stephanie Haverlack, a graduate student studying sea otter feeding habits in Southeast. "They'll start off with clams and crabs and urchins and abalone. They work those populations down to very low levels before going after less-desirable prey like cockles, chitons and marine worms."

Many of Southeast's best clam beds and crab-fishing areas have been decimated by sea otters. Commercial catches of Dungeness crab are down, and area Natives who once harvested from traditional clam beds now find the beds empty.

"After the otters moved in here in the late '70s, they totally wiped out our subsistence crabs and clams," said Mark King, a Chugach native from Cordova and member of the Alaska Sea Otter Commission. "There are some real small cockles, but no large ones like we used to harvest. They're down to starfish and blue mussels and worms."

Other species have been hit hard too, said UAF's Shirley.

"Abalone stocks along islands exposed to the open ocean where sea otters were first introduced will probably never come back now, because of the sea otters," Shirley said. "There used to be a small but vigorous fishery there. People blamed the decline on the fishermen, but in fact it may have been the continuing increase in otter populations."

The damage sea otters wreak on shellfish is due to their need to keep warm against the cold North Pacific. Although otters have the densest fur of any mammal, they lack the insulating layer of blubber that protects seals and other marine mammals. So otters must burn a lot of energy to stay warm.

To get it, otters eat up to 30 percent of their body weight each day to stay warm, Estes said. That translates into a lot of crab.

"One study done in Prince William Sound found that a sea otter could eat 14 adult Dungeness crabs per day, if that's the only thing it ate," Shirley said. "If you take 10,000 and multiply it by 14, you can see that the current population of sea otters could eat the entire commercial Dungeness catch in Southeast Alaska in less than two weeks."

To be sure, sea otters alone are not responsible for the region's declining crab stocks. Other factors include fishing, natural crab population cycles, ocean temperature and other predators. But as otters continue to increase, Southeast's ecosystem appears headed toward a time reminiscent of the days just before the Russians arrived.

"I think commercial fishermen have seen the handwriting on the wall," Shirley said. "The otters are coming back, and we're basically getting our crab numbers back to a natural level."

Next stop, Glacier Bay

Just a few years ago, Glacier Bay National Park had no sea otters. Today close to 500 reside there.

At the same time, Dungeness crab stocks in the bay have declined 35 percent during the past seven years, said Shirley, who studies the bay's crab stocks.

"All of the bays show the same downward decline," Shirley said. "Whether or not that is due to sea otters or to a long-term cycle, we don't know."

For years, the National Park Service has tried to ban commercial crab fishing in waters it claims. Crab biologist Jim Taggart of the U.S. Geological Survey said the growing otter population may soon make the bay unprofitable for commercial fishermen.

"That's an interesting detail in all of the negotiations . . . over the plan to close the park to commercial fishing," Taggart said. "A significant amount of money may be allocated to buy out Dungeness crab fishermen so that the park can be closed to fishing. And yet, in a relatively short period of time, there is probably not going to be any fishery . . . because of otter predation."

Running for cover

But Dungeness crabs may have found an escape, according to Karen Scheduling. She's finishing her master's degree study on the distribution of crabs in Southeast -- in bays with sea otters and those without them. One of the bays, Dundas Bay in Icy Strait, has had a growing sea otter population since 1989.

"There is something interesting happening there," Scheduling said.

Scheduling said the bay used to have large numbers of Dungeness crab in the shallow areas. Shortly after sea otters moved in, Scheduling started catching fewer Dungeness crabs in her traps. Fishermen have encountered similar shortages, she said.

"There are still Dungeness there but now they are found primarily at depths sea otters can't reach," Scheduling said. "We found lots of them at depths close to 600 feet, far out of reach of sea otters and probably too deep for fishermen to bother with," Scheduling said. "The population may be reacting in that it doesn't come up into the shallows much anymore."

Scheding can't say for sure whether these deep-dwelling crabs are escaping sea otters, are there because of a migration pattern or have always been there. Still, when she looked for Dungeness crabs in areas lacking sea otters, she found them in shallow water but not in deep water.

