Interactions of multiple factors contribute to infestations of jellyfish

Jennifer E. Purcell

Western Washington University, USA
National Sun Yat-sen University, Taiwan, ROC

Co-authors:
Shin-ichi Uye, Hiroshima University, Japan
Wen-Tseng Lo, NSYSU, Taiwan, ROC
Casimir Rice, Watershed Prog, NOAA/NWFSC, USA

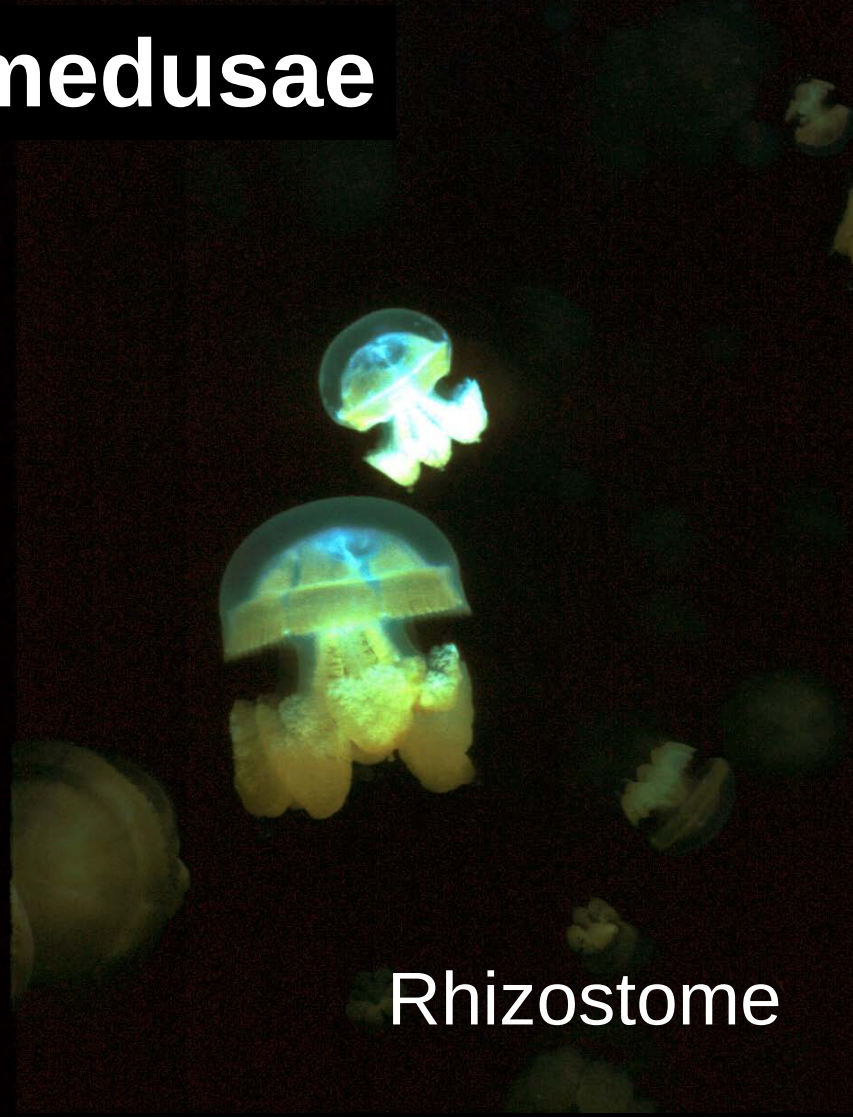
Why should we care about jellyfish?

- Important consumers of ichthyoplankton and zooplankton (both predators and competitors of fish)
- Great abundances interfere with fishing
- Clog power and desalination plant intakes
- Cause health concerns for swimmers, reduce tourism
- Generally detrimental to human enterprise, except for jellyfish fisheries

Scyphomedusae

Semaeostome

Coronate

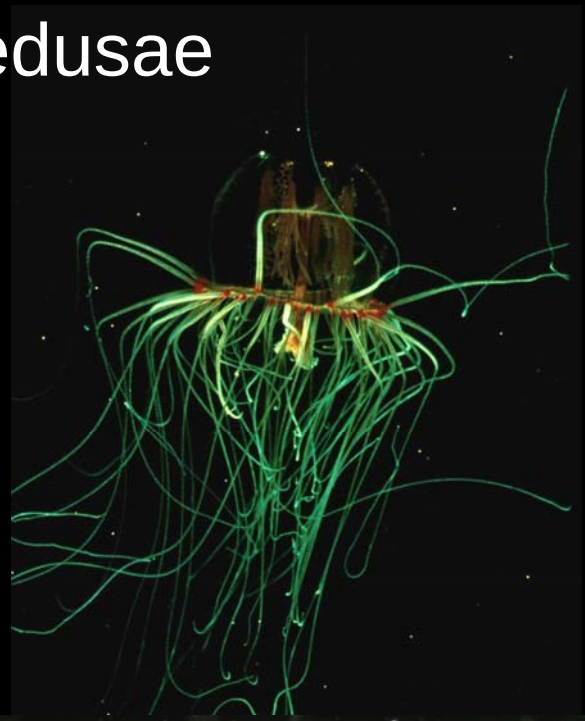


Rhizostome

Cubomedusae (box jellies)

