FOREIGN TRADE PATTERNS DRIVE BALLAST WATER DELIVERY TO SAN FRANCISCO BAY, CA

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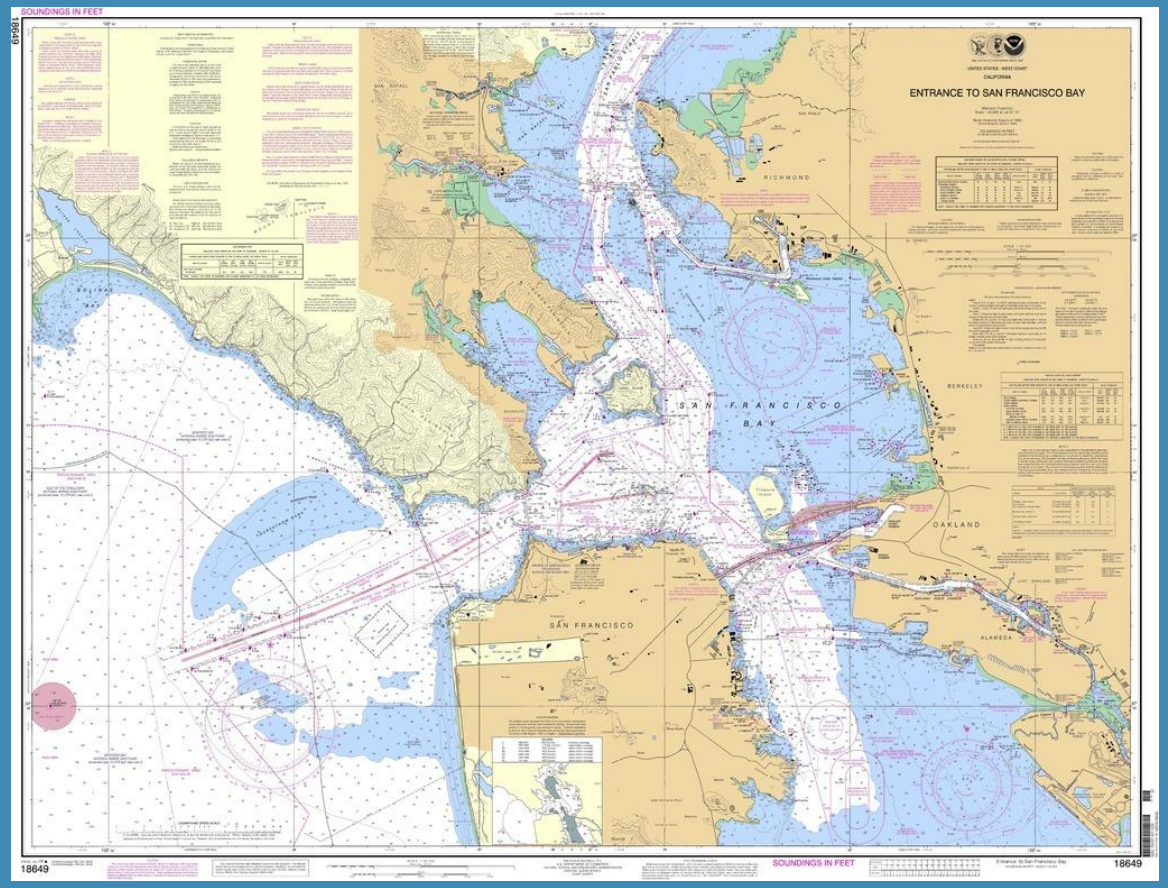
WHY SAN FRANCISCO?



- Heavily invaded & history of invasion
- Varied, saline to estuarine habitat
- Ample trade partners and patterns that influence vessel behavior
- Invasion strongly influenced by propagule pressure and disturbance
- High potential for secondary spread

DATA SOURCES
2006 – 2014

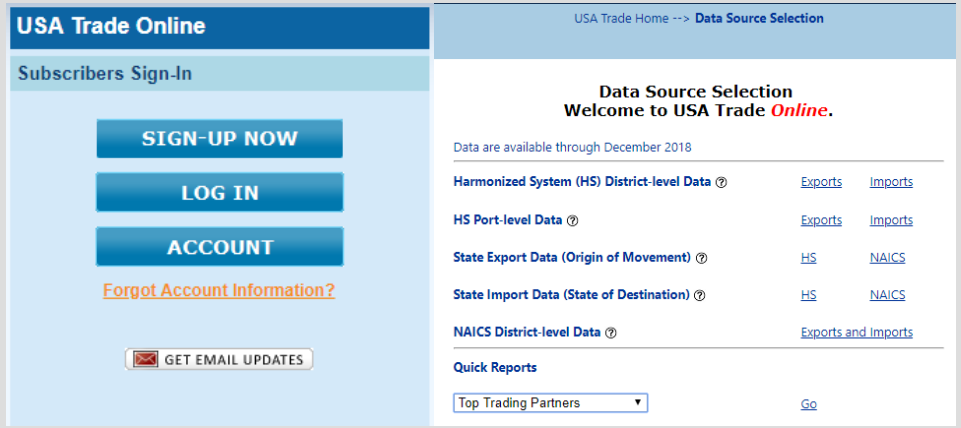
NBIC

- https://nbic.si.edu/
- Jointly managed by SERC & USCG
- ~94% reporting compliance rate
- Coastwise: ballast water does not transit beyond combined US & Canadian EEZs
- Overseas: ballast water does transit beyond combined US & Canadian EEZs