Bubbling Up

Back in Icy Strait, researchers Bodkin and Kelly bobbed atop a gentle ocean swell in their 25-foot Boston Whaler, watching their computer's readout of sea otter No. 23's dive.

"They are fairly rapid swimmers," Bodkin said. "It takes them only about 90 seconds to get down to 300 feet. With a maximum dive time of four to five minutes, that doesn't leave them with much time on the bottom."

Having tracked more than 4,000 otter dives in Southeast, Bodkin and Kelly have found that otters routinely dive deeper than previously thought. "They are effectively foraging twice as deep as we thought," Kelly said.

After a few minutes, the number on the computer screen began changing again.

"He's on his way up," Kelly said. "Twenty meters. Ten . . . five, four, three . . ."

Bodkin watched through a high-powered spotting scope as the otter broke the surface about a quarter-mile away. It rolled onto its back, then quickly pried open the shell of a large clam and slurped its meaty contents, oblivious to its role in the ecosystem.

Doug Schneider is the science writer at the Alaska Sea Grant Program at the University of Alaska Fairbanks.

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Faunal Extinctions and Coral Reefs; What Can Hobbyists Do?

by Ronald L. Shimek, Ph.D.

www.reefkeeping.com/issues/2005-07/rs/feature/index.php

.....they are trying to manage or conserve. These are the coral reef equivalents of European "hedgerow ecologists" arguing about the maintenance of diversity in the remnant tangle between fields where once there was only forest.".....

Keystone Species

Many of the changes to coral reefs that we are now seeing have nothing to do with direct human perturbation of the basic reef community, but rather the effects are due to the alteration of numbers

or complete removal of "keystone" species. Keystone species are species whose actions determine the structure of an ecological community or ecosystem. First described from the rocky intertidal zone of the Pacific Northwest, the concept has been since shown to have wide latitude (Paine, 1966, 1974; Paine and Levin, 1981). The rocky intertidal zone of Washington's outer coast is comprised of a series of zones. Significantly simplified, a zone of barnacles is found in the highest intertidal zone of this region. Below this is a zone of mussels, then a zone of different barnacles, and then a zone of rugged brown algae of several species, collectively called kelp. Paine found that this characteristic zonation pattern was dependent upon the predation of a sea star, *Pisaster ochraceus*, which foraged in the intertidal zones for its food, either mussels or barnacles. If the sea star was removed, the whole layered system of segregated zones disappeared, to be replaced by a mat of kelp growing from the highest intertidal zone down deeply into the subtidal. What Paine found was that a very complex community was totally dependent on the actions of one of the community's hitherto presumed minor members. It is apparent that what is happening to coral reefs (and many other marine communities) all over the world today is the removal of one or more keystone species with the resultant collapse of the community structure.

In one of the more interesting ironies, it now appears that at least the offshore areas adjacent to beaches that Paine worked on were themselves altered by the removal of keystone predators, possibly about a century before he started his work in the 1960s. The predator that was removed was the sea otter, and its removal by the Russian fur traders and their enslaved Aleuts changed the marine environment all up and down the west coast of North America in what has to be yet another of the many examples of this type of perturbation. The Russians started settling along the southern coast of Alaska in the early eighteenth century and by the middle of the nineteenth century were harvesting animals and exploring as far south as central California. The primary object of their attention was the sea otter, whose fur was in high demand. In the course of their exploitation of this small mammal, the Russians effectively exterminated it.

Sea otters were absent from most of North America's Pacific coast when American colonization of the coast began in earnest in the mid-nineteenth century. By about 1920, when the first studies of the coastal communities that could be styled as being modern ecological science began, otters were pretty much forgotten. There were a few relict populations of the animals in the Aleutians and in the waters off Hopkins Marine Station in Pacific Grove, California. Along the coast, there were huge subtidal populations of several species of abalone, mostly in central Californian waters, and small localized kelp beds along the majority of the coast, although there were some larger beds in both Alaska and southern California.