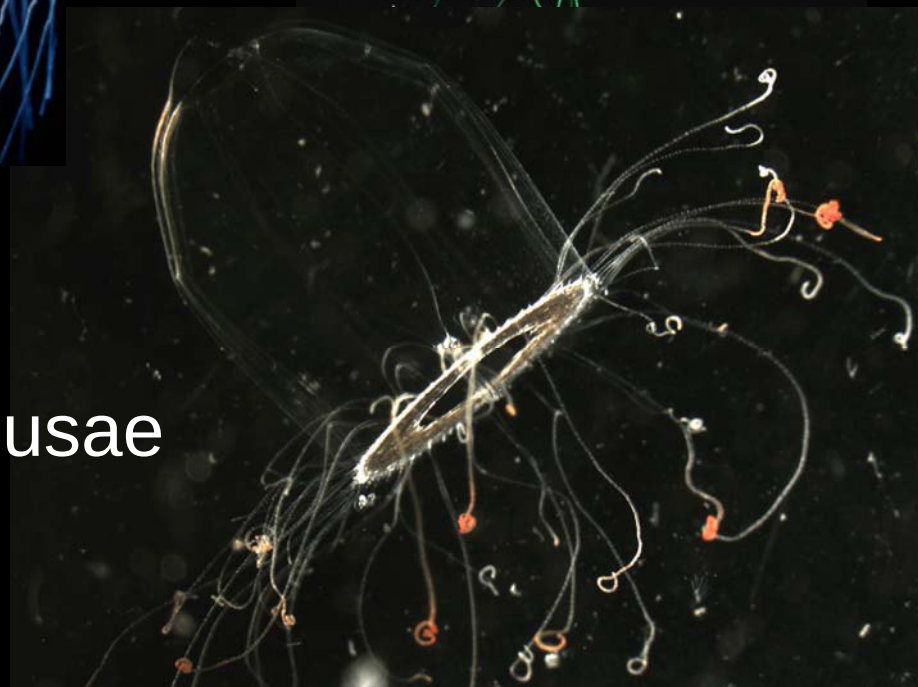
Hydromedusae

Anthomedusae



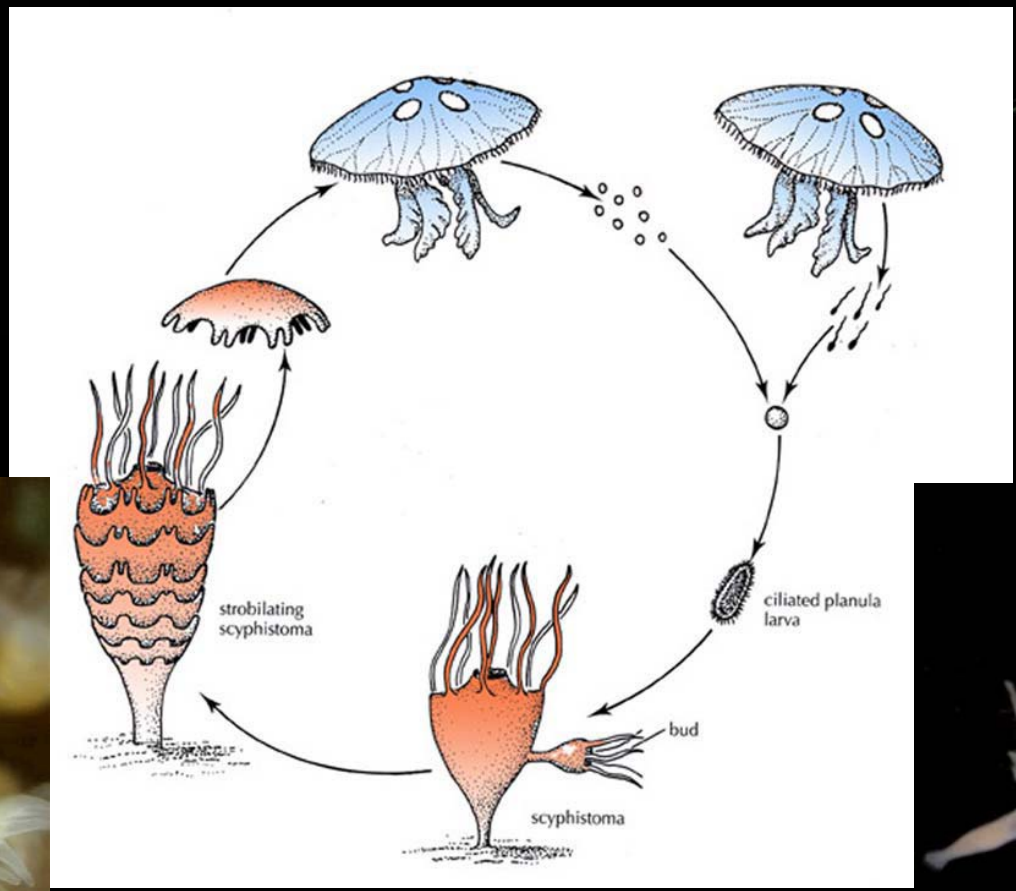
Leptomedusae

Trachymedusae



Jellyfish life cycle

ephyra



medusa

strobilation

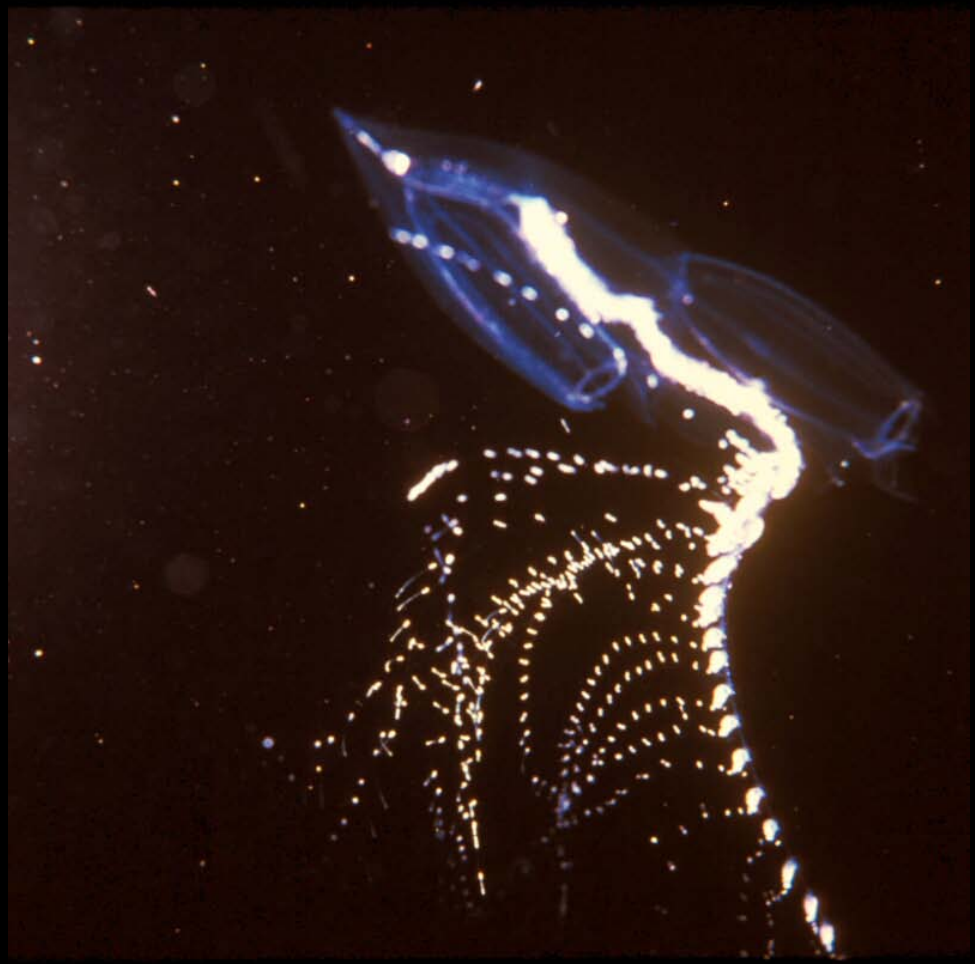
Polyp budding polyps

http://jellieszone.com/scyphomedusae.htm

Siphonophores

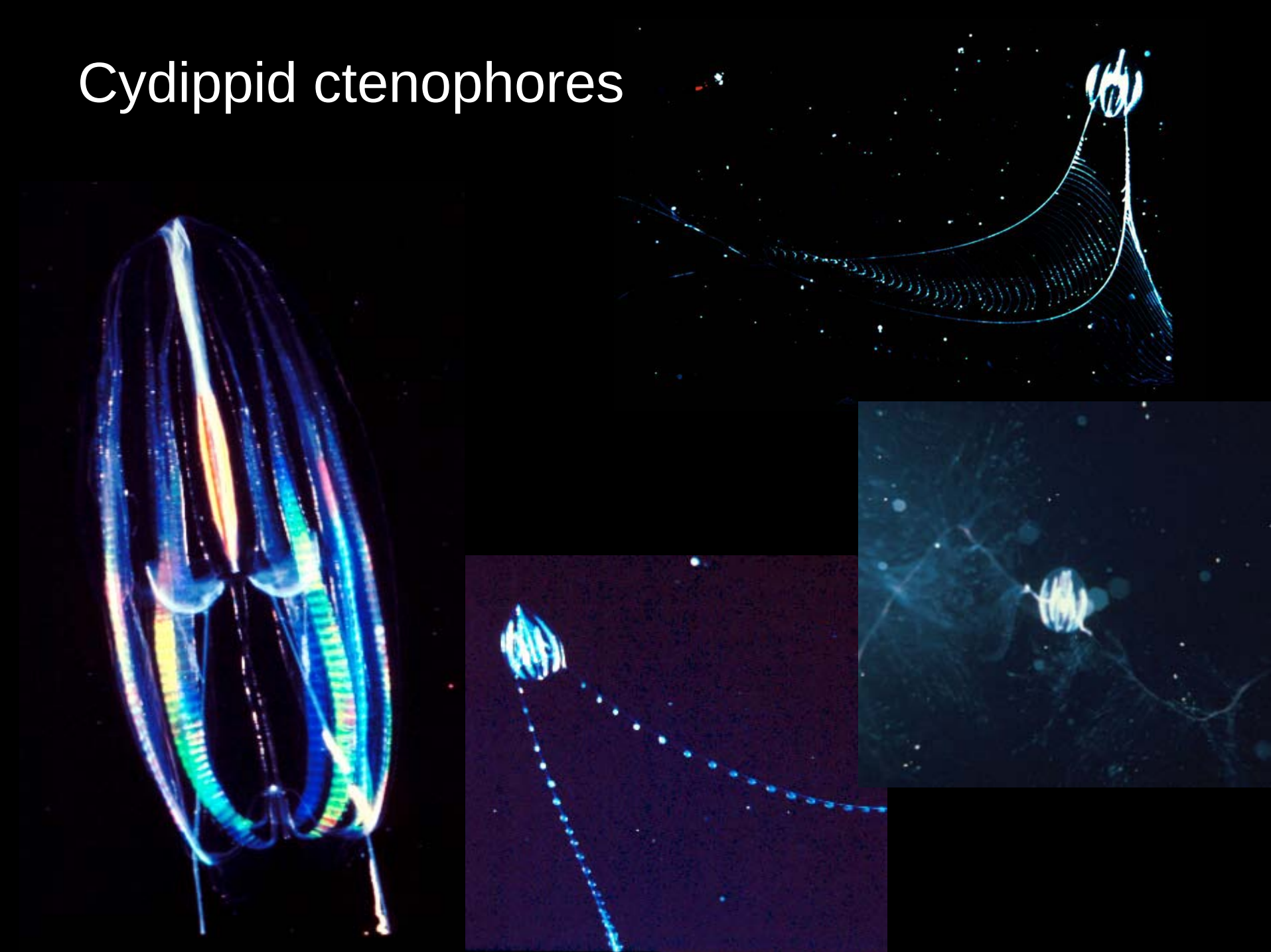
Cystonects

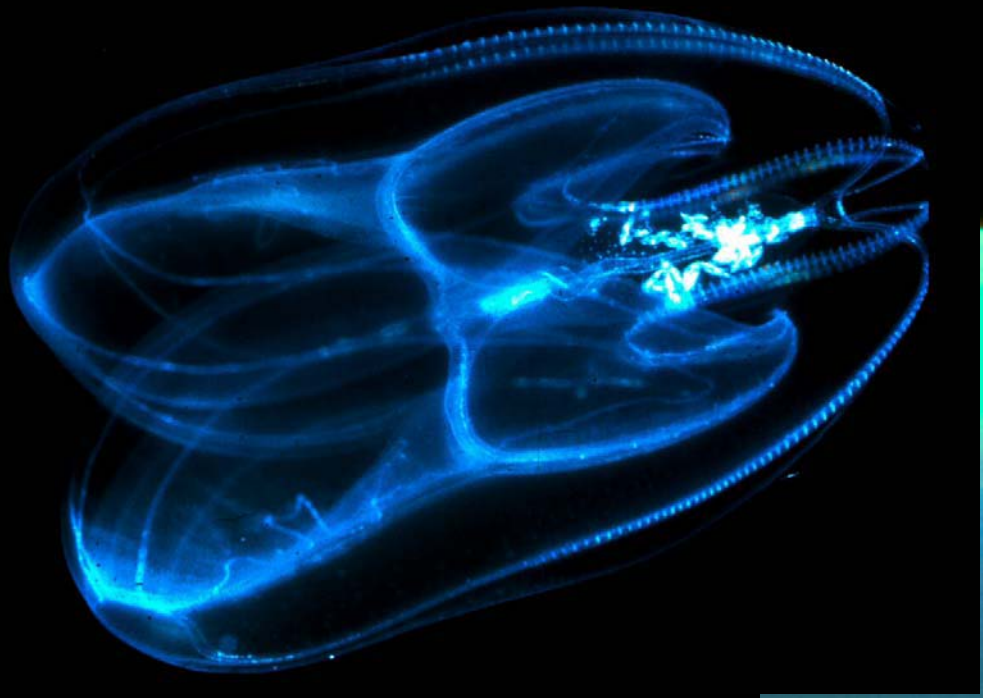
Calycophorans

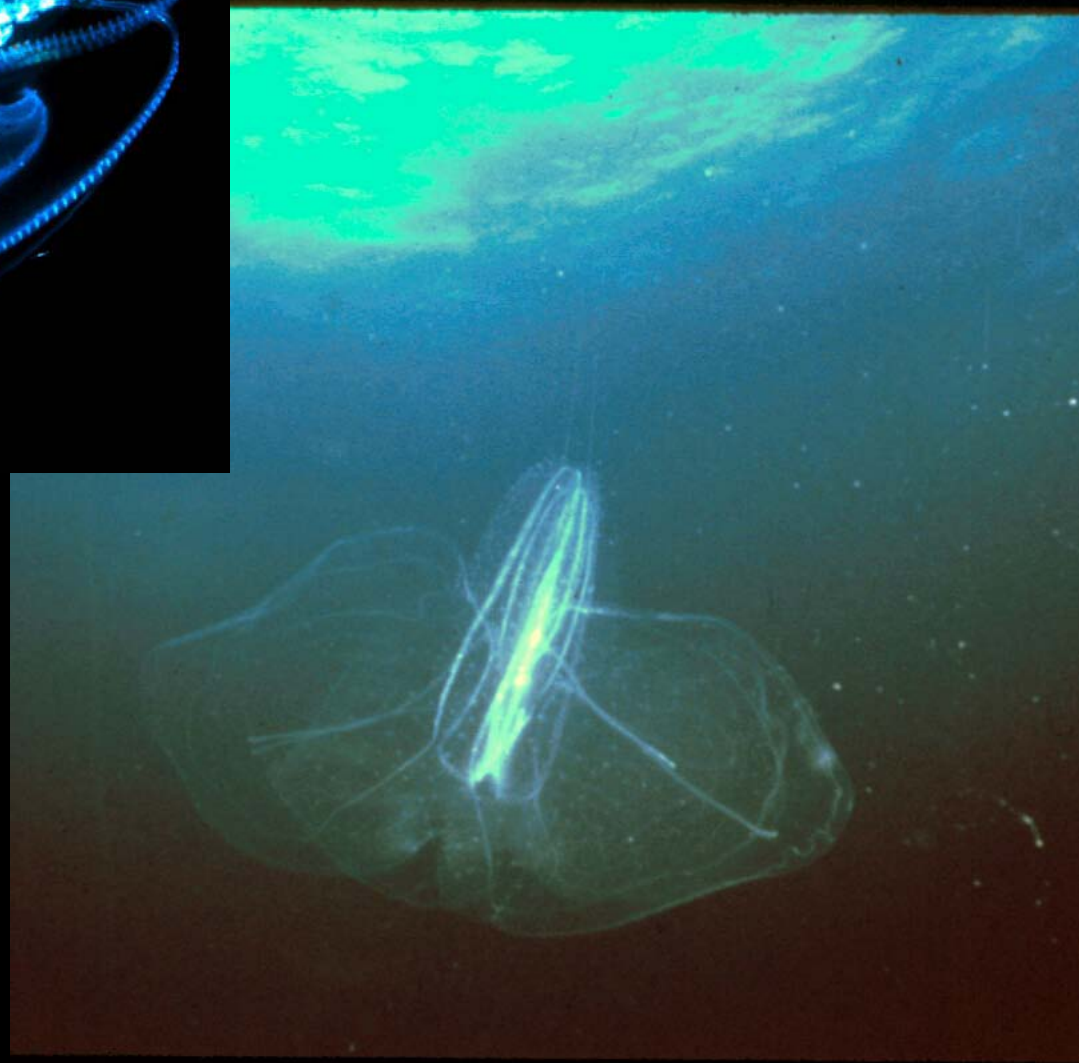


Physonects

Cydippid ctenophores







Lobate ctenophores

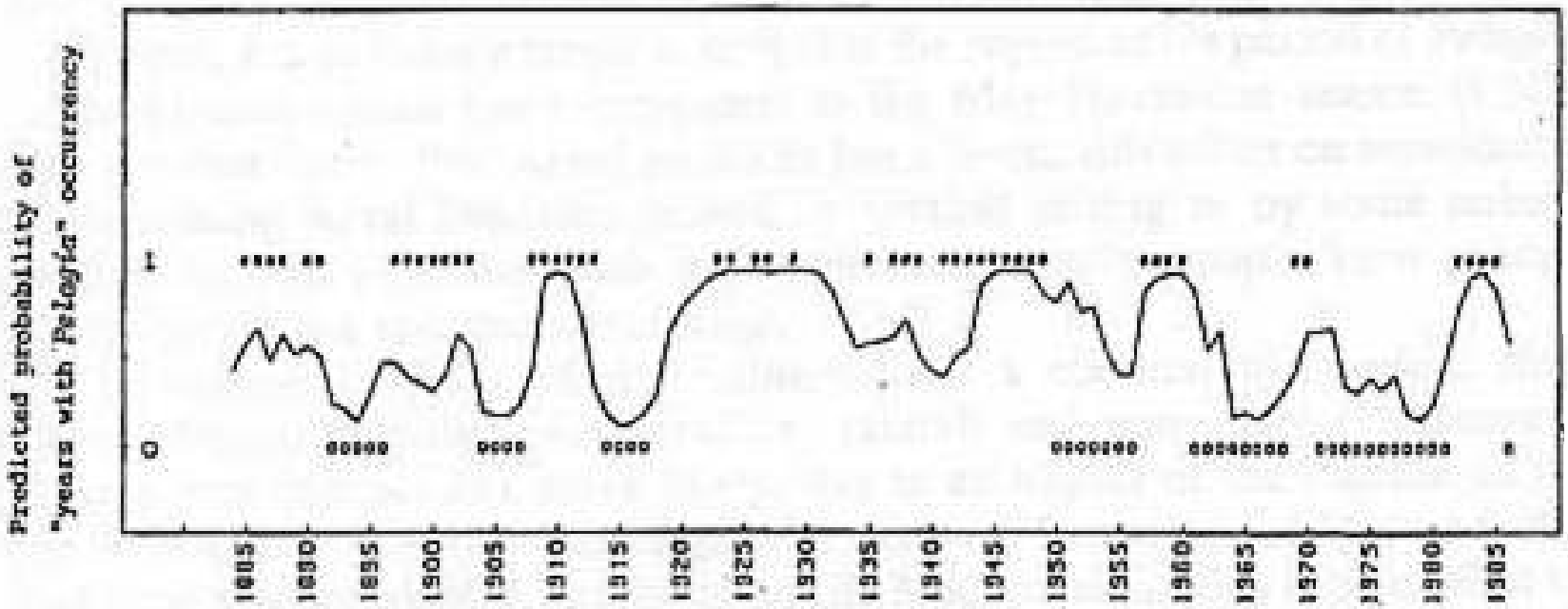
Possible causes of jellyfish increases

