As nations around the world's largest lake bicker over oil rights, the wildlife of the Caspian Sea is in a state of siege from which it may never recover

Caspian Ecology Teeters On the Brink

ASTRAKHAN, RUSSIA—Lev Khuraskin stepped gingerly across the shoal, avoiding the dead seagulls and cormorants rotting in the sand and their squawking, orphaned chicks. The rail-thin biologist, his face leathered from decades on the sun-drenched Caspian Sea, crept up to a seal lolling near the water and straddled it, pressing his hand against the back of its neck to subdue it as a colleague skittered over to draw blood. Fit seals don't like being messed with, but this emaciated and listless male submitted calmly. "It's very ill," says the team's leader, Vladimir Blinov of VECTOR, Russia's State Research Center of Virology and Biotechnology.

The seal that lay dying on Malyi Zhemchuzhnyi Island is one of the latest casualties in the Caspian Sea's unfolding ecological drama. Sturgeon, prized for their caviar, are hovering near enough to oblivion that three of the five nations around the Caspian's shores—Azerbaijan, Kazakhstan, and Russia—agreed last June to an unprecedented 6-month ban on fishing the species. Too little, too late, some fear. "The question is whether the species can be saved at all," says Lisa Speer of the Natural Resources Defense Council (NRDC), a nonprofit based in New York City.

Adding to the mounting horror of ecologists, *Mnemiopsis leidyi*, a comb jelly notorious for having devastated anchovy populations in the Black Sea, invaded the Caspian a few years ago. New findings suggest that this voracious free-floater has done a similar number on the Caspian's kilka, or sprat, by "driving numerous species of zooplankton toward extinction," says ecologist Henri Dumont of Ghent University in Belgium. *Mnemiopsis* is more bad news for the seals, which feed on kilka and are already reeling from epidemics of canine distemper virus in 1997 and 2000 that killed thousands.

If the Caspian's wildlife only had natural invaders to deal with, that would be bad enough, but this lake—the largest in the world—is a pressure cooker of political and commercial forces. Ranged around its shores are the growing economy of Russia in the north and fundamentalist Iran in the south, with Muslim ex-Soviet republics in between. Both Russia and the United States are vying for influence in the region, a process accelerated by the war in nearby Afghanistan.

Complicating the picture are the Caspian's vast oil reserves. The Soviets largely ignored this resource, but the newly independent republics are keen to exploit it. Production in the Caspian is expected to ramp up fivefold to 5 million barrels a day by 2020. "For the time being, there's no proof that oil exploration or extraction will pose a major hazard to the Caspian environment—if it's done properly," says Arkadiusz Labon, a Toronto-based fisheries consultant who coordinated a major fish stock survey in the Caspian last year. However, he and others note, a major spill—always a possibility in this geologically unstable region (see sidebar)—could spell disaster.

Oil in troubled waters

Two millennia ago the Caspian was a sacred place for Zoroastrians, who would meditate at temples near jets of flaming gases that vented from the naphtha-rich sands of the Apsheron Peninsula, a nub of land jutting into the Caspian in present-day Azerbaijan. Later generations of Persians, still awestruck by the pillars of fire, recognized a commodity and by the late 1500s were scooping petroleum from shallow wells.

True development of the oil fields began in 1875 when Ludvig and Robert Nobel, brothers of renowned Swedish industrialist Alfred, bought up land near Baku. Boring deeper wells, they and their crew learned how to work Apsheron's fickle semifluid sands. Oil production increased by 50 times over the next decade, reaching 1 million tons a year. When after a brief independence Azerbaijan was absorbed into the Soviet Union, the Nobels were out and central planning was in.

Although the Soviets discovered three giant oil fields in the Caspian basin, they left them mostly untapped. They found it easier and less costly to extract oil from their vast petroleum reserves in western Siberia and even went as far as banning offshore drilling in the north Caspian to protect the sturgeon's feeding grounds and spawning migration routes.

Following the collapse of the Soviet Union, oil investments from the West poured into the Caspian, turning the region into a "Wild East." But although oil exploration has not yet had a major impact on local ecology, the same cannot be said for fishers out to make a fast buck by harvesting the Caspian's other precious resource: caviar.

Of fish and jellyfish

With their long snouts and ridged, scaleless bodies, the young sturgeon swimming circles in a glass tank at the Caspian Fisheries Research Institute here in Astrakhan look more like baby dinosaurs than fish.