By the middle of the twentieth century, the coastal intertidal communities had been studied a bit, and were largely thought to be more-or-less "pristine" (Ricketts and Calvin, 1939). The subtidal zone had effectively not been examined at all. The offshore populations of several species of abalone had been harvested for several decades, and fishermen considered them an inexhaustible resource. Initially, they were collected by hard hat divers, but by the 1960s they were harvested using SCUBA.

Around 1965, some changes started to occur that would have some rather interesting consequences. Subtidal scientific investigations of the marine environment got their start, mostly in the waters of northern Puget Sound, but also around several marine labs in central California. As a result of these studies, some of the Californian abalone were collected and were thought to be about 150 years old. These older abalone appeared to be largely [senescent](#) animals; they produced few gametes and were largely non-reproductive. Young abalone were effectively absent from the populations.

Additionally, all along the coast were found huge beds or aggregations of red and green sea urchins (*Strongylocentrotus franciscanus* and *S. droebachiensis*, respectively). As an example, in 1972 I found one "herd" of green urchins that was several hundred meters long, dozens of meters wide and at least one meter thick. It must have contained millions of animals, and as it moved across the

bottom, the urchins ate everything they encountered. In the wake of this aggregation was bare, polished rock. Recently, it has been determined that in addition to the abalone being 150 years old in 1970, many of the red sea urchins were of a comparable age (Ebert and Southon, 2003).



Figure 2. *Strongylocentrotus franciscanus* (left) and *S. droebachiensis* (right), the red and green sea urchins eaten by sea otters. The red urchins are about ten inches (25 cm) across the spines; the green one, about three inches (7.5 cm).

AND THESE CONDITIONS WERE CONSIDERED TO BE "NORMAL!"

With the beginning of environmental awareness in the late 1960s, sea otters were protected by law. Sea otters have one very important attribute that facilitated their protection; they are [photogenic](#) and [cute](#) as the dickens. With their protection in place, southern sea otter populations rebounded and additional populations were started by transplanting animals throughout their old range. By the mid-1970s, sea otters were experiencing a resurgence in their southern populations and were spreading throughout their old range. This resulted in several quite predictable but relatively unforeseen consequences. First, given that sea otters are voracious predators, their predation on [sea urchins](#) led to an expansion of kelp beds, or more correctly, kelp forests, in the southern part of their range. Concomitantly, the industry that harvested kelp for its economically important byproducts increased dramatically. Second, the [sea otters devastated the remnants of the old abalone](#) populations. [Many of these populations had already been severely reduced by abalone fishermen](#), and the additional predation by the sea otters, that were much more efficient than the fishermen at harvesting the abalone, put significant economic pressure on the fishermen. As a result, abalone fishermen started shooting the sea otters.

The sea otters, however, had some powerful friends in the [kelp harvesters](#). There were reports of kelp harvesters shooting at abalone fishermen to deter them from shooting at the sea otters. As a result of this free-for-all and the resultant "wonderful" publicity, coupled with a realization that marine mammal populations all along the coasts of the United States were being devastated by fishermen and development, the Marine Mammal Protection Act was passed. This resulted, at least on paper and in near shore areas, in the federal protection of marine mammal populations. This has led to an increase in some marine mammal populations, mostly in the southern near shore regions. [Offshore populations, however, have continued to plummet.](#)

This protection of this particular keystone species, however, appears to be a classic case of "too little, too late." [Many of the California abalone populations are going extinct.](#) This is due to predation by sea otters and fishermen coupled with poor reproduction and larval recruitment. In addition, new diseases of the abalone are being found which are wiping out the remnant

populations that have been overfished (Haaker, *et al*, 1992). Where the otters are found, kelp beds are reappearing, often where none had been reported in "historical" times. These beds drastically change the fish populations and fisheries of those areas. These may be termed changes back to "normal" conditions, but simply put, we don't know what the "normal" conditions ever were.

