Invaders for sale: the potential for new invasions via live organisms in aquarium, aquascape, seafood, aquaculture and bait trades

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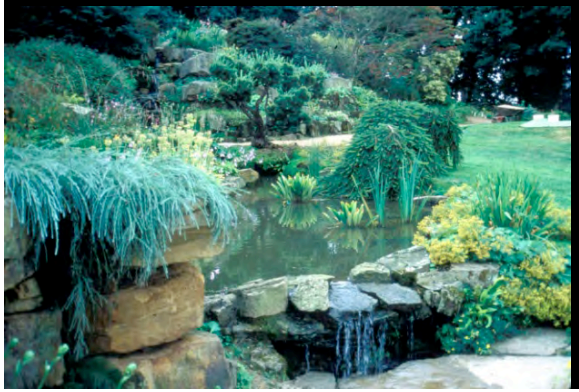
Invasions and Live Trade

- Several of the most important vectors for marine invasions involve imports, exports, sales and distribution of non-native species
- Will discuss vectors as well as intentional vs. unintentional introductions, live vs. 'fresh' and legal vs. illegal live trade
- Discuss how little we know about these vectors and suggest some obvious solutions

Pathways of Introduction

- Release from home aquariums
- Escape of live seafood products
- Dumping of live bait containers and packing materials
- Escape from backyard ornamental ponds



Pathways of Introduction

- Transfers of aquaculture products or fish stocks
- Intentional introductions to establish new fisheries
- Intentional introductions for restoration/landscaping

Comparative Studies

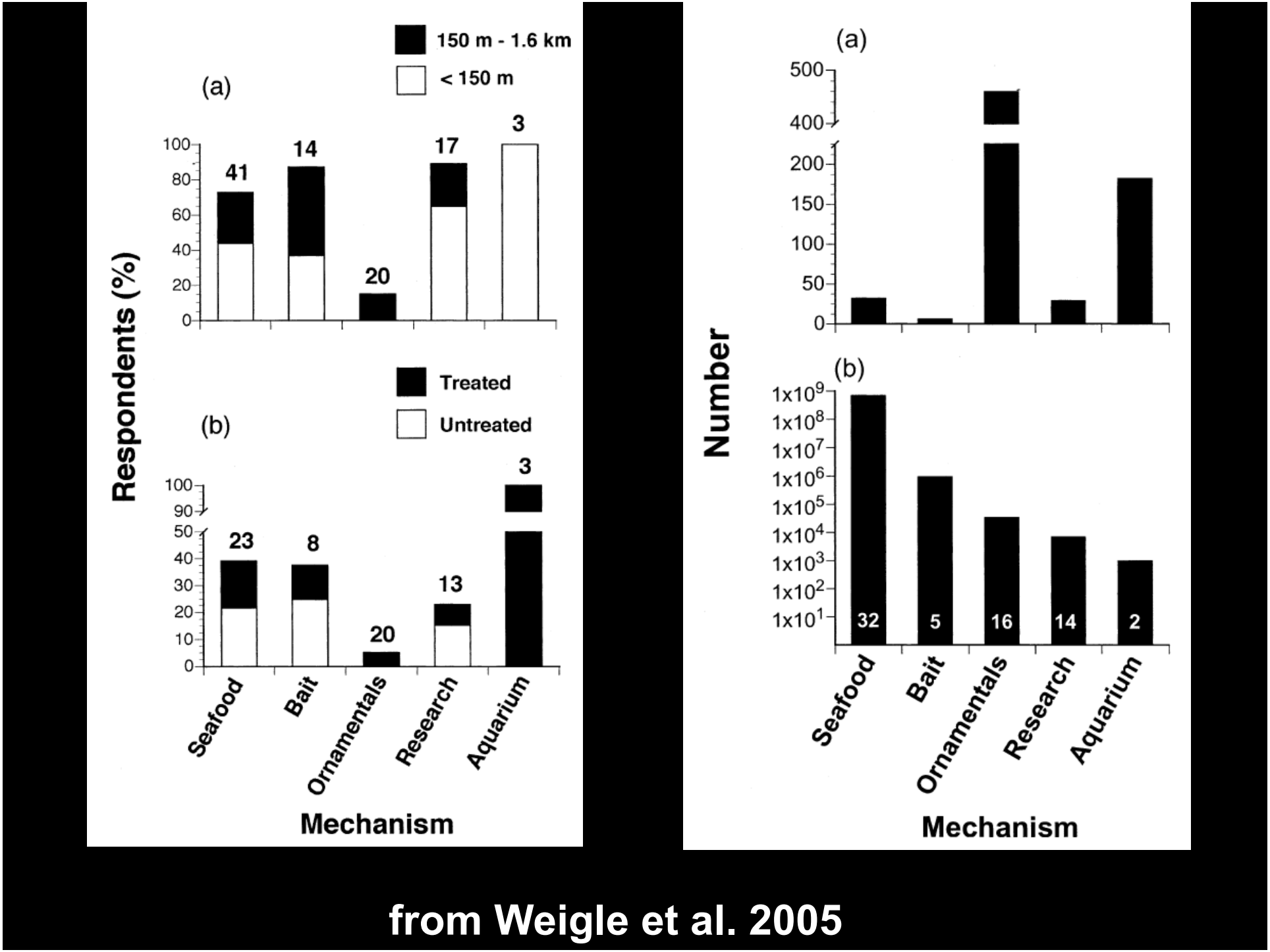
- Very few studies have tried to quantify even the relative importance of different vectors involving live trade of organisms
- Some regional efforts to understand a subset have provide some insights into approx. volume and diversity of live trade

Live Marine Species

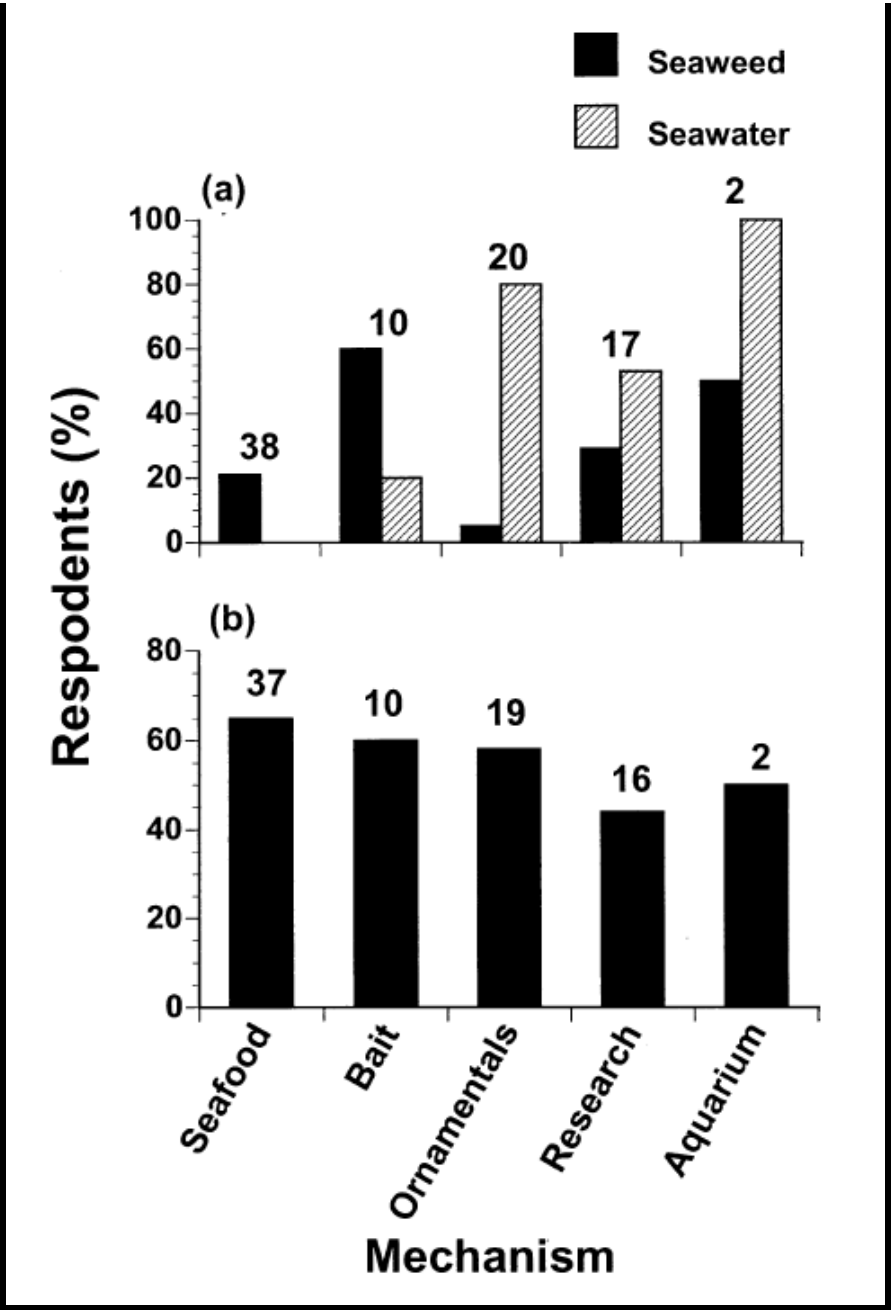
- Weigle et al. (2005) studied several industries/organizations that could potentially hold/sell/distribute live or fresh marine organisms
- They identified over 1000 entities in the coastal Massachusetts region
- Included seafood, aquaculture, bait, ornamental aquariums, research institutions, public aquaria and restoration projects

