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Providing current information on monitoring and controlling the spread of harmful nonindigenous species.

The Spartina Invasion of San Francisco Bay

By Debra R. Ayres and Donald R. Strong

Invasive species often exhibit resistant characteristics. Even the extreme ecological conditions of tidal salt marshes, high salinity, and anoxic soils, do not exclude invasive species. The inter-tidal, salt marsh habitats of San Francisco Bay were invaded by a non-indigenous smooth cordgrass, *Spartina alterniflora*, which was intentionally introduced from the Atlantic seaboard for erosion control in the early 1970s (Callaway and Josselyn 1992). This invader hybridized with native California cordgrass, *Spartina foliosa*, and produced hybrid swarms that can potentially spread down the inter-tidal gradient and cover the naturally open mud (Ayres et al, 1999).

The salt marshes and inter-tidal areas of San Francisco Bay are invaluable. Only a small fraction of the original extent of this habitat remains. Most has been diked, drained, and filled over the last century (Macdonald 1977). The remaining salt marshes of San Francisco Bay are home to valuable native species, including two federally listed endangered animal species, the salt marsh harvest

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Figure 1. *Spartina alterniflora* in San Francisco Bay

Snakeheads Represent an Increasing Threat to U.S. Waters

By Robert G. Howells, James D. Williams, and Walter R. Courtenay, Jr.

Snakeheads (Family Channidae) have long been recognized as a potentially problematic species if introduced and established in U.S. waters. In fact, Texas prohibited some or all species in this family as far back as the mid 1960s (Howells 1999). Since then, at least a dozen other states have added snakeheads to their prohibited species list. Original concerns focused on periodic importation by the aquarium trade and fear of release; however, recent shipments of living fish to seafood markets have highlighted an entirely new area of concern.

Also called serpent-headed fish, snakeheads are elongated, torpedo-shaped fish from tropical Africa and southern Asia (Nelson 1994). The name snakehead comes from the presence of large scales on the head, reminiscent of the large epidermal scales or cephalic plates on the heads of snakes, and the forward placement of the eyes on the head. Snakeheads have long dorsal and anal fins as well as rounded caudal fins and resemble the bowfin, *Amia calva*. Snakeheads vary in size, with one or two species reaching only about six inches in length as adults, but others may exceed four feet and weigh more than 44 pounds

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mouse, *Reithrodontomys raviventri*, the California clapper rail, *Rallus longirostris obsoletus*, and the federally listed endangered plant, soft bird's beak, *Cordylanthus mollis mollis*. These salt marshes support fisheries and recreation, and serve essential ecosystem functions such as flood control. The open mud of San Francisco Bay is the primary habitat of one of four Audubon Society "Hemispheric Reserves" for shorebirds. California cordgrass, *Spartina foliosa*, forms a natural lower boundary to salt marsh vegetation and provides essential habitat for a variety of native vertebrates and invertebrates, making the plant an essential component of natural California salt marshes. *Spartina foliosa* is a short cordgrass that grows sparsely, rarely attaining height greater than 75 cm. It is restricted to high elevations on the inter-tidal plane, and does not grow lower than the average high water level. This characteristic leaves mud areas open in Pacific estuaries. Other native cordgrasses do not exist on the Pacific coast. The range of *Spartina foliosa* extends from Bodega Bay, 100 km north of San Francisco, into Baja California, Mexico. Thus, biotic threats to the salt marsh habitats of San Francisco Bay could readily spread southward, even into Baja California.

> *Without control, the invader and hybrids will spread from south San Francisco Bay northward to threaten the North Bay and the Sacramento River estuary.*

The original control efforts with invasive smooth cordgrass, *S. alterniflora*, in San Francisco Bay centered upon ecological competition with native California cordgrass, *S. foliosa* (Callaway and Josselyn, 1992). What was thought to be invasive smooth cordgrass, initiated growth earlier in the spring, had grown 10-fold the above-ground and 2-fold the below-ground annual biomass, grew as much as 60 cm taller, and spread laterally 1.5 times faster than the native. In a field competition experiment, 75% of cleared patches were re-colonized by what was inferred by these authors to be pure smooth cordgrass. The invader produced more flowers and set more seed, and its seeds had higher germination than the native. Finally, what was believed to be pure smooth cordgrass grew as high or higher in the marsh, and from 9-20 cm lower, than the native, suggesting a lack of refuge in San Francisco Bay for California cordgrass from competition with this aggressive exotic species. After further studies, the majority, if not all, of the plants considered to be pure smooth cordgrass in this pioneering work, turned out to be hybrids between the invading *S. alterniflora* and the native *S. foliosa*.

Recent studies suggest that hybrids between native California cordgrass and the invasive smooth cordgrass are probably the most menacing of the more than 200 known non-indigenous species in this "world's most invaded estuary" (Cohen and Carlton, 1998). If left uncontrolled, this invasion has the potential to convert the salt marshes and open mud of San Francisco Bay into vast stands of hybrid and invader cordgrass, which will accumulate sediment, elevating the marsh. The probable ecological outcome can be seen from the results of the spread of hybrid *S. anglica* in England 100 years ago. After hybridization and chromosome doubling led to the formation of *S. anglica*, this hybrid was sufficiently vigorous to displace the native European cordgrass in the English marshes and even the introduced *S. alterniflora* parent. As *S. anglica* spread, the numbers of wading birds were reduced in invaded marshes; these birds feed upon open mud but not within *S. angelica* (Goss-Custard et al. 1995). Rapid sediment accretion elevated English marshes by as much as four cm/year and periodic dieback silted navigation channels (Ranwell 1964). Today, dense stands of *S. anglica* remain in some English estuaries changing navigational routes and estuary flow patterns (Raybould 1999).

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Using nuclear DNA markers, genes of the invader *S. alterniflora* have been found to spread rapidly through San Francisco Bay cordgrasses (Ayres et al. 1999). Already, California cordgrass is very rare in three marshes where alien smooth cordgrass and/or hybrids were deliberately planted. In these three sites, inter-specific hybrids and smooth cordgrass now grow in high densities. Recently opened salt ponds in the area, such as Cogswell marsh in Hayward, CA, are vulnerable to colonization by hybrid seed.