CREDIT: NPA GROUP

Pillars of Fire, Poison Gas—and Gobs of Oil, Too

The Caspian's geopolitical stardom belies its humble origin 10 million years ago as a brackish, landlocked remnant of the long-gone Tethys Sea. Born in an era of violent tectonic activity, the Caspian remains a seismic hot spot today where oceanic crust creeping northward thrusts beneath continental crust underlying the Caspian's upper basin. The result is a hellish seascape, wracked by earthquakes and riddled with hydrocarbon seeps and mud volcanoes, that poses a huge challenge for oil extraction—and offers loads of scientific puzzles. "To say the geology is well understood is far from true," says geologist Mike Simmons, managing director of CASP, a research institute in Cambridge, U.K., that has done extensive fieldwork in the Caspian.

One complex phenomenon that scientists are still trying to fathom is the Caspian's wildly varying sea levels. Levels had dropped so low about 5.5 million years ago that the lake shriveled to little more than a desert puddle in its southern basin. "It must have been a bizarre and unique environment," says Simmons. Unstable sea levels continue to be a hallmark, rising more than 2 meters between 1978 and 1994 followed by a steady decline since. Fluctuations in evaporation rates and the flow of the Caspian's tributaries can only partly explain sea-level dynamics.

A peculiar topography presents its own set of challenges for both the sea's denizens and oil companies. The Caspian is only 10 meters deep on average in the stable northern basin, but it reaches more than 1 kilometer in depth in the southern basin. Thanks to "one of the most rapid subsidence rates known on the planet," Simmons says, sediments reach a whopping 25 kilometers thick in parts of the southern basin. As new sediment piles up, water trapped in the clayey lakebed comes under crushing pressures. The clays flow like pressurized fluid, moving upward through fractures in the sediment. The mud escapes from cones—"mud volcanoes"—that can grow so tall that they form islands in the deep waters. Geologists take a keen interest in what mud volcanoes can reveal about the Caspian's underbelly, as the cones disgorge rock from many kilometers deep. "They provide us with precious data," says Simmons.

Geological wonderland. A CASP researcher samples one of the Caspian's tamer mud volcanoes.

The majority of the Caspian's 220 mud volcanoes burble meekly. But a few should not be messed with. Last October, for instance, a cone erupted violently south of Baku, sending muck, rocks, and flaming gases dozens of meters into the sky—the ancient Zoroastrians' pillars of fire. In 1959, one monster on the Markarov Bank reportedly shot flames and debris an astounding 10 kilometers into the air and gouged a half-kilometer-wide crater in the lakebed. "You cannot predict when they are going to erupt," says geophysicist Mike Bilbo, British Petroleum's Caspian external affairs chief. Drill rigs can't sit too close to the mud volcanoes, which destabilize the lakebed around them—as the Soviets discovered after losing several rigs.

The North Caspian is no less daunting. The oil there is also under high pressure, and it's sour: It's mixed with poisonous hydrogen sulfide gas. "The technical problems are immense," says Gregory Ulmishek of the U.S. Geological Survey in Denver. "But so is the prize," he says: an estimated 23 billion barrels of oil yet to be discovered.

Oil firms and ecologists alike dread an accident in the newly discovered Kashagan field off Kazakhstan, which could release tons of hydrogen sulfide into the shallow northern waters. Such an ecological nightmare could overshadow the decades of leaks and spills from the South Caspian's Soviet-era wells, some of which are still pumping crude oil. At these operations, says Bilbo, "there are no work practices that are recognized in the West in terms of environmental controls."

But often it doesn't take a human hand to unleash the Caspian's malignant forces. The region's natural hydrocarbon seeps "may have an important role in causing water and air pollution," notes Casey Moore of the University of California, Santa Cruz. Natural seepage, he says, "may be erroneously attributed to human sources"—just one of many features of the unruly Caspian that elicit wonder and are impossible to tame.