- Climate change
- Eutrophication
- Aquaculture
- Fishing
- Species introductions
- Multiple factors

Climate change

- **Directly affects jellyfish growth and reproduction rates**
- **Changes ocean productivity**

Pelagia noctiluca in the Mediterranean Sea 1805-1985 from Goy et al. (1989)



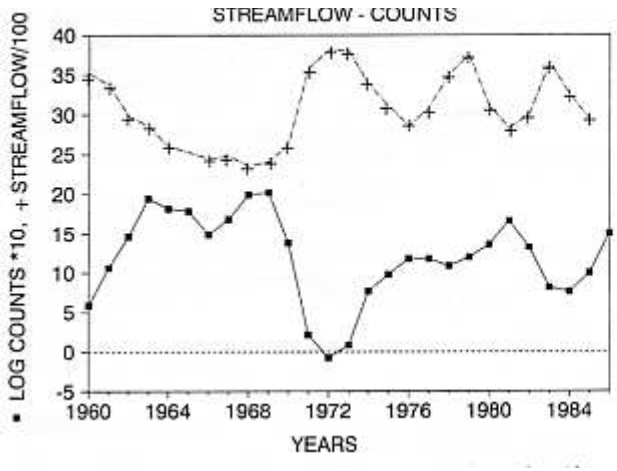
Years with

Years without

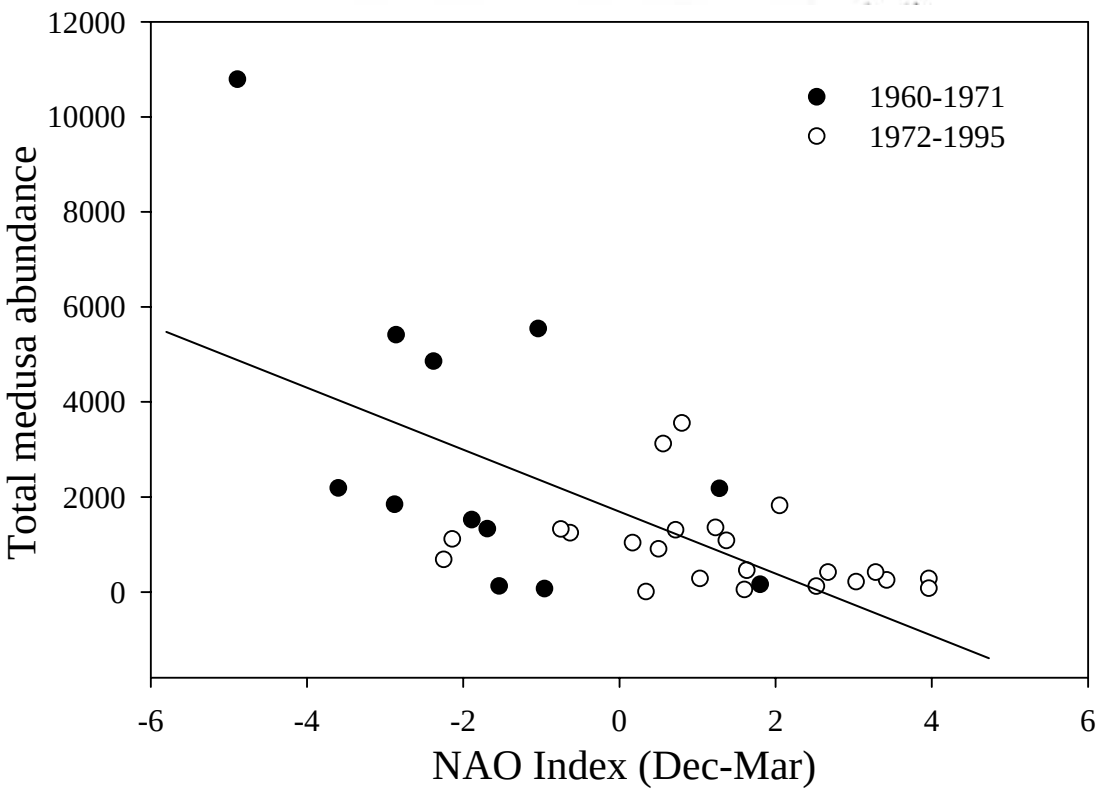
- Warm temperature
- Low rainfall
- High atmospheric pressure

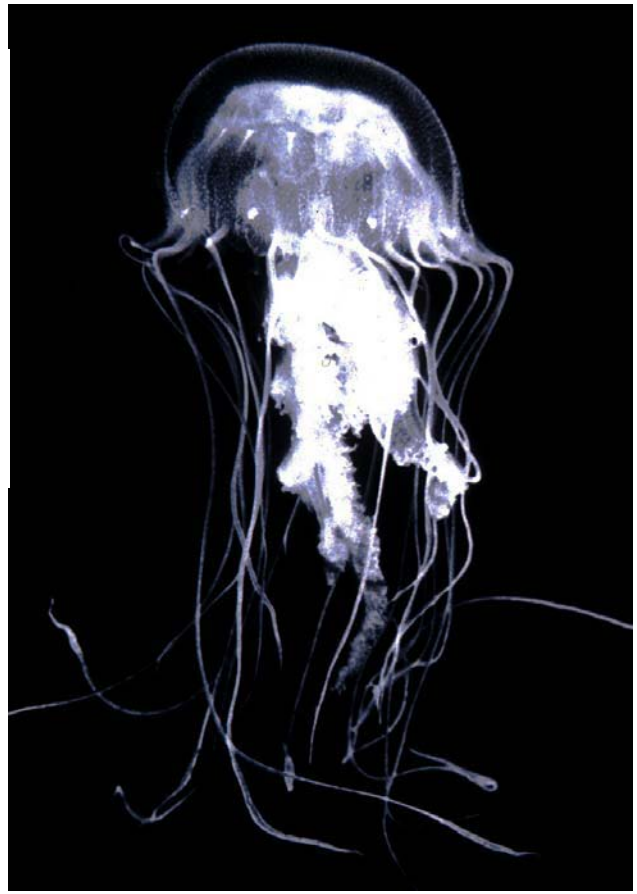
Chrysaora quinquecirrha in Chesapeake Bay 1960-1995

From Cargo & King (1991)



