Introduced copepods and ecological change in estuaries of the Pacific coast of the United States

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Collaborators:

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Olga Kalata, University of Washington School of Aquatic and Fishery Sciences

Mark Sytsma and Robyn Draheim, Portland State University

Overview

1. Background and chronology of introduced copepods on the west coast of North America

2. Plankton surveys of large estuaries—the lower Columbia River and San Francisco Bay

3. Periodic surveys of smaller estuaries in British Columbia, Washington, Oregon, and California

4. Case histories and ecology of two species of invasive calanoid copepods

Chronology of Invasive Copepods in the Northeastern Pacific

Oithona davisae	1963	San Francisco Bay
Sinocalanus doerri	1978	San Francisco Bay
	2002	Columbia River
Limnoithona sinensis	1979	San Francisco Bay
Pseudodiaptomus marinus	1986	San Francisco Bay
Pseudodiaptomus forbesi	1987	San Francisco Bay
	2002	Columbia River
Pseudodiaptomus inopinus	1990	Columbia River*
Acartiella sinensis	1993	San Francisco Bay
Tortanus dextrilobatus	1993	San Francisco Bay
Limnoithona tetraspina	1993	San Francisco Bay
	2003	Columbia River

*Does not occur in San Francisco Bay

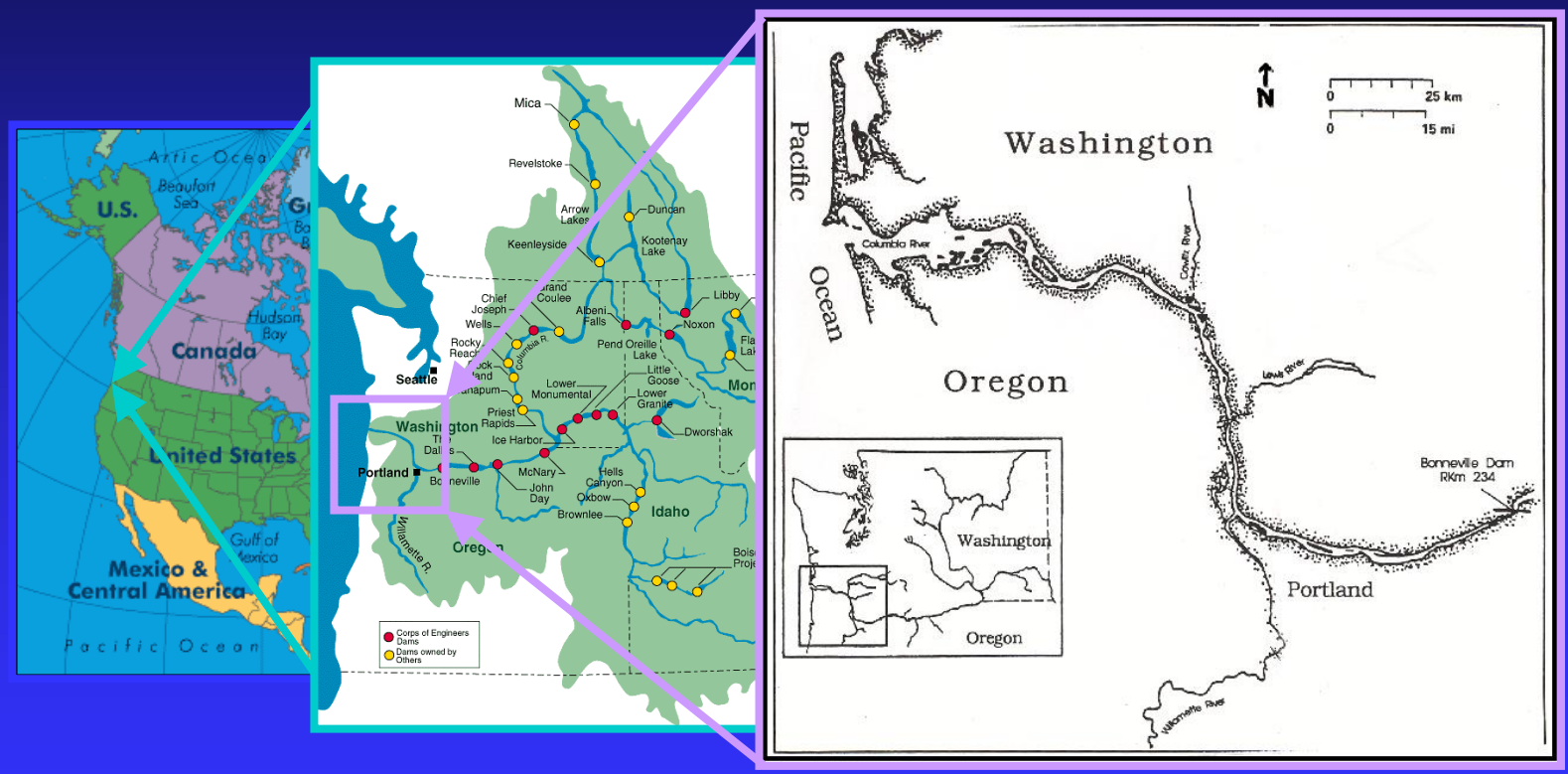
Aquatic Nonindigenous Species in the Changing Columbia River Estuary, USA

Robyn Draheim – Portland State University
Jeff Cordell – University of Washington
John Chapman – Oregon State University
Mark Sytsma – Portland State University

Lower Columbia River Aquatic Nonindigenous Species Survey

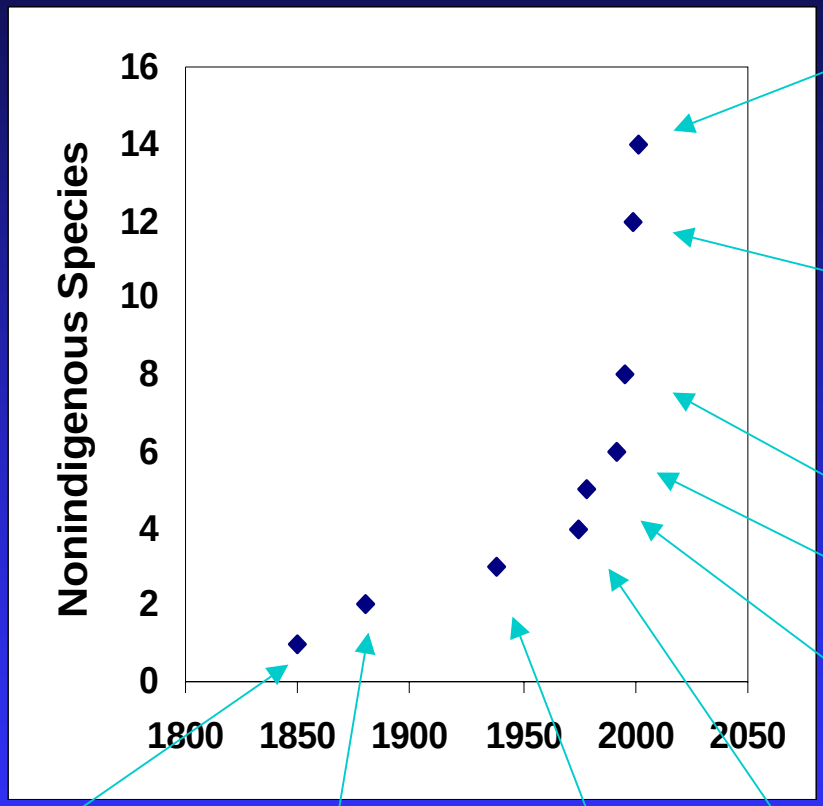
- Identified in the National Invasive Species Act of 1996 (NISA)
- Portland State University, Oregon State University, University of Washington
- Implemented in Fall 2001
- Conducted first year of sampling in 2002
- Conclude research in Fall 2003