–TIM BURNHILL

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CREDIT: MIKE SIMMONS/CASP

But having long outlived the dinosaurs since debuting in the fossil record 200 million years ago, the venerable sturgeon is facing its toughest test yet. The Caspian is home to the world's biggest population of sturgeon. The sea's four major varieties—stellate sturgeon, or sevruga (*Acipenser stellatus*), Russian sturgeon (*A. guldenstadti*), Persian sturgeon (*A. persicus*), and beluga (*Huso huso*)—supply about 90% of the total caviar harvested worldwide. It's a lucrative commodity: As *Science* went to press, one firm, Tsar Nicoulai Caviar, was advertising sevruga caviar at $1448 per kilogram. Beluga roe, meanwhile, was fetching more than $2500 per kilogram. Russia alone says it hauled in $40 million last year from caviar exports, although some observers claim that the figure for legal exports was closer to $100 million.

The sturgeon's enemies are legion, but poachers may be taking the heaviest toll. Last year they fueled a shadow caviar market estimated at $400 million, according to Russia's Interior Ministry. Rampant poaching since the Soviet meltdown has sent sturgeon stocks crashing, with beluga numbers less than 10% of what they were 2 decades ago, the government estimates. Last year Russia began working with Interpol to try to crack down on smuggling, but most observers say it will take years, if not decades, to stamp it out. Other factors in the decline include dams on the Volga River that cut off access to spawning areas, and perhaps pollutants that accumulate in fat and may render eggs infertile. "The whole ecology of the rivers has changed," says biologist Ellen Pikitch of the Wildlife Conservation Society in New York City.

Recognizing the seriousness of the situation, the secretariat of the Convention on International Trade in Endangered Species (CITES) got three Caspian nations to agree to a 6-month moratorium on fishing sturgeon last June. Some experts contend that the ban, which ended on 1 January, did little

good for the sturgeon, because it took hold after the main fishing season in the spring.

A recent census of Caspian fish corroborates that view. Last summer, the Caspian Environment Programme (CEP), a World Bank and European Union initiative, undertook a rare comprehensive survey of Caspian fish stocks. Over 6 weeks last August and September, the CEP team used sonar to chart and characterize fish populations everywhere but in the coastal waters of Turkmenistan, which did not allow access. Sonar is an imperfect technique, particularly for bottom-feeding fish like sturgeon, so the team captured and released fish as well.

Soon a scene of the past? Russians haul in sturgeon on the Volga delta near Astrakhan.

Although the researchers are still analyzing their data, the emerging picture is dire indeed. "We found very few mature sturgeon," says Labon. "That's a sure sign of dramatic overfishing." As expected, the team found ample young sturgeon, indicating that hatcheries in the Volga delta and Iran have averted total calamity. But the hulking fish are late breeders, taking years to reach sexual maturity. That means poachers and other fishers will be netting more and more juveniles in an increasingly frustrating search for caviar.

Labon argues that a 10-year fishing ban—without loopholes such as a permissible "scientific" catch—is essential to rescue the sturgeon from extinction. However, a total moratorium could backfire by driving the entire caviar trade underground, argues NRDC's Speer. Her organization, for one, is campaigning for a ban on trade of beluga only, the most endangered species. It will make that pitch when the CITES standing committee on sturgeon meets in March to review this year's proposed catch quotas. NRDC will also lobby the next conference of CITES parties in November to elevate beluga to the most endangered Appendix One list, which would ban beluga export from any signatory nation.

The sturgeon is not the only Caspian fish under siege; some other species are facing a more insidious, if spineless, threat. First sighted off the Iranian coast in 1998, the comb jelly *Mnemiopsis* within months had managed to swarm across much of the rest of the Caspian. The delicate, luminescent creature, looking more like a miniature starship than an animal, appears to have stowed away in the ballast water of ships in the Black Sea, reaching the Caspian via the Volga-Don Canal.

Based on the jelly's voracious habits in the Black Sea, researchers expected it to gulp its way through the bottom of the Caspian's food chain, grazing on zooplankton that are the staple of kilka and many other fish. Over the past couple of years, says Labon, professional fishers along the Caspian have been asking, "Where have all the kilka gone?" In Iranian waters, Ghent's Dumont adds, "they don't catch anything but jellies now." The CEP fish survey spotted this decline. According to Labon, the survey found that kilka and herring populations "are severely depressed" compared to 2 years ago. His team is still crunching numbers to determine precisely how much these fish have declined.

A kilka crash is bad news for the fishing industry in Iran, where there's a big market for the sprats. But for the beleaguered seals that feed on kilka, it could be a crushing blow.