Live Marine Species

- They distributed surveys asking about facilities, variety and volume of import/exports, and familiarity with invasions
- They found 399 entities that sold/ distributed live/fresh marine species
- Aquaculture, restoration projects and med/veterinary schools reported none



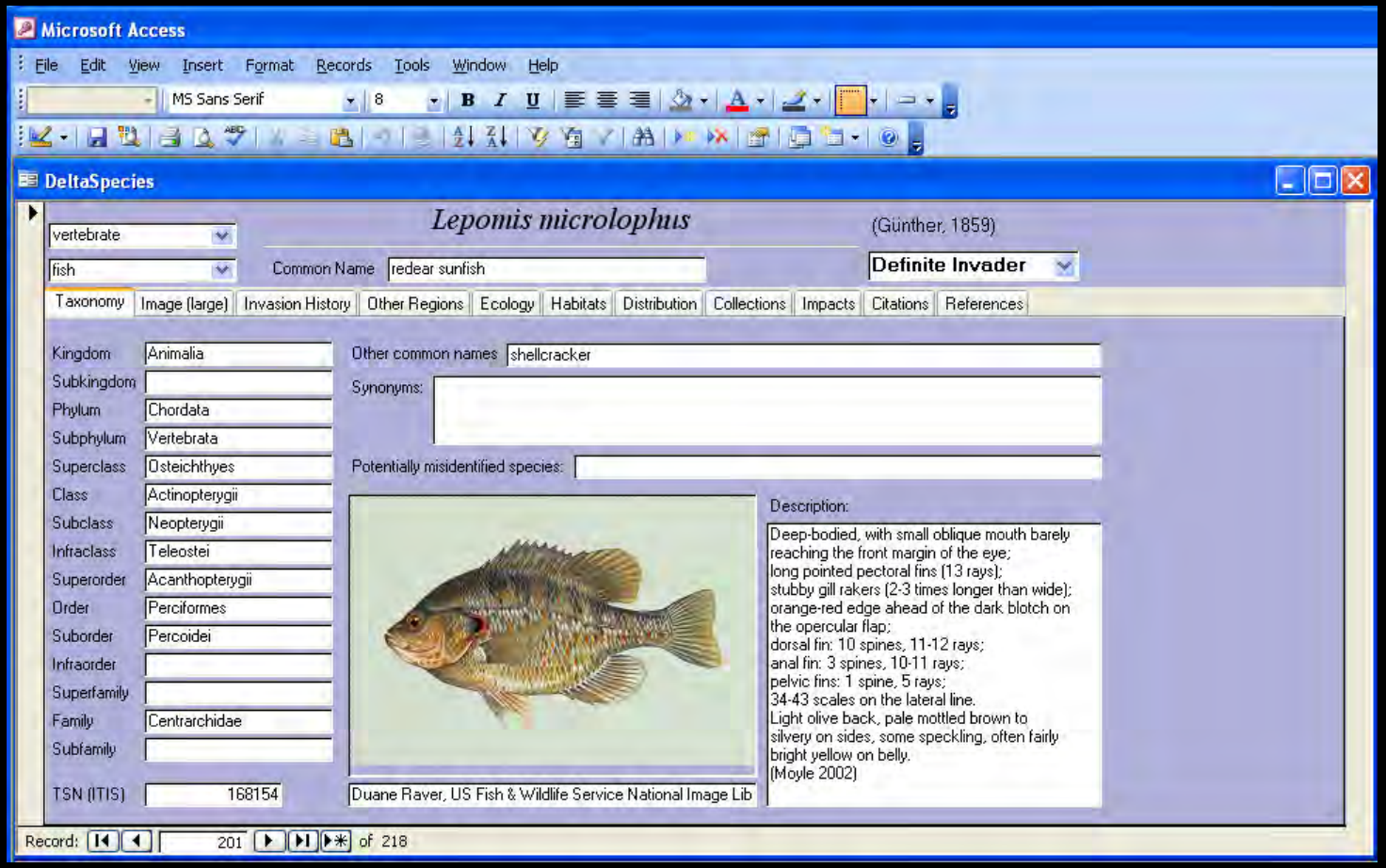
from Weigle et al. 2005



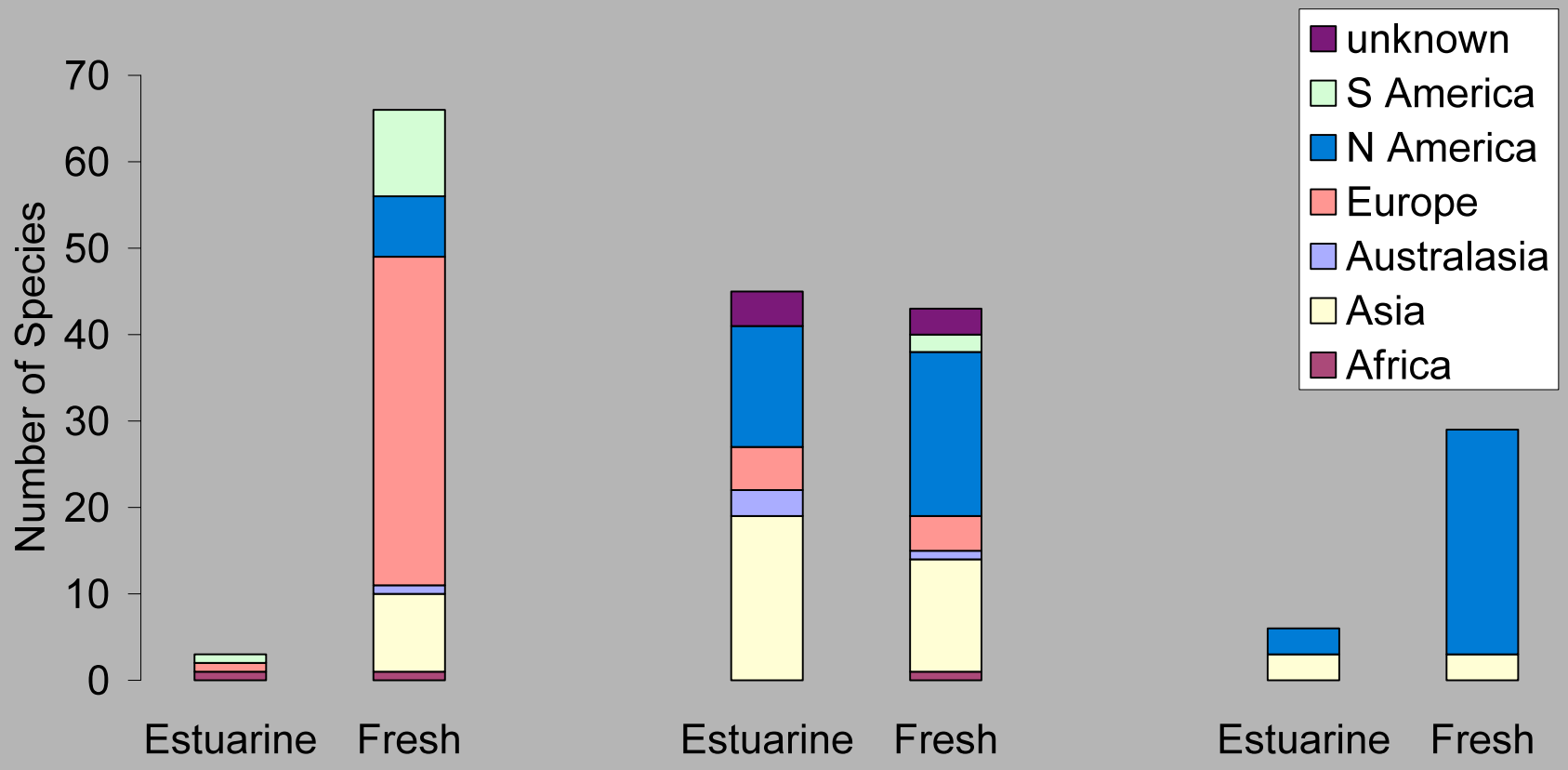
from Weigle et al. 2005

San Francisco Bay Delta

from Light et al. 2006

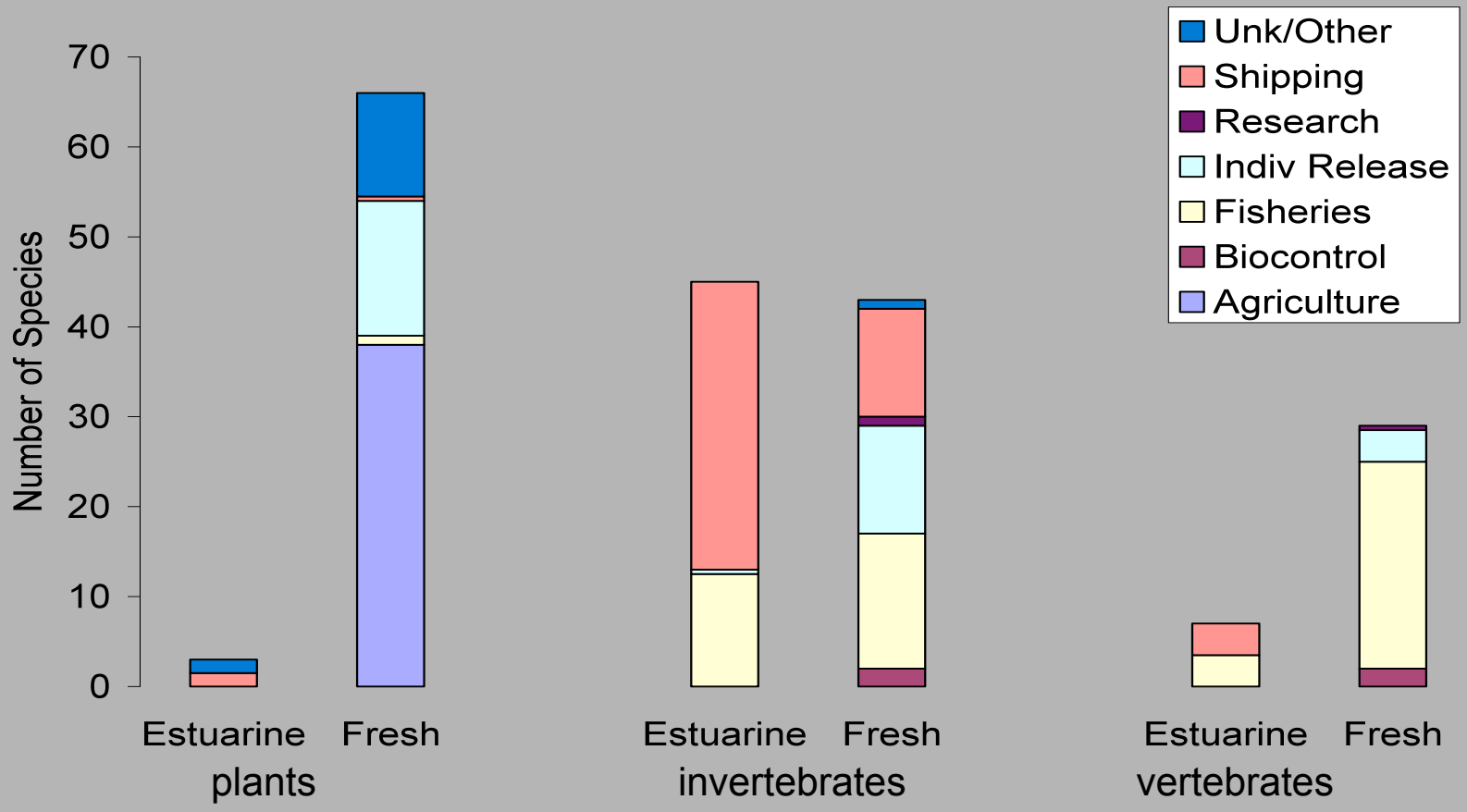


Invasion Source by Taxa



from Light et al. 2006

Invasion Vector by Taxa



from Light et al. 2006

Restoration and Landscape

- *Spartina alterniflora,* the eastern salt marsh cordgrass has had dramatic impacts on estuarine ecosystems in California and Washington (Grosholz et al. 2009)
- *Spartina alterniflora* was intentionally introduced from the eastern U.S. (native) in 1975 by US Army Corp of Engineers for marsh restoration
- It was intentionally planted in WA >100 y.a. as an ornamental