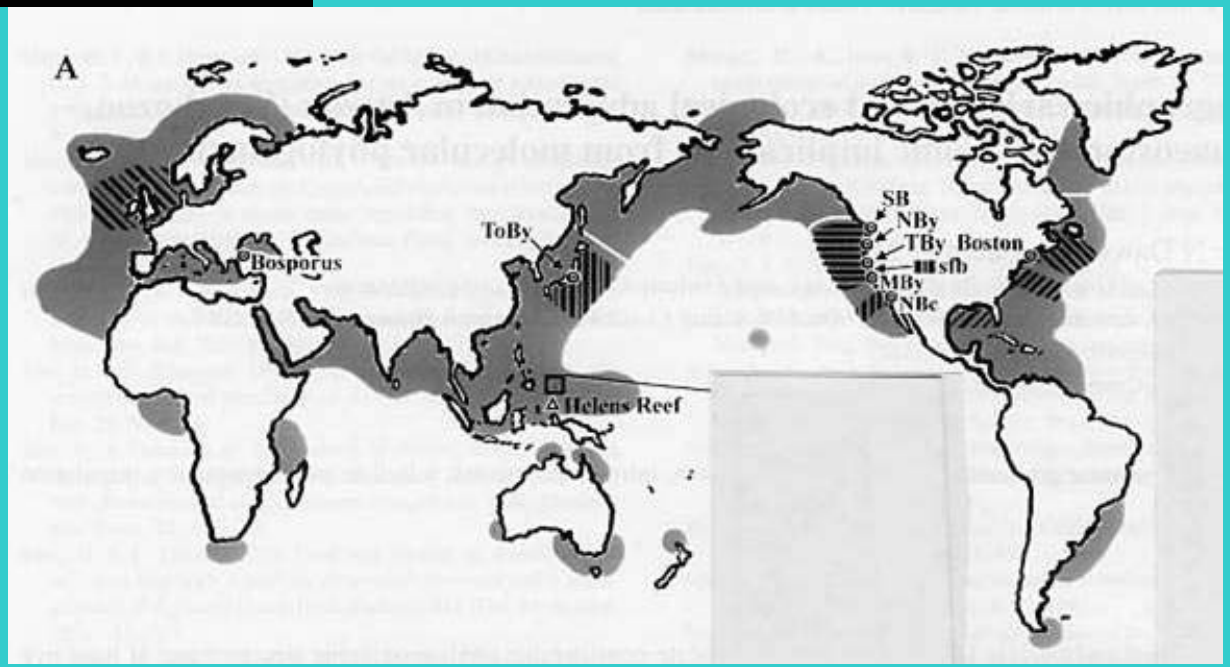
From Purcell & Decker (2005)





- Low Jan-Jun streamflow
- High salinity
- Warm May temperature
- Negative NAO index

Aurelia spp. around the world

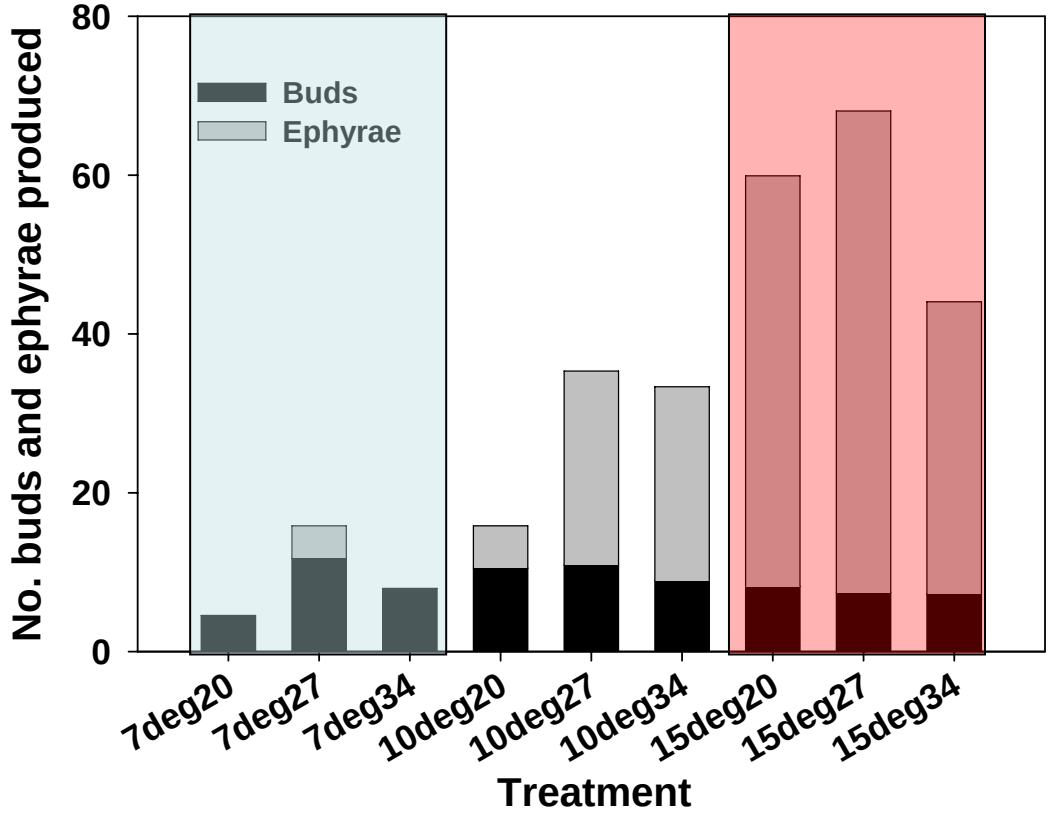


[map from Dawson & Martin (2001)]

Aurelia labiata
total polyp & ephyra production 104 d
7, 10, 15°C
Salinity 20, 27, 34
(n = 24)

Warm temperature increased number and proportion of jellyfish

Similar results for 2 other species



	Temp.	Salinity	Interaction
# Buds	<0.0001	<0.01	<0.001
# Ephyrae	<0.0001	NS	NS
Total	<0.0001	NS	NS
Ephy/total	<0.0001	<0.0001	<0.0001

