crease for its entire $323 million nuclear physics program in the Administration's 2000 budget request to Congress now being assembled. A 6-year boost would enable Bates's 85 employees to finish three experiments scheduled through 2004 and plan for "an orderly shutdown without disrupting a lot of people's careers," says physicist Konrad Gelbke of Michigan State University in East Lansing, who chairs the NSAC. New funds would also preserve experiments planned for the Alternating Gradient Synchrotron at Brookhaven National Laboratory in New York, which produces hadron particle beams prized by physicists. The experiments are imperiled by the loss of funding from DOE's high-energy physics program at the end of 1999.

The squeeze on Bates is caused in part by the growing demands of the Jefferson accelerator, with 423 full-time staff and more than 1000 users. Jefferson officials have estimated their $70 million annual budget needs to be raised by at least $3 million to avoid cutting back on experiment time. "The hard decision is whether you need to have two electron machines," says Hamish Robertson, a panel member from the University of Washington, Seattle.

Funds saved by canceling the hadron experiments and closing Bates—which has a budget of about $8 million a year—would also be used to preserve smaller grants to university-based researchers. DOE spends about $15 million on 40 projects at 32 universities. The panel noted that the projects, most of which have budgets of less than $500,000, help maintain "a balanced scientific program."

At MIT, however, officials are bullish that their accelerator will survive. "The quality of our science is not the issue," says Bates director Richard Milner, noting that the Symon report gave "excellent" and "outstanding" ratings to the facility's experiments. Such arguments have already won over one key DOE official. Acting nuclear science chief Dennis Kovar says the report "is going to help us make the case that added funds would realize real benefits to research." –DAVID MALAKOFF

ECOLOGY

Sea Otter Declines Blamed on Hungry Killers

Sea otters spend much of their days playing, drifting with the tide, and filling their bellies with the soft meat of shellfish and sea urchins—a lazy lifestyle that many of us might envy. But ecologists know that sea otters off the Alaskan coast, at least, play a pivotal role in marine ecosystems: By dining on sea urchins, the animals help preserve kelp forests that feed a range of species, from barnacles to bald eagles. Now, however, this "poster child of marine near-shore ecology," as Robert Paine of the University of Washington, Seattle, calls the sea otter, appears to be fighting for its survival.

On page 473, a team led by James Estes of the Biological Resources Division of the U.S. Geological Survey and the University of California, Santa Cruz (UCSC), has documented a 90% crash in sea otter populations in western Alaska's Aleutian Islands since 1990, with devastating effects on kelp forests. The reason for the crash, Estes believes, is that killer whales, never before known to eat sea otters, appear to be snacking on the creatures, apparently because their usual food source—seals and sea lions—is declining. "This reflects real desperation for the orca. They're eating popcorn instead of steaks," says ecologist Paul Dayton of the Scripps Institution of Oceanography in La Jolla, California.

Orca fodder. Alaskan sea otters may be victims of shifts in the whales' food chain.

Experts call the study a vivid example of an ecological cascade operating on a vast scale. "It's a heroic effort, and it's a terrific find," says Paine. The research has policy implications, too: Estes asserts that the chain of events leading to the otter's decline may have been triggered by a boom in commercial fishing in the Bering Sea. "It raises the possibility that overfishing can have a wide array of effects on species that we wouldn't expect to be impacted," he says.

Once hunted to the brink of extinction by fur traders, Alaska's sea otters resurged in the 20th century. But near some Aleutian islands, the otters were slow to rebound. In the 1970s, Estes and others found that off these islands, sea urchins had mowed down Pacific kelp beds, depriving fish of vital habitat and leaving the sea floor barren. Around islands with healthy otter populations, however, the kelp and its associated species flourished.

Despite the patchiness of their recovery, otter populations seemed healthy overall through the 1980s. Beginning around 1990, however, Estes's group and others noticed that the animals were becoming scarcer. Along a necklace of the Aleutians spanning 800 kilometers, Estes's group estimates that otter numbers have plummeted from about 53,000 in the 1970s to 6000 last year. The ecological consequences have been severe, the team reports: On Adak Island, for example, where otters now number about 300, sea urchin are booming and kelp density is down 12-fold.