Spartina Invading Open Mudflat

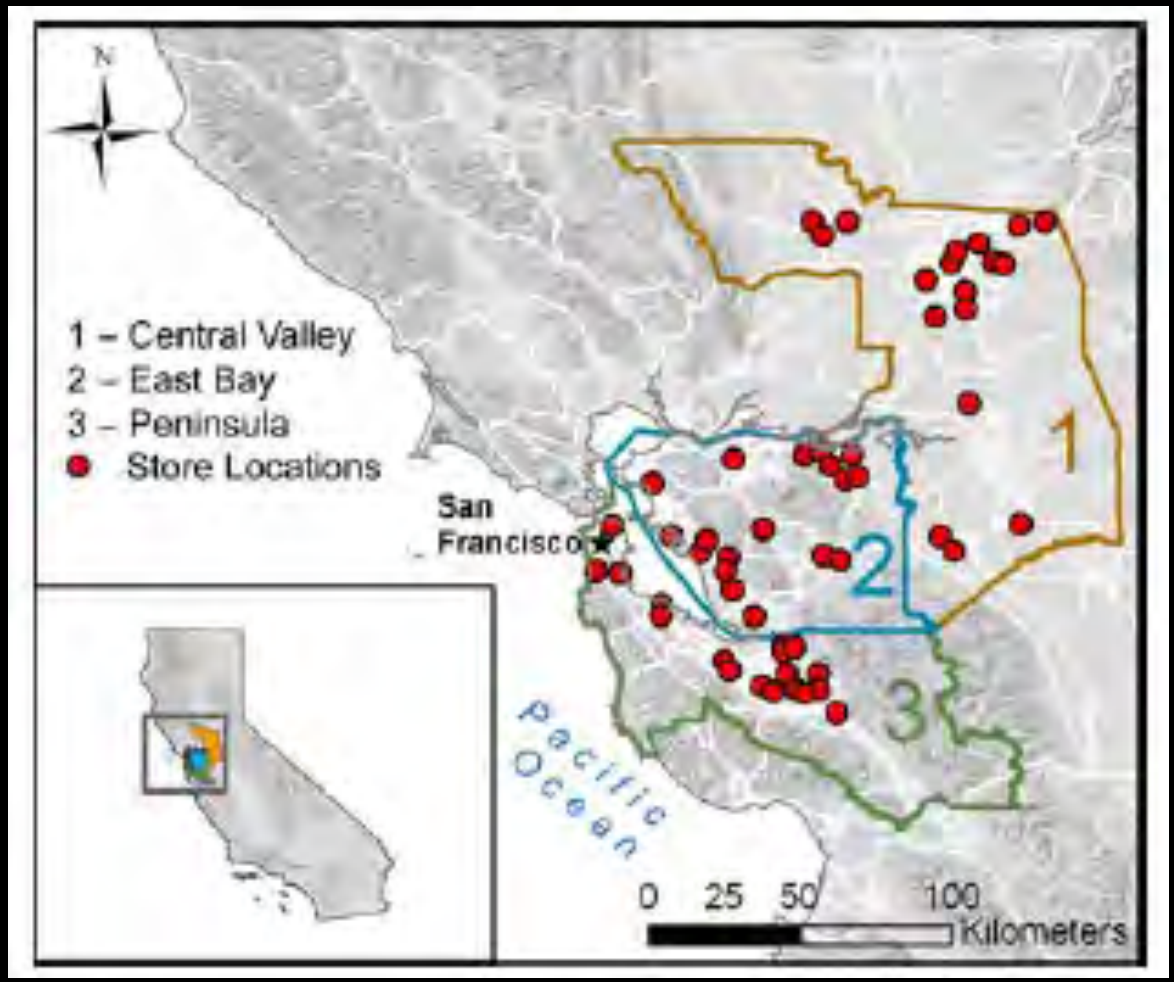
Aquarium Introductions

- Many non-native species of fish, invertebrates and algae sold in U.S.
- In CA, there are 900 non-native species of fish for sale in aquarium stores
- Pets commonly "released" when get too big or aggressive
- How many could potentially be established?

Potential Aquarium Fish Invasions

- Chang et al. (2009) investigated the number of fish species for sale in SF Bay area and Sacramento aquarium stores
- They surveyed the number of fish taxa and approximate sales volume in both large (big box) and small aquarium/pet stores

Distribution of Aquarium Stores

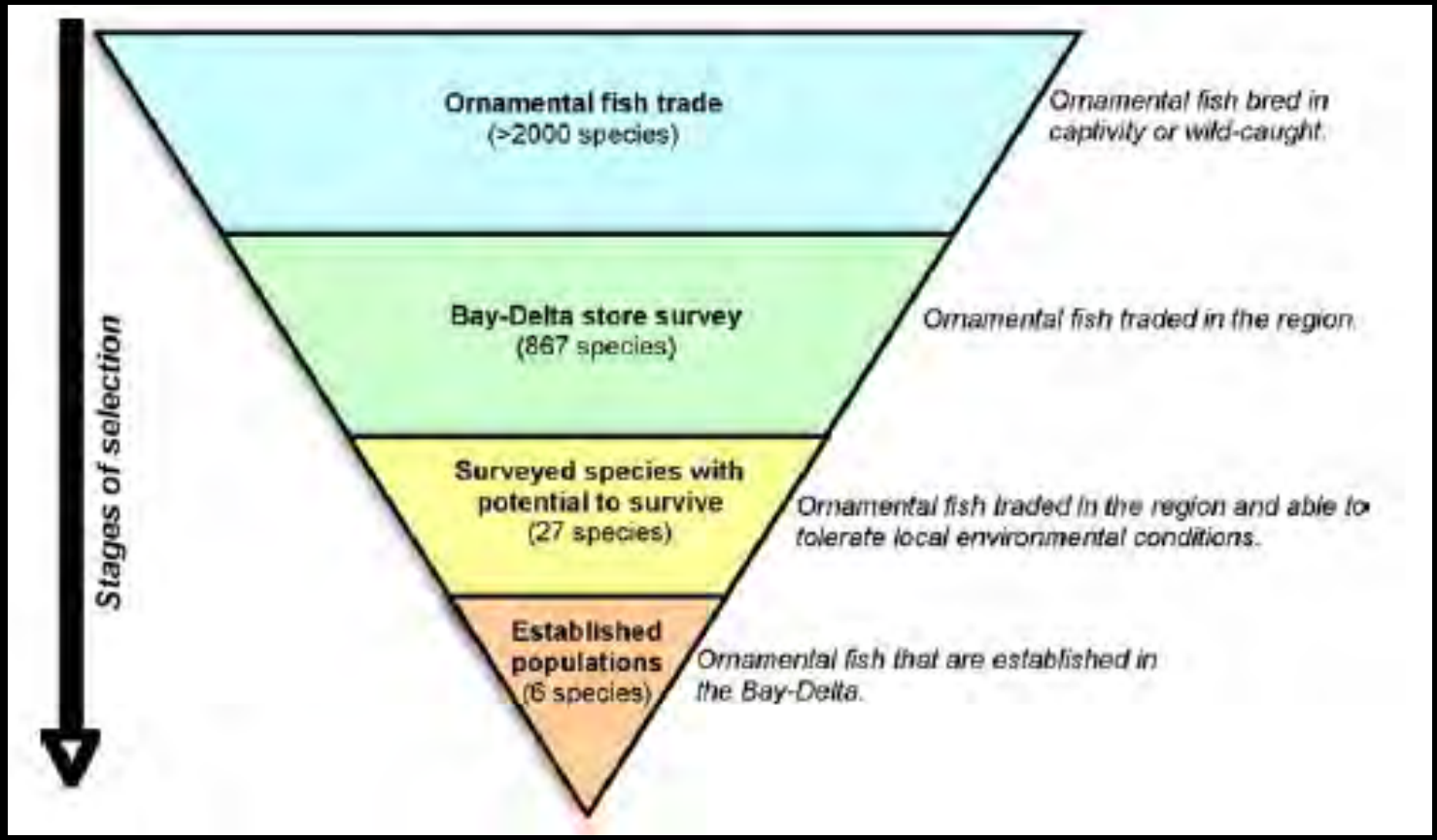


Chang et al. 2009

Potential Aquarium Fish Invasions

- Used archived data to determine mean winter minimum for areas of SF Bay over past ten years
- Used FishBase (www.fishbase.org) and other data to determine physiological tolerances of fish in trade
- Estimated 'cold and warm scenarios' based on climate change predictions

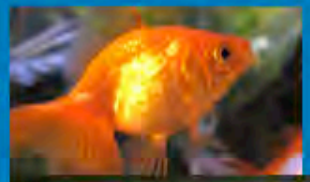
Increasing Temperatures and Potential Fish Invasions



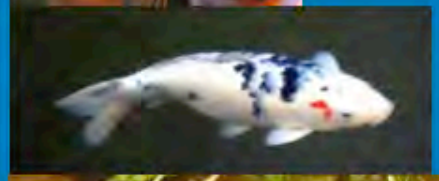
Potentially Invasive Freshwater Fish

Colder Scenario

Goldfish*



Koi



Rosy red minnow

* *Established in the SF Bay-Delta region*

Warmer Scenario

Channel catfish*

Mosquito fish*

Dojo loach

Blue catfish

Bull rout

Garra pingi

Chang et al. 2009

Chang et al. 2009

Potentially Invasive Saltwater Fish

Colder Scenario

- Red Scorpionfish
- Yasha Hase Goby

Warmer Scenario

- Flying Gurnard
- Sergeant Major
- Scrawled Cowfish
- Orange Filefish
- Angelfish (4 species)
- Clown Goby
- Anemone Fish (3 species)
- Damsel (2 species)
- Porcupine Pufferfish
- Red Grouper
- Moray Eel (3 species)
- Banded Cat Shark
- Sargassumfish
- Western Jumping Blenny
- Triggerfish (2 species)
- Bigeye Squirrelfish