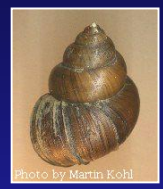
Columbia River

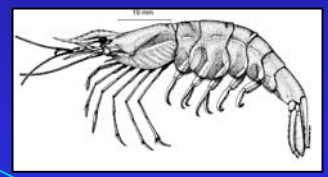


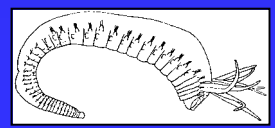
Columbia River Estuary

Species Accumulation Over Time in the Lower Columbia River

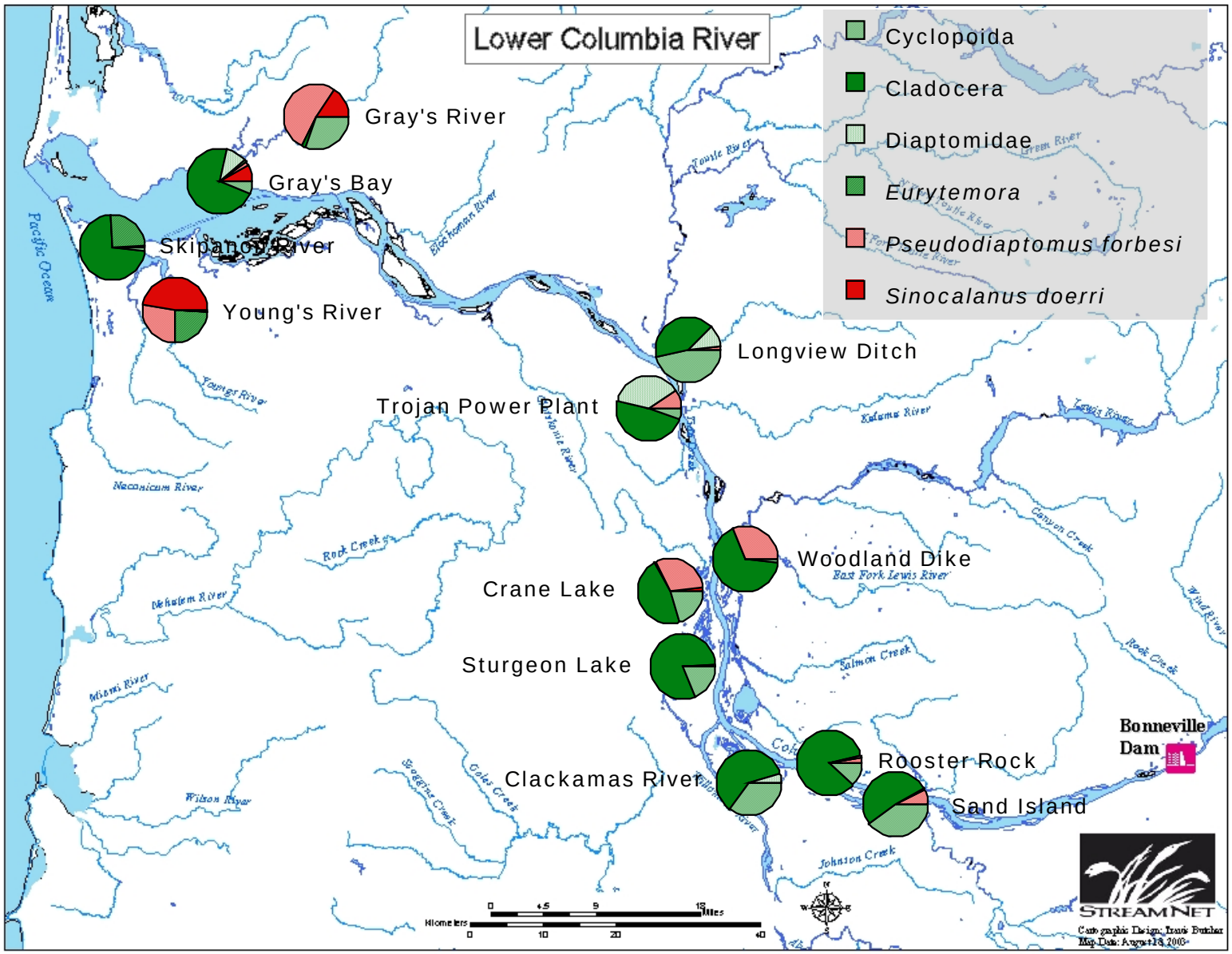


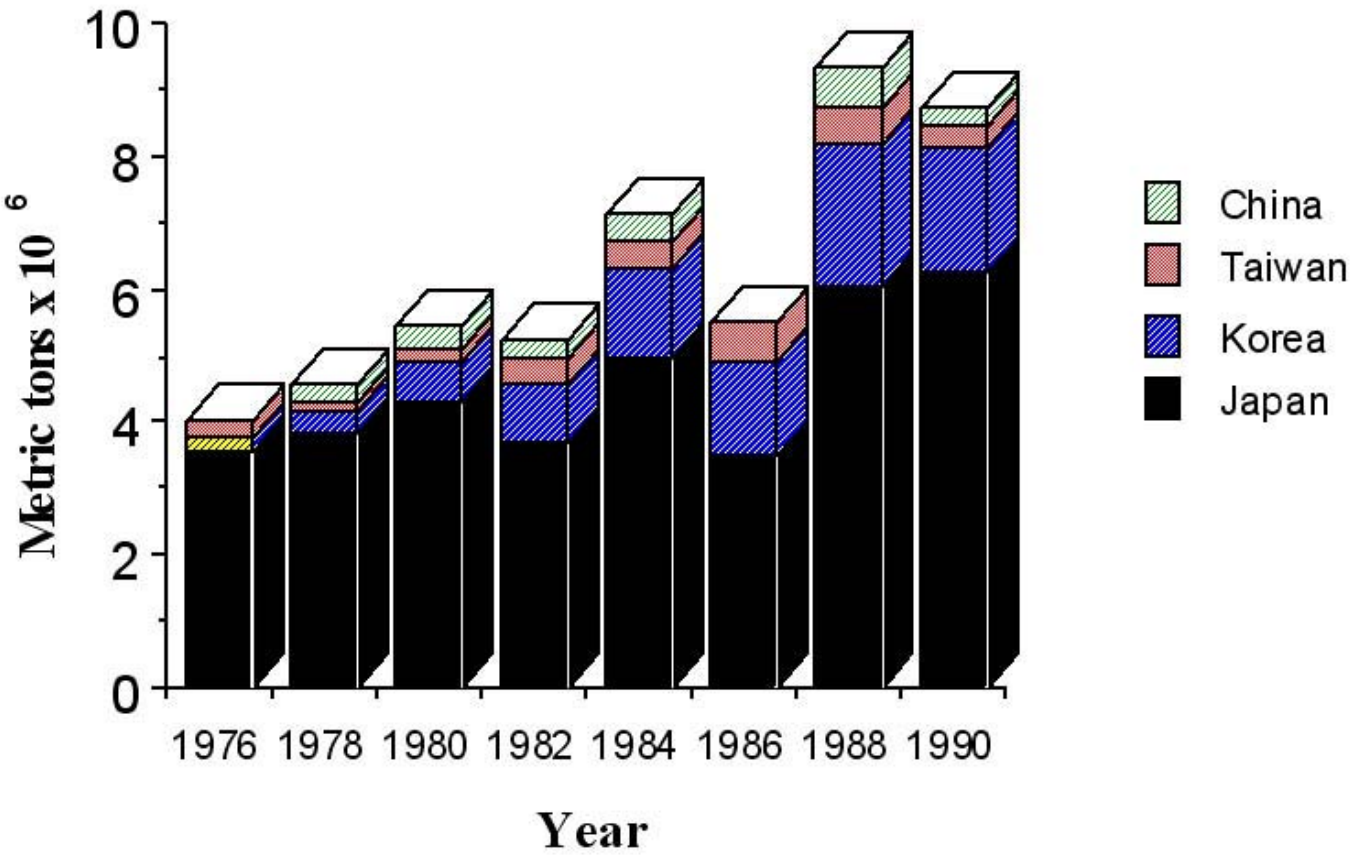






Percent Numerical Composition of Holoplankton in the Lower Columbia River, June, 2003

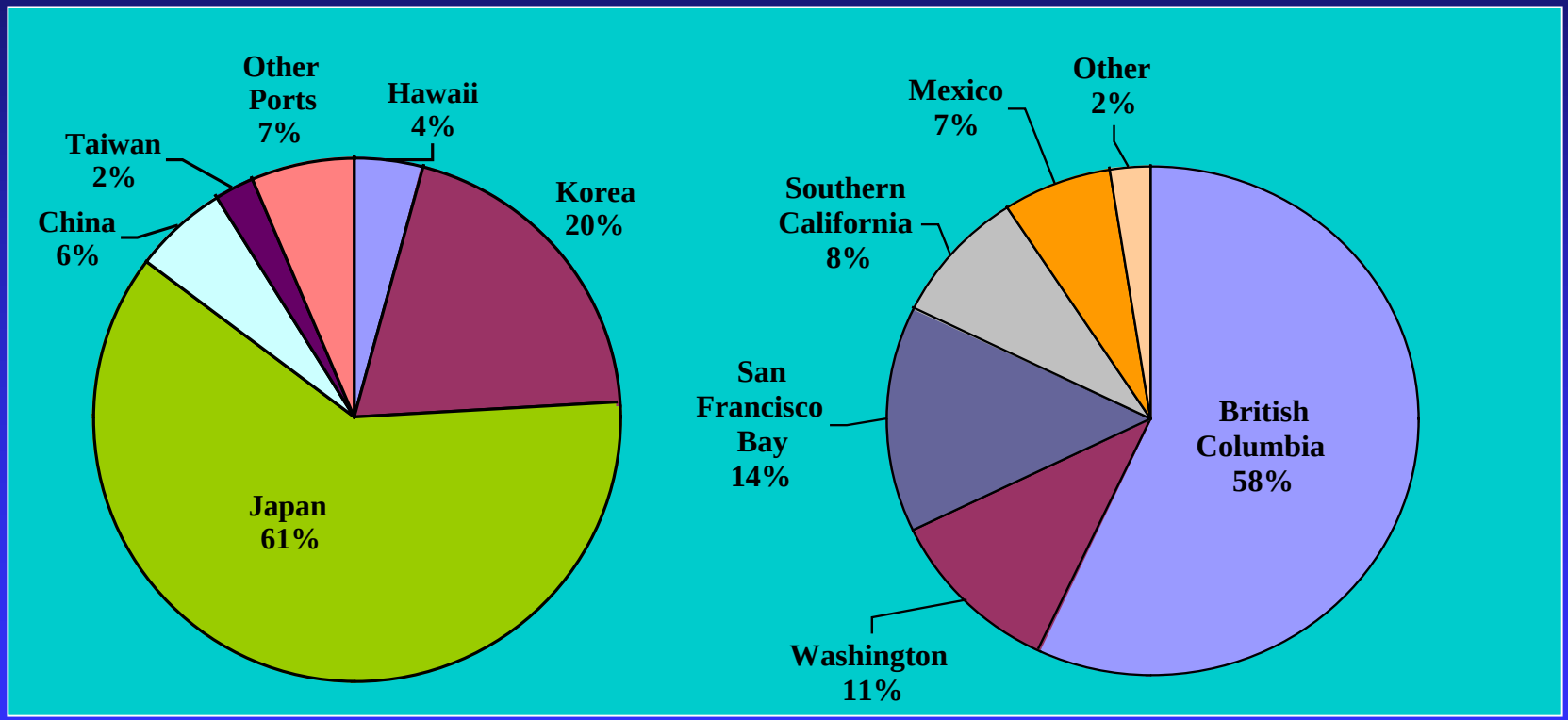




Net Tonnage of Ballasted Ships Entering the Columbia River from Asian Ports, 1976-1990.

Shipping and Ballast Water in the Lower Columbia River

Distribution of Last Port of Call



Transoceanic **Coastal**

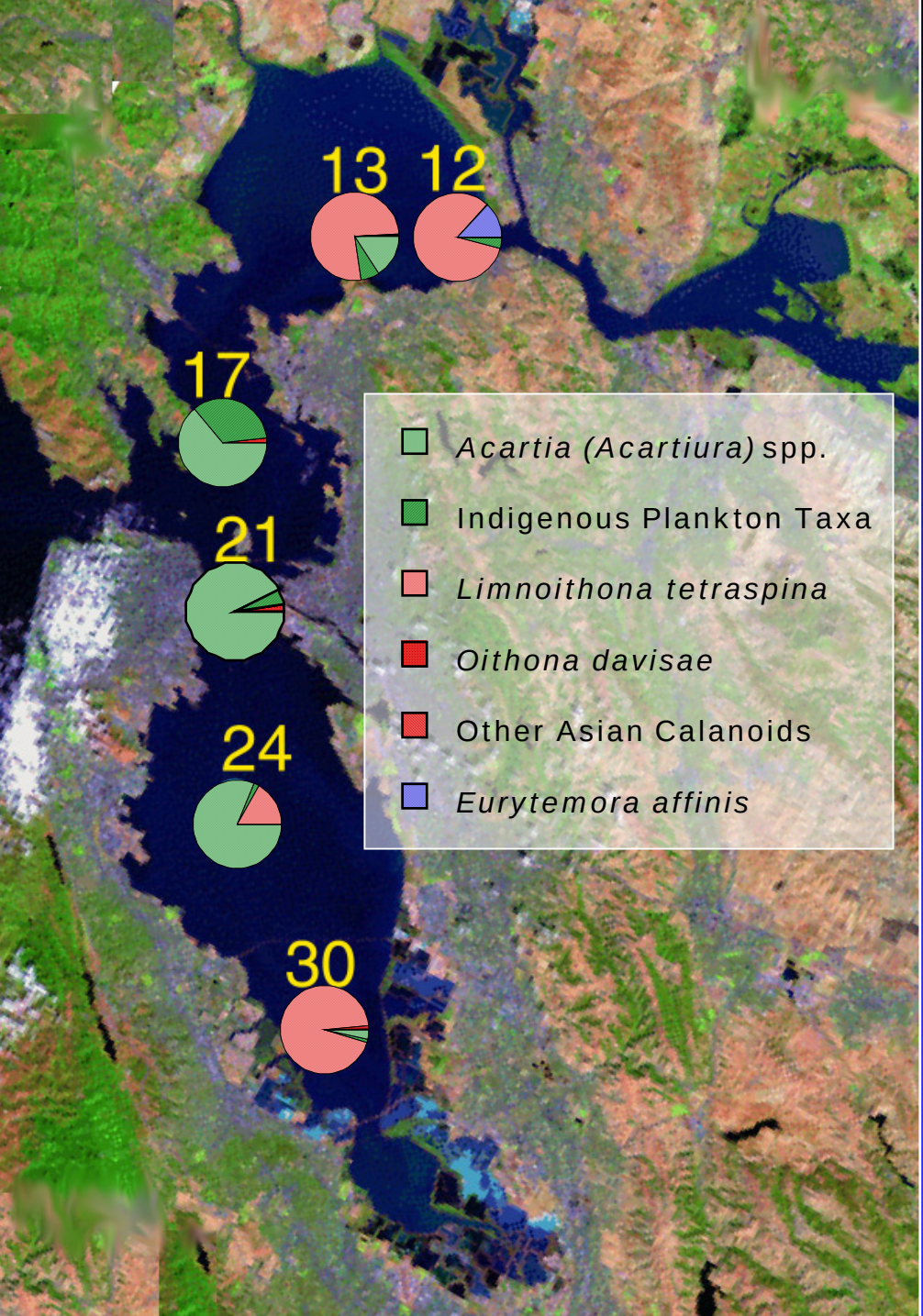
From Vinograd 2003

Plankton Surveys in San Francisco Bay

- Bi-monthly vertical plankton hauls at six stations, 73μm mesh net
- Ongoing, but only 1997-1999 samples analyzed
- Two stations in upper bay, two in central bay, and two in south bay