Hunting a killer

It has been a tough few years for the Caspian's seals. Two years ago, a mystery epidemic killed several thousand of them, including many young ones. A CEP seal ecotoxicology team, led by Susan Wilson of the Tara Seal Research Centre in Northern Ireland, and the VECTOR group—working independently—unmasked canine distemper virus as the likely villain (*Science*, 22 September 2000, p. 2017). When seals began dying in droves again last spring, both teams headed out to different parts of the Caspian to find out why.

Hard times. The CEP ecotoxicology team's Hormoz Asadi observes a seal on the Apsheron Peninsula. The comb jelly *Mnemiopsis leidyi* (*top*) may have abetted last year's die-off.

Their preliminary, unpublished findings suggest that canine distemper is not the seals' only foe. After sampling dead or dying seals washed up on the Apsheron Peninsula, Wilson's team found that—unlike what they had observed in 2000—the victims were mostly adults. Analyzing tissue back in the lab along with samples from Iran and Turkmenistan, Wilson and her team so far have found no sign of canine distemper or any other virus.

Wilson's team believes that pollution may be a contributor to last year's die-off. The researchers are now testing their samples for levels of the pesticide DDT and other long-lived pollutants. Such chemicals are also the prime suspect in the seals' plummeting birthrate, says Wilson. But she and her colleagues are pursuing other lines of inquiry, including bacterial infections and poor nutrition.

The VECTOR team's findings add more intrigue. Blinov's group says it detected a flu strain last spring, similar to one that jumped from birds into people in Hong Kong in 1997, in some of the dead seals they had sampled in 2000, as well as a nearly identical strain in a single sick seal in Russia's Lake Baikal. "If avian viruses could overcome host barriers and infect humans in Hong Kong and cause pandemic outbreaks in seals," says Blinov, "we thought, 'What might occur tomorrow?' " Tests for virus in seals sampled last year on Malyi Zhemchuzhnyi Island are still under way, but they have come up negative so far.

That jibes with the CEP ecotox findings, but it fails to penetrate the mystery of where canine distemper is lurking, or whether the avian influenza that VECTOR spotted was a red herring or a continuing threat to the seals. Wilson speculates that canine distemper, at least, could reemerge in a couple of years. She notes that the evidence is looking more solid that distemper was behind a mass die-off in 1997 and may periodically afflict Caspian seals.

If canine distemper does resurface next year, the seals could be in for a double whammy. Both the CEP and VEC-

CREDITS: (LEFT TO RIGHT) HANS-JÜRGEN BURKARD, COURTESY OF *CAVIAR EMPTOR*; S. WILSON; LAURENCE P. MADIN/WOODS HOLE OCEANOGRAPHIC INSTITUTION

TOR teams have reported that many ill or dead seals were underweight and some were emaciated, which may point to a food shortage. Wilson carried out a limited survey of seal feces collected on Apsheron last year and found that kilka appeared to make up only a tiny proportion of their diet, suggesting that the seals had to make do with less-nutritious prey. "We need to extend these diet studies," Wilson says. But it does seem to bear the tentacle-marks of *Mnemiopsis*.

Dumont and other experts argue that steps must be taken quickly to rein in *Mnemiopsis*. After *Mnemiopsis* levels in the Caspian last fall exceeded those ever reached in the Black Sea, a scientific advisory committee called on littoral nations to approve plans to unleash a predator this spring to control the invader. Their choice was *Beroe ovata*, a heftier comb jelly that dines almost exclusively on *Mnemiopsis*. *Beroe* slipped into the Black Sea in 1997 and quickly brought the villain to heel. There, *Mnemiopsis* populations had plunged so low by last year that it was hard to find specimens for analysis. *Beroe*, says Dumont, "is almost too good to be true."

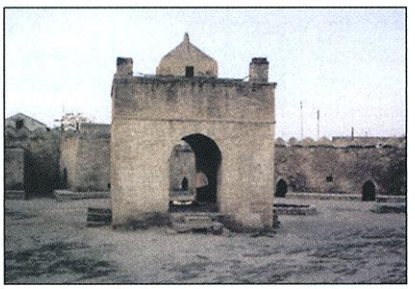
Azerbaijan and Iran are pressing hard for *Beroe* to be introduced, but it's unclear whether the other Caspian governments will climb aboard. Signs look unfavorable for agreement on something as contentious as biological pest control—no matter how benign *Beroe* would appear—when tensions are already running high over oil rights.