Aquarium Introductions

- The invasive alga *Caulerpa taxifolia* (Med.) had huge impacts in Mediterranean where no control measures were used (now *C. racemosa v. cylindracea* has invaded a larger area)
- In 2001 *C. taxifolia* (Med.) invaded two locations in CA (San Diego and Orange Co.)
- It cost more than $6 million over six years for eradication

Introduced Algae

- Invasive *Caulerpa taxifolia* rapidly covered thousands of hectares of the northern Mediterranean in the 1980-90s
- Grow to depth of 100 m impacting native species (overgrowth, Ceccherelli et al. 2002) and local fisheries (Meinesz 1999)
- Subsequent invasion by *C. racemosa* is adding to impacts (Piazzi et al. 2005)

Introduced Algae

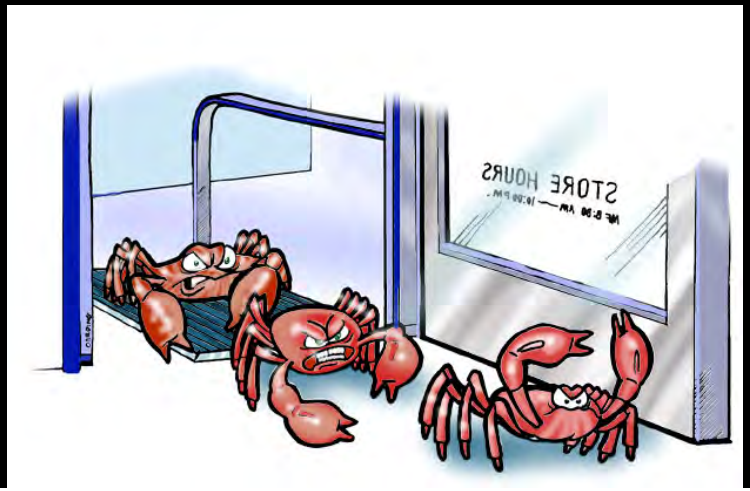
- Surveys of aquarium stores were conducted by Zaleski and Murray (2006)
- 50 stores were surveyed (specialist ornamental aquarium), no large stores sold algae
- They found *Caulerpa* spp. in 58% of stores and 14 species

Invasive Algae

- Stamm et al. (2006) sampled algae from 100 aquarium stores in Florida and California and 90 internet sites
- The found over 50% sold *Caulerpa* from 14 spp.
- Genetics revealed only one sample represented an invasive strain
- Found 12% misindentification rate
- Concluded invasive strains only identified through genetic analysis

Aquaculture and Live Seafood

- Many species of non-native fish and invertebrates (clams, oysters, mussels, clams) are sold on live seafood market
- Potential for release during storage or after sale



Aquaculture and Live Seafood

- Introduction of economically important species to establish new fisheries
- Possibility that Chinese Mitten Crabs were intentionally introduced
- Many impacts including clogging fish salvage facilities in

Aquaculture

- Movement of abalone stocks introduced a parasitic polychaete *Terebrasabella heterouncinata* from S. Africa
- Parasite infestations shut down production and impacted facilities for several years costing millions of dollars

Live Seafood

- Expanding market for live seafood increases possibilities of new introductions
- Many avenues for escape or release including water used for holding and cleaning
- Even with 'fresh' or even frozen seafood, real danger for pathogen introduction (e.g. virus in frozen herring)

Live Seafood

- Chapman et al. 2003 found 24 spp. of live non-indigenous bivalves for sale in NW grocery stores
- Eleven of these 24 species have established populations
- Bivalves for sale were largely viable and estimated several additional species might become established

Live Bait

- Non-native species of fishes and many species of invertebrates are sold live as bait
- Bait boxes (worms) may contain up to two dozen other species (Cohen et al.)
- Poorly regulated, little inspection, little or no consideration of associated diseases
- Example: 66,000 *Namalycastis abiuma* were imported from Viet Nam in a two year period

Seven foot long
"Nuclear Worm"
(*Namalycastis* sp.)

Live Bait

- Bait surveys conducted by USFWS (Sherfy and Thompson 2001)
- Examined four import classifications (Harmonized Tariff Codes)
  - Worms, live
  - Bait, other than worms
  - Aquatic inverts, NESOI (not elsewhere specified or included
  - Fish, live, NESOI
    - Bait likely in under other codes as well

Live Bait

- Over a two year period, 1.6 million kg of bait came in from 44 countries arriving through 55 ports
- This totaled 1.6 million kg of bait with a value of $78 million

Table 1. Summary data for cargo imported into the United States under four Harmonized Tariff Codes, 1998–2000. Data source: US Customs Service.

	Importing Countries	Ports of Entry	Number of Shipments	Total Value (US)	Quantity Imported (kg)
Aquatic Invertebrates, NESOI	23	28	3,520	$ 4,313,449	1,572,502
Bait, Other Than Worms	2	4	58	$ 498,368	0
Fish, Live, NESOI	32	30	1,376	$ 3,508,368	9,121
Worms, Live	17	31	6,211	$ 70,279,336	94,740
Total	44	53	11,165	$ 78,599,521	1,676,363

from Sherfy and Thompson 2001

Table 2. Major source countries for imports of four Harmonized Tariff Codes into the United States, 1998–2000. The top 10 countries are shown for each Code, except for Bait, Other Than Worms, which was imported from only 2 countries during this period. Data source: US Customs Service.

	Bait, Other Than Worms	Aquatic Invertebrates, NESOI	Worms, Live	Fish, Live, NESOI
Australia		$ 356,278	$ 2,426	$ 209,275
Belgium			$ 827,960	
Canada	$ 493,950	$ 2,438,114	$ 65,076,260	$ 1,468,535
Chile			$ 38,664	
China		$ 133,359		$ 339,757
France			$ 1,817,943	
Italy				$ 23,000
Japan		$ 328,598	$ 10,220	
Malaysia				$ 46,182
Mexico		$ 237,970		$ 558,783
Netherlands			$ 1,413,190	
New Zealand		$ 236,602		
Panama		$ 85,000		
Russia				$ 29,850
South Africa	$ 4,418			
South Korea		$ 377,562		
Taiwan				$ 279,594
Thailand				$ 29,730
Turkey			$ 4,300	
United Kingdom		$ 68,438	$ 1,059,049	
Vietnam		$ 13,182	$ 20,041	$ 454,197

Table 3. Mode of transport for imports of four Harmonized Tariff Codes into the United States, 1998–2000. Data source: US Customs Service.