Change in Zooplankton Community Composition,1980 v. 1997

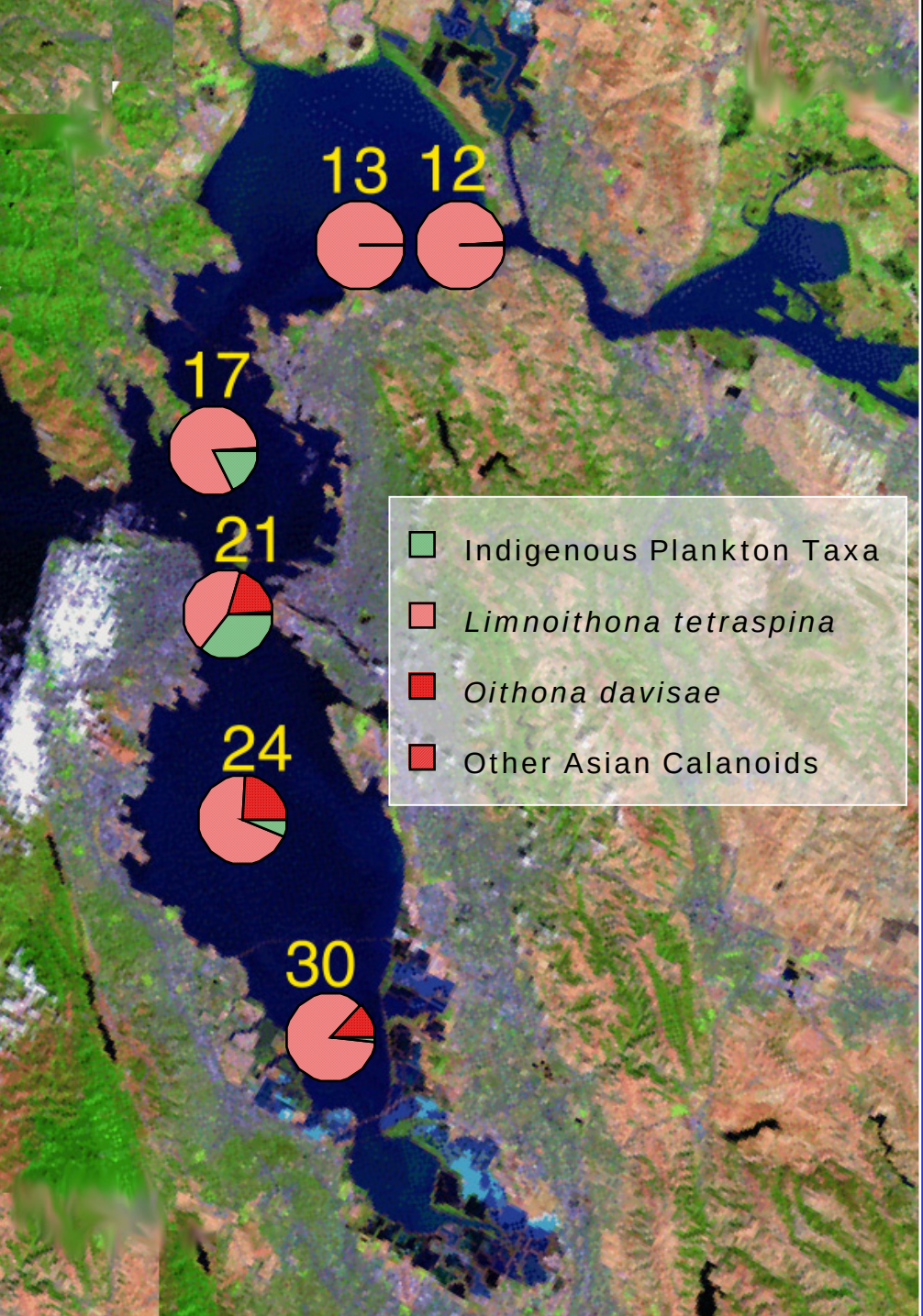
	Frequency of Occurrence (%)			
	Jan-May		Jun-Dec	
	1980	1997	1980	1997
Copepods				
Acartia (Acartiura) spp.	81	100	38	89
Acartia californiensis	1	11	51	44
Paracalanus spp.	12	78	17	67
Eurytemora affinis	26	44	23	0
Sinocalanus doerri	**13**	**33**	**18**	**0**
Oithona davisae	**7**	**100**	**31**	**100**
Oithona similis	3	22	6	56
Corycaeus sp.	7	22	7	44
Microsetella spp.	6	33	6	44
Tortanus dextrilobatus	**0**	**67**	**0**	**78**
Pseudodiaptomus marinus	**0**	**33**	**0**	**89**
Limnoithona tetraspina	**0**	**100**	**0**	**67**
Cladocerans	10	33	7	0
Meroplankton				
Cirripedia	43	0	55	33
Spionidae	52	33	66	22
	τ = 0.031, P<0.9		**τ = -0.284, P<0.2**	



Percent composition of holoplankton ≥ 73 µm in San Francisco Bay, March, 1998

Species of Non-indigenous copepods in San Francisco Bay

Cyclopoida
Limnoithona sinensis
Limnoithona tetraspina
Oithona davisae
Calanoida
Pseudodiaptomus forbesi
Pseudodiaptomus marinus
Sinocalanus doerri
Acartiella sinensis
Tortanus dextrilobatus



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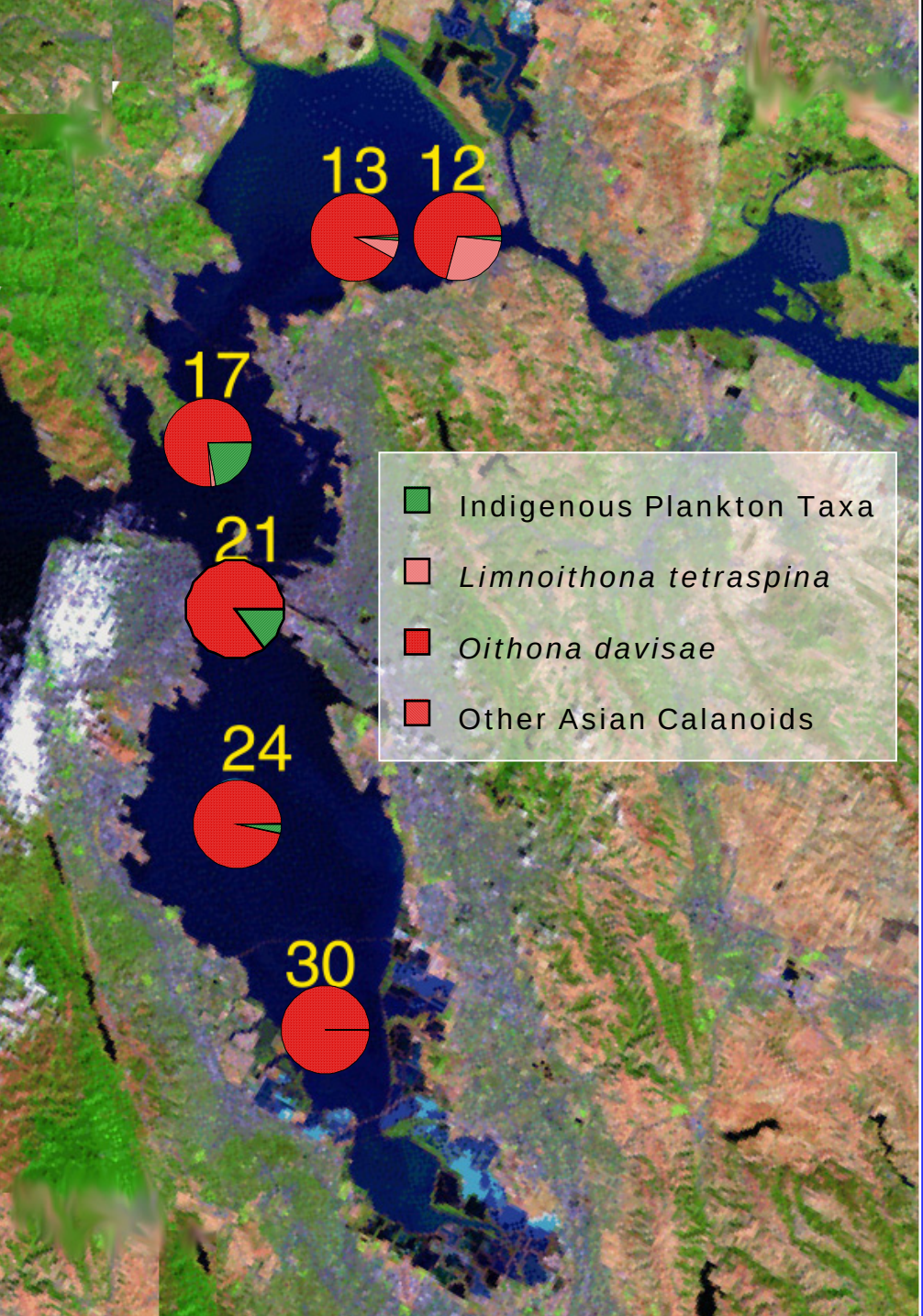