Through a combination of nuclear DNA analysis, field observations on flowering, and repeated attempts to cross the two species, researchers have discovered that the formation of an inter-specific F1 hybrid is an extremely rare event. However, crossing between hybrids and *S. foliosa* readily occurs. Research leaders have concluded that the sweep of invader genes through native cordgrass populations is driven by hybrids. Thus, spread of hybrids to other marshes in California could be more immediately threatening to the native species than introductions of *S. alterniflora* itself

With chloroplast DNA (cpDNA) researchers have studied patterns of maternity in hybrid cordgrass (Anttila et al, 2000). CpDNA is maternally inherited, providing information on the seed-parents of hybrids. *S. foliosa* had but a single chloroplast haplotype, and this was unique to California cordgrass. *S. alterniflora* from the native range along the Atlantic coast of North America had three chloroplast haplotypes. The most significant findings of the study were that hybridization between *S. alterniflora* and *S. foliosa* in San Francisco Bay has proceeded in both directions. The majority, 26 of the 36, of hybrids contained the *S. foliosa* cpDNA haplotype , indicating that in the majority of instances, the seed parent of the hybrids was native California cordgrass. Nine of the hybrids analyzed contained cpDNA haplotypes of the invading *S. alterniflora*, which indicates that the alien is not immune from hybridization itself.

Researchers have found that some genotypes of hybrid cordgrass grow more rapidly and ultimately taller than either parental species. This vigorous morphology has particular significance for growth in the salt marsh habitat. A reasonable hypothesis is that taller plants can survive and flourish at greater depths on the inter-tidal plane, consistent with the difference in height and growth between the two parental species. Tidal submergence time controls the distribution of cordgrasses on the inter-tidal plane; *S. alterniflora* in Long Island extends over 1m farther down the tidal plane than *S. foliosa* in San Francisco Bay (Hinde, 1954). Thus, hybridization could create genotypes that encroach upon the open mud of Pacific estuaries even farther or more rapidly than the alien species alone.

Invasion by *S. alterniflora* and hybrids is a dynamic process that raises the inter-tidal plane by means of the accretion of sediment within the densely packed canes of the invader and hybrids. This means that the total area of the encroachment will be even greater than if there was no feedback between elevation of the site and occupation by alien and hybrid cordgrass. Robust hybrids are predicted to overgrow native cordgrass, as discovered in the work of Callaway and Josselyn (1992). A further prediction is that the hybrids will even out-compete *S. alterniflora* in areas of co-occurrence. From ecological competition alone, the eventual result could be the elimination by hybrids of the invader itself as well as the elimination of native cordgrass. Growing far down onto the mudflat, hybrid cordgrass, strengthened by genetic contributions from both parents, may be the final successor of Bay marshes, replacing primarily open inter-tidal mud flat habitats with dense populations of hybrid cordgrass. Ecosystem impacts to the San Francisco Bay estuary and beyond will be devastating.

Cordgrasses disperse primarily by seeds that float on the tide (Daehler and Strong 1994). Seeds are set in late summer and fall and germinate in late winter and spring on the mud of the inter-tidal plane. Seedlings are usually scarce, and by the second year of growth, the characteristic circular clone of stems can be seen spreading outward from the initial position of the single seedling tiller.

Without control, the invader and hybrids will spread from south San Francisco Bay northward to threaten the North Bay and the Sacramento River estuary. Hybrid seeds will float from the Golden Gate and ultimately find their way into estuaries at Bolinas, Drakes Estero, Tomales Bay, and Bodega Bay, CA (Daehler and Strong 1996). Similar dispersal has already occurred from the invasion of smooth cordgrass in Willapa Bay, WA to the north (K. Sayce, personal communication). Absent control, native ovules would be swamped by hybrid pollen, producing hybrid swarms that overwhelm each marsh in succession leading to the extinction of *S. foliosa* and the transformation of the native ecosystem.

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(Smith 1945; Nelson 1994; Talwar and Jhingran 1992). There are about 27 species in the Family Channidae (Musikasinthorn and Taki 2001). Currently, most authorities place species indigenous to Asia in the genus *Channa* and the remaining three African representatives in *Parachanna*. Other scientists have restricted *Channa* to *C. asiatica*, the only species that lacks pelvic fins, and considered all others *Ophicephalus* (sometimes misspelled *Ophiocephalus*) (Nelson 1994; Sterba 1967; Lee and Ng 1991: Fuller et al. 1999).

Snakeheads are related to air-gulping anabantoid fish, like the familiar Siamese fighting fish, *Betta splendens*, and have an accessory breathing organ. As a result, these species may endure waters with low dissolved oxygen levels and survive long periods out of water if kept moist. In fact, they are obligate airbreathers and will “drown” without access to atmospheric oxygen (Lee and Ng 1991). Some species can hibernate in mud during droughts or winter conditions. Sterba (1967) and Lee and Ng (1991) noted that certain snakeheads are able to wiggle overland, similar to walking catfishes (*Clarias* spp.). All species are aggressive predators, consuming fishes and other forms of aquatic life. Nest-guarding adults have even been reported to attack humans. Predatory behavior and willingness to bite is reflected in colorful local names that translate to “freshwater tyrant” and “cobra fish.” Some people incorrectly believe their bite is poisonous or that those who eat snakeheads will be transformed into lions.

Their abundance, wide distribution, and tolerance of adverse conditions contributed to the snakehead’s popularity as food throughout much of southern and eastern Asia. The ability to survive for days in a fish monger’s damp wicker basket enhanced the importance of these fish in Asia. These same traits prompted sailors to carry live snakeheads as a source of fresh food, resulting in releases at sites throughout the Indo-Pacific, including Hawaii.