	Bait, Other Than Worms	Aquatic Invertebrates, NESOI	Worms, Live	Fish, Live, NESOI
Vessel		$ 603,467	$ 1,713,042	
Road	$ 493,950	$ 2,428,201	$ 64,173,392	$ 1,971,097
Air	$ 4,418	$ 1,068,879	$ 4,392,902	$ 1,533,853

from Sherfy and Thompson 2001

Backyard Ponds

- Aquatic horticulture is fastest growing segment of industry
- 16 million backyard ponds
- Little regulation regarding placement near waterways or flood security

Backyard Ponds

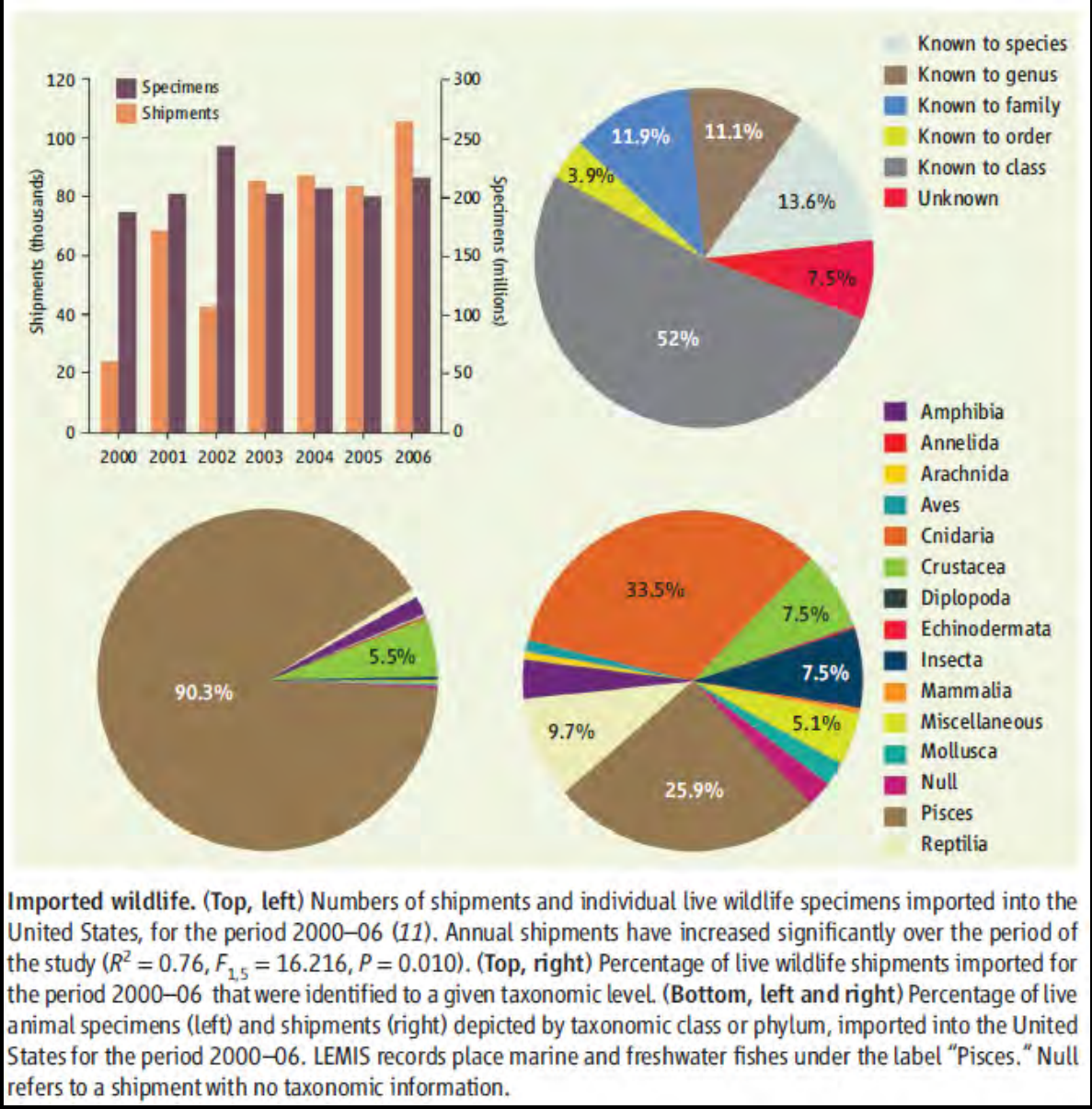
- Control of aquatic weeds costs $ millions in many states
- In CA millions $$ every year to control just a few species
  - *Hydrilla*
  - Water hyacinth (*Eichhornia crassipes*)
  - *Egeria densa*
  - Eurasian watermilfoil (*Myriophllum spicatum)*
- Some species like water hyacinth still widely sold

Marine Ornamental Trade

- Zajicek et al. 2009 surveyed marine ornamental literature and data bases
- Found 1500 species, 200 corals, 500 other inverts
- 20 million fishes, 10 million coral pieces, 10 million other invert specimens
- US is leading consumer and Pacific region (Indonesia, Philippines, South Pacific) the largest source

Linking Overconsumption by USA with Sea Level Rise

New Yorker August 28, 2006, p. 23



Imported wildlife. (Top, left) Numbers of shipments and individual live wildlife specimens imported into the United States, for the period 2000–06 (*11*). Annual shipments have increased significantly over the period of the study ($R^2 = 0.76$, $F_{1,5} = 16.216$, $P = 0.010$). **(Top, right)** Percentage of live wildlife shipments imported for the period 2000–06 that were identified to a given taxonomic level. **(Bottom, left and right)** Percentage of live animal specimens (left) and shipments (right) depicted by taxonomic class or phylum, imported into the United States for the period 2000–06. LEMIS records place marine and freshwater fishes under the label "Pisces." Null refers to a shipment with no taxonomic information.

Diversity of Live Imports

Smith et al. 2009.
Science

Diversity of Live Imports

- Smith et al. 2009 states "The poor taxonomic reporting… suggests a need to tighten protocols and makes it impossible to fully assess the biological diversity of wildlife entering the U.S."
- Blundell and Mascia (2005) find differences between Customs and CITES for invertebrate import/export volumes ranging from 300-5000%

Fixing the Screens

- Legislation similar to H.R. 669 that would authorize screening of *new* species for sale
- For species currently in trade, petitions could be made to screen suspected invasive species (e.g. Burmese pythons)
- Funds for screening would come from businesses making future profits (could have some type of patent)
- Testing would be conducted by independent 'agency' with
- Businesses could not claim intellectual property

Fixing the Screens

- Live imports: US Customs Service (USCS), USFWS and USDA
- In 2000 there were THREE USFWS agents for the entire Port of San Francisco
- In interviews, they mentioned (off the record) that they unlikely to inspect more than 1% of shipments
- Not just better regulations, more and better enforcement

Beyond Legal Live Trade

- A screening system for non-indigenous species in the live trade will address the whole problem
- NIS of economic value are brought in 'under the radar'
- Black markets exist for a number of species of value but of unknown extent