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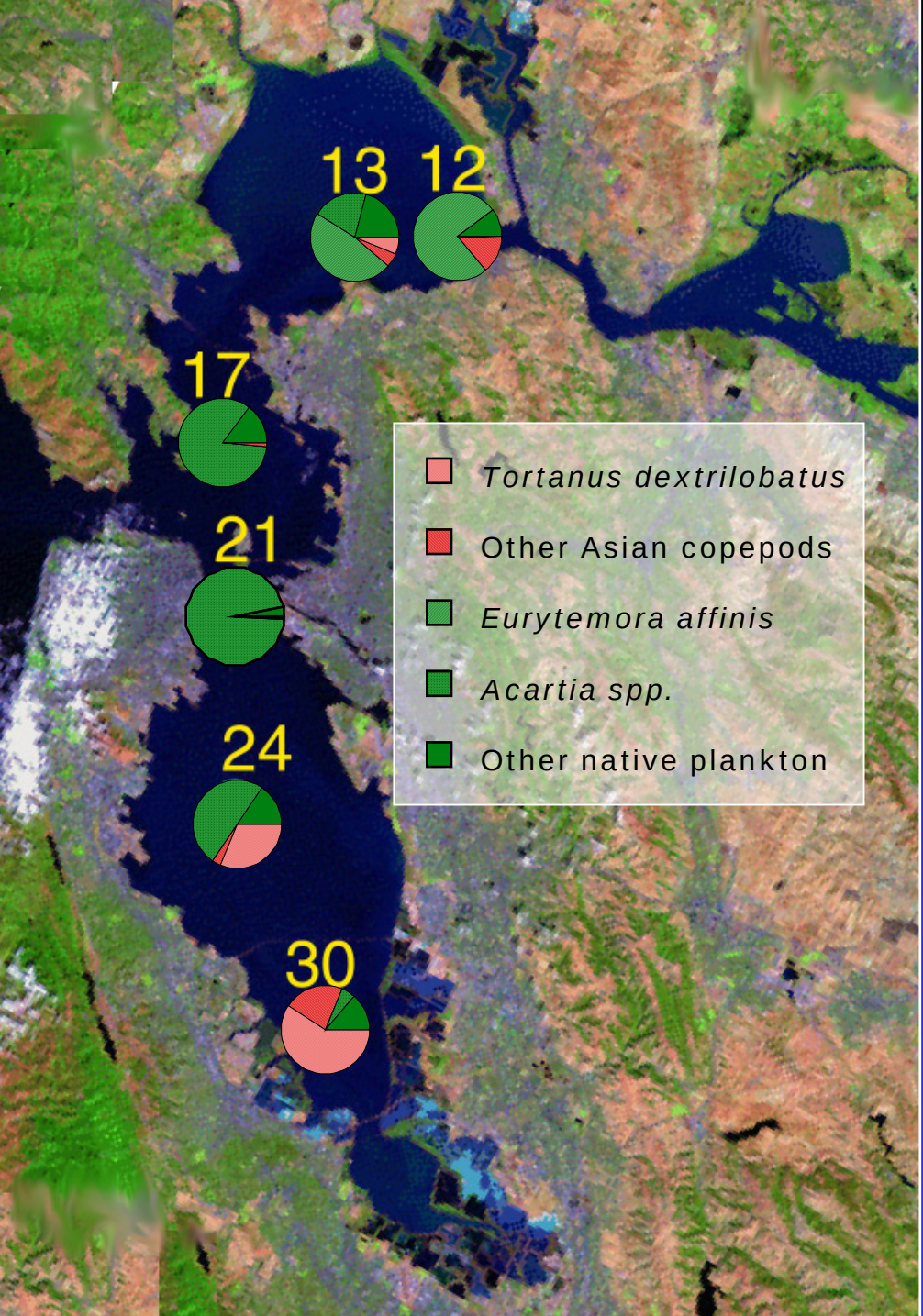
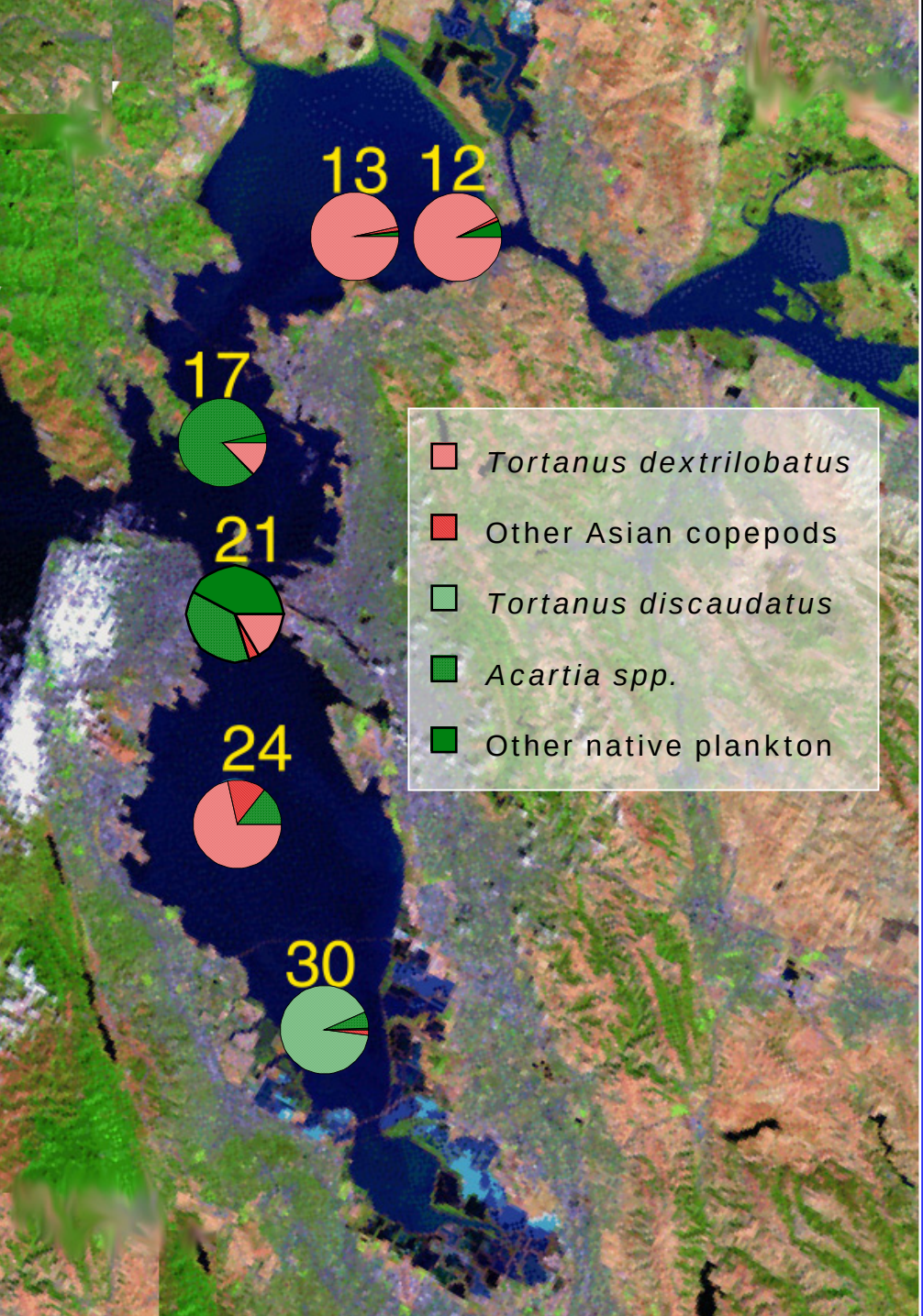
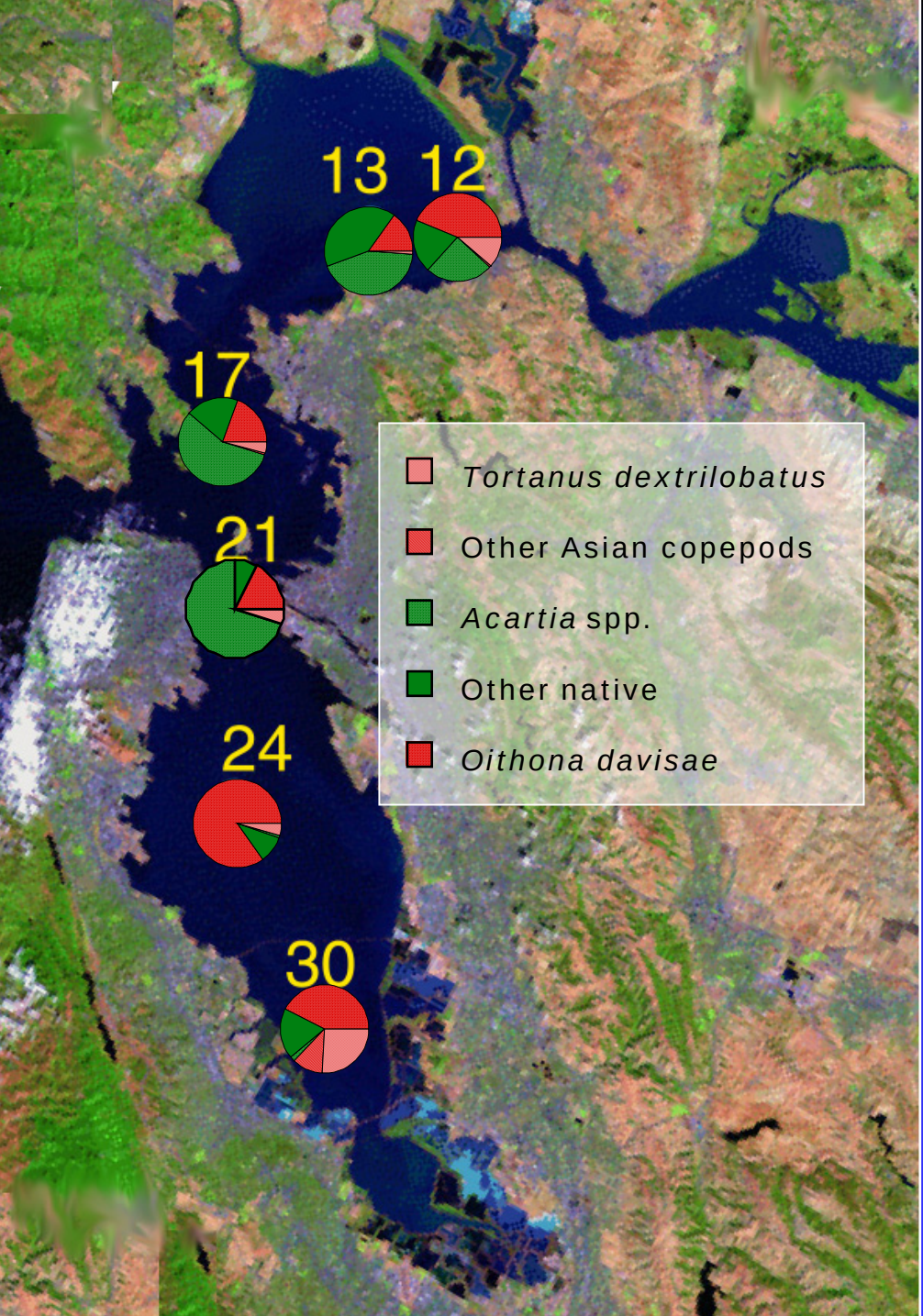