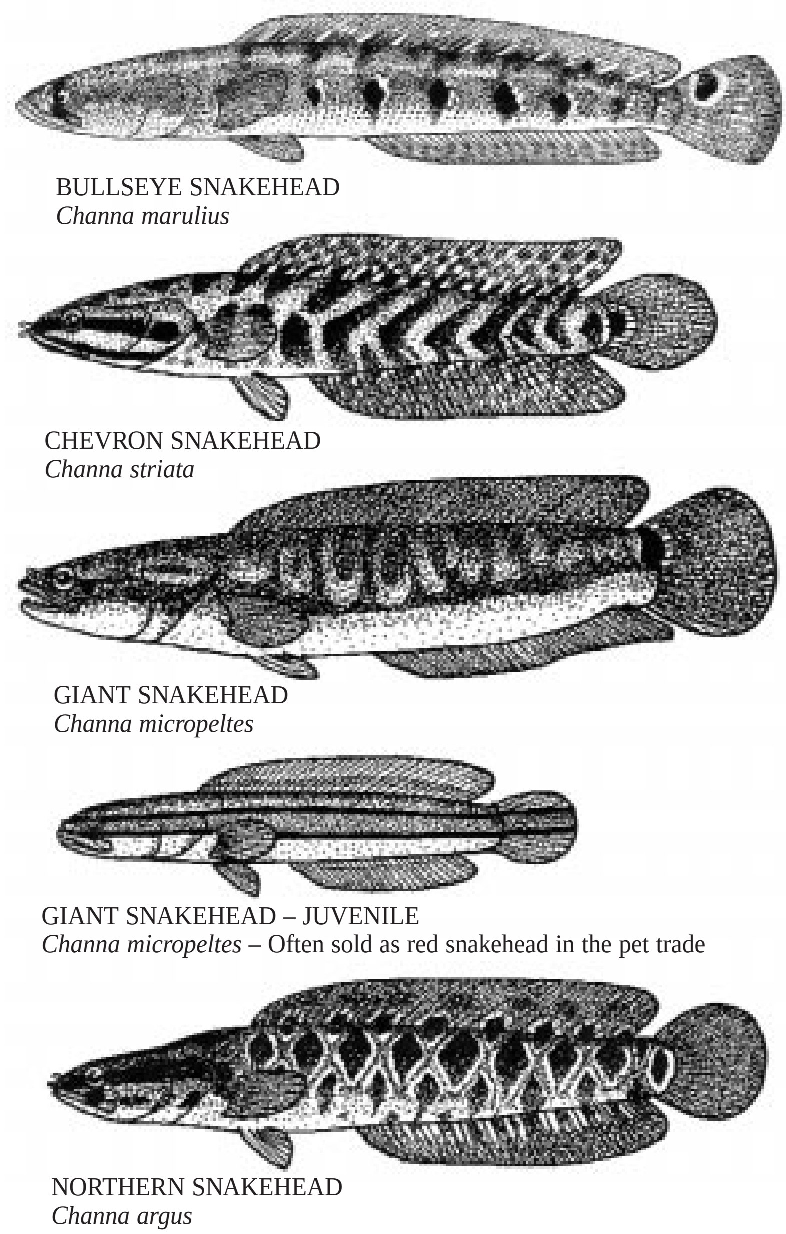

Figure 1: Four snakeheads (Channidae) that are known to have been imported into the U.S.
Illustrations by R.G. Howells

The pet trade, both past and present, periodically imported an array of snakehead species for sale to U.S. aquarists. However, they were primarily a curiosity and not a mainstay species for the industry. One species, giant or red snakehead, *C. micropeltes*, also called Malabar snakehead, may have appeared more frequently than other taxa because its juveniles are attractively patterned with black lateral stripes and red pigmentation, which disappear in the adults. This species may reach about three feet in length and 44 pounds in weight. It has been released at a number of locations in the U.S., but is a tropical species that has not established here (Fuller et al. 1999).

Bullseye snakehead, *C. marulius* (sometimes also called Indian or giant snakehead), has been released and established in southern Florida (Florida Fish and Wildlife Conservation Commission 2001). Scientific sources report lengths to four feet (Munshi and Srivastava 1988); Talwar and Jhingran (1992) list it to five feet and more than 60 pounds in areas of its native range. Although heavily-toothed and among the largest snakeheads, bullseye snakeheads appear to lack the cold tolerance necessary to invade areas north of Florida. Nevertheless, its long-term impact on Florida ecosystems remains to be determined.

Chevron snakeheads, *C. striata* , have been introduced more widely than any other species. Populations have been established at a number of Indo-Pacific locations (Welcomme 1988; Maciolek

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1984). Prior to 1900, this species was released, and is currently established, in Hawaii. Chevron snakehead is not known to be established in the continental U.S. This species also reaches about three feet in length.

The most recent snakehead threat has been posed by the northern snakehead, *C. argus*, also known as Amur, eastern, spotted, eyed, or argus snakehead. Its distribution in eastern Asia includes China, Korea, and upstream in the Amur River into Russia. This species was introduced in tributaries of the Aral Sea, Kazakhstan, in 1963. There, it became established and abundant, and is fished commercially (Baltz 1991). It has also been reported in Czechoslovakia (Holcik 1991). Its ability to hibernate and survive cold winter temperatures and droughts suggests it could easily survive in much of the U.S. if released. Sizes of this fish have been reported to 33 inches and 15 pounds. Although occasionally offered by the aquarium trade, availability of northern snakeheads has been limited. Moreover, this species has long been a favored food fish in much of southeastern Asia. In 2001, live snakeheads were sent to Texas and probably elsewhere, imported by way of New York. Texas Parks and Wildlife Department game wardens found large numbers of northern snakeheads being sold alive, as well as iced and frozen, in ethnic food markets in Houston in July and August, 2001. Raids that seized specimens and paper work tracked their origin to a local distributor near Houston who had obtained them from the source in New York City.

Disturbing aspects of the Houston snakehead discovery include the large numbers found, the particular species involved, and the importation and transfer network used to bring these fish to the U.S. and then distribute them to regional and local dealers, and finally to consumers. The fact that snakeheads had been prohibited in Texas for several decades was certainly known to some of the individuals involved. Yet, the large live food fish trade presented a ready outlet for this fish, which was selling at the high price of $9.99 per live 12-14 inch fish.

This species' potential length of nearly a yard, aggressive behavior, and toothed jaws suggest an obvious ability to negatively impact local aquatic resources if this fish should ever be released. It should be noted that Texas restrictions do not prohibit sale of dead snakeheads on ice or frozen, only of living individuals that are potential ecological threats. Fortunately, to date snakeheads have not been reported in Texas waters.

State regulations prohibiting any importation, sale, culture, or possession of snakeheads remain in place in Texas. Exotic species alert fliers were prepared and distributed following the July-August discoveries. Nonetheless, most compliance with such regulations remains largely voluntary. Individuals opting to ignore existing laws can often do so without being detected. Additionally, while some other states also prohibit snakeheads, no federal regulations against importation and sale exist. At present, several internet aquarium-fish dealers regularly offer to sell and ship at least five to six species of snakeheads, including *C. argus*. An aquarist anywhere in the country could order northern snakeheads or any other species though the mail and remain ignorant of the ecological risk such exotic fishes pose or the laws that may have been violated obtaining them. Public education and understanding, and perhaps additional regulations, will be necessary to reduce the risk posed by this group of exotic fishes.