Possible causes of jellyfish increases

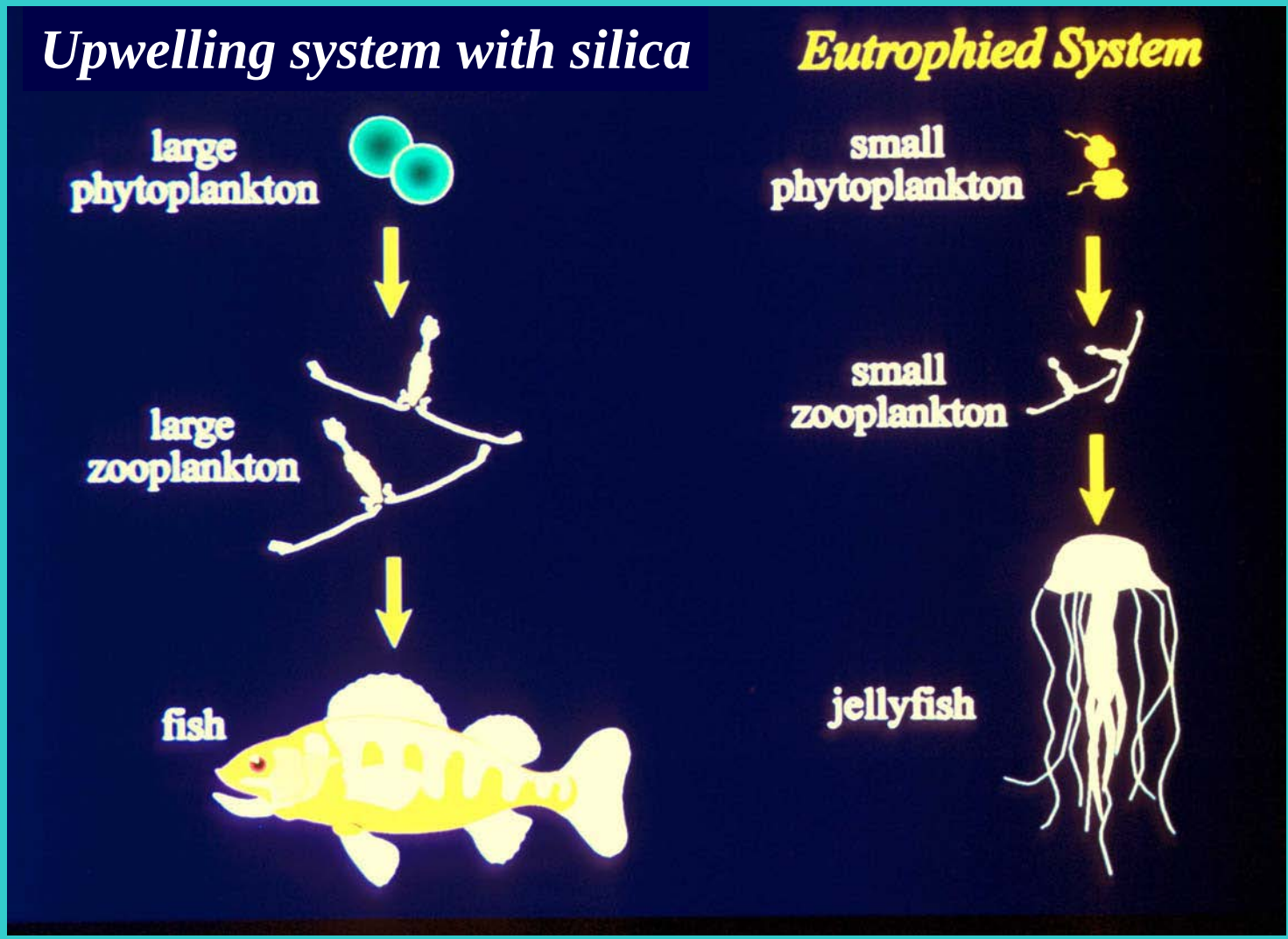
- Climate change
- Eutrophication

Eutrophication

- Increases food
- Changes food sizes
- Leads to hypoxia
- Reduces water clarity

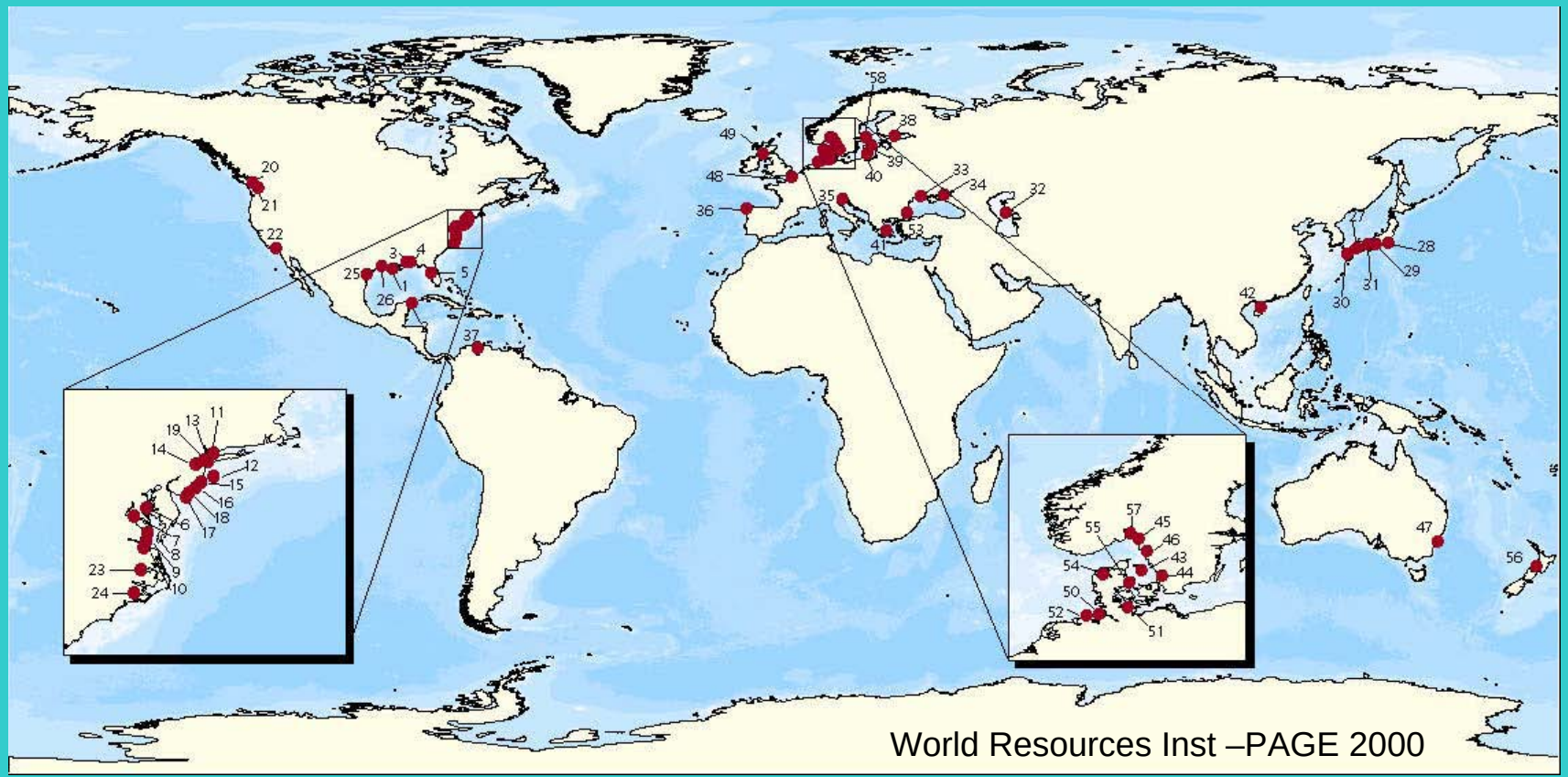
Eutrophication changes the food web structure

First proposed by Greve & Parsons, 1977; modified by Sommer et al. 2002



Hypoxia (low dissolved oxygen) occurs world-wide in coastal waters

- < 2-3 mg O_2 l^{-1} is considered hypoxic
- Fish avoid or die in waters of 2 mg O_2 l^{-1}



Jellyfish are more tolerant of hypoxia than fish

- ***Mnemiopsis*** **ctenophores live for > 72 h at 0.5 mg O_2 l^{-1}**
- ***Chrysaora quinquecirrha*** **medusae live > 96 h at 1 mg O_2 l^{-1}; their polyps can live and reproduce at 0.5 mg O_2 l^{-1}**
- **Several other jellyfish species are very tolerant of hypoxia (reviewed in Purcell et al. 2001; see Rutherford & Thuesen 2005)**

Eutrophication and development reduce water clarity

- Most fish are visual feeders and prefer larger prey; smaller foods in turbid water are poor for fish
- Jellyfish are non-visual feeders; small prey in turbid waters are OK

Evidence for jellyfish predominance in a Norwegian fjord with reduced water clarity (Eiane et al. 1999)

Possible causes of jellyfish increases

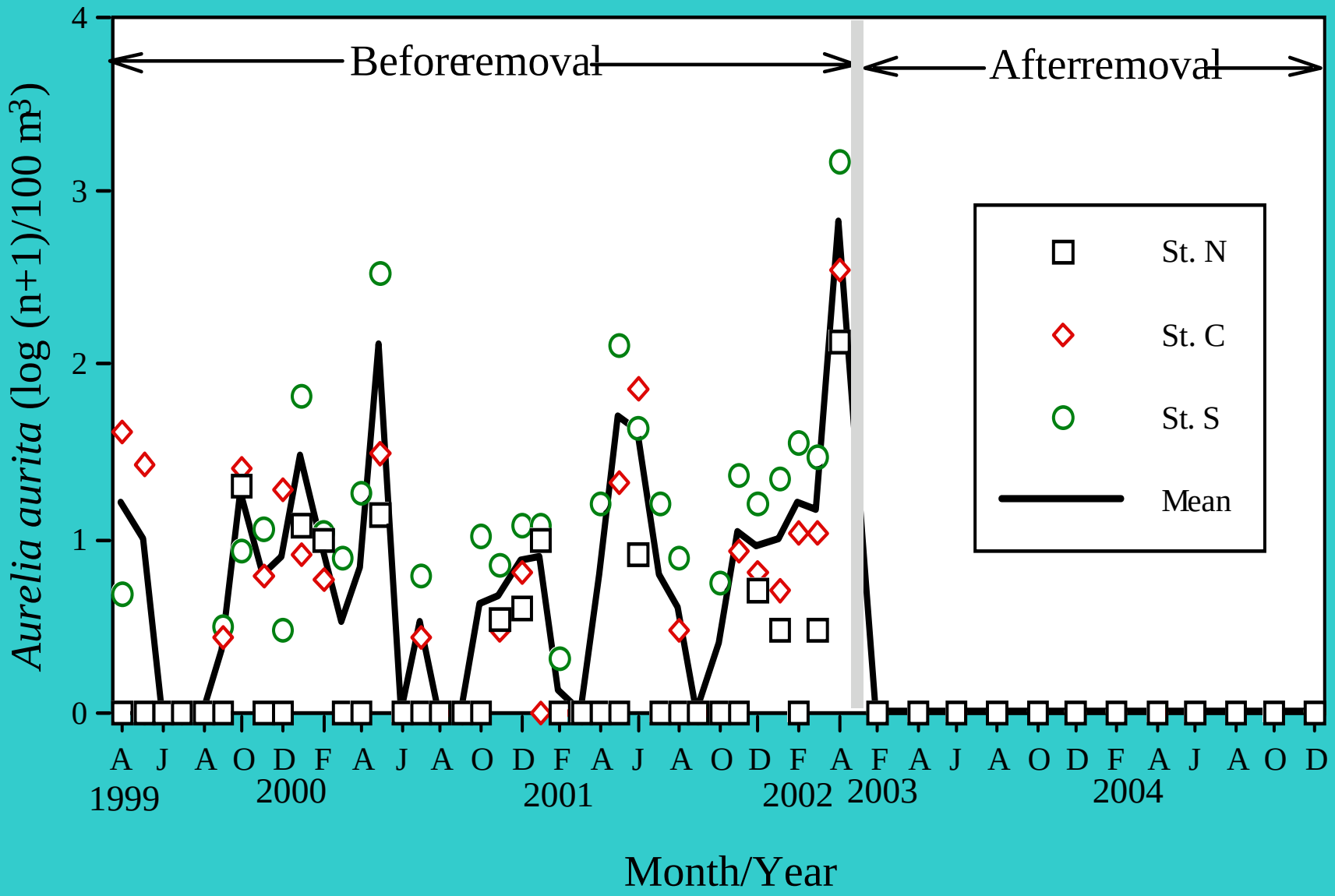
- Climate change
- Eutrophication
- Aquaculture

Aquaculture

- **Adds substrates for jellyfish polyps**
- **Adds foods**
- **Directly adds jellyfish**

Oyster racks in Tapong Bay, Taiwan before 2003 (Lo, unpubl.)

Jellyfish in Tapong Bay 1999-2005 before and after oyster pen removal (Lo, unpubl.)



Many different structures may add substrate for polyps and hydroids

- Aquaculture pens
- Docks and marinas
- Breakwaters
- Oil platforms
- Artificial reefs