Percent composition of plankton ≥ 500 µm in San Francisco Bay, March, 1998



Percent composition of plankton ≥ 500 µm in San Francisco Bay, May, 1998



Percent composition of plankton ≥ 500 µm in San Francisco Bay, September, 1998

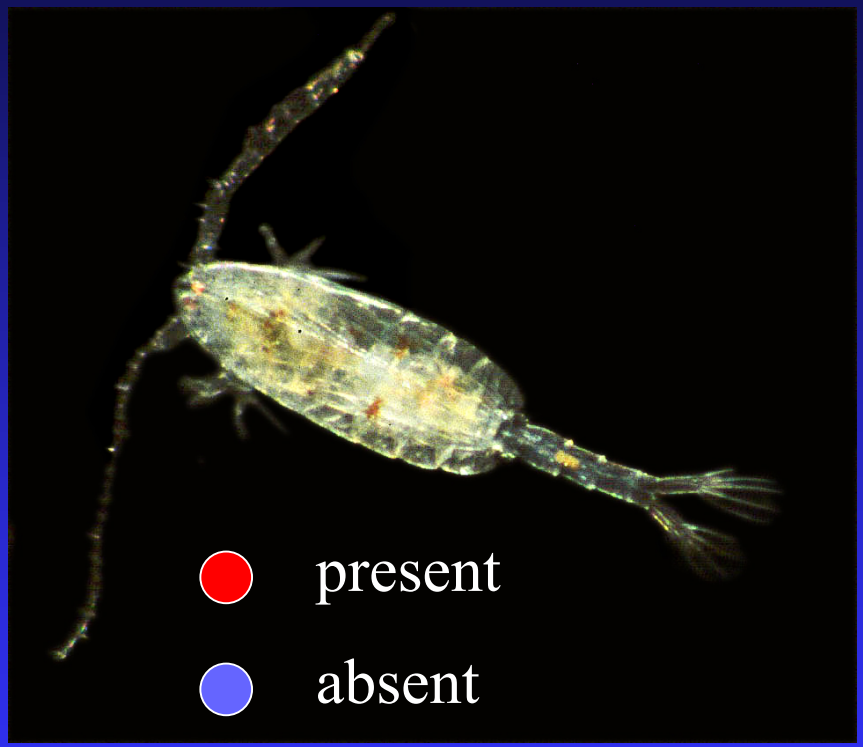
Plankton surveys of smaller estuaries

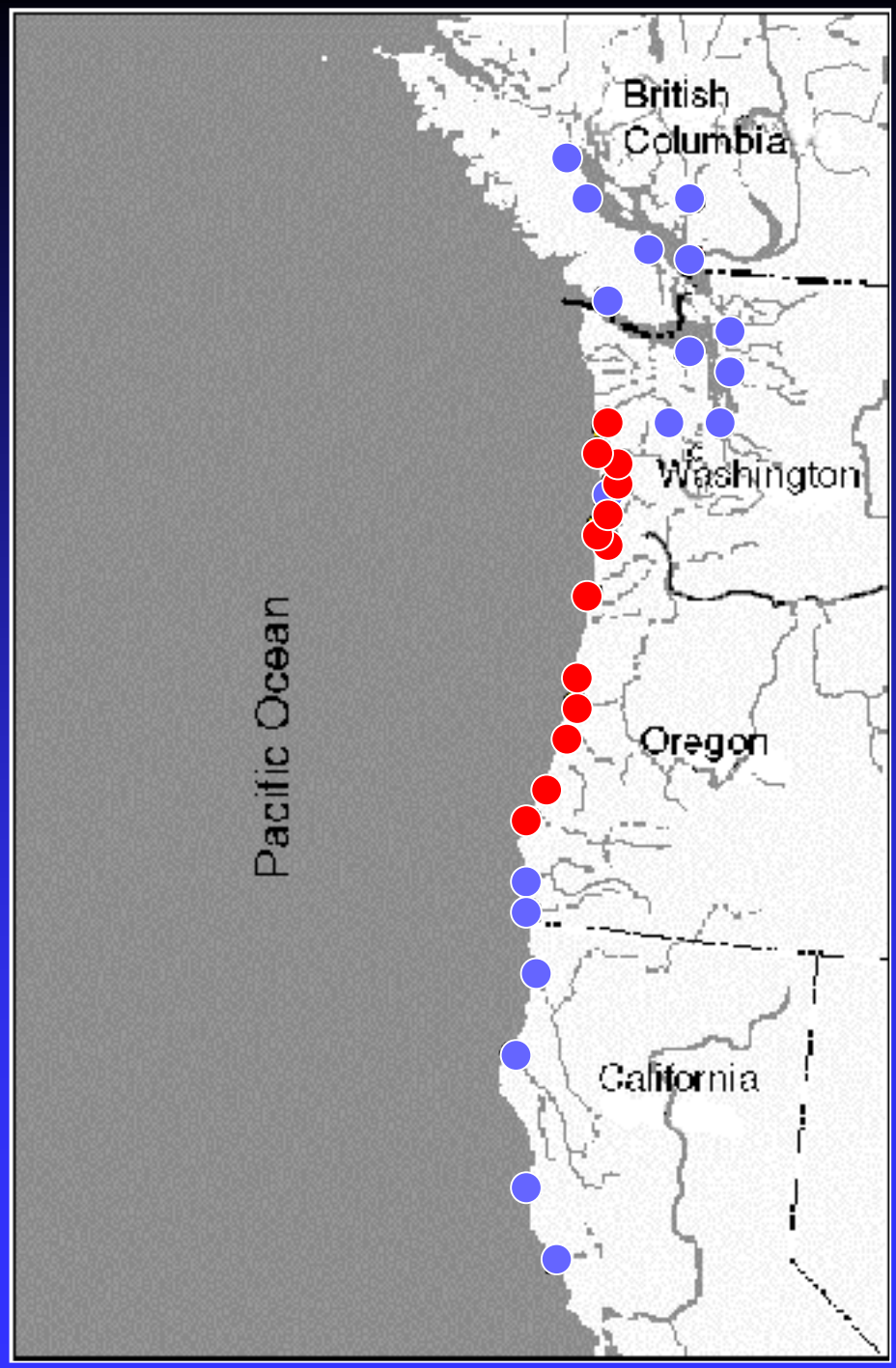
- In 1992, 1996, and 2000, up to 21 estuaries between southern British Columbia and northern California were sampled

- Bottom salinities of >10, ~9, 6, 3, and 0 psu during summer-fall low-flow period

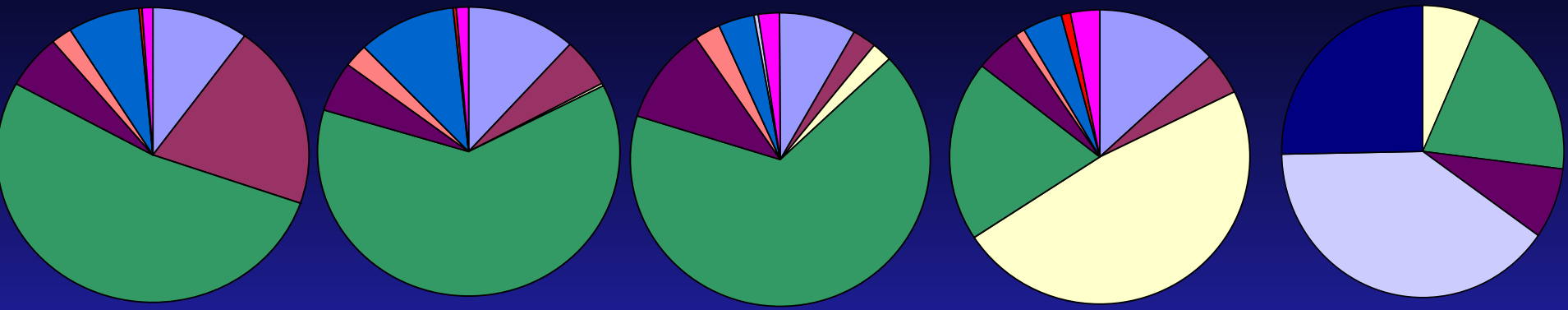
- Vertical haul from a small boat with 250µm mesh net

Pseudodiaptomus inopinus

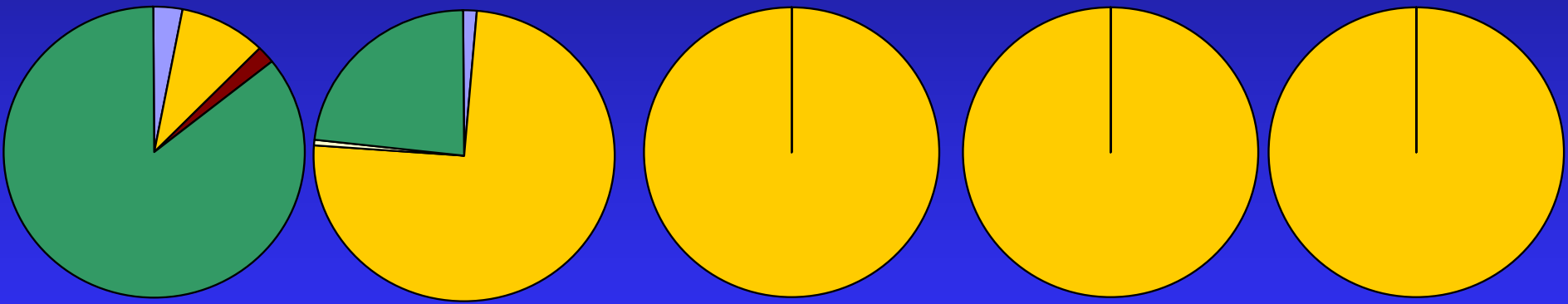




Percent numerical composition of copepods across salinity gradient in 14 west coast estuaries without *P.inopinus*



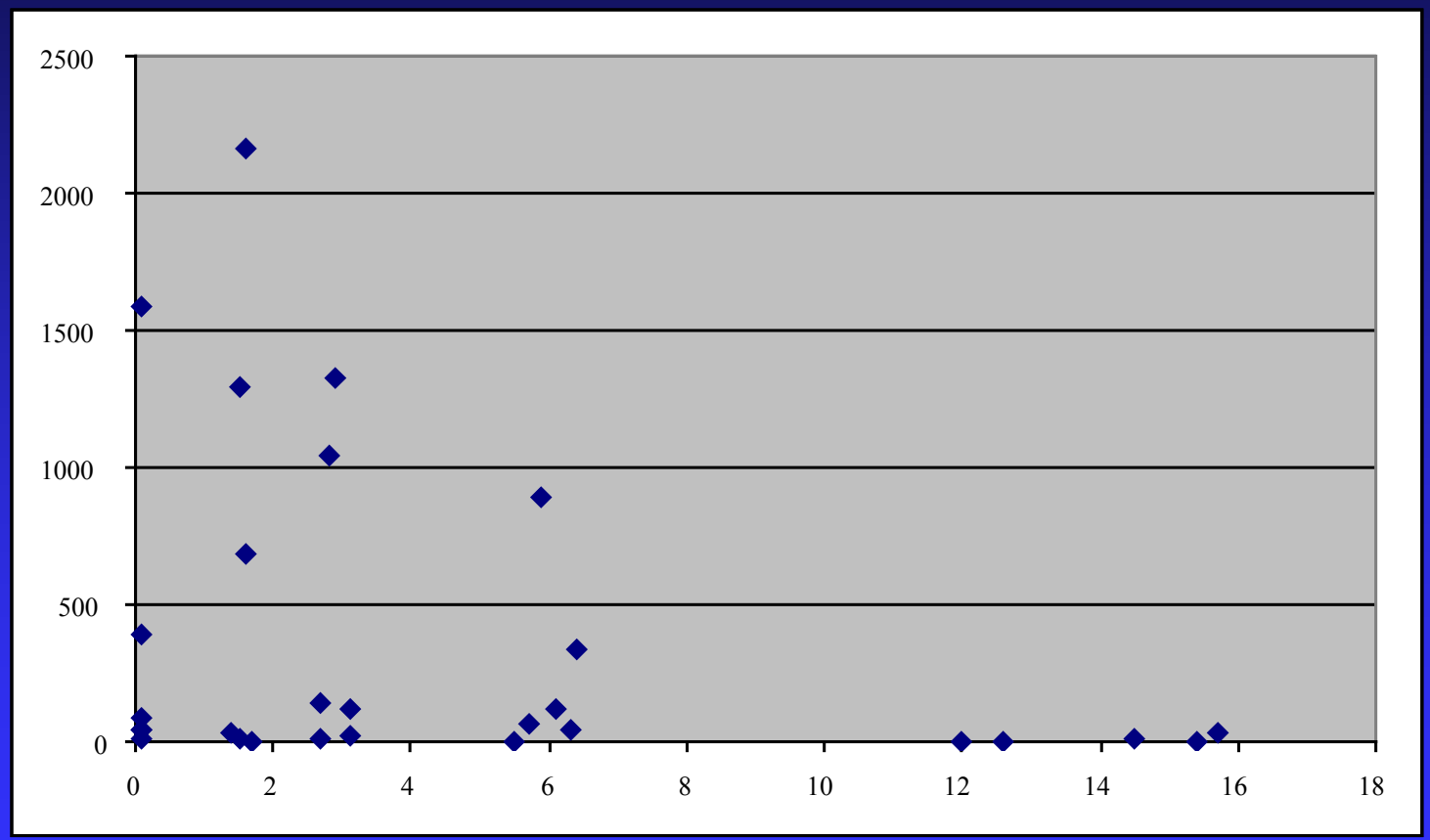
in 7 west coast estuaries with *P.inopinus*



> 10 psu → 0 psu

Paracalanus sp.
E. americana
Cyclopidae
Corycaeus sp.
P. inopinus
Acartiura spp.
Acartia tonsa
E. affinis
Oithona similis
Other Copepods

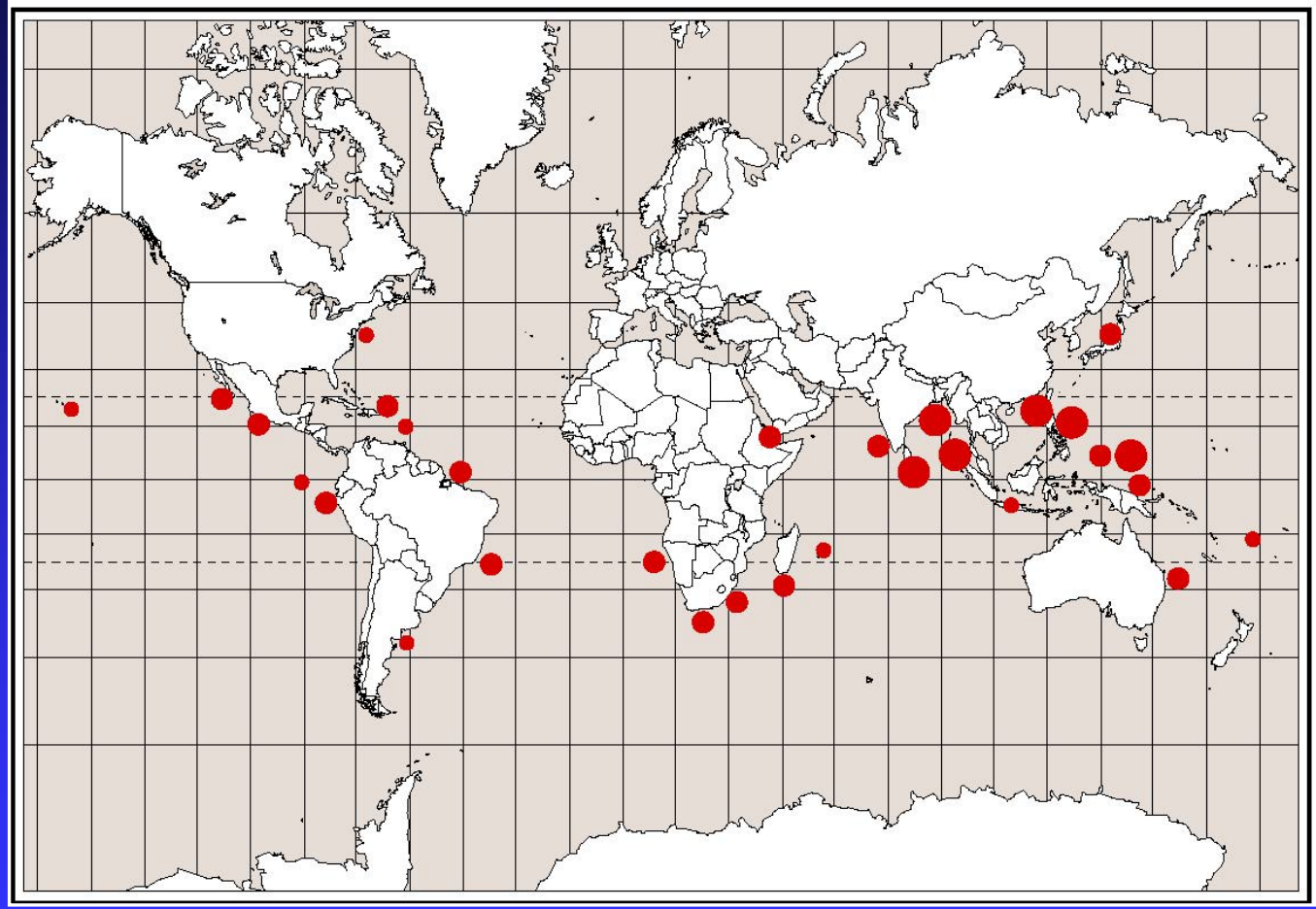
Abundance of *Pseudodiaptomus inopinus* in relation to salinity in seven Pacific northwest estuaries