All along the Pacific coast, the ecosystem of about 20 years prior to any given writer's efforts is generally regarded by that author as being "pristine" or "normal." For an interesting view of this phenomenon, I urge the readers to check out the classic book on the intertidal ecology of the California coast, *Between Pacific Tides*, first written by Ed Ricketts and Jack Calvin, and first published in 1939. It has been periodically revised, roughly every 10 to 15 years, by editors of varying competence and the changing vision of what is considered to be "pristine" is very illuminating.

HOWEVER, We Have NO Idea What Constitutes "Pristine" In Any Ecosystem Along The Pacific Coast.

As elsewhere, Pacific coastal aboriginal fisheries were awesomely efficient. As an example, I have done a lot of my research at the Bamfield Marine Sciences Centre, which is located in the town of Bamfield, located on the south side of Barkley Sound, Vancouver Island, British Columbia, Canada. Today, I estimate the whole population of the Barkley Sound region to be around 3,000 people. Some historians and archaeologists, however, estimate that its [population](#) 300 years ago may have ranged from about 5,000 to more than [10,000](#) people. The native populations in this area had an economy based on whaling and fishing the rich salmon and marine mammal fisheries surrounding Vancouver Island. Remains of the native "whaling" stations can be found, and it is evident that they harvested immense quantities of these and other marine mammals. Not all of these animals were keystone predators, but some of them surely were. In effect, the nearshore communities have been severely and significantly altered as long as man has been on them.

Shimmering comeback

Innovative fisheries are reviving California's treasure, the incomparable abalone.

By Russ Parsons
Times Staff Writer

June 16, 2004

Cayucos

It is an odd spot for a miracle, this motley collection of beachfront shacks and sea-scoured concrete tanks clinging to a sunburned bluff above the Pacific just north of Morro Bay. But it's hard to describe what is happening at the Abalone Farm any other way. Here, the abalone — so rare in the wild that it is illegal to catch it commercially — is making a comeback.

Consider this: Abalone is so tightly protected that it can legally be caught only by sport fishermen north of San Francisco Bay and only if the fishermen are free-diving, without breathing equipment. Anything else is illegal. And yet, abalone appears on the Monterey Bay Aquarium's list of "best choice" seafood. But only in its farmed form, of course, and that quite likely means that it comes from the Abalone Farm, which accounts for more than half of the fresh abalone eaten in this country.

Abalone was once considered a California icon, as much a part of summer as surfboards, cut-off jeans and bonfires at the beach. It was so common it could be collected from rocks exposed by low tides.

It is a marine gastropod (family *haliotidae*, genus *Haliotis*), a snail that lives in the sea. In fact, if you try to imagine a very big, very stylish snail sporting a streamlined shell that looks something like a '50s or '60s bathtub Porsche, you'll be very close.

The part of the abalone that we eat is its large muscular foot. Raw, it is very tough. When eaten as sushi, this translates as a pleasing crunchiness. If it is to be cooked, abalone is almost always tenderized by pounding, just as you would flatten a scaloppine of veal or a chicken-fried steak. It must also be heated very quickly or it becomes rubbery.

Properly prepared, abalone has a texture that is nearly buttery. The flavor is beguiling, like a combination of a very sweet, very tender calamari steak with the lingering, subtle shellfish flavor we associate with oyster or crab.

It is no wonder people went so crazy for it. Still, it is a shame. In a relatively short span, abalone went from being almost as common as mussels to so overfished that only last-minute legislation and the intervention of advanced aquaculture could save it from oblivion.

But if you equate modern miracles with high technology, you'll be disappointed in the Abalone Farm.

The shellfish are kept in a series of plastic buckets and tanks that are housed in what seem like a series of rickety boathouses and barracks. When the abalones are big enough, they graduate to the concrete tanks, roughly 4 feet square and divided by plywood walls.

Because abalones are relatively clean and well-behaved creatures, their aquaculture is regarded as a model of ecological sustainability. They live in seawater that is pumped from the bay below and are fed kelp that is harvested from the forest just beyond where the surf breaks, on dark red dulse seaweed that is grown at the farm and on naturally occurring algae that grow in the tanks.