A clue to this puzzling decline appeared in 1991, when researchers witnessed for the first time a killer whale eating an otter. The whales had been thought to shun otters because the animals provide few calories compared to larger, fat-laden harbor seals and Stellar sea lions. Since that initial shocker, ecologists have documented 12 cases of orcas eating otters, often swallowing them whole or first crashing down on the otters, perhaps to stun them.

Estes says he "was really skeptical" at first that the orca attacks could explain the otter declines. But if otters were dying of disease or starvation, their carcasses should be washing up on beaches—and they are not. A series of observations persuaded his group that orcas are the likely culprit. Estes and his colleagues figured that, given the thousands of days they have logged watching otters and the six attacks they've seen, the probability that attacks had occurred, unwitnessed, before 1991 was near zero. They also tagged with radio transmitters 17 otters in a lagoon that orcas can't reach and 37 otters in an open bay; over 2 years, deaths were much higher in the bay. "That provided a very startling contrast," Estes says. Finally, the team calculated that the number of observed killer whale attacks on otters, extrapolated to the general population, could account entirely for the observed declines. Remarkably, as few as four whales could be decimating otters along 3300 kilometers of shoreline between the Kiska and Seaguam islands. Says ecologist Mary Power of the University of California, Berkeley, "It's just mind-blowing that as few as four whales could cause an ecosystem effect over such a huge part of the Earth."

The researchers don't know exactly what is prompting the whales to eat otters, but they suspect it's related to a plunge in sea lion and seal populations in the western North Pacific since the 1970s. The reason for those declines is itself controversial, although one possibility is that intensified trawler fishing in the Bering Sea has sharply curtailed or altered the food supply for sea lions and seals. But as a National Research Council report noted in 1996, changes in fish populations could also be related to warmer ocean temperatures stemming from a shift in deep currents since the mid-1970s, as well as the local extinction of baleen whales, which has allowed one fish—pollock, which are low in fat—to flourish. Andrew Trites of the Uni-

CREDIT: T. M. WILLIAMS/UCSC

versity of British Columbia, who has done studies of the sea lion declines sponsored by the fishing industry, says he's scrutinized the timing of the declines and the fisheries buildup and "I don't see a connection." Dayton tends to agree that overfishing "is too simplistic. ... The cause of the killer whale shift is probably very complicated."

Estes, however, believes overfishing is the most likely suspect—and he warns that the lesson applies far beyond Alaska. Fisheries are collapsing around the world, he notes, and as with the otters, if scientists looked more closely they might find the effects "very widely manifested in coastal ecosystems. We were lucky just to have been sitting on this and seen it when it happened. But very likely, they're the sorts of things we should be worrying about elsewhere." **–JOCELYN KAISER**

ATMOSPHERIC CHEMISTRY

Deep Chill Triggers Record Ozone Hole

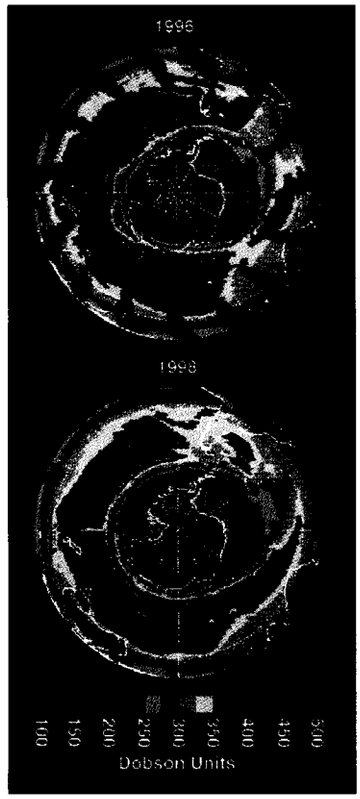
In theory, the ozone hole that reopens each year over Antarctica should gradually heal as international regulations choke off the flow of ozone-destroying chlorine compounds into the stratosphere. But little about atmospheric chemistry is that simple, as this year's Antarctic ozone hole testifies. It is almost as severe as any seen before, and it stretches over an area larger than North America, a new record. Unprecedented stratospheric cold is driving the extreme ozone destruction, say researchers. Some of the high-altitude chill, they add, may be a counterintuitive effect of the accumulating greenhouse gases that seem to be warming the lower atmosphere.

