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The Great Invaders
A new ecosystem is evolving in San Francisco Bay. We have no idea what it is, or where it's going

- Glen Martin

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Andy Cohen already knew Asian clams were a significant factor in the changing ecosystem of San Francisco Bay when he headed out to collect invertebrates on an exceptionally low tide at Port Sonoma a few years ago.

But he didn't have a visceral grasp of the issue until he put on his rubber boots and trudged out on the mudflats, following the receding water.

"I began digging, and the clams were incredibly thick, packed together like walnuts," said Cohen, an environmental scientist with the San Francisco Estuary Institute who specializes in invasive species.

"At one point I stood up and looked over the flats," said Cohen. "As far as the eye could see, the surface of the mud had this nubbly texture, and I realized it was all Asian clams. Tens of thousands of acres of them, all of San Pablo Bay, really. And I knew it was the same way in the South Bay, and the shallow portions of the Central Bay. It was an enlightening moment."

A drab, unassuming mollusk averaging the size of a thumbnail, the Asian clam -- Corbula amurensis -- has transformed San Francisco Bay. In vast portions of the estuary's intertidal zone, it has displaced virtually all other invertebrates, reducing biological diversity to almost zero.

More than that: It has altered the very way energy flows through the bay's ecosystem. Before the clam showed up in the 1980s, large portions of the bay supported extravagant phytoplankton blooms. This algal plankton nourished huge populations of zooplankton, which buttressed a vast aquatic food web, ranging from tiny fish and crustaceans to big halibut and leopard sharks.

But the clams, voracious consumers of both phytoplankton and young zooplankton, changed all that. They became so numerous -- in places reaching densities of 50,000 per square meter -- that they sucked up the plankton. All of it. For the most part, the plankton blooms are gone.

"They've basically changed the bay from a pelagic (mid-water) system to a benthic (bottom) one," said Cohen. "In the process, they made many prior studies of the estuary obsolete. Before the clam, we had logged 20 years of productivity cycles for the North Bay. Then the clam comes in, and it's literally a new ecosystem. That's 20 years of knowledge down the drain."

San Francisco Bay and the Sacramento-San Joaquin River Delta constitute the West Coast's most significant estuary. Historically, it was a great biological engine that steadily churned out millions of metric tons of fish and shellfish. Its vast food web supported everything from phytoplankton to marine mammals.

The estuary is hardly moribund today, but its productivity has declined, the inevitable corollary to water diversions, urban development and wetland reclamation for agriculture.

Too, the animals and plants that currently inhabit the bay and delta tend to be "exotics" -- invasive species from other continents that have reproduced so exuberantly that they've pushed out the local mollusks, crustaceans, hydroids, bryozoans and aquatic grasses. Cohen estimates that at least 250 exotic species have become established in the estuary.

Thus, the bay is no longer a native ecosystem: It is a hodgepodge of foreign species that is constantly in flux, and no one knows which ones will gain ascendance where, or for how long.

The best we can hope for, says Cohen, is to prevent new exotics from invading the system. Ships still carry the larvae and ova of exotic species in their ballast water, and yacht bilgewater also has its share of hitchhikers. Fishermen toss leftover bait -- pile worms from the East Coast, various minnows from all sorts of places -- into the water after a day's fishing. Aquariums full of strange fish, snails and amphibians are dumped in convenient sloughs once their owners become bored or inconvenienced. A new system is evolving in the bay. We have no idea what it is, or where it's going.

Still, there's a ray of hope: Pending state legislation supported by the Estuary Institute would put tight strictures on the release of ballast water in and around the bay; chances for passage in the coming year look good. Under the 2003 reauthorization of a 1999 bill that established ballast water discharge regulations, a panel was formed to make recommendations for further restrictions. The members -- who included Cohen -- drafted rules that would constitute the toughest discharge standards in the world. The State Lands Commission is expected to approve the recommendations in the next couple of months, and the California Legislature could include them in a bill by the end of the year.

The standards will require all ships to achieve zero or near zero organism discharge levels by 2016. The variance is keyed to organism size -- smaller critters are harder to kill than big ones, so the standards are slightly relaxed for them. Water will be either be retained in the ship or pumped to tanks on land; treatment could include heat, ultraviolet radiation or chemicals.

"Ballast water is the key to everything," said Cohen. "Effective action on any of the other

problems, such as the aquarium, seafood or bait trade, really hinge on effective action on ballast."

If implemented, the bill should reduce the entry of nonindigenous species to about double "background" level -- the rate at which exotics float, swim or sluice into the bay naturally.

"That may not sound so good, but it represents a dramatic improvement," Cohen said. "Currently, the invasion rate is perhaps several thousandfold above the background level."