"We're very low-tech," says Brad Buckley, the farm's sales manager. "We've learned we have to work with the abalone on its own natural level. There are no glitzy shortcuts."

The abalones don't seem to mind. At any given time, the farm houses between 4 million and 6 million of them. They sell a million a year; most goes to sushi bars in Southern California and the Bay Area, but about a third is shipped to Asia.

As rustic as the setting might be, the Abalone Farm is thoroughly modern when it comes to getting its product out. Almost every day an overnight delivery truck pulls up the dirt road to pick up a load of abalone. Orders placed before noon by phone or on the website can be delivered anywhere in the country the next day.

\$100 a pound, uncooked

A couple of times a week, another truck comes in and picks up big loads to be delivered to wholesalers, like Chol Pak's Pacific Fresh Fish Co. downtown, which sells to Southern California sushi bars and markets such as Assi Market in Koreatown. Because of its scarcity, fresh abalone is extravagantly expensive. Ready-to-cook steaks from the Abalone Farm run about \$100 a pound (enough for six to eight moderate servings).

Pak says Koreans like abalone as sashimi and also as an ingredient in rice porridge called *jeonbok-juk*. Another steady customer is the classic Pico Rivera steakhouse Dal Rae, which serves them either "almodine" or served with caper sauce or lemon butter (a \$52 entree).

Although the flavor is the same, old-timers who remember wild abalone as big as dinner plates are not likely to be impressed by the size of these farmed specimens. Most are harvested when they're about as big as your palm. A few super-achievers are as big as your entire hand. The abalones range in weight from 3 1/2 ounces to 8 ounces, which will yield 1- to 2-ounce steaks.

It takes an abalone four years to get to this size, and that is considered the prime of its growth spurt. It may take five or six years more for an abalone to add an extra inch or two. Those hubcap-size monsters you see in old pictures had to have been 40 or 50 years old.

Abalone has been eaten in California for centuries, if not millenniums. Abalone shells are common in coastal middens, ancient garbage dumps left by Native Americans.

The first commercial abalone fishermen were the Chinese, who, beginning in the 1850s, dried them and shipped them back home. In the early part of the 20th century, the Japanese took over and used their advanced knowledge of early deep-sea diving techniques to harvest them more efficiently.

But it wasn't until after World War II and Jacques Cousteau's popularization of scuba equipment, which permitted even deeper, less restricted dives and extended stays under water, that fishermen were able to go after abalone in a really big way.

The commercial fishery peaked in 1957 with a harvest of more than 5 million pounds. Beginning in the late 1960s, the bottom fell out. By 1992 the total harvest was 500,000 pounds. Two years later it was 322,000 pounds.

Prices rose with the increasing scarcity. What a diver could get for 100 dozen abalone in the early 1960s he might get for 10 dozen in the 1970s and for a dozen in the 1980s. With that kind of money at stake — it's estimated that at its peak abalone brought in \$20 million a year — the fishery was very hard to regulate. (It still is, though for different reasons: Last month Fish and Game nabbed a couple of poachers by Mendocino with more than 400 abalones in their truck.)

Looking at a graph of abalone landings is like looking at a ball bouncing on a tabletop. For a couple of decades it goes up and down but always maintains a certain minimum level. Then the ball reaches the edge and drops straight down to the floor.

What happened is what biologists call serial depletion.

The abalone family is made up of several varieties, some more desirable than others, some easier to catch than others. As the most desirable, easiest to harvest abalones disappeared, they'd be replaced in the statistics by those that were less desirable and harder to catch. You start out collecting abalones at low tide in Venice and wind up deep-diving for them off the Channel Islands.

Finally, there was almost nothing left.

Gradually, between 1993 and 1997, the commercial abalone fishery in California was shut down.

As guilty as man was in the abalone's demise, there is no escaping the fact that the shellfish is partly to blame as well. In fact, it seems nearly miraculous that it has survived as long as it has.