Culture and release of edible jellyfish to increase fishery

- **Rhizostome jellyfish *Rhopilema esculenta* are reared and released**

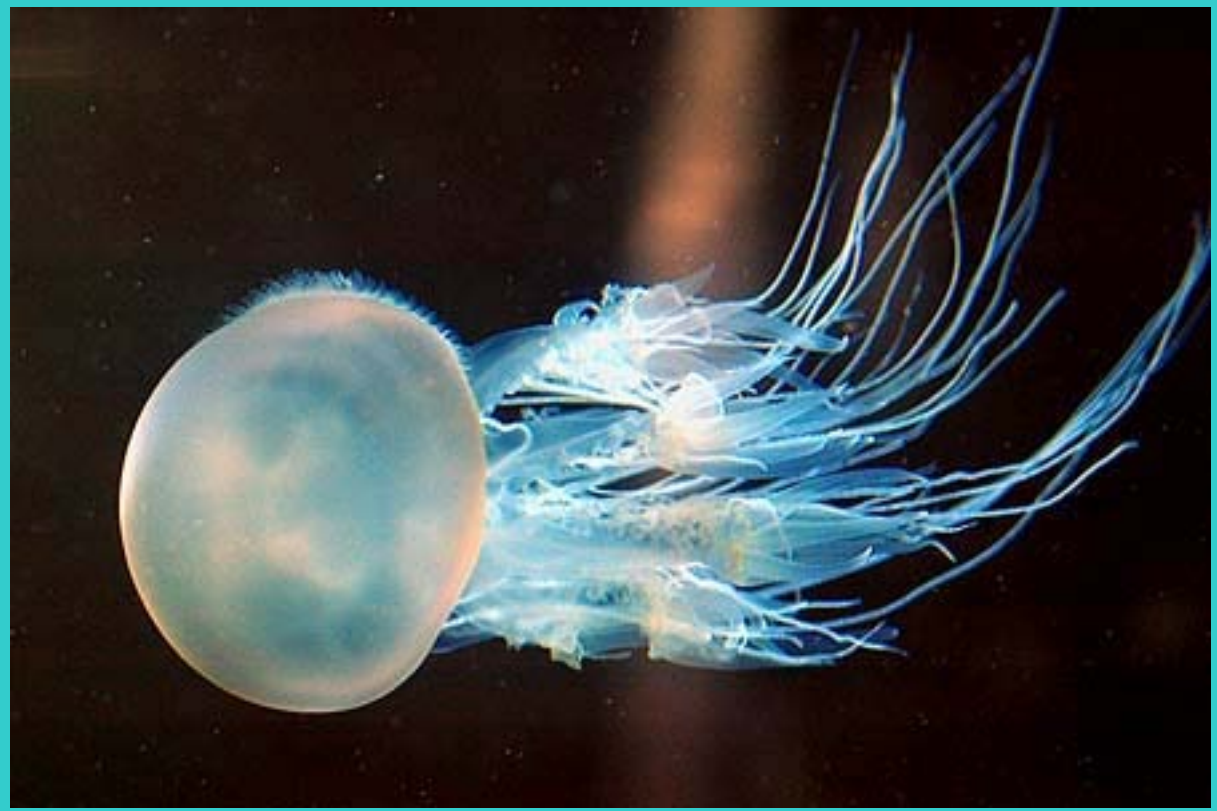


Photo: © Johnny Jensen

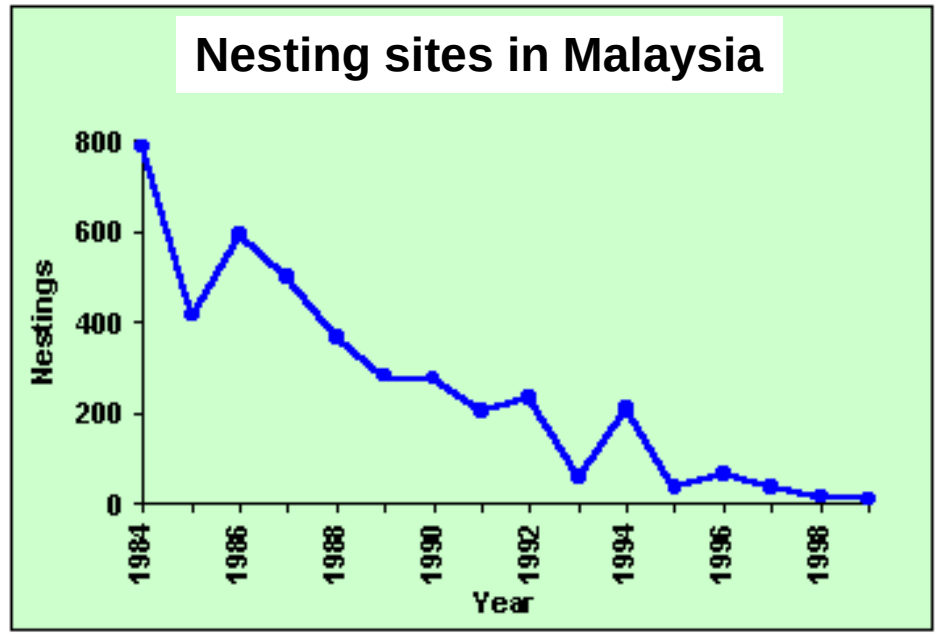
Possible causes of jellyfish increases

- Climate change
- Eutrophication
- Aquaculture
- Fishing

Fishing

- Removes predators of jellyfish
- Removes competitors of jellyfish
- Changes food web structure

Leatherback turtles are in severe decline in the Pacific, and eat jellyfish



http://www.seaturtlestatus.org/

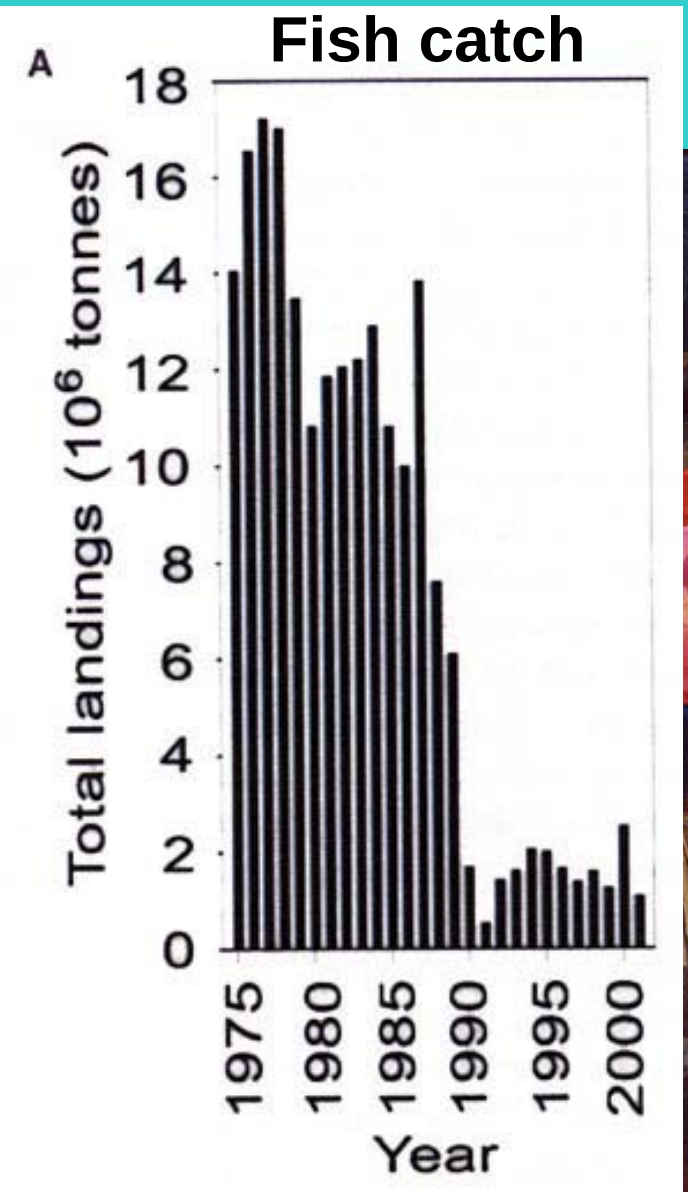
Turtle declines are due to

- Intentional harvest
- Fouling in fishing gear
- Collisions with ships
- Pollution

There are many other predators of jellyfish that may be reduced by fishing

- Other turtle species
- Many fishes, notably molas, chum and pink salmon, butterfish, mackerels, dogfish sharks
- Birds, such as parakeet auklets, albatrosses

Fishing reduced anchovy and sardines competitors for zooplankton in Namibian Benguela Current (Lynam et al. 2006)



2001

Chrysaora hysoscella

***Aequorea* sp.**

Possible causes of jellyfish increases

- Climate change
- Eutrophication
- Aquaculture
- Fishing
- Species introductions

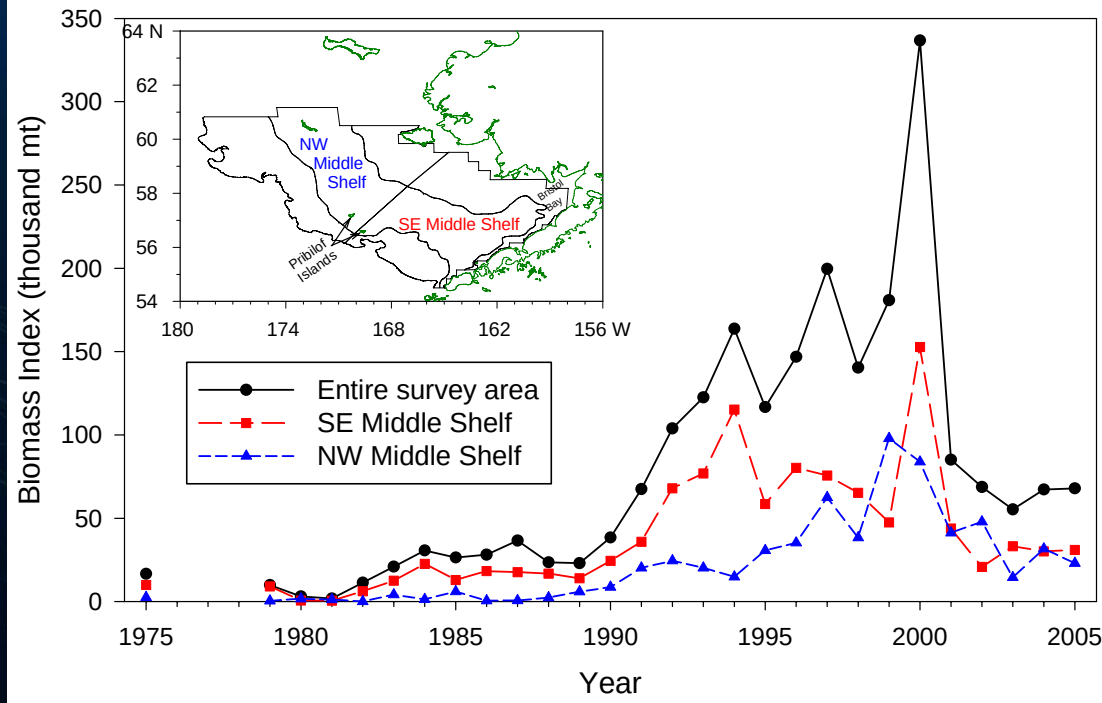
Species introductions

- **Several jellyfish species have been accidentally introduced around the world**
  - ***Craspidacusta sowerbii*** **-- freshwater jellyfish in all continents ex. Antarctica**
  - ***Moerisia lyonsi*****,** ***Blackfordia virginica, Maeotias inexspectata*** **– many estuaries in US**
  - ***Cordylophora caspia*** **– US Great Lakes**
  - ***Aurelia aurita*** **-- multiple introductions**
  - ***Rhopilema nomadica*** **–Mediterranean Sea**
  - ***Phyllorhiza punctata*** **– E. Pacific, SW Atlantic, Gulf of Mexico, Caribbean and Mediterranean seas**
  - ***Cassiopea andromeda*** **– Hawaii and other places**
  - ***Drymonema dalmatinum*** **– Gulf of Mexico**
  - **Ctenophores** ***Mnemiopsis leidyi & Beroe ovata*****– to Black Sea, spread to Azov, Mediterranean, and Caspian seas**

Possible causes of jellyfish increases

- Climate change
- Eutrophication
- Aquaculture
- Fishing
- Species introductions
- Multiple factors

Chrysaora melanaster in the SE Bering Sea 1975-2005 (from Brodeur et al. in press)