This year's Antarctic ozone hole is a whopper in every sense. Seen from a National Oceanic and Atmospheric Administration (NOAA) satellite, the area of depleted ozone extends over about 26 million square kilometers, the largest observed since annual holes first appeared in the late 1970s. Measured by balloon-borne instruments ascending from the South Pole, the layer of total ozone destruction extends from an altitude of 15 kilometers to 21 kilometers. That's higher than ever seen before, says ozone researcher David Hofmann of NOAA in Boulder, Colorado. And by 5 October, the total amount of ozone over the South Pole had dropped to 92 Dobson units, Hofmann says; only in 1993 was the ozone hole deeper, when the catalytic effect of debris from the 1991 eruption of Mount Pinatubo in the Philippines helped drive ozone down to 88 Dobson units. (Normally there are about 280 Dobson units of ozone over the pole.)

The deep chill that gripped the Antarctic stratosphere this past austral winter is to blame, say Hofmann and other scientists. Every winter, it gets cold enough there—below –78°C—to form the icy stratospheric clouds that catalytically accelerate the destruction of ozone by the chlorine from chlorofluorocarbons (CFCs). This year, the area cold enough to form polar stratospheric clouds "is larger than anything we've seen to date" for the same time of year, says meteorologist Melvyn Gelman of NOAA's Climate Prediction Center in Camp Springs, Maryland. "There's much less heat being pumped up into the stratosphere than usual," he says.

No one knows just why, but an underlying cooling trend in the stratosphere—induced by, of all things, greenhouse gases—is probably aggravating the situation, researchers say. Although greenhouse gases warm the lower atmosphere, they cool the stratosphere by radiating heat to space, creating an "icehouse effect." Recent computer modeling has suggested that greenhouse cooling might greatly worsen the nascent ozone hole over the Arctic (*Science*, 10 April, p. 202). And a new modeling study, published in the 1 October *Geophysical Research Letters* by M. Dameris of the German space agency DLR in Oberpfaffenhofen and colleagues, points to effects on Antarctic ozone, too. By 2015, their model says, ozone at lower latitudes will begin recovering as CFC controls take effect, but the chilling effect of greenhouse gases will have kept the Antarctic ozone hole as severe as ever.

–RICHARD A. KERR



One of the worst. The 1998 Antarctic ozone hole (bottom, inside the blue) is the biggest ever and is deeper than most, as shown by a comparison of the gray area with 1996 (top).

CREDIT: (TOP) GREG VAUGHN/ALLSTOCK/PNI; (BOTTOM) NASA/GSFC

ScienceScope

BILLFISH PLAN NOT SHARP ENOUGH?

A new plan to protect Atlantic billfish such as marlin and sailfish doesn't go far enough to protect dwindling stocks from accidental catches, fisheries experts say. The guidelines, released last week by the National Oceanic and Atmospheric Administration (NOAA), are the first of 39 new conservation plans covering key fish species required by a 1996 law designed to prevent overfishing.

It has been illegal for commercial fishers to sell Atlantic billfish since 1988, but the fish are still legally caught in tournaments and accidentally snared by longlines intended for swordfish and other species. Russell Nelson of the Florida Marine Fisheries Commission says localized bans on longline fishing would reduce the accidental "bycatch" by more than 25%, while causing only a 5% loss in swordfish catches. He hopes such statistics convince NOAA to impose such a ban. The plan is open to public comment until early next January.

WHITE HOUSE ORDERS STUDY OF INTERNATIONAL ENERGY R&D

President Clinton is seeking expert input on global energy research. To get the most from U.S. spending on international collaborations aimed at understanding global warming and other issues, he has asked the President's Committee of Advisers on Science and Technology (PCAST) to review U.S. involvement in international energy R&D projects.

The request follows a PCAST study of domestic energy R&D issued a year ago. Led by Harvard environmental policy professor John Holdren, it helped boost the president's 1999 budget request for energy research. Now, Holdren will produce a sequel with an international flavor. The report, due in April, will tally what various U.S. and international agencies already do and offer advice for the coming decades. White House official Sam Baldwin says the panel will focus on applied research, but could comment on anything from fusion research to clean coal technology in China.

Contributors: David Malakoff, Gretchen Vogel, Jocelyn Kaiser