- **Ecological Consequences of Invasive Copepods: *Two Case Studies from the Northeast Pacific***


Pseudodiaptomus inopinus

World Distribution of the Genus Pseudodiaptomus



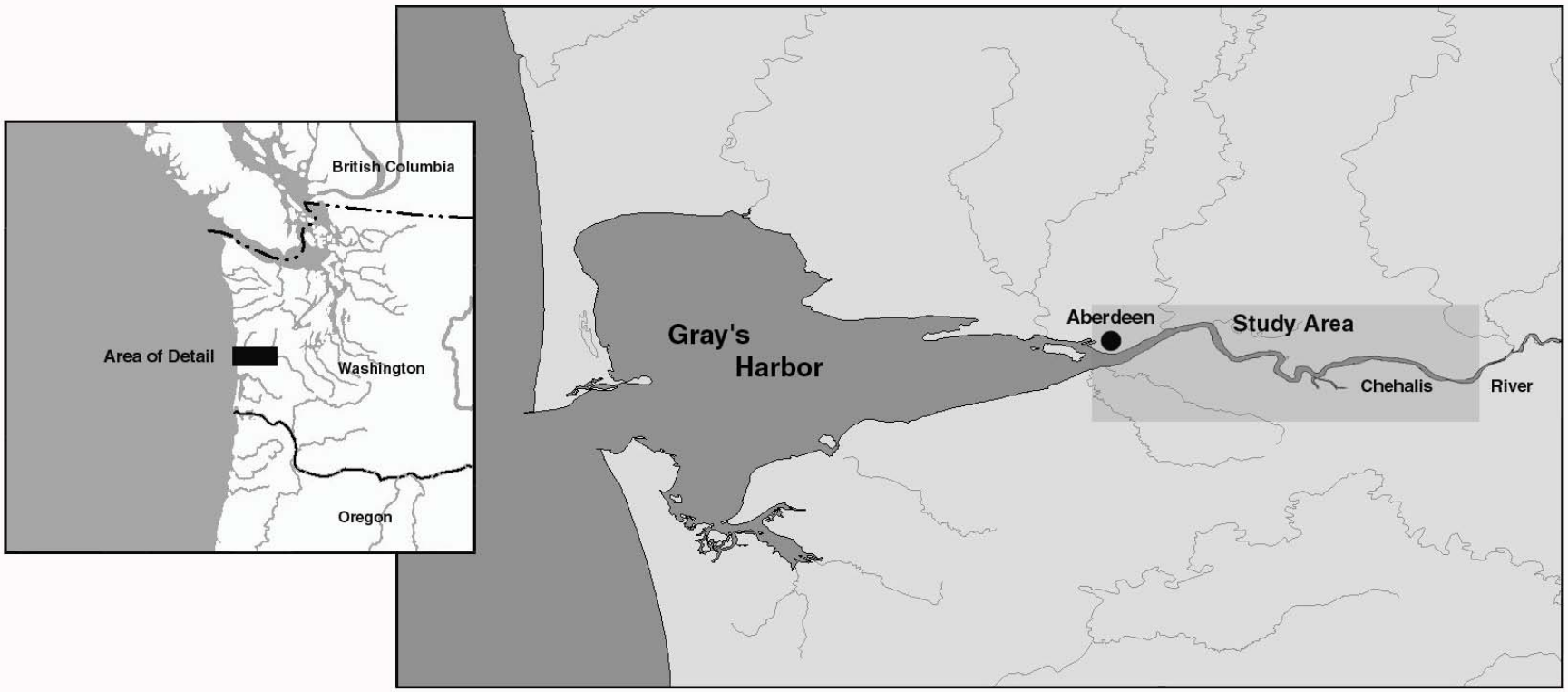
Number of Species

one

2 - 6

7 - 15

Pseudiaptomus inopinus in the Chehalis River, Washington



Study of Chehalis River, Washington

- Twice monthly sampling at three stations in brackish-oligohaline region for 17 months
- Vertical plankton net hauls
- Bottom sled net for invertebrate predators
- Beach seine for fish predators
- Diet analyses
- Diel vertical migration study using pump sampling

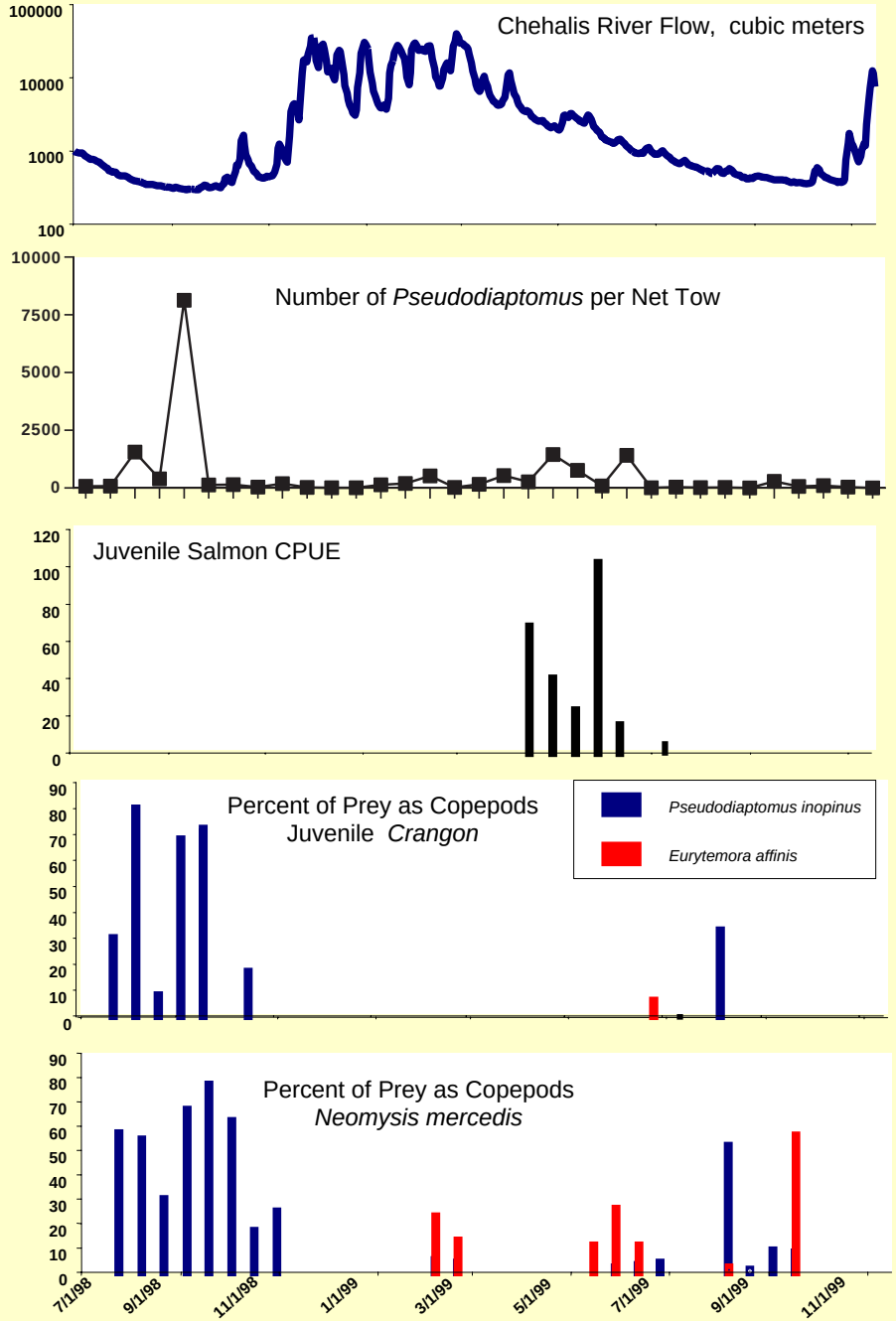
River flow

Number of Pseudodiaptomus

Juvenile salmon catches

Number of copepods in juvenile *Crangon* shrimp

Number of copepods in *Neomysis*

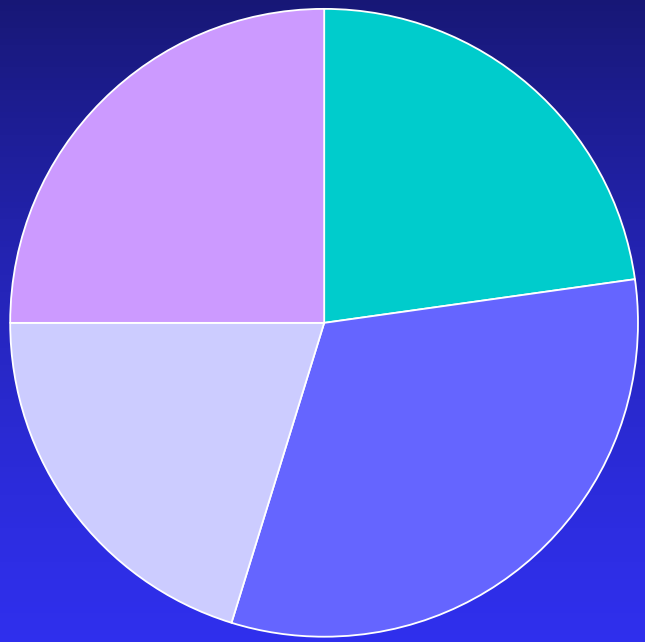


Diet of Invertebrate Predators, Chehalis River, 7/98 – 11/99

***Crangon* juveniles**

n = 243 predators

n = 562 prey



Pseudodiaptomus inopinus

Pseudobradya sp.

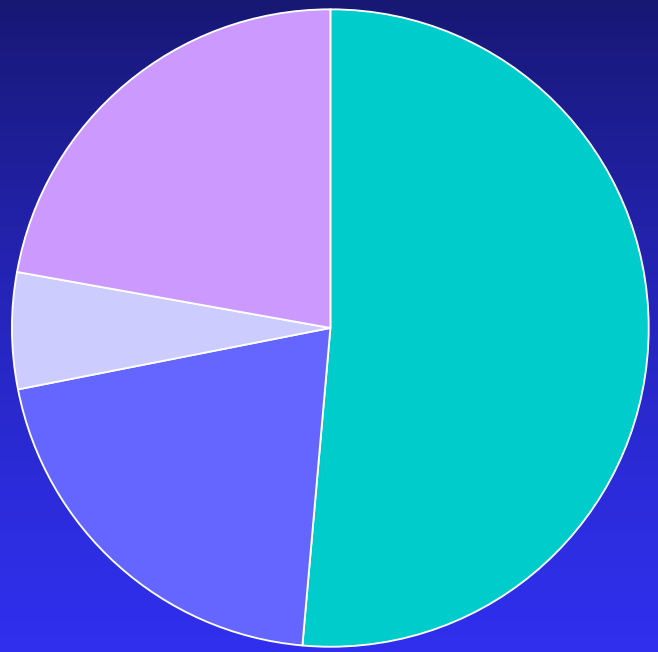
Corophium spp.