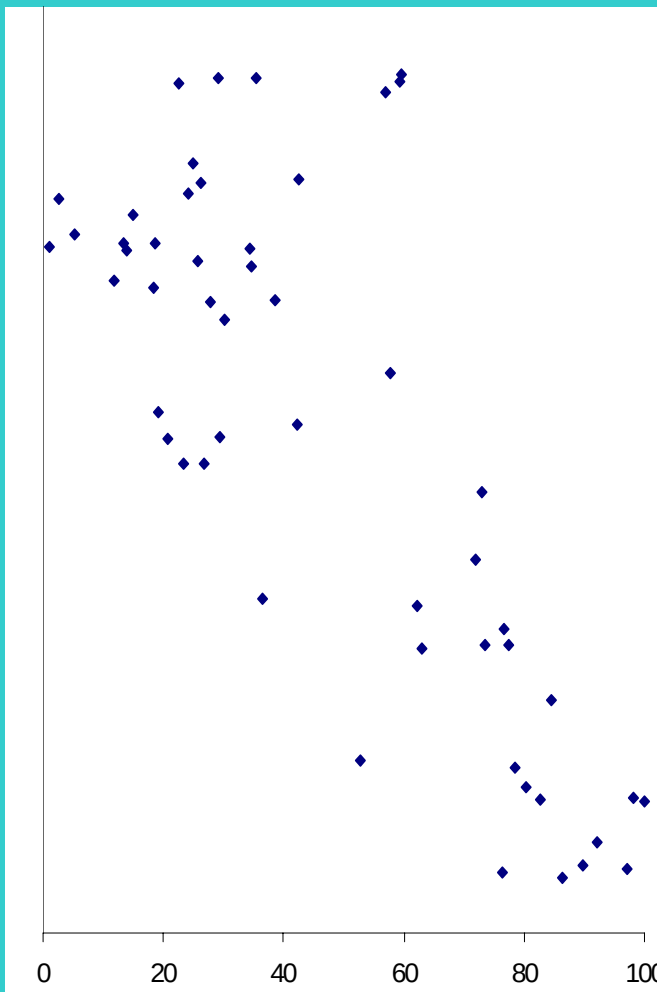
COOL WARM HOT

Favorable conditions for *C. melanaster* in the SE Bering Sea 1975-2005 (Brodeur et al. in press)

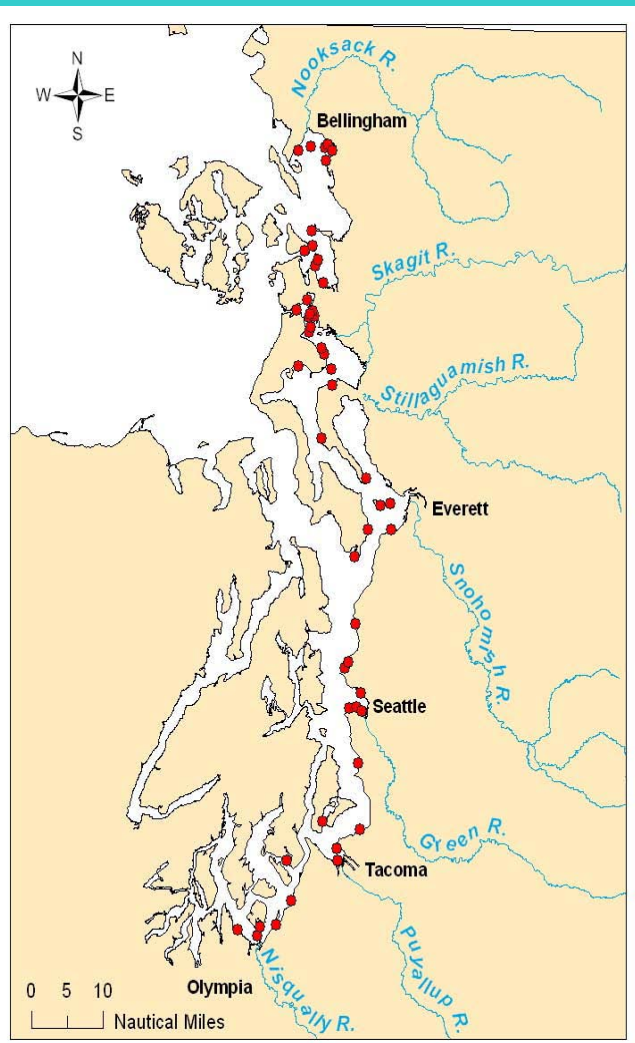
- Climate
  - Temperature (moderate)
  - Ice cover (moderate)
  - Mixing (low in spring)
  - Currents (low)
- Food web affects
  - Amount, timing, and size of food available (Late spring bloom, smaller copepods)
- Fishing
  - Competitor abundance—walleye pollock are heavily fished

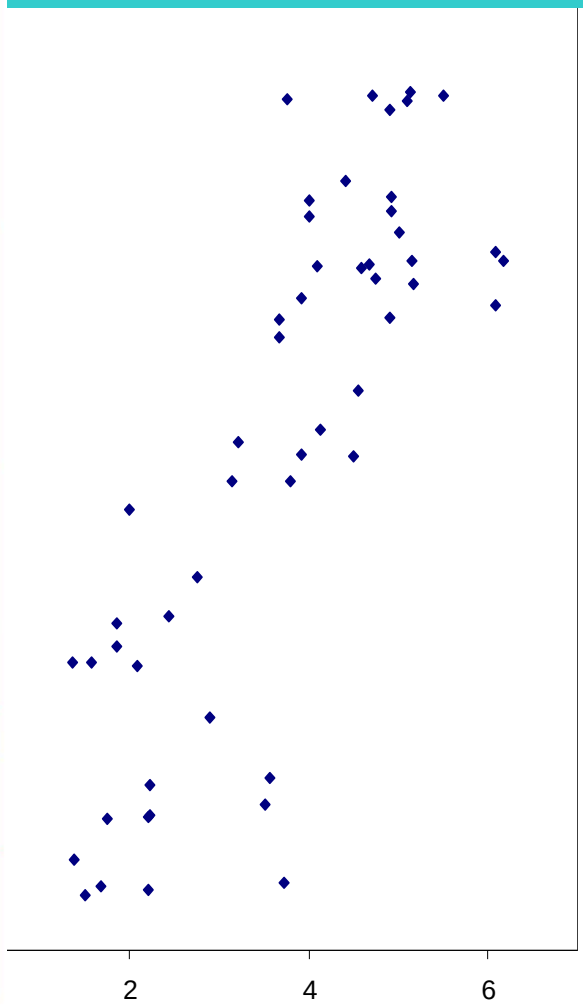
All factors affect polyps AND medusae

Fish and Jellyfish in Puget Sound, WA, USA, May- Sept 2003 (C. Rice, unpubl.)



Mean % Jellies





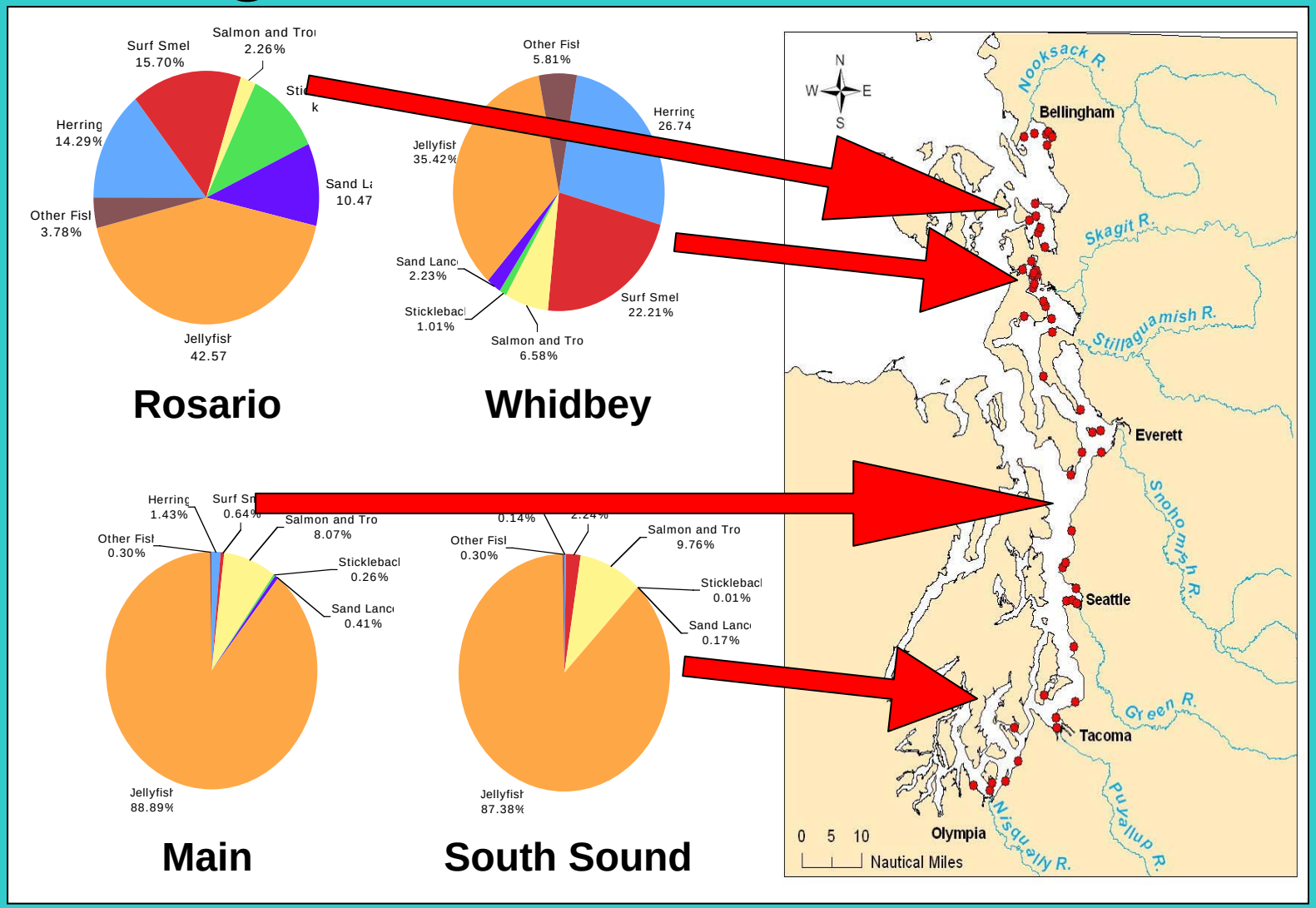
Fish Species Richness

Puget Sound coastline

North
Bellingham

South
Seattle

Fish and jellyfish biomass in Puget Sound (May – September 2003)



Possible factors affecting fish and jellyfish in Puget Sound, WA, USA (C. Rice unpubl.)

- Climate?
- Eutrophication and development
  - Greater in south, favor jellies (high nutrients, low oxygen, reduced water clarity)
- Fishing?
- Aquaculture?
  - Greater in south, more chum salmon predators, and other competitors

Factors affect polyps and medusae

What does this mean for the future?

• Climate change	• Increasing
• Eutrophication	• Increasing
• Aquaculture	• Increasing
• Fishing	• Increasing
• Species introductions	• Increasing
• Multiple factors	• Increasing

Will jellyfish populations increase?

If they do, is that a problem?