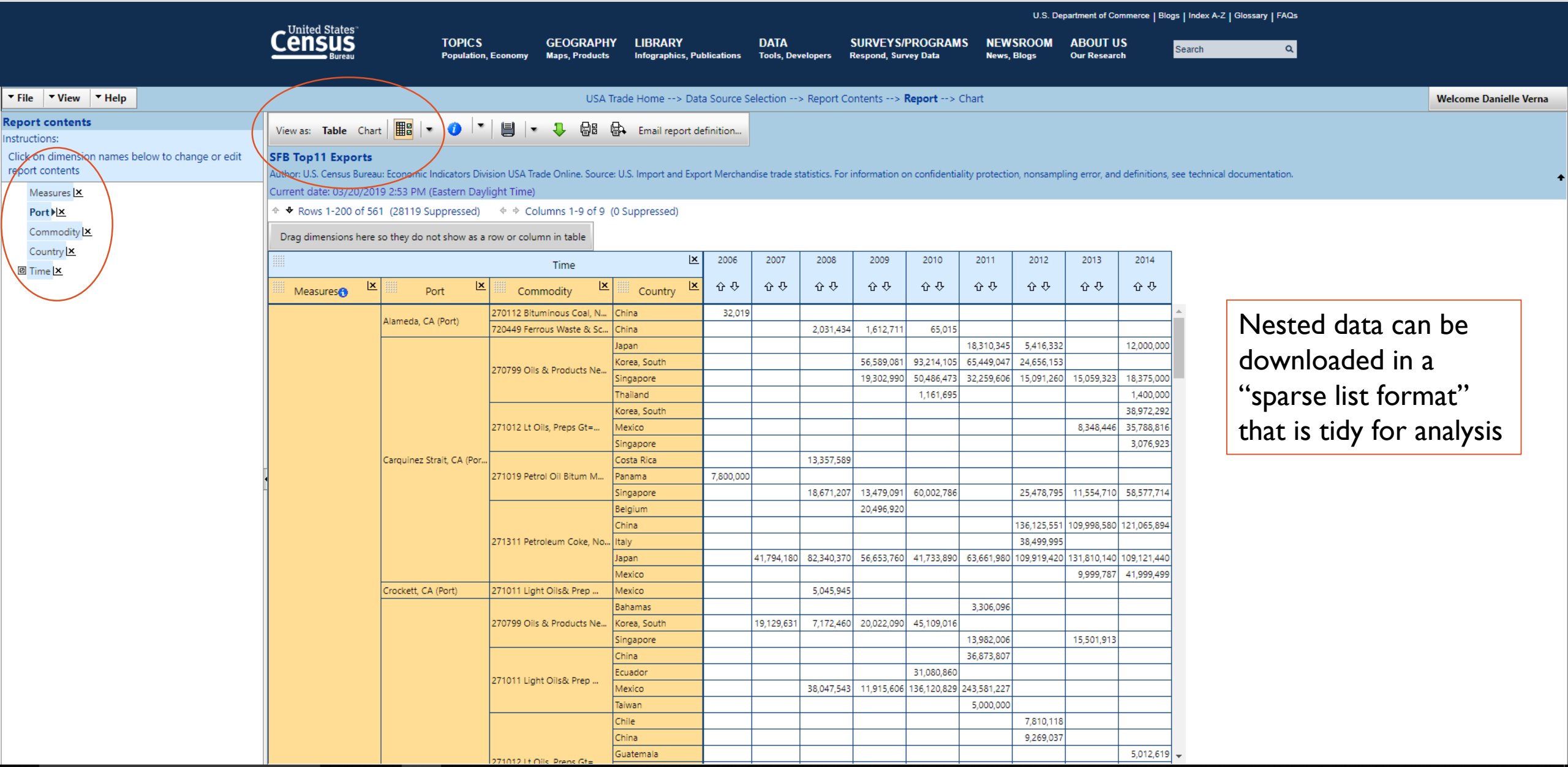
National Ballast Information Clearinghouse NBIC

USA TRADE ONLINE

- https://usatrade.census.gov/
- Provided by the US Census Bureau
- US import & export data
- States, Districts, & Ports
- HS codes (2,4, 6 digit), NAICS codes