The following is a partial rogues' gallery of some of the estuary's most intriguing resident invaders. Additional examples, mostly of "fouling" organisms -- species that attach themselves to pilings, rocks or ship hulls -- can be found on the San Francisco Estuary Institute's Web site at www.sfei.org.

ASIAN CLAM

Corbula amurensis

First noted in the mid-1980s, this bivalve probably constitutes most of the benthic biomass in the bay. Its vast numbers have resulted in a drastic reduction in plankton in the North Bay, which may be adversely affecting the delta smelt, an endangered native fish considered an indicator of estuary health.

The clam also has the unfortunate propensity of concentrating selenium in its tissues, an element that is toxic at moderate to high levels. This may be having a malign effect on fish and aquatic birds that feed on the clam, specifically white sturgeon and northern scaup.

Some researchers say some control could be established on the clam in the North Bay by altering the way water flows through the delta. Historically, the delta was almost wholly brackish, with fresh water from the Sacramento and San Joaquin Rivers mixing with salt water from the San Francisco Bay. Today, the system is bifurcated, managed in the upper reaches as a freshwater reservoir for the giant government pumps that send water to Southern California. The lower delta -- which from a hydrological point of view once included Suisun and portions of San Pablo bays -- has essentially become an extension of salty San Francisco Bay.

The current "tidal prism" of the delta could be changed, say some scientists, by removing some of the region's westernmost levees. This would allow a greater intrusion of brackish water into the North Bay, killing the clams. Or that's the hope, at least.

EASTERN SOFTSHELL CLAM

Mya arenaria

From the perspective of a seafood connoisseur, there are certainly worse invaders than the softshell clam, a large bivalve much esteemed on the East Coast for its succulent flesh.

Eastern softshells probably found their way into the estuary as unnoticed adjuncts to the 19th century's oyster trade, when large quantities of East Coast oysters were established throughout

the bay. Their populations may have been bolstered later through intentional plantings by steamed-clam enthusiasts. By the 1880s, they were the most common clam sold in San Francisco fish markets. By the beginning of the 20th century, they had supplanted the native bent-nose clam in most of the bay's intertidal zone. Softshell clam harvests declined throughout the 20th century due to pollution, siltation of the beds and overexploitation, but they are still common, in some areas reaching densities of 1,000 per square meter.

HYBRIDIZED ATLANTIC CORDGRASS

Spartina alterniflora

What happens when you take an East Coast marine grass and transplant it to the West Coast? In one case, at least, it cross-pollinates with a related western species and mutates into a voracious vegetal monster, turning vast portions of the bay's most productive tidal flats into ratty greenswards.

Atlantic cordgrass was first introduced to San Francisco Bay in the 1970s, when the U.S. Army Corps of Engineers thought it might be a good way to stabilize levees on Alameda Island.

Wrong. The robust intertidal grass stabilized levees just fine, but it also started swapping genes with California cordgrass, a less-vigorous relative found from Bodega Bay to Baja. The result of this unholy union is a fast-spreading hybrid that has already taken over 1,500 acres of the bay's tidal flats, and threatens a total of 69,000 acres.

A bay full of hybridized cordgrass would be a catastrophe. Tidal mudflats support huge invertebrate communities, which in turn sustain benthic fish, shorebirds and waterfowl. Those same flats covered with hybridized cordgrass would support -- well, hybridized cordgrass -- and little else.

The California Coastal Conservancy hopes to eliminate the existing stands by spraying them with a low-toxicity herbicide over the next few years. Most environmental groups support the program, but some opposition has developed from groups worried that the herbicide has not been proved completely safe .

WATER HYACINTH

Eichhornia crassipes

This species illustrates the fact that it's possible to be both beautiful and completely noxious. An aquatic plant from South America, the water hyacinth has bright green leaves and exquisite lavender blossoms. It was first introduced into California - probably as an ornamental plant - in the 1900s, and it found the conditions congenial.

Too congenial. The water hyacinth doesn't so much reproduce as metastasize. By the best accounts, it is the fastest-growing plant in the world, able to double in volume every 10 days under optimum conditions -- such conditions being days with long photoperiods and hot temperatures. In other words, days like you get in the delta during the summer. It often forms

tangled mats of vegetation 6 feet thick. And it is mobile, with bits and clots floating with the river currents and tides, each a potential node of exploding greenery when a quiet eddy or backwater is attained.

The water hyacinth has long been the premier bete noir for boaters, anglers and farmers in the delta. It clogs waterways and overwhelms marinas like aquatic kudzu, depleting water of oxygen, much to the distress of fish. And if there is a plant more adept at clogging agricultural pump intakes, no one has identified it.

It's clear that water hyacinth can't be eliminated in the delta, but minimal controls have been established through herbicide spraying. This, however, is an extremely controversial practice, given concerns about the high levels of toxic chemicals already present in delta waterways.