Other

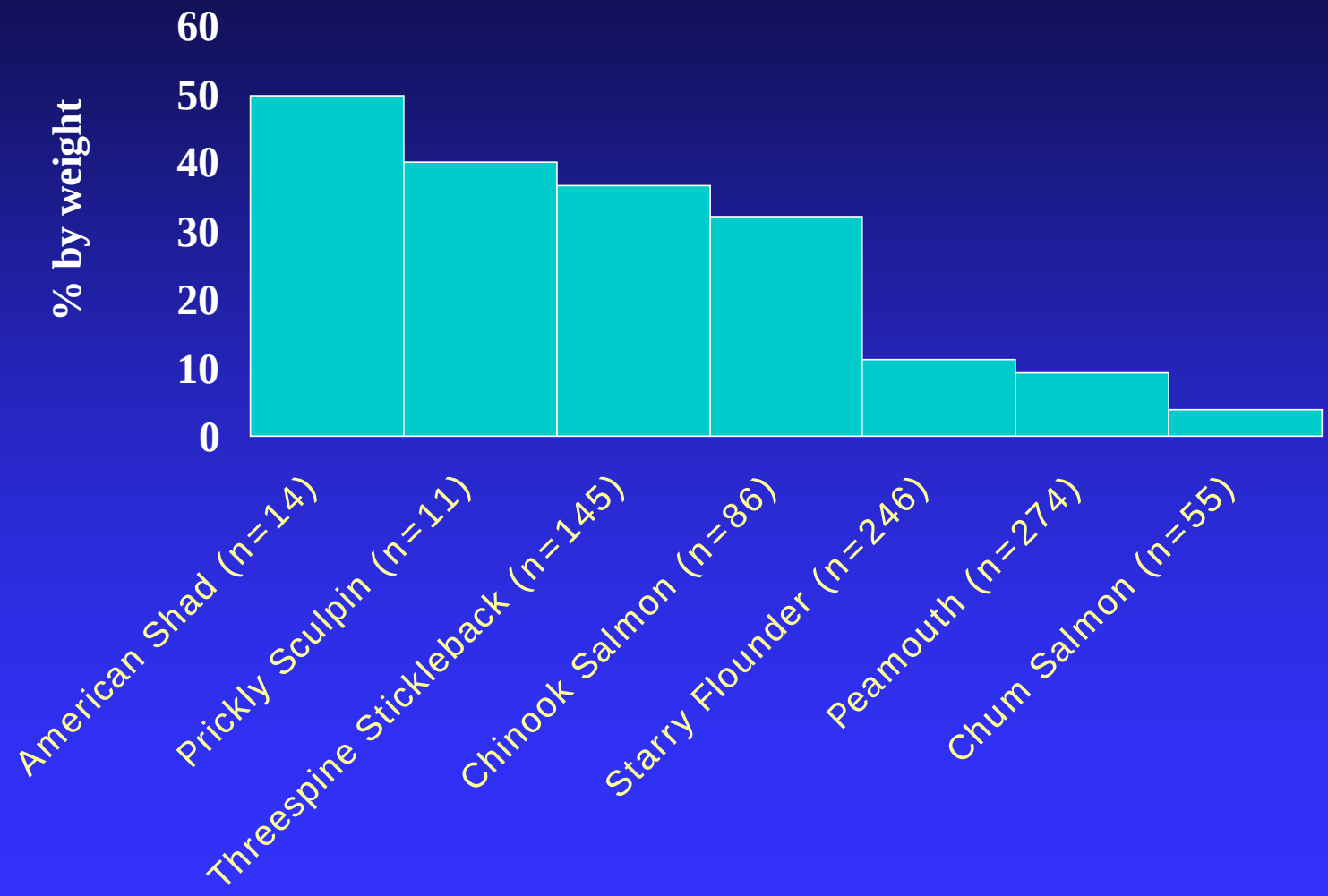
Neomysis mercedis

n = 667 predators

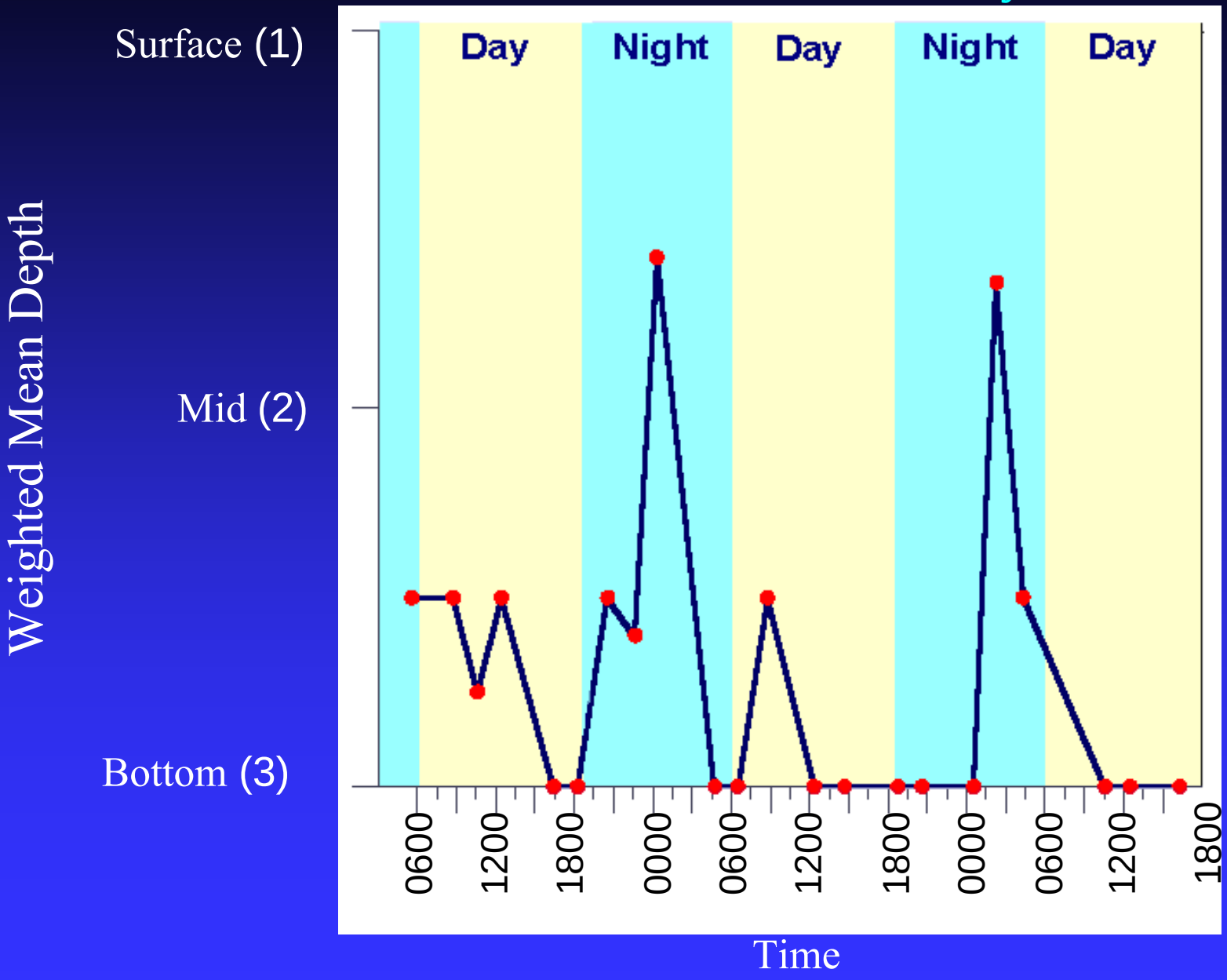
n = 1,272 prey



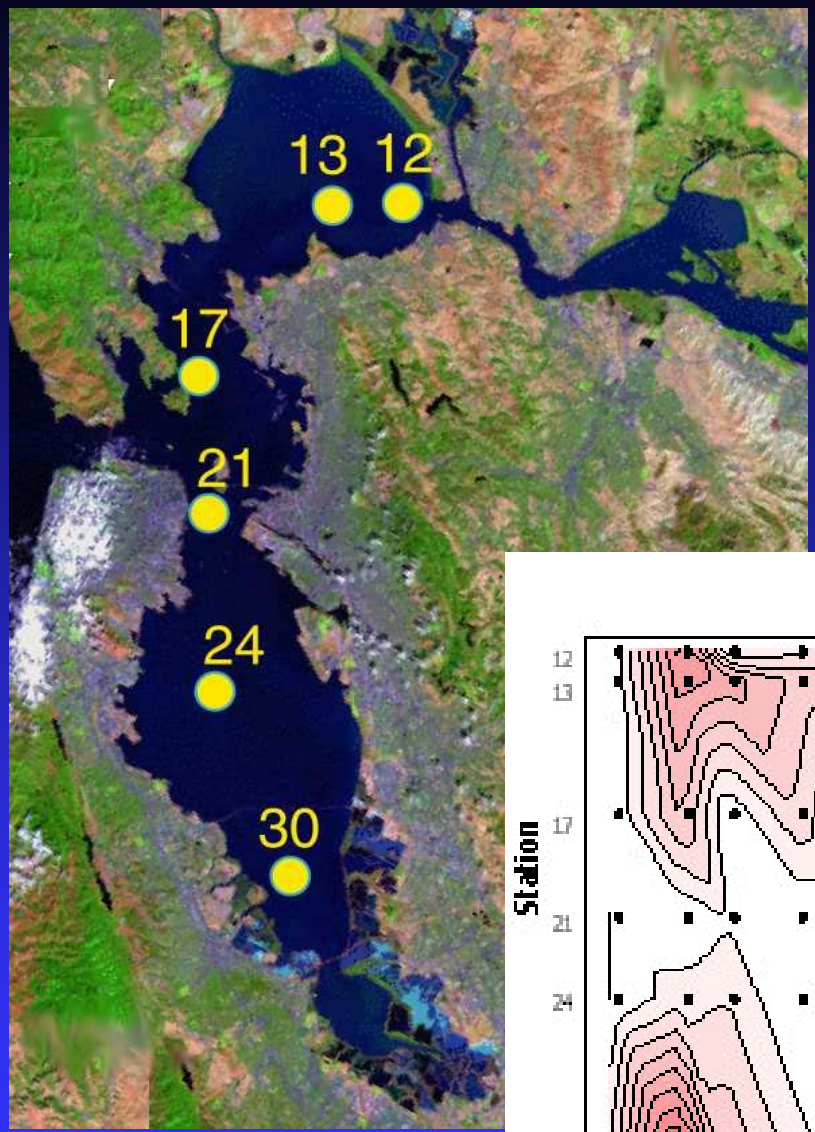
Percent Contribution (by weight) of *Neomysis* in Fish Diets, Chehalis River, 7/98 – 11/99



Pseudodiaptomus inopinus Vertical Distribution
Chehalis River, 6 PSU Bottom Salinity