USA TRADE ONLINE



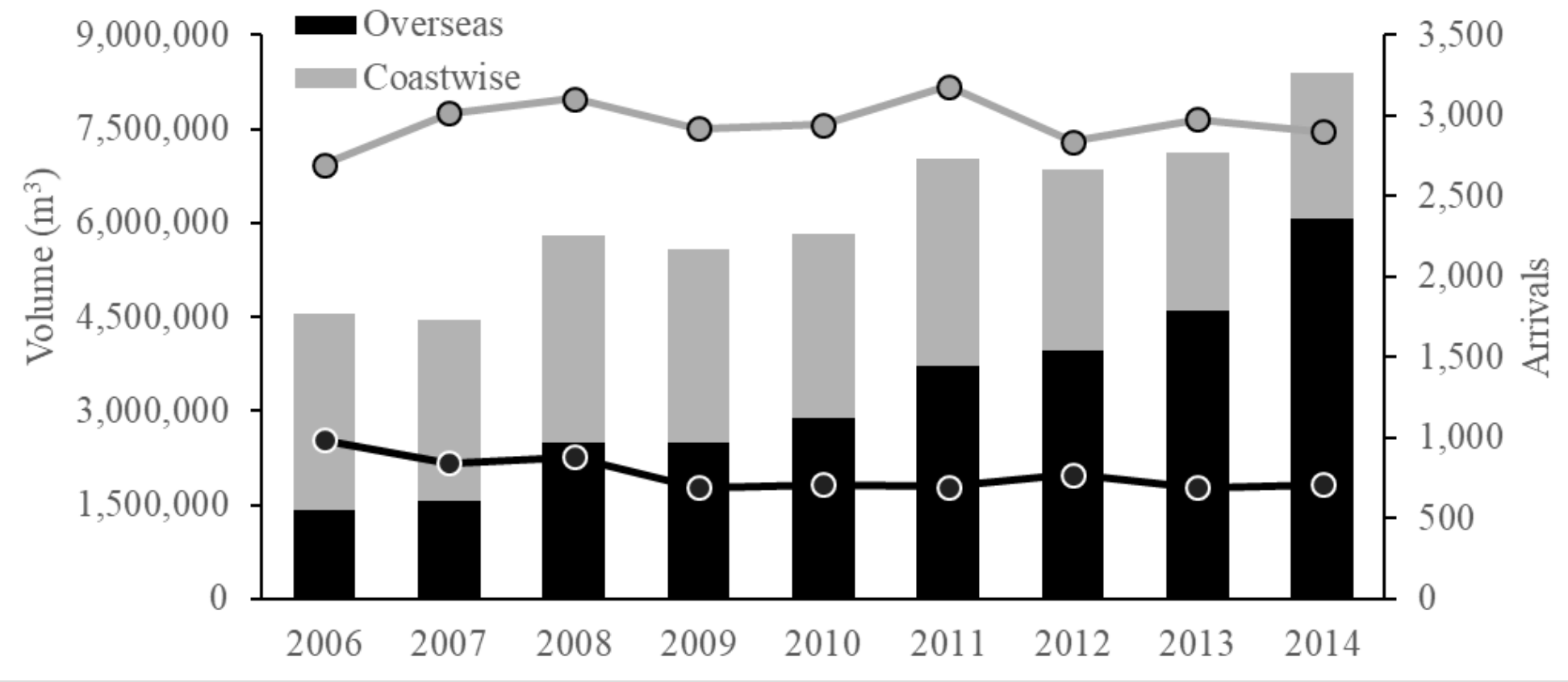
Measures	Port	Commodity	Country	Time	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Alameda, CA (Port)	270112 Bituminous Coal, N...	China		32,019								
		720449 Ferrous Waste & Sc...	China				2,031,434	1,612,711	65,015				
	Carquinez Strait, CA (Por...	270799 Oils & Products Ne...	Japan							18,310,345	5,416,332		12,000,000
			Korea, South					56,589,081	93,214,105	65,449,047	24,656,153		
			Singapore					19,302,990	50,486,473	32,259,606	15,091,260	15,059,323	18,375,000
			Thailand						1,161,695				1,400,000
		271012 Lt Oils, Preps Gt=...	Korea, South										38,972,292
			Mexico									8,348,446	35,788,816
			Singapore										3,076,923
		271019 Petrol Oil Bitum M...	Costa Rica				13,357,589						
			Panama		7,800,000								
			Singapore				18,671,207	13,479,091	60,002,786		25,478,795	11,554,710	58,577,714
		271311 Petroleum Coke, No...	Belgium					20,496,920					
			China								136,125,551	109,998,580	121,065,894
			Italy								38,499,995		
			Japan			41,794,180	82,340,370	56,653,760	41,733,890	63,661,980	109,919,420	131,810,140	109,121,440
			Mexico									9,999,787	41,999,499
	Crockett, CA (Port)	271011 Light Oils& Prep ...	Mexico				5,045,945						
		270799 Oils & Products Ne...	Bahamas							3,306,096			
			Korea, South			19,129,631	7,172,460	20,022,090	45,109,016				
			Singapore							13,982,006		15,501,913	
		271011 Light Oils& Prep ...	China							36,873,807			
			Ecuador						31,080,860				
			Mexico				38,047,543	11,915,606	136,120,829	243,581,227			
			Taiwan							5,000,000			
		271012 Lt Oils, Preps Gt=	Chile								7,810,118		
			China								9,269,037		
			Guatemala										5,012,619

Nested data can be downloaded in a "sparse list format" that is tidy for analysis

NBIC:

- 33,558 arrivals
- 55,584,402 m^3 of ballast water

THROUGHOUT SAN FRANCISCO BAY: Arrivals remained steady while ballast water discharge increased annually