GREEN CRAB

Carcinus maenas

Small but voracious, this European crustacean was first noted in San Francisco Bay in 1994. Researchers were worried that it would both displace native crabs -- including the commercially important Dungeness, which use the bay as a nursery -- and chow down on all the local mollusks. Green crabs have an exceedingly robust appetite, and will sometimes dig 6 inches into the mud for clams. The crab showed up in Tomales Bay at roughly the same time as it appeared in San Francisco Bay, and commercial shellfish producers soon noticed damage in their stocks of oysters and Japanese littleneck clams. Since then, the predation has moderated. Scientists think that the crab, an accomplished predator, is also serving as prey for Dungeness crabs, leopard sharks, bat rays and sturgeon. In other words, while green crabs have secured a niche in Northern California's estuaries, they aren't overwhelming the systems as originally feared.

MITTEN CRAB

Eriocheir sinensis

In the late 1990s, it was feared this would be the Crab That Ate the Delta. Originally from Asia, mitten crabs are catadromous: They spawn in salt water and mature in fresh water, the opposite of anadromous species such as salmon. They first showed up in the South Bay in 1992. By 1994, they were in San Pablo Bay, and by 1996 they had swarmed the entire delta.

In 1998, crabs migrating downstream from the Sacramento River and tributaries of the San Joaquin River to spawn clogged the screens at the huge government water project at Tracy by the tens of thousands. Since then, their numbers have dropped somewhat, but researchers note that in other areas that have been invaded by mitten crabs -- Europe, specifically -- their populations tend to cycle through dips and peaks.

Mitten crabs are easily identified by the "mittens" of soft bristles that cover their claws. They are considered delicacies in Asia, where a gravid female -- one bursting with roe -- can fetch up to $20.

But their presence in the bay is problematic for a few reasons. First, they are omnivorous, and like all crabs, have robust appetites; so they could exert a negative effect on native fish species.

Second, they like to dig -- often and deep. Millions of mitten crabs riddling the delta's already inadequate levees could contribute to widespread failure of the earthen barrier system that keeps salt water from intruding on farmlands, cities and the government pumps that send fresh water to Southern California.

Finally, mitten crabs are hosts to a fluke that can infect and sicken humans. The parasites haven't been detected in Bay Area mitten crabs, nor have the various species of snails that are intermediate vectors for the fluke been found.

The possibility of a human health impact has kept state agencies from authorizing the one method that might effectively scotch the crab -- commercial harvest. With expected premium prices for gravid females, it's possible the base population of crabs could be greatly reduced by a market fishery.

But biologists worry that a commercial fishery could provide incentives for the illegal transplanting of the crabs to other waterways in California and beyond, compounding rather than reducing the problem.

CHANNELED WHELK

Busycotypus canaliculatus

These edible -- by many accounts, delicious -- East Coast snails were imported to San Francisco by Italian fishmongers in the early 19th century, who sold them as "pear conchs." They can sometimes still be found in Bay Area Chinese fish markets, and it is presumed they came to the estuary through the commercial trade.

They were first recorded in San Francisco Bay in 1938, and are now the biggest snails in the system: on his desk, Cohen keeps a channeled whelk shell collected in the bay that is close to 7 inches long.

Channeled whelks are relatively common in the bay and are active predators of other shellfish, wandering the mud flats for clams, mussels and oysters. On the East Coast, they are notorious pests in commercial oyster beds. As there are no shellfish operations in San Francisco Bay, they are not a concern for local seafood enterprises. They may, however, be supplanting native snails from their former niches or affecting native shellfish through predation.

ATLANTIC MUDSNAIL

Ilyanassa obsoleta

A tiny, nondescript gastropod from the East Coast of North America, the Atlantic mudsnail isn't as noteworthy for what it is as for what it harbors: A tiny parasitic flatworm, or shistosome.

The larvae of these shistosomes can burrow beneath the outer dermal layer of human beings,

causing an irritating skin eruption known as Swimmer's Itch. Two outbreaks of itch have been recorded in San Francisco Bay: One in 1954, and one last June, both in Alameda. Swimmer's Itch outbreaks are difficult if not impossible to predict, but as long as Atlantic mudsnails live in the bay, future incidents can't be discounted. And by any evaluation, it looks like the snails are here to stay. They probably hitchhiked to the bay on oysters imported from the East Coast in the 19th century, and were first noted in 1907.

OYSTER DRILL

Urosalpinx cinerea

This small snail has a macabre method of feeding. Employing a rasp- like organ called a radula and corrosive glandular secretions, it drills tiny, symmetrical holes through the shells of oysters, barnacles, clams and mussels, inserts its proboscis, and sucks out the soft tissues.