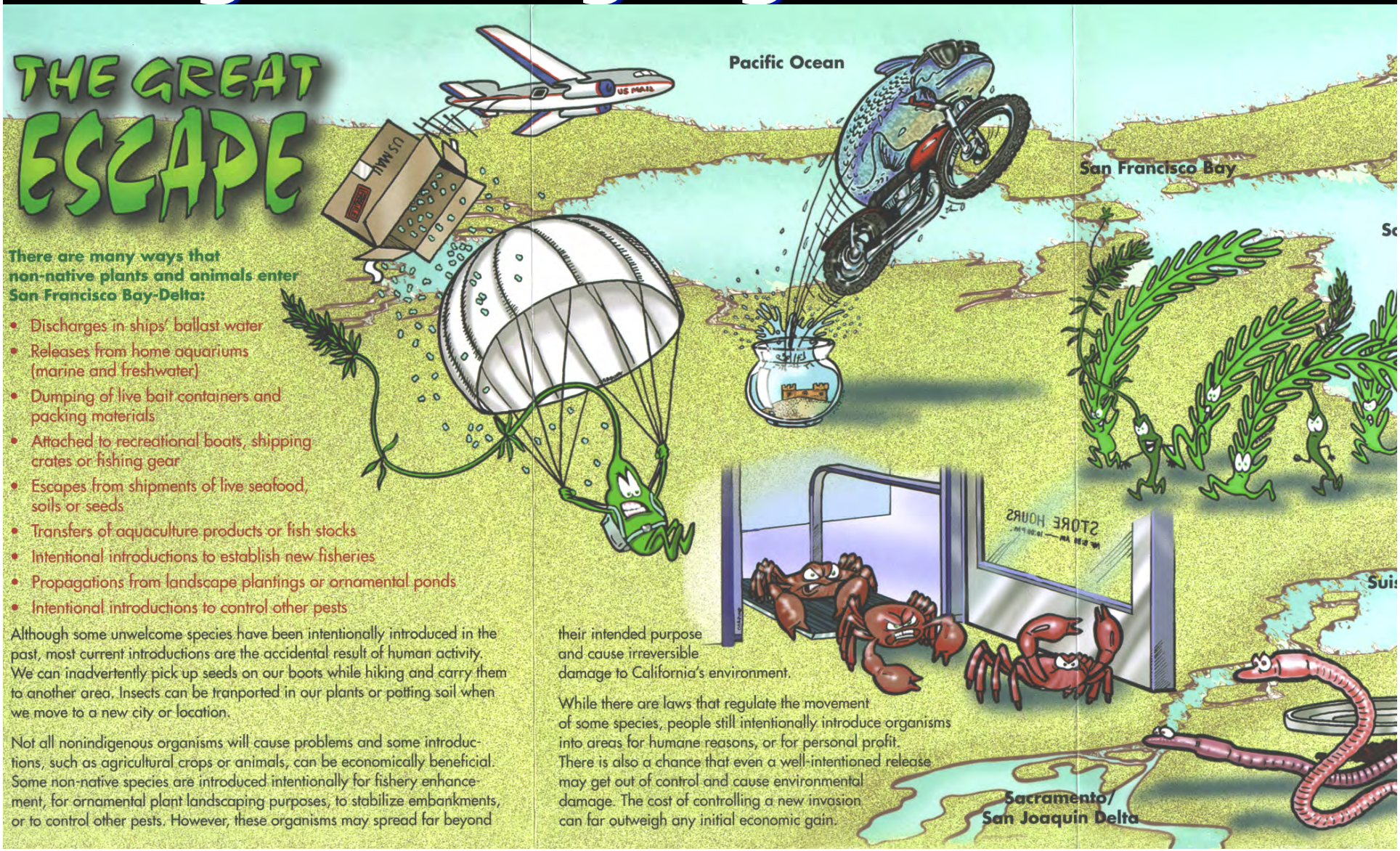
Beyond Legal Live Trade

- In the San Francisco Bay area (and likely other metropolitan areas) there is a market for the Chinese Mitten Crab (Chinese Hairy Crab)
- Interviews revealed that East Bay restaurants can provide Chinese Hairy Crab meals for parties with 'proper connections'
- Difficult to know the size of this market or how many crabs are smuggled in

Need for Multicultural Outreach

- We need to communicate our messages to recent/current immigrant cultures
- Risks of importing organisms need to be widely understood
- Health risks are critical as well
  - High mercury levels in introduced mitten crabs
  - Potential for new disease introduction

English Language Brochure



There are many ways that non-native plants and animals enter San Francisco Bay-Delta:

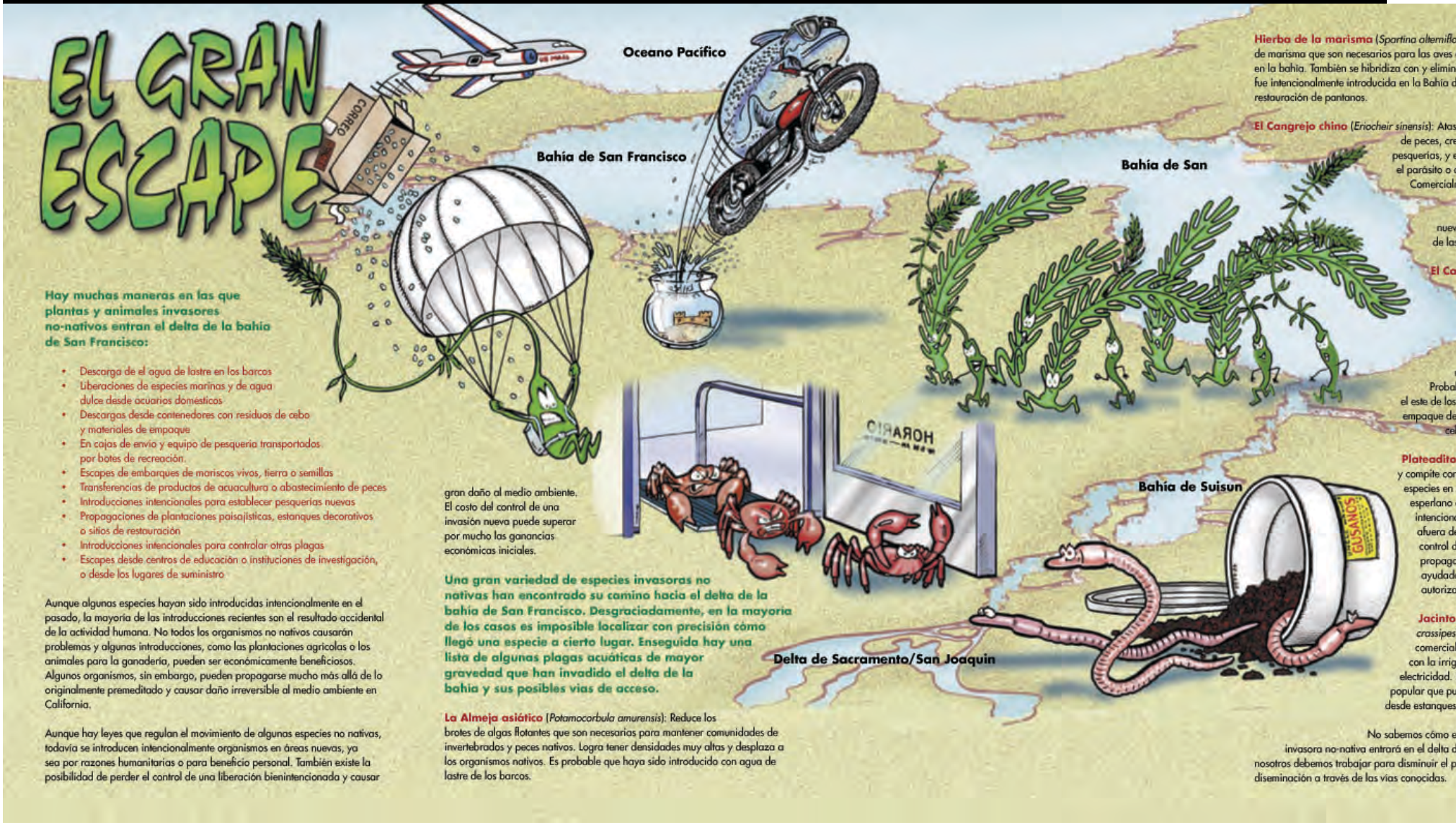
- Discharges in ships' ballast water
- Releases from home aquariums (marine and freshwater)
- Dumping of live bait containers and packing materials
- Attached to recreational boats, shipping crates or fishing gear
- Escapes from shipments of live seafood, soils or seeds
- Transfers of aquaculture products or fish stocks
- Intentional introductions to establish new fisheries
- Propagations from landscape plantings or ornamental ponds
- Intentional introductions to control other pests

Although some unwelcome species have been intentionally introduced in the past, most current introductions are the accidental result of human activity. We can inadvertently pick up seeds on our boots while hiking and carry them to another area. Insects can be tranported in our plants or potting soil when we move to a new city or location.

Not all nonindigenous organisms will cause problems and some introductions, such as agricultural crops or animals, can be economically beneficial. Some non-native species are introduced intentionally for fishery enhancement, for ornamental plant landscaping purposes, to stabilize embankments, or to control other pests. However, these organisms may spread far beyond their intended purpose and cause irreversible damage to California's environment.

While there are laws that regulate the movement of some species, people still intentionally introduce organisms into areas for humane reasons, or for personal profit. There is also a chance that even a well-intentioned release may get out of control and cause environmental damage. The cost of controlling a new invasion can far outweigh any initial economic gain.