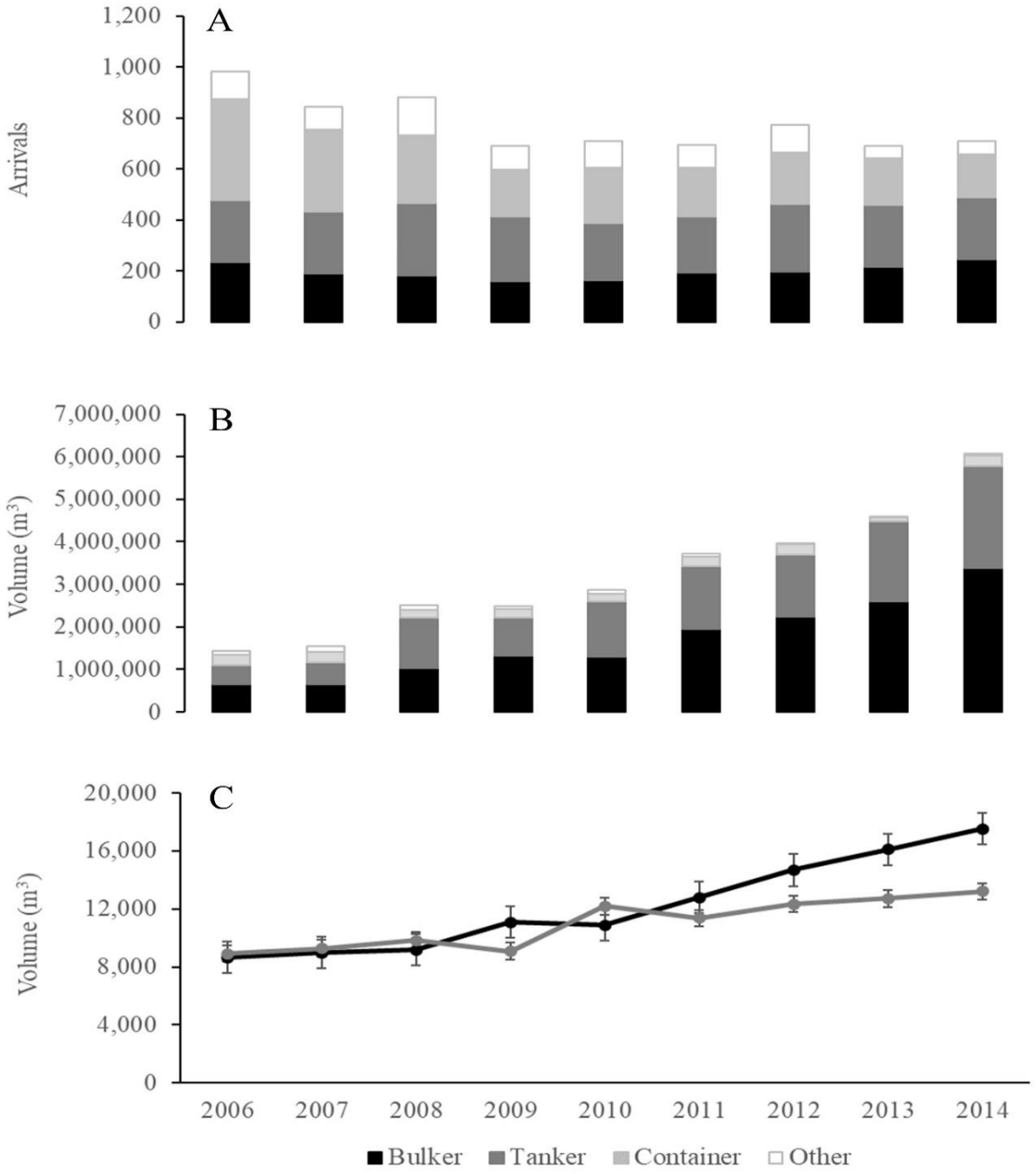


Overseas vessels in SF Bay

Arrivals →

Ballast water discharge →

Mean BW discharge per vessel →



SHIP TYPE MATTERS:
Bulkers and tankers discharged most ballast water

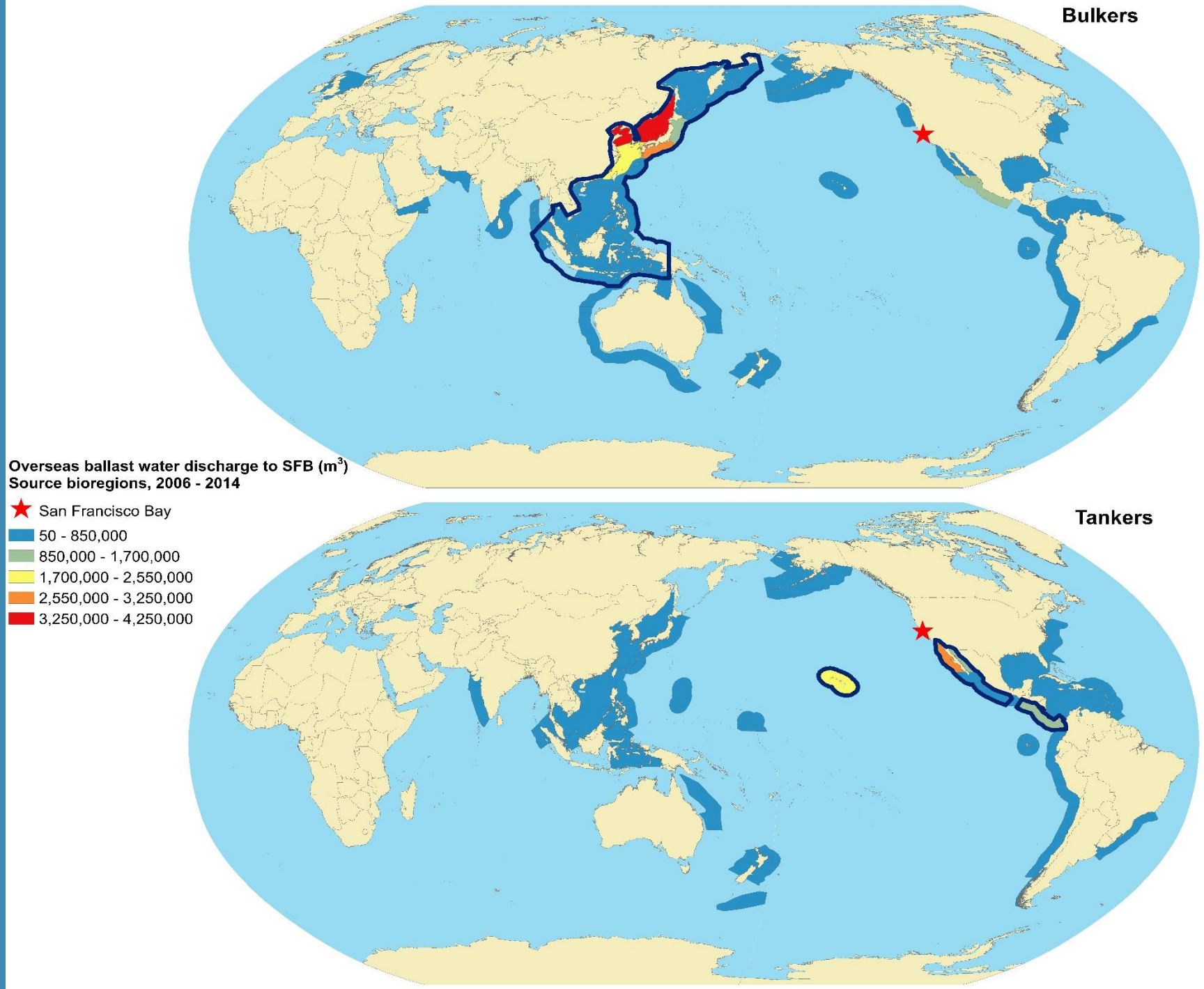
- ~50% of total arrivals from containerships
- 87% of total ballast water from bulkers & tankers
- 91% of overseas ballast water from bulkers & tankers

https://asia.nikkei.com/Business/Markets/Commodities/China-s-coal-cuts-push-up-bulk-carrier-rates