Political hardball

Like 49ers staking claims in California, the five littoral nations have asserted overlapping territorial claims in the Caspian itself. Last summer, Iranian gunships chased an Azeri research vessel out of waters claimed by both countries. A meeting planned for last October at which the countries had agreed to demarcate borders was abandoned after the 11 September terror attacks, although the leaders of Azerbaijan and Turkmenistan are scheduled to visit Moscow later this month in part to revive the negotiations.

The Caspian nations are playing hardball because their oil is considered a major prize by Western powers. The newly independent states could act as a counterweight to OPEC, because the Caspian oilfields would greatly augment the few reserves—including Siberia and the North Sea—not controlled by the Middle East–dominated cartel. Caspian oil "can offset [OPEC's] efforts to keep prices high and their use of high prices for political dictates," says Brenda Shaffer, research director of Harvard University's Caspian Studies Program.

Apart from Russia, the three countries with the largest Caspian reserves—Azerbaijan, Kazakhstan, and Turkmenistan—have welcomed alliances with the West, which they think will help them convert their black gold into cash and limit Russian influence in their affairs. Beyond oil and gas, the region is important to the United States, which "needs to develop friends like Azerbaijan and Kazakhstan in the Muslim world, due to their clear separation of religion and state," says Shaffer. Russia, meanwhile, has bolstered its sphere of influence by strengthening ties with Iran and forming alliances with other ex-Soviet littoral states.



Eternal flames. At the Surakhany Fire Temple, ancient Persians meditated on Baku's perpetually burning hills, including the Kirmaky gas seep (*left*).

Sound like a powder keg waiting to be lit? Quite so, says Terry Adams, a senior associate at Cambridge Energy Research Associates and founding president of the Azerbaijan International Operating Company oil consortium: "The seeds of future Caspian conflict were planted early." And with an international effort to safeguard the Caspian's ecology nowhere in sight, the lake itself can only suffer in the process. –RICHARD STONE

CREDIT: MIKE SIMMONS/CASP

MEETING INFECTIOUS DISEASES

New Weapons in the Battle of the Bugs

CHICAGO—Postponed from its original late-September schedule following 11 September, a meeting* on infectious diseases sponsored by the American Society for Microbiology finally convened here last month. Two families of potential antibiotics had attendees talking, and one team presented a possible treatment for the deadly tropical Chagas disease.

Giving Chagas the Kiss-Off

You may call it just a kiss, but a quick peck from a kissing bug can mean big trouble. The cockroach-sized insects spread the parasite that causes Chagas disease, also known as American trypanosomiasis. Left untreated, the infection lingers for decades, causing devastating heart and intestinal problems that kill 50,000 people a year. No effective drugs exist for the more than 16 million people, most of them poor people in Central and South America, who have chronic infections. But a new strategy, so far successful in lab dishes, aims to stop the parasite in its tracks.

The approach, presented by Julio Urbina of the Venezuelan Institute for Scientific Research in Caracas and his colleagues, blocks the parasite from making ergosterol, a fatty, cholesterol-like molecule that the parasite needs to keep its cell membranes working properly, among other key functions. "It's a very promising target," says parasitologist Juan B. Rodriguez of the University of Buenos Aires, Argentina.

The kissing bug emerges at night from thatched roofs and cracks in the walls of adobe houses. It bites sleeping people and defecates on their skin, depositing the parasite. When people scratch the bite or touch their eyes or mouth, the parasite, a protozoan called *Trypanosoma cruzi,* enters its victim. Others are infected from their mothers at birth or when nursing, and still others receive transfusions of contaminated blood.

In the past decade, South American governments and the World Health Organization have funded a campaign to cut Chagas transmission by plastering walls, spraying insecticide, and pushing blood banks to screen for the parasite. The campaign has been remarkably effective, but new drugs for Chagas disease are still desperately needed for the millions who are already, or will become, infected. The two drugs used today to treat acute cases have severe side effects, and they can't touch parasites that have burrowed into the heart and intestine of chronically infected patients.

To find a new Chagas drug, Urbina's

* Interscience Conference on Antimicrobial Agents and Chemotherapy, 16–19 December 2001.