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The New Zealand Mudsnail Invades

By David C. Richards

The invasion of exotic species is rapidly approaching habitat destruction as the number one cause of biodiversity loss, worldwide (Enserink 1999). Within the last 100 years, invasive species have been documented to have caused the extinction of 20 to 40% of the world's fish, reptile, bird, and mammal species (Enserink 1999, Reid and Miller 1989, Cox 1999) with the highest extinction rates occurring in freshwater aquatic environments (Cohen and Carlton 1998, Byers 2000). Despite this unprecedented loss of biodiversity, predicting the establishment of an exotic species in a new environment and its subsequent impact on native species/ecosystems is difficult, at best (Coblenz 1990, Reichard and Hamilton 1997, Shigesada and Kawasaki 1997).

Since the mid 1800s the New Zealand mudsnail, *Potamopyrgus antipodarum* (Gray)(Family: Hydrobiidae), a predominantly freshwater species, has spread throughout Europe, Asia, and Australia. In about the last 15 years, it has invaded North American waters and is now well established in several of the major river drainages throughout the western U.S., including the headwaters of the Missouri and Columbia Rivers and the worlds first national park, Yellowstone. Until recently, the impacts of the New Zealand mudsnail on aquatic ecosystems in the U. S. have been unknown, but were anticipated to be great due to its ability to attain extremely high densities.

Figure 1. New Zealand mudsnail, *Potamopyrgus antipodarum*
Photo courtesy of Billings Gazette

New Zealand mudsnail, *Potamopyrgus antipodarum* (Gray)

The New Zealand mudsnail, *Potamopyrgus antipodarum* (Gray), a medium-sized hydrobiid is native to New Zealand, but has also been established throughout waters in Europe, Asia, and Australia since the mid 1800s. It is not considered a nuisance species in New Zealand but has been reported to increase in density in degraded habitats and can be considered an indicator species (Towns 1981). Until recently in Europe, the New Zealand mudsnail was thought to have been a native European species, *Potamopyrgus jekinsi* (Smith), which it is often reported as. *Potamopyrgus jekinsi* is synonymous with *P. antipodarum*. Because it was considered a native species, little research has been conducted on its impacts on aquatic ecosystems in Europe. The New Zealand mudsnail possibly invaded Europe, Asia, and Australia by hitchhiking on various aquatic ornamental plants (Gangloff 1998). Another mode of invasion may have been via ship ballast water, as this species can tolerate habitats of slight salinity.

In the western U.S., *Potamopyrgus antipodarum* reaches a maximum shell length of about 6.0 mm (specimens from Cassia Creek, southern Idaho, D.L. Gustafson collector) but are typically from 4 to 5 mm (Richards et al. unpublished data). They can reach 11 mm in shell length in their native habitat. *Potamaopyrgus antipodarum* has a hardened operculum, which it can close during adverse conditions. This species has even been reported to pass through a trout's digestive tract, unharmed (Ryan 1982).

In New Zealand, both sexual and parthenogenic populations occur. All known *P. antipodarum* in the western U.S. are parthenogenic, live-bearers; they are all females and do not have to mate with a male to produce offspring. Therefore, they can be considered a clonal species in the western U.S. According to Dr. Mark Dybdahl (pers. com.), all populations examined in the western U.S. are of the same clone and are most likely from a New Zealand, rather than a European, population.

New Zealand mudsnails in the western U.S. can produce young throughout the year depending on water temperatures and conditions, although the majority of their reproduction occurs between March and October. Reproduction is severely curtailed in the winter months in most rivers in the West (Richards et al. unpublished data). In the Snake River near Hagerman, ID, and in Darlington Ditch Spring Creek near Three Forks, MT, females start to produce embryos at 3 mm shell length, with larger snails producing more offspring (Richards et al. in prep). New Zealand mudsnails greater than 3 mm collected from the Snake and Madison River drainages contain between 10 and 90 (mean 21.6) embryos or 'neonates' in their brood pouches at any one time (Richards et al. 2000). Thus, their reproductive potential is tremendous. For example, under theoretically ideal conditions, with no mortality, 6 generations per year, and 50 offspring produced per snail, in one year a single female can be responsible for the production of 3.125 x 10^8 more snails!

Distribution, densities, and habitat preferences

Dr. Peter Bowler first discovered the New Zealand mudsnail (NZMS) in the mid-Snake River near Hagerman, ID, in 1987. By then its densities were already quite high. Subsequently, five

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species of mollusks, native to the Snake River drainage were listed under the U.S. Endangered Species Act as "threatened" and "endangered", in part due to the proliferation of the New Zealand mudsnail. By 1989, it was clearly the most dominant species in that entire section of the Snake River (Bowler 1991). It most likely was introduced into the Snake River several years earlier from one or more individuals escaping one of the many aquaculture trout farms in the area.

In the late 1980s, the NZMS was also discovered in high densities in the Madison River near West Yellowstone, MT, by Montana Power Company biologists and in a separate investigation by Dr. Dan Gustafson of Montana State University. During this time, the mudsnail had also been reported in the mouth of the Columbia River, Oregon, and in Lake Ontario, Canada/U.S.

Since the mudsnail was first discovered in the Snake and Madison Rivers in the late 1980s, it has spread 'faster than a snails pace' and has been documented in numerous rivers in ID, WY, and MT. It also now occurs in three of the four major river drainages in Yellowstone National Park and in Grand Teton National Park.

New Zealand mudsnail densities in western rivers can be extremely high. In May 2001, density estimates were 10,000 to 20,000/m^2 and distributed uniformly in the Owens River, near Bishop, CA. Estimates of *P. antipodarum* densities range between 10,000/m^2 to 500,000/m^2 in the mid-Snake River and associated springs, depending on habitat and season. The highest recorded densities that have been reported are 800,000/m^2 in Lake Zurich, Switzerland, where this species had colonized the entire lake in less than seven years (Bowler 1991, Dorgelo 1987).