Like many other invasive shellfish, they were imported to the bay in the 19th century during the oyster trade. The first specimens were collected in Brisbane in 1890, and they are now found throughout the bay.

Their impact on native species at this point may be minimal, probably because most of the benthic organisms in the bay are exotics. Indeed, Asian clams are now one of the drill's primary food sources.

YELLOWFIN GOBY

Acanthogobius flavimanus

Gobies are small, bottom-dwelling fish with gargoyle-like faces and interesting behaviors. Lively and alert, they typically inhabit burrows in the tidal flats, which they retreat to rapidly when alarmed during foraging expeditions. They use their large pelvic fins to anchor themselves to rocks in heavy tides and currents.

Of the eight species of goby in the bay -- six native and two exotic -- the yellowfin, at 6 to 8 inches, is the largest. Hailing from Japan, Korea and northern China, it first showed up in the bay in the 1950s, presumably in ballast water.

Gobies are fairly unassuming fish, so the major problem with alien gobies isn't predation of native critters. Rather, it's displacement: Expansive as the bay's mudflats are, there is nevertheless a finite amount of goby habitat. One native goby -- the tidewater goby -- is already extinct in San Francisco Bay, presumably because it was denied sufficient lebensraum by its invasive cousins.

Still, the yellowfin goby has some positive qualities. Their ova and young are probably significant contributors to the estuary's food web, and the mature fish are excellent bait for sport fish such as sturgeon, halibut and striped bass.

STRIPED BASS

Roccus saxatilis

If there was ever an exotic species with a large popular constituency, this is it. "Stripers," as they are fondly and colloquially known, were first introduced into San Francisco Bay by angling clubs in 1879. They are big -- weighing up to 90 pounds -- delicious and beautiful, with silvery-white flanks marked with distinctive dark stripes.

Following introduction, striped bass quickly established themselves in the bay and became second only to salmon as the estuary's most popular food and sport fish.

Like salmon, striped bass are anadromous, spawning in fresh or brackish water and migrating to salt water to mature. For years, the California Department of Fish and Game used a striped bass index -- basically, a population survey -- to help evaluate the biological health of the delta.

Today, striped bass are sometimes bad-mouthed in scientific and political circles -- they are an invasive species, after all, and have been implicated in the consumption of endangered fish, such as winter-run chinook salmon smolts and the delta smelt.

But anglers are still enthusiastic champions of the species, and it looks like stripers may have gotten a bum rap on their impact on native fish. Some of the state's top fisheries experts note striped bass and salmon have co-existed happily for a century, and it has only been in the past 20 years that the delta's native fish have tanked. Ominously, striper populations have declined by more than two-thirds in the same period. Water diversions and toxic chemicals in the delta, researchers say, are hitting both native fish and striped bass hard: Ironically, the most popular exotic in the estuary may be the one that proves the easiest to eliminate.

Aqua Incognita: Tokyo Bay

Japan has been a generous contributor of invasive species to San Francisco Bay, but with exotics, it's tit for tat. Tokyo Bay is becoming quite the showcase for nonindigenous species. So far, said Andy Cohen, environmental scientist with the San Francisco Estuary Institute, at least 25 exotic species have been recorded in the bay.

"But the true number is probably much higher than that," Cohen said.

Some of Tokyo Bay's exotics are from California, including a nudibranch -- or sea slug -- known as the Lake Merritt cuthona. The little marine mollusk was first collected in Oakland's urban lake, which has egress to San Francisco Bay.

Another California transplant to Tokyo is a small spider crab from Southern California, Cohen said.

"It got there by way of San Francisco Bay," Cohen said. "It showed up here first from the south state, then wound up over there." It is assumed most of Tokyo Bay's exotics arrived there in ballast water, Cohen said.

Along with the crab, Tokyo and San Francisco share several other marine exotics: barnacles from the Atlantic and Indian oceans, an Atlantic sea squirt, a tubeworm from the Indian Ocean,

a mussel from the Mediterranean.

Compared to San Francisco Bay, Tokyo Bay is terra -- or aqua -- incognita when it comes to exotics. Cohen wants to help change that.

"We'd like to collaborate with our Japanese colleagues on a survey over there, and then we hope to bring them back here," he said.

San Francisco Bay has an extremely high number of Japanese species, said Cohen, "and we've always wondered about that. We don't know if Japanese estuaries support a comparable ratio of Western North America species."

Until recently, Japanese biologists haven't expressed much concern about exotic species, and even now they aren't exactly alarmed.

"My impression is that Japanese scientists don't see it as a problem to the degree that we do," Cohen said. "Here, we're concerned about preserving natural systems. There, the emphasis is more about the support of commercial fisheries. They're concerned about maintaining species that can be eaten."

-- G.M.

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