Bulkers →

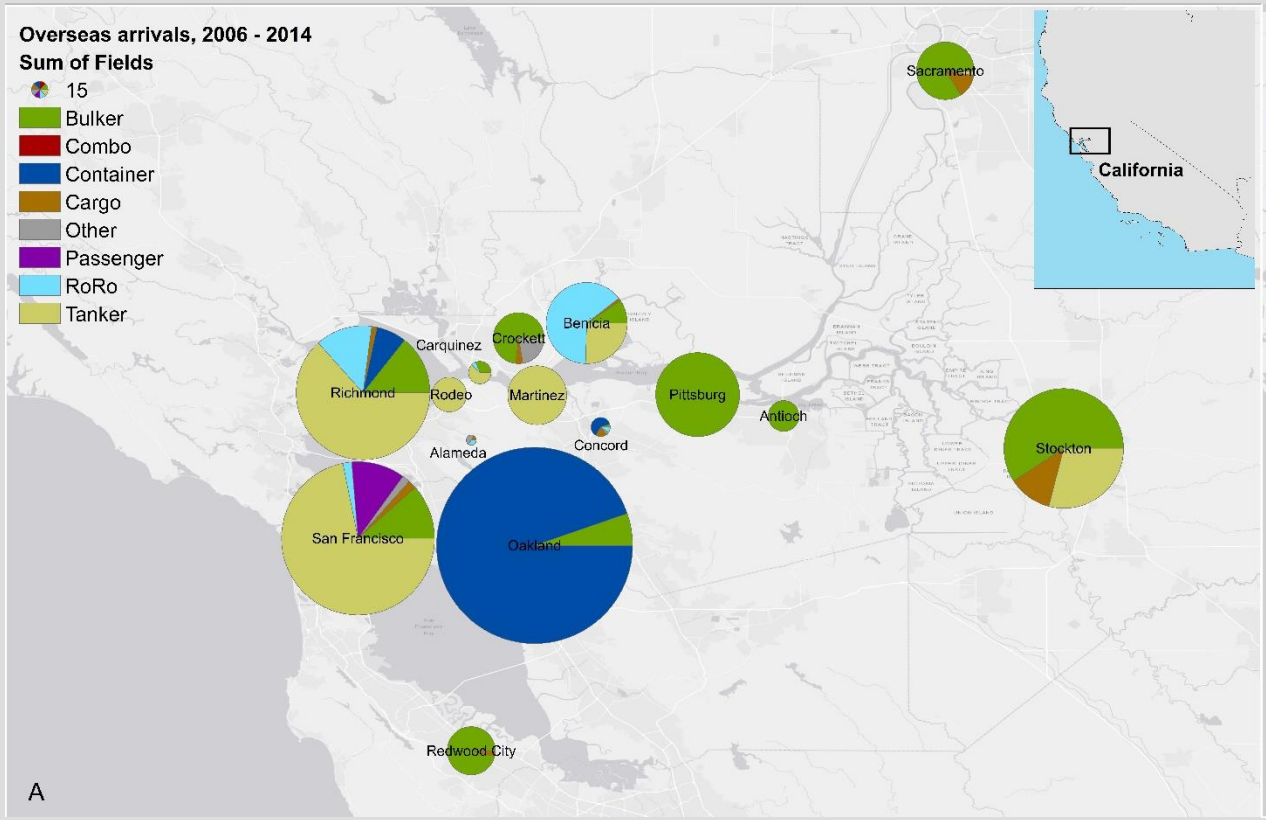
Overseas ballast water source regions

Tankers →

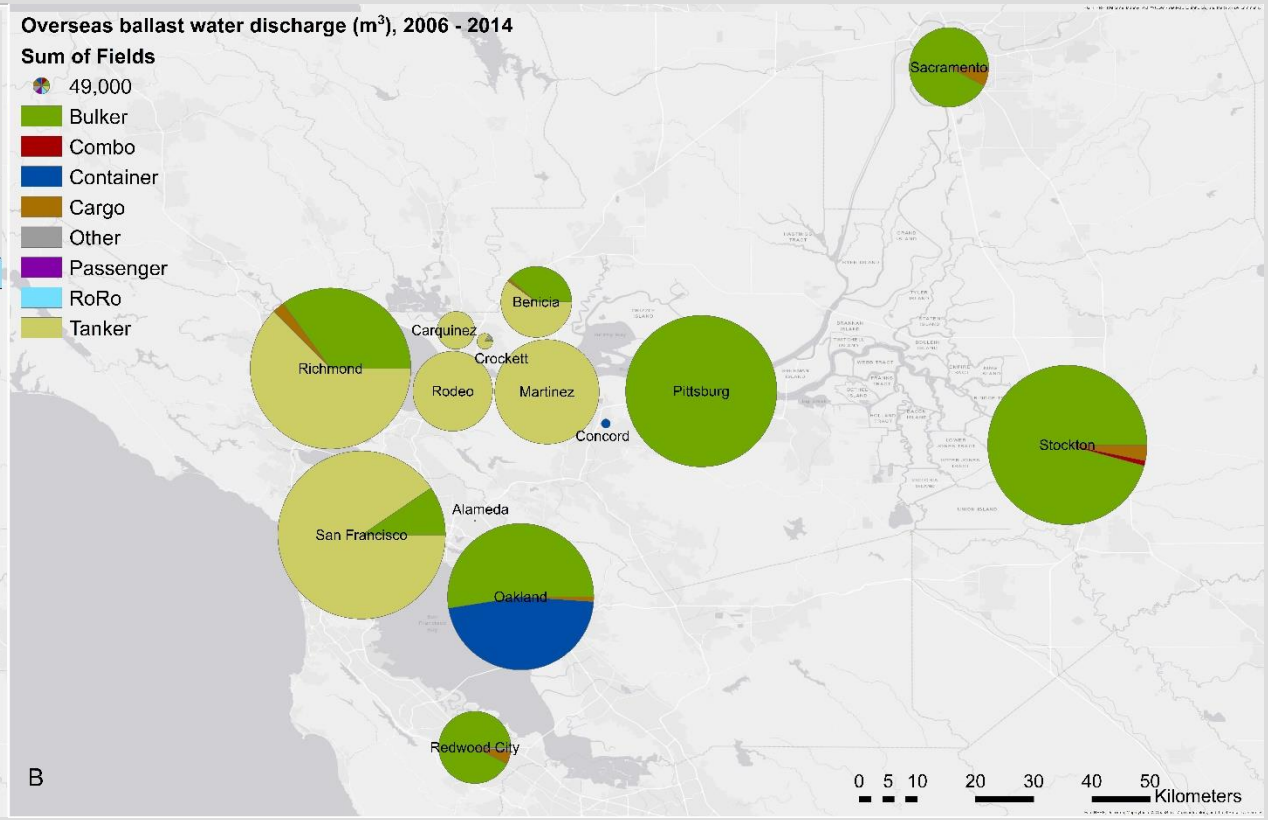


Arrivals and ballast water discharge varied spatially by vessel type

OVERSEAS ARRIVALS

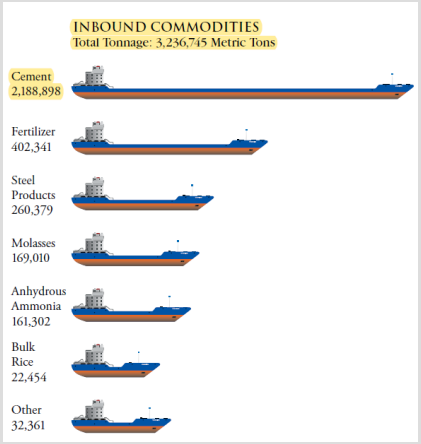


OVERSEAS BALLAST WATER (m^3)