New Zealand mudsnails appear to do well in most river habitats in the western U.S. Researchers have found them in all habitats examined in the mid-Snake River and associated springs, except for high-gradient cold-springs. They occur in silt, sand, cobble, riffle, run, and vegetated habitats. Shinn (pers. com.) even reported them in high abundance at depths up to 60 feet in the Snake River. They do however appear to be limited by unstable substrates associated with spring runoff and by colder temperatures and probably will not reach high densities in cold, headwater streams. Mudsnails will proliferate in cool springs and spring creeks, as well as in waters with moderate winter temperatures. Population decreases of NZMS have been reported in winter by Gustafson (pers. comm.), Shinn (pers. com.), Kerans (pers. com.), and researchers at EcoAnalysts, Moscow, ID. The New Zealand mudsnail has not been reported in any natural lakes in the western U.S. but it does occur, often at high densities, in the reservoirs of the mid-Snake River, ID (Shinn pers. com.). State and federal trout hatcheries may also provide suitable habitat for mudsnails and indeed several of the state hatcheries in southern Idaho support mudsnail populations. Therefore, trout hatcheries may be an unsuspecting vehicle for transporting mudsnails to new sites.

The New Zealand mudsnail is here to stay in the western U.S. Its impacts on native aquatic flora and fauna could be significant if nothing is done to control its spread.

Potential Ecological and Economic Impacts

To date, very little data has been reported or research conducted on the impacts of the New Zealand mudsnail on native macroinvertebrate populations or aquatic ecosystems. Predictably, densities reaching 500,000/m^2 and comprising more than 90% of the invertebrate biomass will have a negative impact.

In a recent study, Chelsea Cada (pers. com.) at Montana State University concluded that the presence of the mudsnail in Darlington Ditch Spring Creek, MT, reduced food resources and densities of native macroinvertebrates. Particularly mayflies, caddisflies, and chironomids, were negatively affected at mudsnail densities of 28,000/m^2.

Dr. Billie Kerans (pers. com.) at Montana State University reported that about a quarter to over half of the macroinvertebrate community consisted of mudsnails in the Gibbon and Madison Rivers in Yellowstone National Park. She also showed a negative correlation between mudsnails and members of mayfly, stonefly, and caddisfly taxa (Kerans pers. com.).

Hall (pers. com.) suggested that these invaders are decreasing whole-stream algal production in the Firehole River in Yellowstone National Park. He also reported that most of the primary production in the Firehole River and Polecat Creek is being consumed by New Zealand mudsnails. The dominant food source in these systems is going to be taken by NZMS rather than into the native invertebrates (Hall pers. com.)

Very little information exists concerning the use of mudsnails as a food resource by fish. Bondeson and Kaiser (1949) and Haynes (1985) reported that mudsnails can pass through trout digestive tracts. NZMS have been found in the alimentary canal of mountain whitefish, *Prosopium williamsoni*, in the Madison River, but the amount of nutrition gained is unknown (Dwyer pers. com.). Obviously, mudsnails are much more difficult to digest, with their hard shells and operculum than are the thin-shelled, native pulmonate snails that do not have opercula or than soft-bodied, aquatic insect larvae.

It appears that, given the limited research conducted to date, the impacts of the NZMS on aquatic ecosystems where it occurs in the western U.S. are large. In addition, tourism and cold-water trout fisheries are a major portion of the economy in the western U.S. Montana's cold water fisheries have been estimated to generate well over $300 million to the state's economy annually, while throughout the western U.S., cold-water fisheries generate over $2 billion annually. It was the general consensus at the First Annual New Zealand Mudsnail in the Western U.S. Conference 2001 that the NZMS will have a significant negative impact on

New Zealand Mudsnail *Continued on next page*

***New Zealand Mudsnail** continued from previous page*

trout fisheries and native invertebrates, including federally listed species.

New Zealand mudsnail control and management

The New Zealand mudsnail is easily transported and, once it becomes established, not easily removed from aquatic ecosystems without disrupting native invertebrate populations. It does not however, survive in dry, warm environments. Desiccation experiments on the NZMS show that small, young snails (1 to 2.5 mm) do not survive for more than a few hours at temperatures above 70˚ F and low humidity's while the larger sized snails (≥ 4 mm) survive for less than 24 hours at 70˚ F (Richards et al. unpublished data). Therefore, it is recommended that anglers thoroughly place their boots in a warm, dry area for at least one day before entering another water body. Alternatively, immersing boots in very hot water or placing fishing equipment in a hot car on a sunny day should kill the snails. In winter, subjecting potentially contaminated fishing equipment to a hard freeze should also kill the NZMS.

Yellowstone National Park officials agree that the New Zealand mudsnail has the potential to be a major problem, which could negatively affect their world-renowned fisheries. National Park Service managers have begun an educational program informing park visitors about the snail's impacts and how to control its spread by anglers (Mahoney pers. com.).

Becker (pers. com.) listed four localized management dilemmas regarding the New Zealand mudsnail in the Owens River, California: the hatchery system, sensitive aquatic ecosystems, water export systems, and recreational and tourist based economy. So far, the NZMS has not yet been documented in the four state hatcheries in the Owens River system. The California state management efforts include: public education through the media, recreational groups, and on-site public notices; agency coordination through an issues paper and monitoring; and a new statewide invasive species coordinator.

Finally, Dr. Mark Dybdahl (pers. com.) is experimenting with biological controls of the NZMS. As a first step in the development of a possible control, he is conducting quarantined laboratory experiments attempting to infect native snails from the western U.S. with tremotodes native to New Zealand that are parasites of the mudsnail (Dybdahl pers. com.).

The spread of the New Zealand mudsnail is not inevitable. Unlike some aquatic invaders, the NZMS has no resistant stage and does not have adhesive structures. Its spread into new river systems is primarily by humans, either anglers or others transporting water-filled containers, such as bait buckets, infected with the mudsnail. With combined efforts, its spread can be controlled.

The New Zealand mudsnail is here to stay in the western U.S. Its impacts on native aquatic flora and fauna could be significant if nothing is done to control its spread. Fortunately, a few researchers and managers are dedicating their time and efforts to understand and manage this invasive species, despite the limited funding available.

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News from the Great Lakes Panel on Aquatic Nuisance Species

ANS UPDATE

Fall/Winter 2001 Volume 7, No. 4

Great Lakes Panel Update

The Great Lakes Panel held its fall meeting Nov. 29-30, 2001, in Ann Arbor, MI. At the meeting, six newly elected at-large members of the Panel were introduced: Allegra Cangelosi, Northeast-Midwest Institute; Helen Brohl, U.S. Great Lakes Shipping Association; Beth MacKay, Ontario Federation of Anglers and Hunters; Rich Mueller, Northeast Technical Services; Robert Baldwin, Michigan Aquaculture Association; and Richard Weidenhamer, Michigan Wholesale Bait Association.