Tortanus dextrilobatus

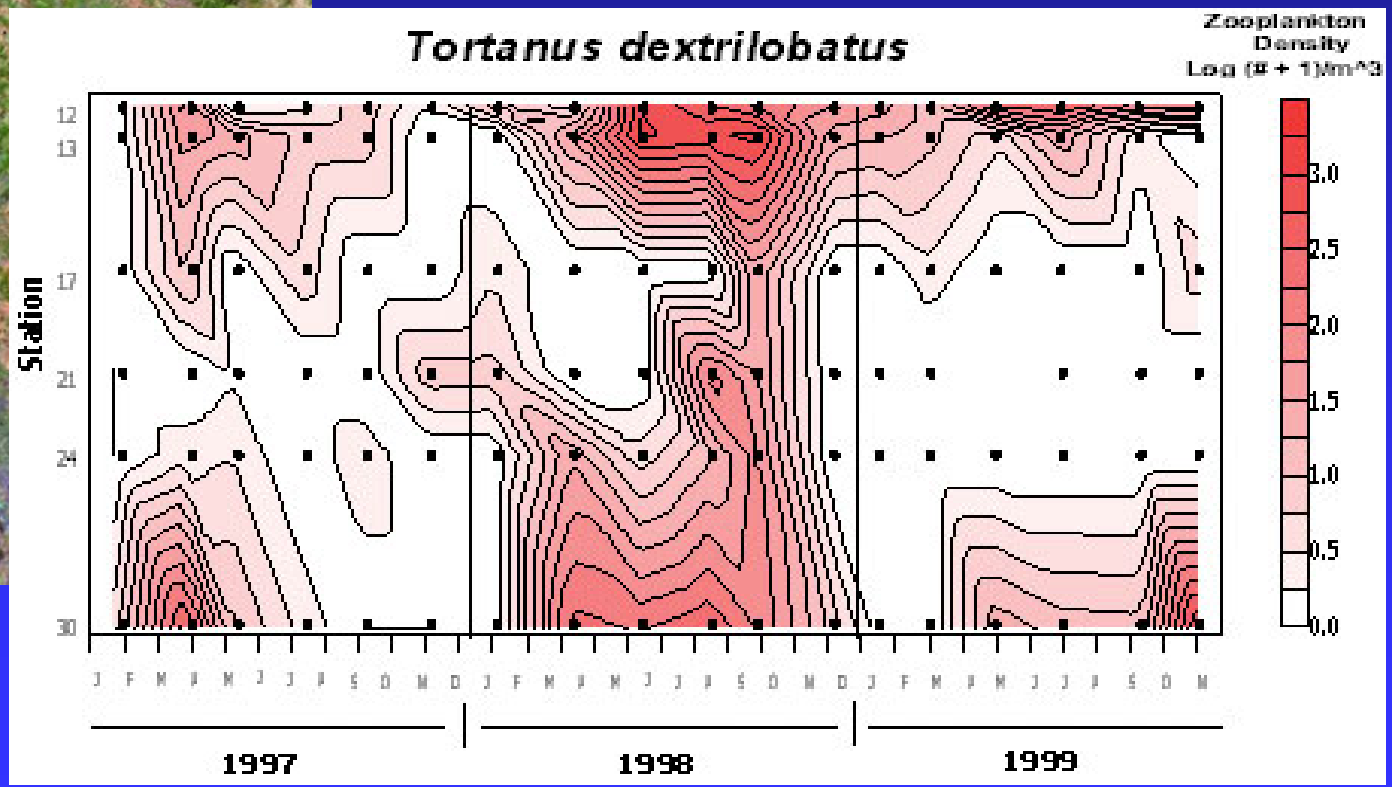


San Francisco Estuary Zooplankton Surveys

Current Analyses include;

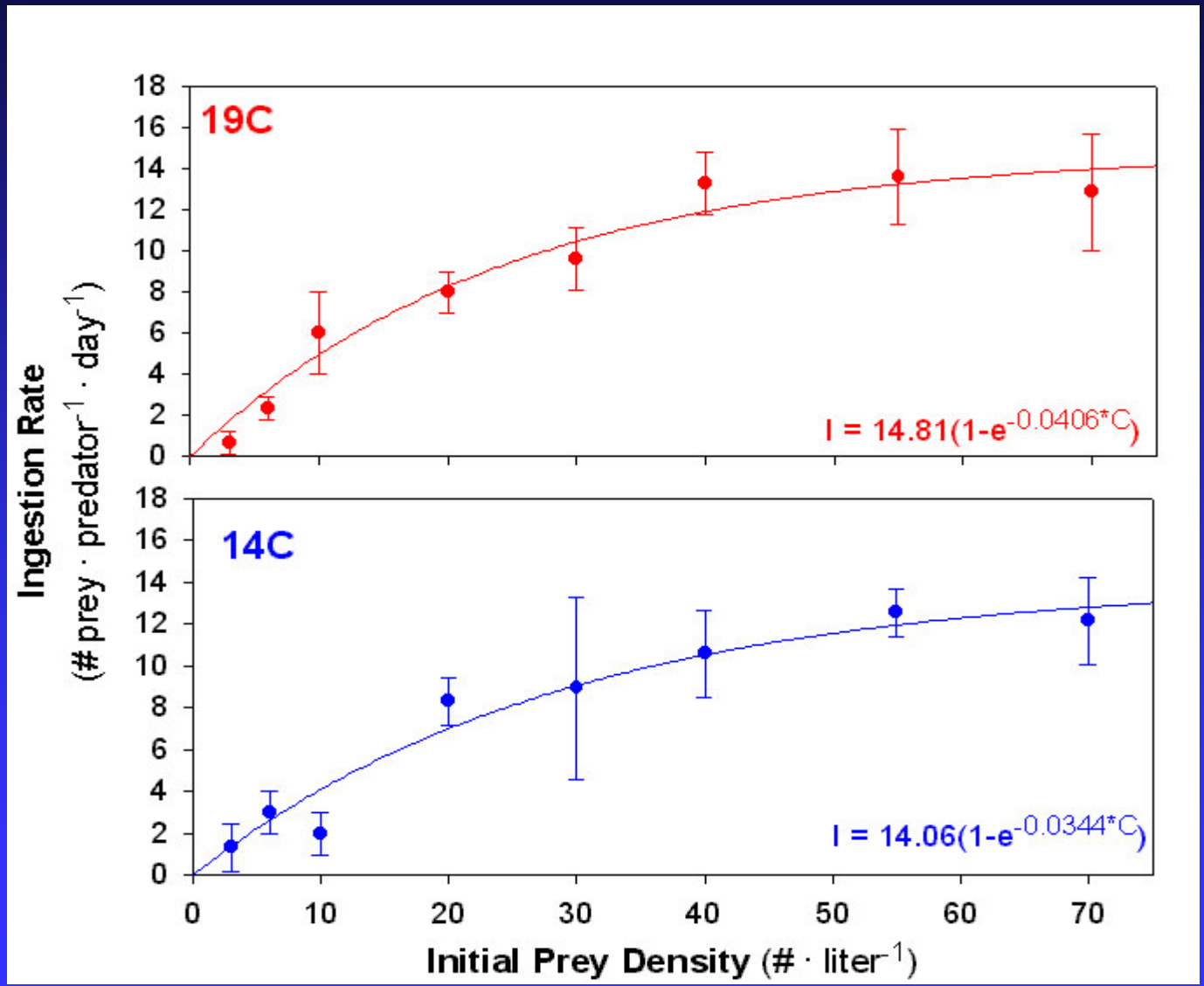
- 6 stations
- 6 months per year

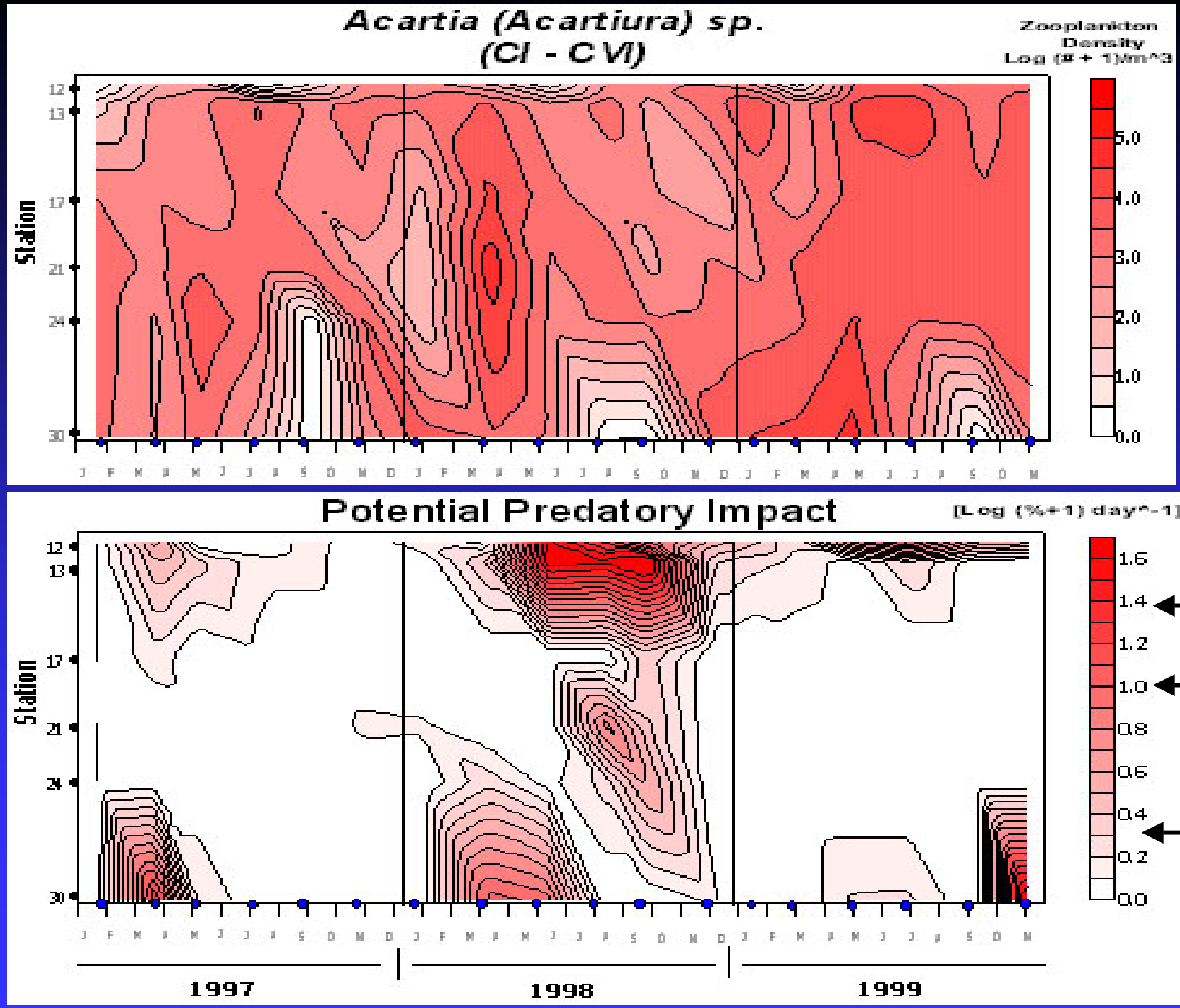
(n = 107)



T. dextrilobatus Functional Response

Acartia (Acartiura) sp. prey (PL = 785 μm)




Acartia (Acartiura) sp.
(CI - CVI)
Zooplankton
Density
Log (# + 1)/m^3
Station
12
13
17
21
24
30
5.0
4.0
3.0
2.0
1.0
0.0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Potential Predatory Impact
[Log (%+1) day^-1]
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
%
25
10
1
1997
1998
1999

Summary of Case Studies

Pseudodiaptomus inopinus

- First observed in the Northeast Pacific in 1990
- Broadly distributed in Washington and Oregon coastal river estuaries
- Abundant ($\leq$ 800 m^{-3}) in the low salinity zone (2-6 psu)
- Vertical distribution is closely associated with the bottom during the day
- Important prey item of the bentho-pelagic invertebrates, but not pelagic fishes, in the Chehalis River

Summary of Case Studies

Tortanus dextrilobatus

- First observed in San Francisco Bay in 1993
- Broadly distributed in San Francisco Bay
- Abundant ($\geq 10^4$ m^{-3}) in both North and South Bays
- Selects larger, native copepods over smaller, NIS copepods in preliminary experiments
- Is one of several other NIS copepods that have resulted in a dramatic change in community composition in SF Bay in last 20 yrs.
- Implications for higher trophic levels and ecosystem productivity currently unknown, but could be profound.