Human problems with jellyfish

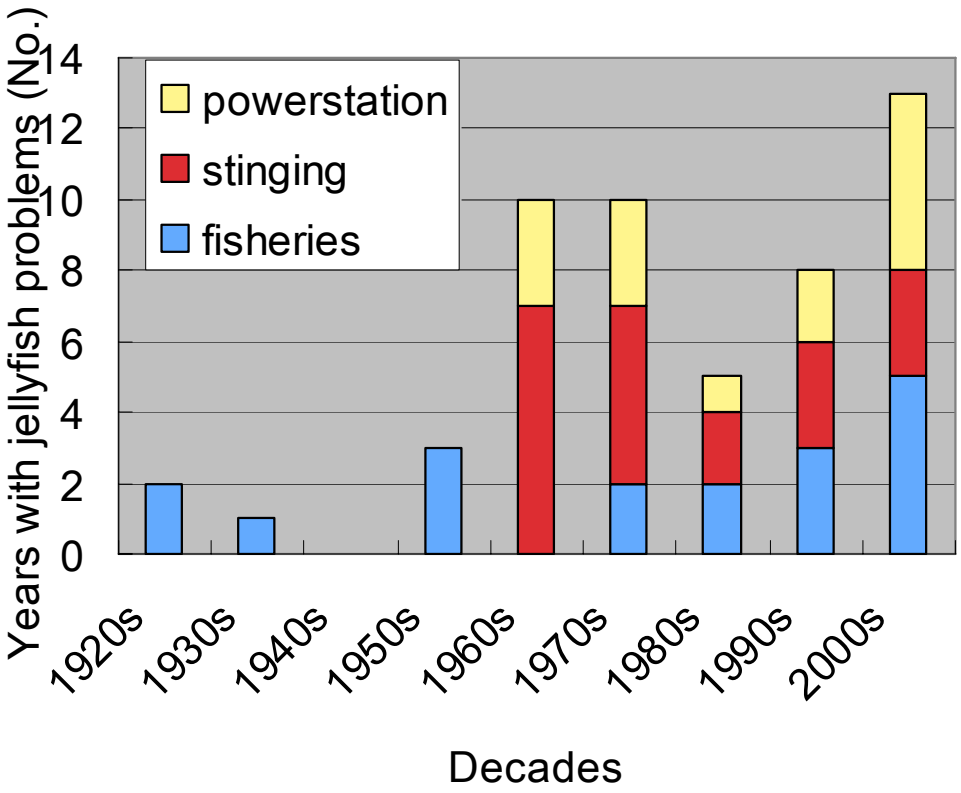
- Interfere with fishing – clog nets, ruin catch
- Kill fish in aquaculture pens
- Clog intake screens of power and desalination plants causing shutdowns
- Sting swimmers and fishermen

Are jellyfish populations increasing?

Aurelia aurita

(Monterey Bay Aquarium)

Problems with jellyfish in Japan (Uye, unpubl.)



Nemopilema normuri (Natl Geogr)

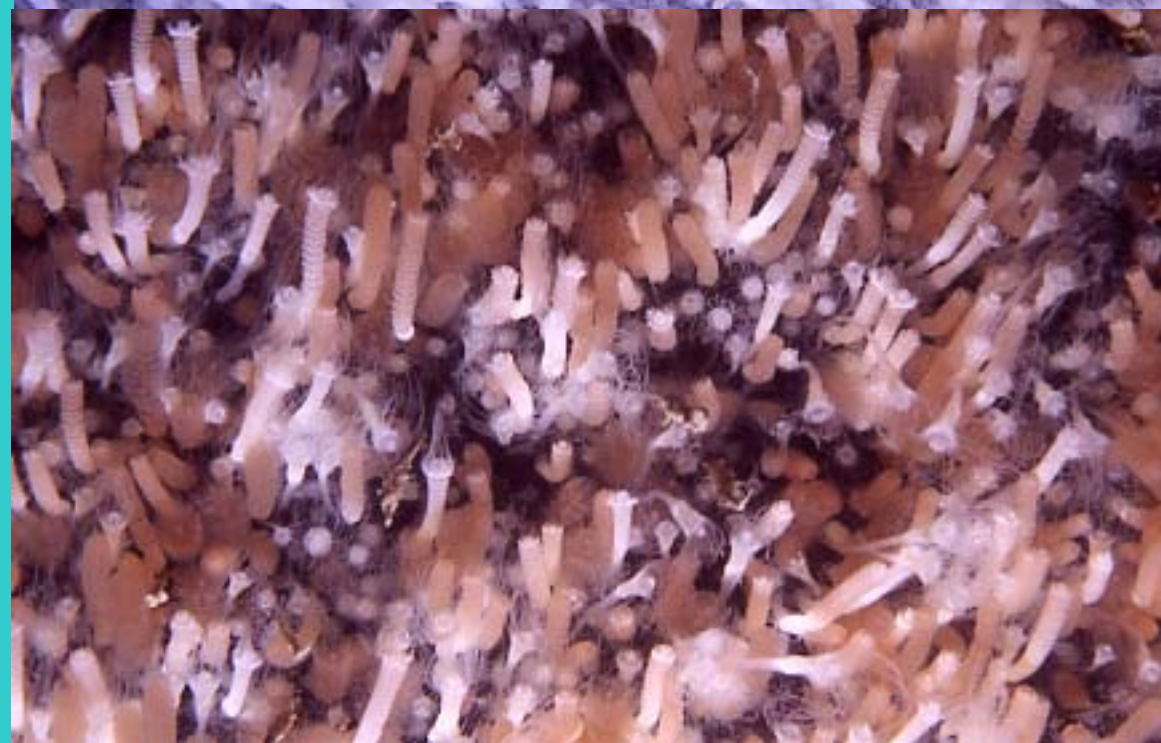
Fisheries catches of the future?

17 Jan 04

Aurelia labiata
10 polyps cm^{-2}

17 Feb 04

13.4 disks $polyp^{-1}$
est. 4,550 ephyrae



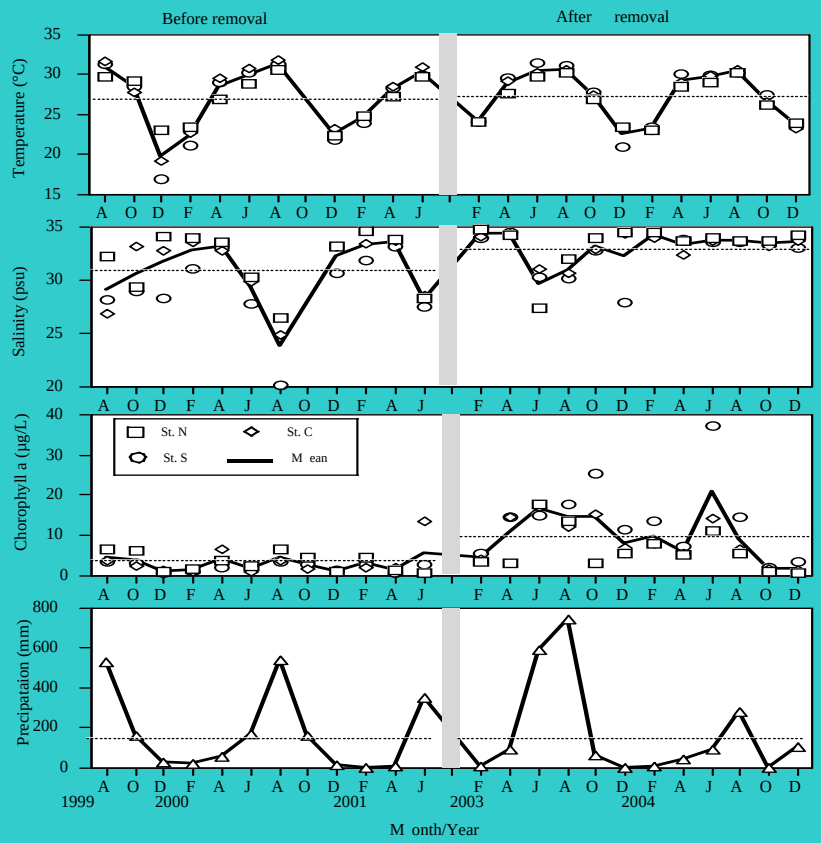


Fig.2. Seasonal changes of Temperature, Salinity, chlorophyll a and precipitation in Tapong Bay before and after the removal of oyster culture pens. Dashed lines indicate annual means.

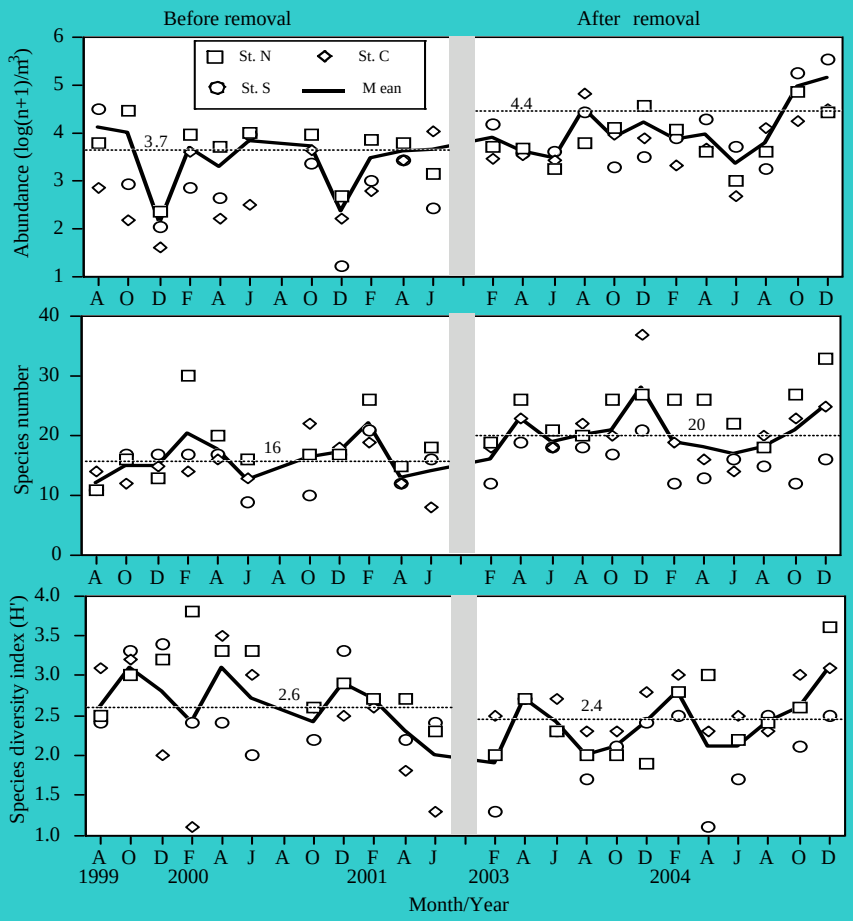


Fig.3. Seasonal changes in numerical abundance, species number and diversity of copepods in Tapong Bay before and after the removal of oyster culture pens. Dashed lines indicate annual means.

Beroid ctenophores