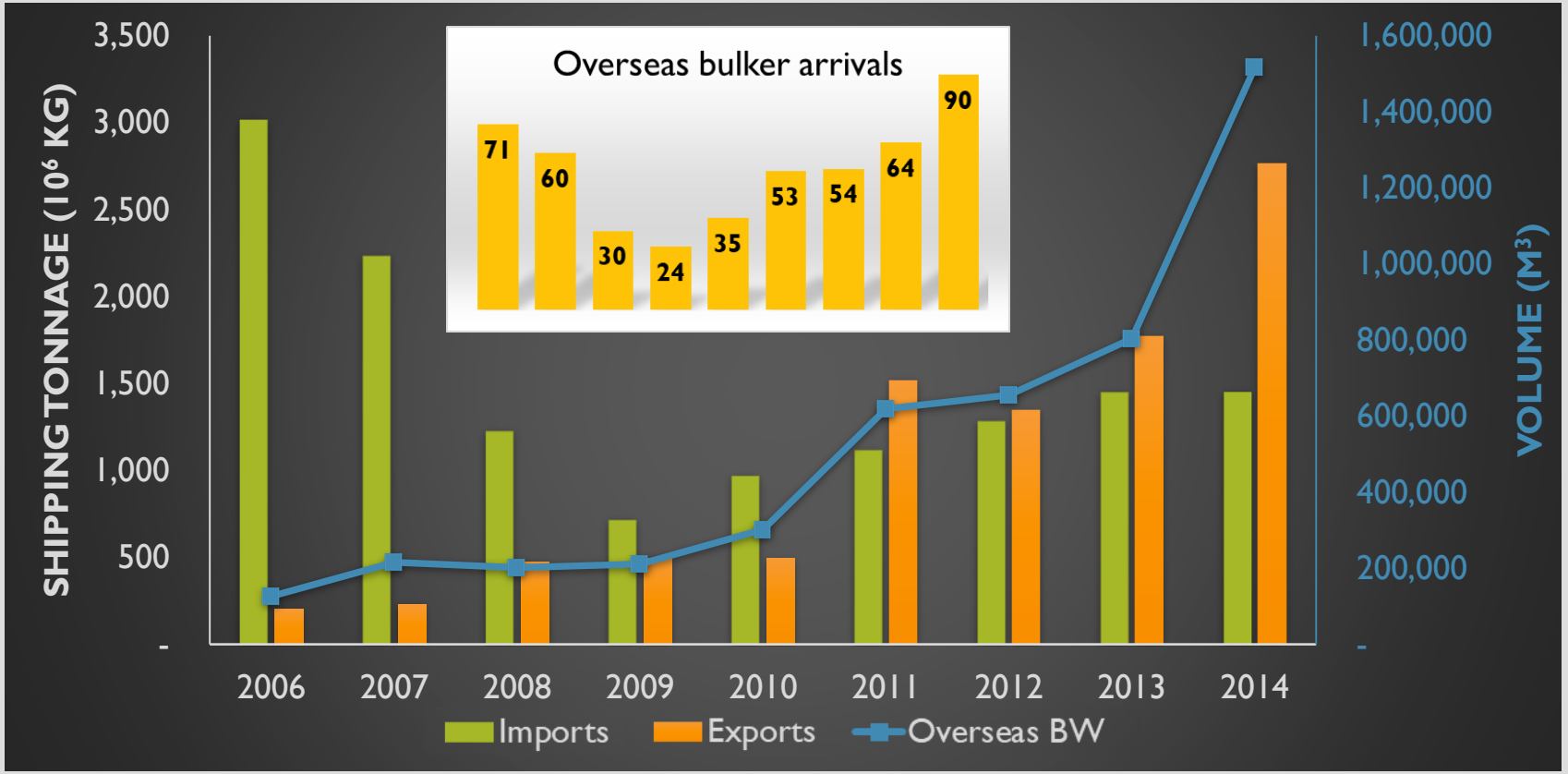
TEMPORAL INFLUENCES OF TRADE

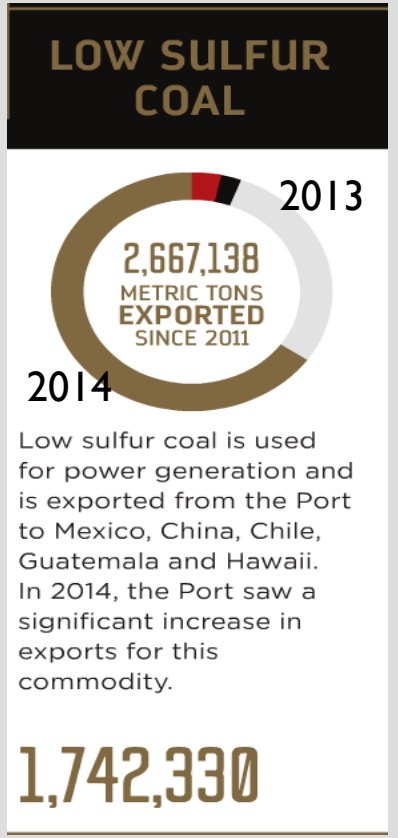
Stockton: low salinity, bulker traffic



2006 Imports: Portland Cement from China to US western states

(Port of Stockton 2006 Annual Report)