In many of the ways that matter most, abalones are extremely inefficient, particularly when it comes to reproducing. They are what are called broadcast spawners, which means they release eggs and sperm into the water when the ocean conditions are just right, regardless of whether another abalone is close by. To produce fertilized eggs, they must truly get lucky.

Because abalones prefer to live in colonies, this usually isn't a big problem. But in a depleted population with males and females scattered farther apart, there are markedly fewer chances of one abalone's being close enough to another to mate successfully.

In this way, a bad situation becomes worse with almost lightning speed.

Along comes the otter

Furthermore, though abalones are fecund (a mature female may produce more than 10 million eggs at a time), they are remarkably unsuccessful as parents. Only a fraction of a percentage of fertilized eggs actually makes it to maturity in the wild.

The Abalone Farm is considered extremely successful with a survivability rate of between 15% and 20%. Such success in nature would soon mean abalones as common as garden snails.

That would be even truer in the absence of natural predators. And that is pretty close to the situation abalones enjoyed from the middle of the 19th century until the modern fishery started.

Ecologists point out that just as the current abalone situation is the result of an extreme imbalance, so was the period of plenty that preceded it. Abalones were so common only because their main predator, the sea otter, had been nearly exterminated by the fur trade.

Cute and cuddly as they are, otters eat abalone like popcorn. A 60-pound sea otter can consume a quarter of its weight in abalone in a day. And the resurgence of sea otter populations south of San Francisco in the 1970s was a factor in the devastation of the abalone population.

The Department of Fish and Game's Abalone Recovery and Management Plan puts it plainly: "The influence of sea otter predation on abalone populations is so strong that sport and commercial abalone fisheries cannot co-exist with established sea otter populations."

(In fact, it adds: "Abalone populations in [S]outhern California are so depleted that the addition of sea otters predation could pose a serious threat to the abalone's continued survival.")

Fresh from the farm

For the foreseeable future, anyway, the abalone most of us eat will have to come from aquaculture. California licenses eight abalone farms, though most of these are either still in the research stage or are extremely small.

After the Abalone Farm, which sells about 225,000 pounds of abalone a year, the next biggest is the Cultured Abalone in Goleta, which sells about 100,000 pounds a year. US Abalone in Davenport sells about 75,000 pounds a year. The Monterey Abalone Co. in Monterey Bay sells about 50,000 pounds a year.

One of the smallest but most interesting abalone farms is in Oxnard. Proteus Seafarms works out of what looks like a converted maintenance garage in the shadow of Reliant Energy's giant Ormond Beach Generating Station.

Proteus has only about 20,000 abalones in its tanks, but these are white abalones, so rare they were declared an endangered species in 2001 (most farms raise the red variety). White abalone was once the most highly sought food variety because it is so naturally tender it doesn't need to be pounded.

But it is extremely hard to find, even in the best circumstances.

In fact, it wasn't even discovered until more sophisticated diving equipment became available in the 1940s because it lives only in depths of greater than 80 feet. Once it was found, it was avidly fished. It is estimated that the number of white abalone has declined 99% in the last 25 years.

Because white abalone are so scarce and live so deep, current estimates of the population are all over the map, ranging from 3,000 animals to 15,000.

But even the best-case scenario still means that Proteus has more white abalones in its garage than live in the entire Pacific Ocean.

Proteus director Thomas McCormick says he hopes next year to be able to release the first mature white abalones back into the wild, with the help of California Department of Fish and Game, the National Marine Fisheries Service, the Channel Islands National Park and the Channel Islands Marine Sanctuary. After that, his goal is to be able to plant 5,000 a year.

Proteus is a nonprofit corporation, and McCormick's primary goal is research. Asked about the white abalone's potential for food, he almost blanches, but he understands. It goes with the territory when you're trying to resurrect one of the ocean's most delectable creatures.

"One of the things about the white abalone is that we really don't know anything about it other than it tastes good," he says. "It was revered. The fishermen always kept white abalone for their own consumption because it was so tender.

"What we're trying to do is slowly build a new population structure. But I don't know whether we'll ever see a self-sustaining population again