Spanish Language Brochure



Hay muchas maneras en las que plantas y animales invasores no-nativos entran el delta de la bahía de San Francisco:

- Descarga de el agua de lastre en los barcos
- Liberaciones de especies marinas y de agua dulce desde acuarios domésticos
- Descargas desde contenedores con residuos de cebo y materiales de empaque
- En cajas de envío y equipo de pesquería transportados por botes de recreación.
- Escapes de embarques de mariscos vivos, tierra o semillas
- Transferencias de productos de acuacultura o abastecimiento de peces
- Introducciones intencionales para establecer pesquerías nuevas
- Propagaciones de plantaciones paisajísticas, estanques decorativos o sitios de restauración
- Introducciones intencionales para controlar otras plagas
- Escapes desde centros de educación o instituciones de investigación, o desde los lugares de suministro

Aunque algunas especies hayan sido introducidas intencionalmente en el pasado, la mayoría de las introducciones recientes son el resultado accidental de la actividad humana. No todos los organismos no nativos causarán problemas y algunas introducciones, como las plantaciones agrícolas o los animales para la ganadería, pueden ser económicamente beneficiosos. Algunos organismos, sin embargo, pueden propagarse mucho más allá de lo originalmente premeditado y causar daño irreversible al medio ambiente en California.

Aunque hay leyes que regulan el movimiento de algunas especies no nativas, todavía se introducen intencionalmente organismos en áreas nuevas, ya sea por razones humanitarias o para beneficio personal. También existe la posibilidad de perder el control de una liberación bienintencionada y causar gran daño al medio ambiente. El costo del control de una invasión nueva puede superar por mucho las ganancias económicas iniciales.

Una gran variedad de especies invasoras no nativas han encontrado su camino hacia el delta de la bahía de San Francisco. Desgraciadamente, en la mayoría de los casos es imposible localizar con precisión cómo llegó una especie a cierto lugar. Enseguida hay una lista de algunas plagas acuáticas de mayor gravedad que han invadido el delta de la bahía y sus posibles vías de acceso.

La Almeja asiática (*Potamocorbula amurensis*): Reduce los brotes de algas flotantes que son necesarias para mantener comunidades de invertebrados y peces nativos. Logra tener densidades muy altas y desplaza a los organismos nativos. Es probable que haya sido introducido con agua de lastre de los barcos.

Hierba de la marisma (*Spartina alterniflo*
de marisma que son necesarios para las aves
en la bahía. También se hibridiza con y elimin
fue intencionalmente introducida en la Bahía d
restauración de pantanos.

El Cangrejo chino (*Eriocheir sinensis*): Atas
de peces, cre
pesquerías, y
el parásito o
Comercial

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El Ca

Proba
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Plateadita
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popular que pu
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No sabemos cómo e
invasora no-nativa entrará en el delta d
nosotros debemos trabajar para disminuir el p
diseminación a través de las vías conocidas.

INTRODUCED AQUATIC PLANTS AND ANIMALS COST CALIFORNIANS MILLIONS!

Do Your Part To Protect Our Waterways. Do Not Release Live Aquatic Organisms!

How YOU Can Stop The Spread Of Invasive Aquatic Plants And Animals.

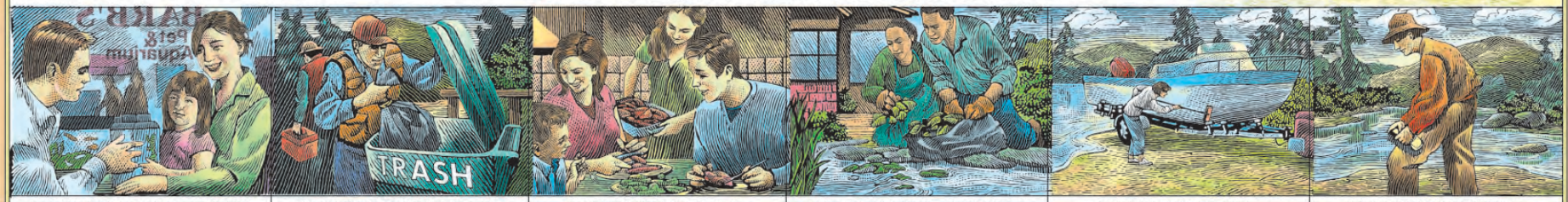
Contact aquarium retailer for proper disposal guidelines for aquatic plants and animals.	Put unused bait and packing material in the trash.	Freeze unused live seafood before disposal.	Replace invasives with native plants. Seal unwanted water garden plants in plastic bag and put in trash.	Clean boats and trailers after use in any water body.	Scrub waders and other gear after fishing. Dry gear in the sun or freeze overnight.

CALIFORNIA BAY-DELTA AUTHORITY

Produced by the RIDNIS Project (Reducing the Introduction and Distribution of Non-native Aquatic Invasive Species Through Education and Outreach), Department of Environmental Science and Policy, University of California, Davis. Funded by the California Bay-Delta Authority under Agreement Number ERP-02-P37.
Poster concept: Holly Crosson and Ted Grosholz. Illustration: Miro Salazar. For additional copies please contact: (530) 752-9151 or tedgrosholz@ucdavis.edu.

外來水生動植物使加州付出上百萬元的代價！
盡力保護我們的水域。請勿放生水生動植物！

您可以如何制止入侵水生動植物的蔓延。



向水族零售商洽詢如何妥善棄置水生動植物。

將未用完的魚餌和包裝材料丟進垃圾桶。

未用完的活海鮮請先冷凍後再丟棄。

以本地植物取代入侵植物。將不需要的水生植物裝入塑膠袋後丟進垃圾桶。

清洗行經任何水域的船隻和拖車。

釣魚後洗刷防水長統靴和其他釣具。將釣具放在日光下曝曬或冷凍過夜。

CALIFORNIA BAY-DELTA AUTHORITY

由 RIDNIS（透過教育和宣導減少非本地水生入侵物種的引入和傳播）專案、環境科學與政策部、加州大學戴維斯分校聯合製作，加州海灣三角洲管理局依據協議號碼 ERP-02-P37 贊助。
海報構想：Holly Crosson 及 Ted Grosholz，繪圖：Miro Salazar，諮詢：(530) 752-9151 或 tedgrosholz@ucdavis.edu 索取額外海報。

Welcome to the website for the

*RIDNIS Project

(*Reducing the Introduction and Distribution of Aquatic
Non-Native Invasive Species Through Outreach and Education)

Project Background and Goals

NIS of concern in San Francisco Bay-Delta

Why are Aquatic Non-Native Invasive Species a Concern?

Links for more Information

Mechanisms of NIS Introduction

Contact Us

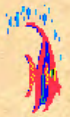
Preventing Introductions

Workshop Information

Recommended Voluntary Guidelines drawn up from the Aquarium Industry Workshop

Recommended Voluntary Guidelines drawn up from the Aquatic Horticulture Industry Workshop

Caulerpa taxifolia (found in California) *Caulerpa taxifolia* Watch Card



Take a look at our completed products

RIDNIS Brochure in Spanish

NEW RIDNIS poster English version

NEW RIDNIS poster Chinese language version

NEW Watch the video, *"The Great Escape: Preventing Aquatic Species Invasion"* in English or in Chinese

The brochure, Recommended Voluntary Guidelines
and posters are in pdf format. If you don't have Adobe Acrobat,
you can download the latest version here to view these products.

Final Conclusions

- More and better information about the ID and volume of species for sale
- Better enforcement of species labeling requirements where possible
- Provide information about species at point of sale
- Enact screening process to identify potentially invasive species

Final Conclusions

- Not everything is 'for sale'
- Need dramatic (not overstated) increase in resources for port inspections
- Revise Harmonized Tariff Codes (eliminate 'human consumption')
- Need for broad-based multilingual education at points of departure and entry

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