The Panel discussed a variety of current policy initiatives, including recommendations for strengthening the National Invasive Species Act; the Panel's position on field tests of ballast water treatment technology; and coordination among the regional ANS panels. Also discussed was a new Great Lakes Commission project on the development of a model rapid response plan for the Great Lakes-St. Lawrence region. The plan will facilitate the timely implementation of measures to maximize the probability of eradication or control. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwayder@glc.org.

Washington Watch

Congress continues to move forward appropriations conference reports, with ANS allocations made in a variety of bills. The Commerce, Justice, and State appropriations bill, Section 1104, funded the NISA/Ballast Water Technology Demonstration Project at $2.25 million. Section 1202 ANS grants received $800,000 to fund the ANS Task Force as well as prevention, monitoring, control, and research of invasive species. Sea Grant ANS research received $3 million, an increase of $200,000 from the previous year. In the Energy and Water appropriations bill, the U.S. Army Corps of Engineers' Aquatic Plant Control Research Program was level funded at $4 million. The Forest Service International Program, which develops biocontrol agents and mitigation strategies, received $5.236 million. Contact: Joy Mulinex, Senate Great Lakes Task Force, Northeast-Midwest Institute, 202-224-1211, Joy_Mulinex@levin.senate.gov.

News from Around the Basin

MICHIGAN: Two projects focusing on exotic species were recently awarded grants through the Michigan Great Lakes Protection Fund. One project will identify reproductive pheromones to which round goby are attracted. This research will be useful in long-term efforts to determine which pheromones might be used as a control tool to keep gobies out of critical spawning grounds of native fish. The other grant provides funding for a ballast water demonstration project that will determine the efficacy of hypochlorite and copper ion as a ballast water treatment. Testing onboard Fednav's ship *Federal Yukon* began in November when the ship returned to the Great Lakes ports. **Contact:** Emily Finnell, MI DEQ, 517-241-7927, finnelle@state.mi.us.

MINNESOTA: Sea Grant, working with state natural resource agencies and the bait industry, developed state-specific posters for bait shops to alert clerks and anglers about measures for preventing the spread of ANS through bait fish. Sea Grant was awarded funding for three outreach projects to: 1) update ANS WATCH ID cards for ruffe, round goby, spiny/fishhook waterfleas, purple loosestrife, and European frog-bit; 2) educate teachers, students, and citizens about ANS through an initiative involving newspapers, workshops, and essay contests across the Great Lakes; and 3) enhance ANS-HACCP (Hazard Analysis and Critical Control Point) training materials and hold six national workshops designed to prevent the spread of ANS via wild harvest fish, stocking, and hatchery operations. The DNR is working on a reprint of *A Field Guide to Aquatic Exotic Plants and Animals* brochure and is looking for partners and revision suggestions. **Contact:** Doug Jensen, 218-726-8712, djensen1@d.umn.edu.

NEW YORK: DEC has been involved with the establishment of the Northeast Regional Panel on ANS. The panel will address both freshwater and marine ANS issues, and will include representatives from U.S. and Canadian federal agencies, regional organizations, user groups, and commercial interests. State and provincial representation will be provided from Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Nova Scotia, New Brunswick, and Quebec. Several organizational meetings have been held to determine roles and responsibilities, plan the organizational structure of the panel, and identify potential participants. The Gulf of Maine Council volunteered to serve as the host agency. The Panel was recognized by the federal ANS Task Force in July 2001, and the first official meeting was held Nov. 26-27, 2001, in Portsmouth, N.H. **Contact:** Timothy Sinnott, NY DEC, 518-402-8970, txsinnot@gw.dec.state.ny.us.

ONTARIO: More than 150 people from across Canada, the United States and other countries attended a *National Workshop on Invasive Alien Species*, held in Ottawa on Nov. 5-7, 2001. The purpose of the workshop was to develop a framework for a Canadian national invasive alien species management plan. A draft of the plan should be completed by September, 2002. The workshop format highlighted U.S. and Canadian speakers, including Kathe Glasner-Shwayder, who discussed the accomplishments of the Great Lakes Panel. Working sessions were conducted to identify issues, principles, and recommended approaches. **Contact:** Alan Dextrase, 705-755-1950, alan.dextrase@mnr.gov.on.ca.

WISCONSIN: A 20-member task force is preparing to submit its final report to the governor in January detailing the resources needed to implement an invasive species program in Wisconsin. Round gobies were discovered in southern Green Bay earlier this summer. UW-Sea Grant has received funding to produce additional *Attack Packs*, proven to be very popular with school programs. Funding also will support a nationally televised fishing and hunting program to inform anglers about ANS impacts and how to prevent their spread. The annual Wisconsin Lakes Convention, scheduled to be held in Green Bay on March 7-9, 2002, will feature four sessions on issues related to invasive aquatic species. **Contact:** Ron Martin, WI DNR, 608-266-9270, martir@dnr.state.wi.us.

National ANS Task Force

The National Aquatic Nuisance Species Task Force will hold its spring 2002 meeting in Alexandria, VA, on Feb. 28 and March 1, following the 11th International Conference. The ANS Task Force, with support from the regional ANS panels, will hold a special session during the conference regarding consensus-building for regional policy on ANS prevention and control efforts.

The Task Force meeting will address several important issues, including the reauthorization of NISA; the strategic planning process of the Task Force; the *Caulerpa Taxifolia* Prevention Plan; the Management Plan for the Chinese Mitten Crab; and State/Interstate ANS Management Plans. All conference participants are encouraged to attend the Task Force meeting. Contact: Sharon Gross, US FWS, 703-358-2308, sharon.gross@fws.gov, www.anstaskforce.gov.

On The Bookshelf

Zebra mussels: Questions and Answers for Inland Lake Managers. **Contact:** Robin Goettel, 217-333-9448, goettel@uiuc.edu.

Invasive Aquatic Plants: What Every Plant Enthusiast Needs to Know. **Contact:** Robin Goettel, 217-333-9448, goettel@uiuc.edu.

Don't Dump Bait! **Contact:** Robin Goettel, 217-333-9448, goettel@uiuc.edu.