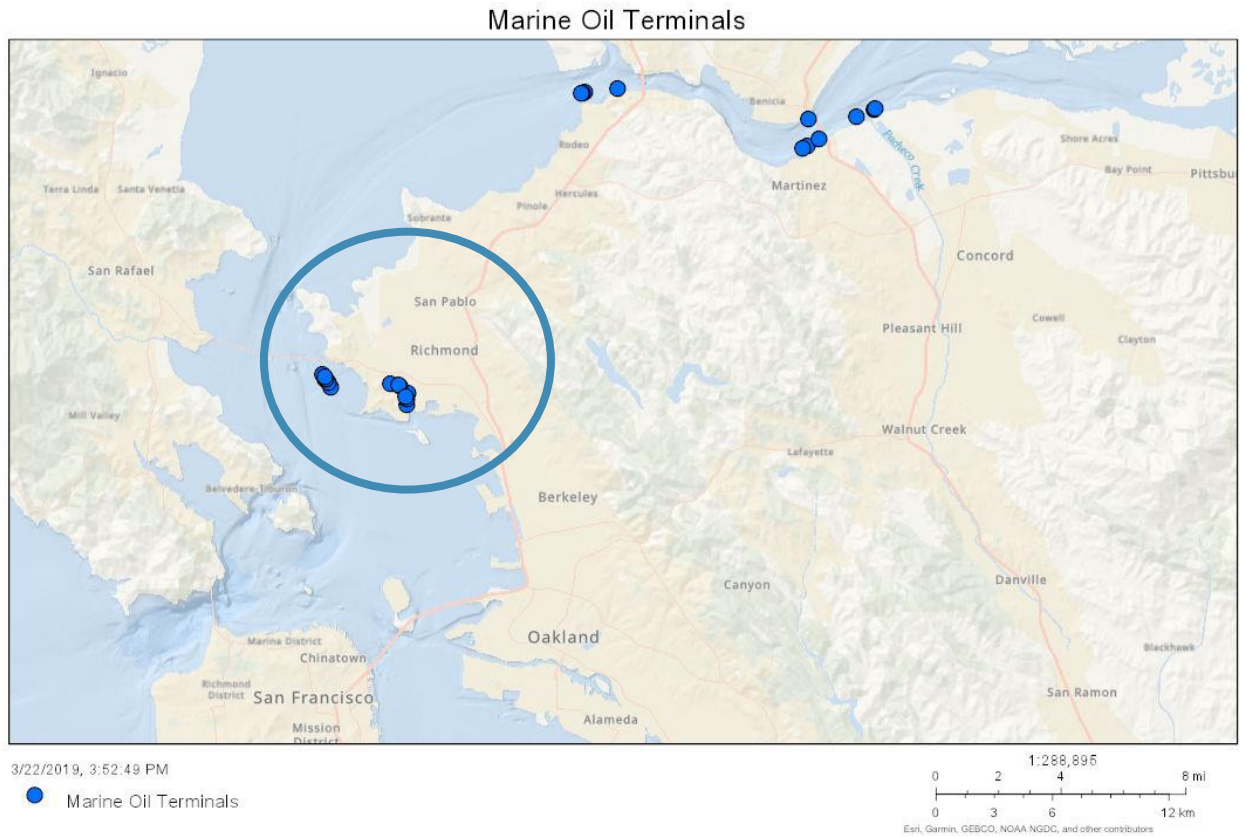


2014 Exports: Coal to Mexico, etc.

(Port of Stockton 2014 Annual Report)

SPATIAL INFLUENCES OF TRADE

Richmond: high salinity, tanker traffic

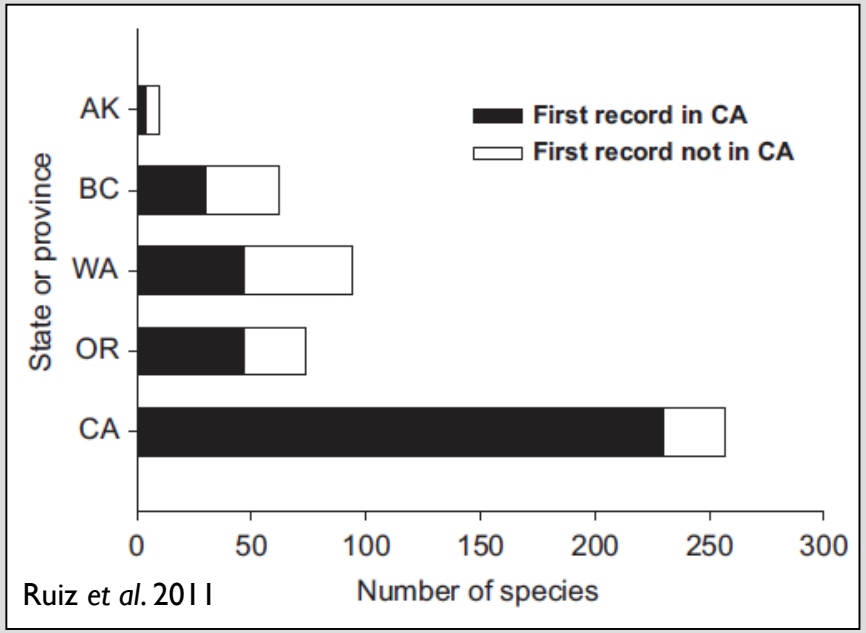


https://www.slc.ca.gov/gis/motmap/

- 3 oil commodities accounted for 68% of exports
- 2/3 of ballast water was discharged by overseas tankers
- Introductions influenced by trade partner, ship type, infrastructure