ESCAPE Compendium Lesson Plans. 2001. $58 each plus shipping. **Contact:** Valerie Eichman, IL-IN Sea Grant, 217-333-8055, eichman@uiuc.edu, www.iisgcp.org and click on *ESCAPE* suitcase.

Community Stewardship Projects on Exotic Aquatic Species. **Contact:** Valerie Eichman, IL-IN Sea Grant, 217-333-8055, eichman@uiuc.edu.

Full copies of the ANS Update, a quarterly newsletter prepared by the Great Lakes Panel on Aquatic Nuisance Species, are available upon request from the Great Lakes Commission. **Contact:** Katherine Glassner-Shwayder, Great Lakes Commission, 734-665-9135, shwayder@glc.org.

San Francisco Bay and Beyond: Invasive *Spartina* Continues to Spread Among

By Debra Smith, Shannon Klohr, Katy Zaremba
San Francisco Estuary Invasive Spartina Project
California State Coastal Conservancy, Oakland, CA

Four nonnative species of *Spartina*, or cordgrass, are quietly spreading in San Francisco Bay; *Spartina alterniflora* and its hybrids with the native *S. foliosa* (see page 37 Ayres & Strong article), *S. anglica*, *S. densiflora*, and *S. patens.* Each of these cordgrass species is a highly aggressive invader capable of inducing physical and biological alteration of Pacific coastal habitats in California, Oregon, and Washington. (Daehler and Strong 1996). At least three of these four species were introduced intentionally to the San Francisco Estuary to revegetate wetland restoration sites in the 1970's.

In 2000, the California State Coastal Conservancy formed the San Francisco Estuary Invasive *Spartina* Project (ISP) in response to a growing need for a regionally coordinated cordgrass control effort in San Francisco Bay. An extensive ground-based survey conducted by ISP in 2001 found that combined, nonnative *Spartina* species have expanded to nearly five hundred net acres over a period of twenty-five years. Ninety-seven percent of the population is *S. alterniflora* or hybrid. The invasion has spread into seven Bay Area counties with some outlying populations of *S. alterniflora* and hybrids established as far as forty miles north of the original plantings. It appears that *S. alterniflora x foliosa* hybrids, in particular, may be poised to aggressively spread into Suisun Bay and possibly upstream into the lower Sacramento River Delta. During the survey, biologists observed that *S. alterniflora* and hybrids establish lower in elevation on the inter-tidal plane than any other native plant species, are choking creeks, tidal sloughs, and flood control channels, and are rapidly colonizing many tidal wetland restoration projects. In heavily infested areas there is significant loss of native species such as pickleweed *(Salicornia*) and *Spartina foliosa* (native California cordgrass). *S. patens* was observed to be directly encroaching on the federally and state endangered soft bird's beak (*Cordylanthus mollis*) in one location.

The San Francisco Estuary, the largest estuary in North America, opens into the Pacific Ocean at the famous Golden Gate. Beyond the Golden Gate, north along the coast, are the smaller pristine estuaries of Drakes Estero and Tomales Bay in the Pt. Reyes National Seashore, Bolinas Lagoon, and Bodega Bay - all part of the Gulf of the Farallones National Marine Sanctuary. Bolinas Lagoon is the only designated Wetland of International Importance (Ramsar Site) within California, Oregon, and Washington. Tomales Bay is currently proposed for such designation. The concern has been that *Spartina* seeds might travel out the Golden Gate with the currents and invade these outer coast estuaries. Prior to October of 2001, each of these important estuaries was believed to be free of invasive *Spartina*.

A Rapid Response Plan

In October 2001, while conducting routine follow-up on local *Spartina* invasions, ISP found a population of *S. densiflora*, originally composed of three plants and believed eradicated in 1999 from Tomales Bay, had re-established and spread. Several mature plants and more than 60 seedlings were growing at the same site, unbeknownst to the landowner. Encouraged by the landowner's interest in identifying and eradicating the plants, ISP quickly decided to expand its geographic scope to include Tomales Bay, and organized a *Spartina* species identification workshop for local Tomales Bay biologists, private landowners, and open space managers for the following week. At the workshop's conclusion, attendees each agreed to survey a section of shoreline for invasive *Spartina* and report findings to ISP. ISP agreed to conduct a portion of the surveys, assist in surveys where needed, coordinate necessary lab tests, and act as central clearinghouse for all collected data. Within three weeks, the bay had been surveyed, two additional populations of *Spartina densiflora* found, and all known populations dug out with a shovel and removed from the area. Ongoing monitoring is planned. The cost for this entire effort of early detection, survey and control was virtually zero due to volunteer efforts and ISP providing expertise, training, and equipment. The incredible interest and response from the local community were essential components to this early detection success story.

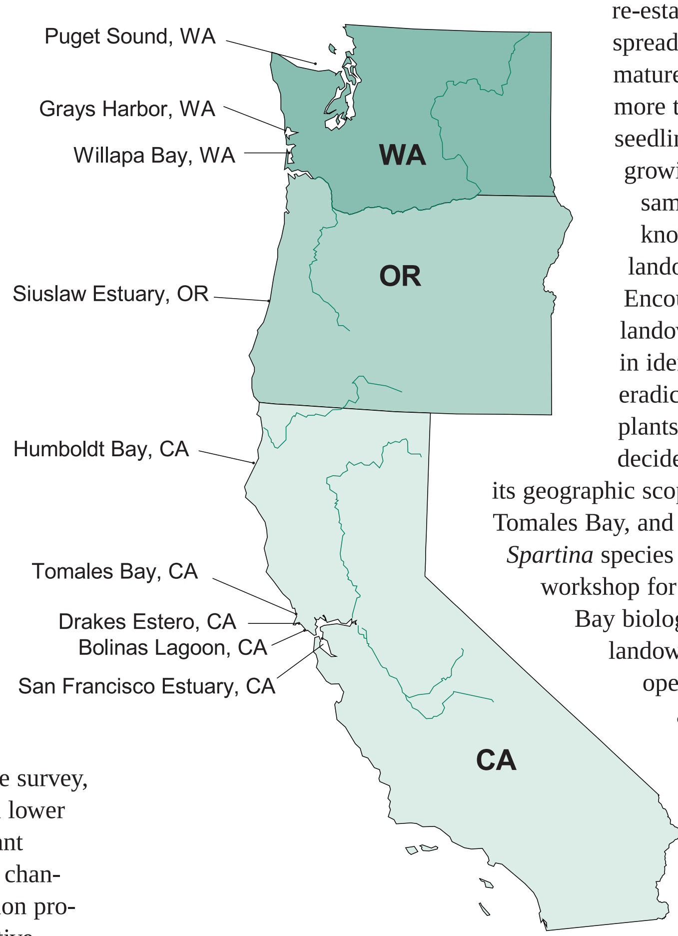

Figure 1. Pacific Coast Estuaries Invaded by Non-native Spartina (2001)

***San Francisco Bay** continued on next page*

Pacific Estuaries

***San Francisco Bay** continued from previous page*

The More You Look, the More You Find

In November of 2001, a biologist who had attended ISP's *Spartina* species identification workshop found a single *Spartina alterniflora* plant in Bolinas Lagoon while kayaking. In December, a concerned hiker in Pt. Reyes National Seashore reported a strange plant in Drake's Estero. Aware of the threat of Spartina, park biologists acted quickly to obtain genetic tests that confirmed this was *Spartina alterniflora*. Each of these plants appears to be several years old. Both of these estuaries were assumed free of invasive *Spartina*. Suddenly all such assumptions seem dangerously suspect. Vectors for these new invasions are not clear. Floating seed, aquaculture, and recreational activities between estuaries are all possible means of introduction. Clearly, all Pacific Coast estuaries need to be surveyed methodically for invasive *Spartina*. Early detection is critical for a successful and cost-efficient prevention and control program.

Surprise *Spartina* findings are not limited to California. In Washington, a wildlife technician conducting a noxious weed survey discovered a tenth of an acre patch of *Spartina densiflora* in Gray's Harbor in December, 2001. This was the first sighting of this species in the state of Washington. Scientists are in the process of identifying another cordgrass sample from north Puget Sound believed also to be *Spartina densiflora*. These continued and unexpected *Spartina* findings in well-studied estuaries further underscore the need for comprehensive surveys of all Pacific Coast estuaries.

The Pacific Coast Spartina Invasion: A Bird's Eye View

Thirty-one estuaries along the Pacific Coast have been identified as vulnerable to invasion by introduced species of *Spartina* (Daehler and Strong 1996). In 2001, five new introductions were detected on the Pacific coast including three in previously uninvaded estuaries. Currently, a total of nine have at least one species of introduced cordgrass. It is critical that vulnerable estuaries be comprehensively surveyed and a rapid response initiated to control any detected populations.

Sharon Klohr, San Francisco Estuary Invasive Spartina Project
California State Coastal Conservancy
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Phone: (510) 526-4628

Literature Cited:

Pickart, A. 2001. The Distribution of *Spartina densiflora* and two rare salt marsh plants in Humboldt Bay 1998-1999. USFWS report.

Daehler, C. C., and D. R. Strong. 1996. Status, prediction and prevention of introduced cordgrass *Spartina* spp. Invasions in Pacific estuaries, USA. *Biological Conservation* 78: 51-58.

Upcoming ANS Meetings and Events

National Invasive Weeds Awareness Week 2002 (NIWAW III)
Date: February 25 - March 1, 2002
Location: Washington, DC
Contact: Rita Trostel
Phone: (970) 498-5767

4th Annual Southeast Exotic Pest Plant Council Symposium
Date: April 3-5, 2002
Location: Renaissance Hotel, Nashville, Tennessee
Hosted by: Tennessee Exotic Pest Plant Council
Contact: Brian Bowen
Phone: (615) 532-0436
E-mail: nighttrain0@home.com

6th Meeting of the Convention on Biological Diversity (CBD) Conference of the Parties
Date: April 8-26, 2002
Location: The Hague, Netherlands
Contact: CBD Secretariat
E-mail: www.biodiversity.org

Evolutionary Consequences of Invasions by Exotic Species
Date: April 12-13, 2002
Location: Minneapolis, Minnesota
Hosted by: University of Minnesota's College of Biological Sciences
For more information:
www.ima.umn.edu/geoscience/spring/bio_invasion

2002 Invasive Species Symposium
Date: June 18-19, 2002
Location: Freeborn Hall, University of California-Davis, Davis, California
Phone: (530) 757-3331
Fax: (530) 757-7943
E-mail: events@ucdavis.edu

European Weed Research Society, 12th International Symposium on Aquatic Weeds
Date: June 24-27, 2002
Location: Papendal National Sports Centre, Papendallaan 3, Arnhem, The Netherlands
Phone: +31 26 370 8389
Fax: +31 26 370 6896
E-mail: ewrs.w2002@hetnet.nl

Send meeting announcements to:
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Deadline for the next issue is May 1, 2002.

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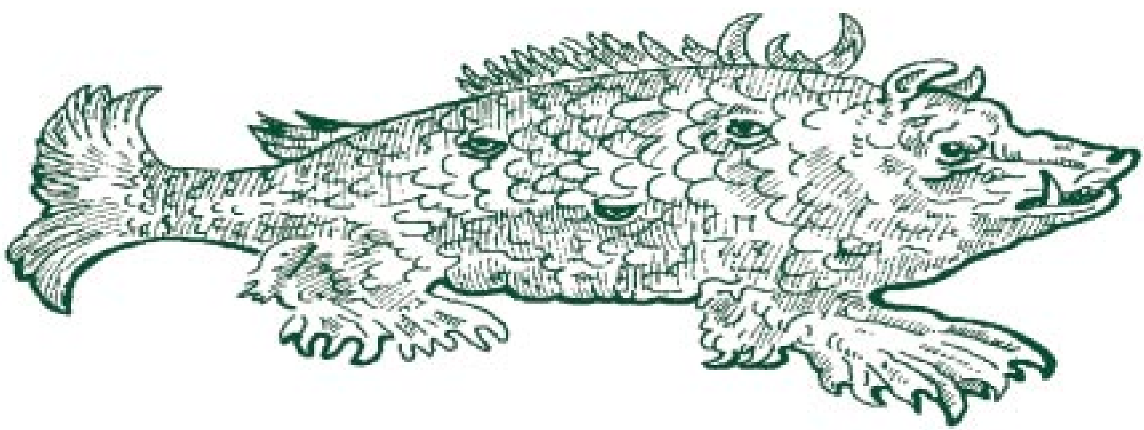

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