ECOLOGICAL INFLUENCES OF TRADE

- Propagule pressure
- Disturbance
- Habitat suitability
- Lag times



Ruiz *et al.* 2011

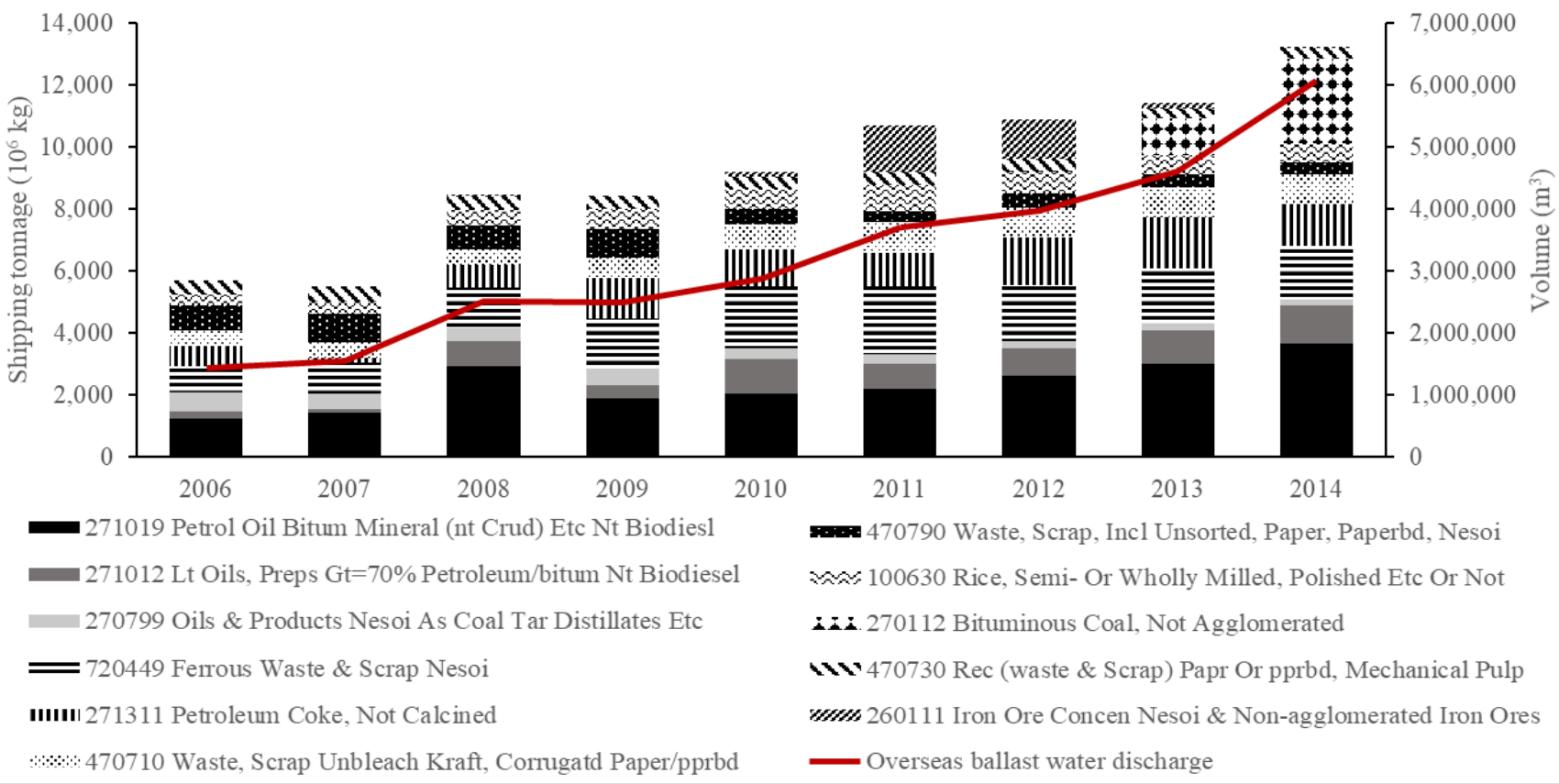
TRADE IN SAN FRANCISCO BAY:
Nearly 4,500 6-digit commodities

- Top **11** commodities by tonnage accounted for **59%** of total shipping exports

8 bulker exports: waste products, petroleum coke, coal, rice

3 tanker exports: petroleum oils

Ballast water delivery increased with the top annual exports from bulkers and tankers

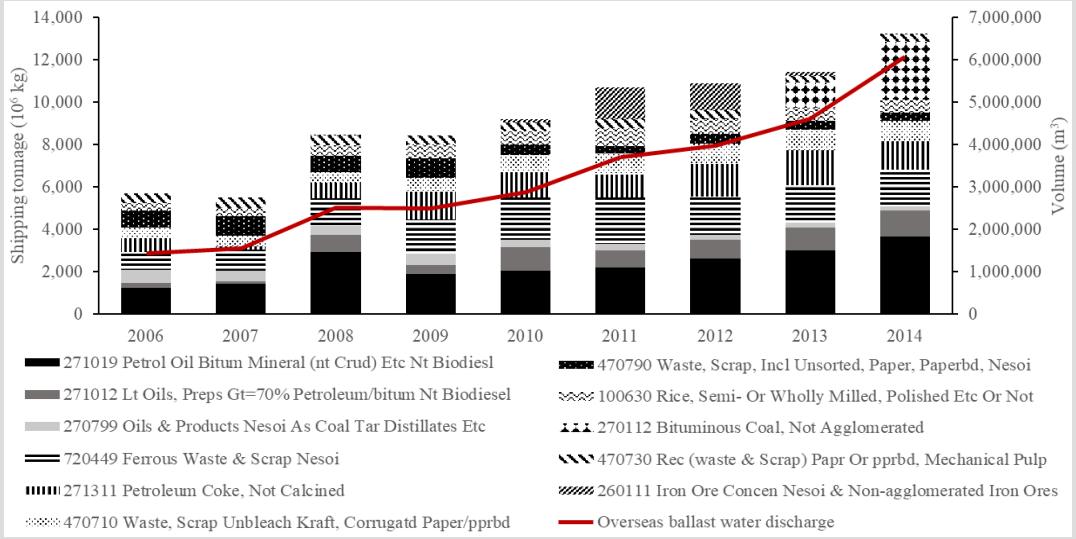


Ballast water delivery increased with the top annual exports from bulkers and tankers

$$y = -2{,}002.38 + 0.6212x_1 + 0.5324x_2$$

y = annual volume of overseas ballast water discharge (10^3 m^3),
x_1 = annual tonnage of exports transported by tankers (10^6 kg),
x_2 = annual tonnage of exports transported by bulkers (10^6 kg)

Adjusted $R^2 = 0.92$



CONCLUSIONS

Trade drives the spatial and temporal magnitude of ballast water delivery to San Francisco Bay

- Established trade patterns lead to repeat introductions from source locations
- Port specialization: specific ship types, concentrated bw discharge & NIS introductions
- These relationships influence our interpretation of long-term ballast water delivery & invasion records

QUESTIONS?