Jellyfish and ctenophore blooms coincide with human proliferations and environmental perturbations

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Human problems with jellyfish

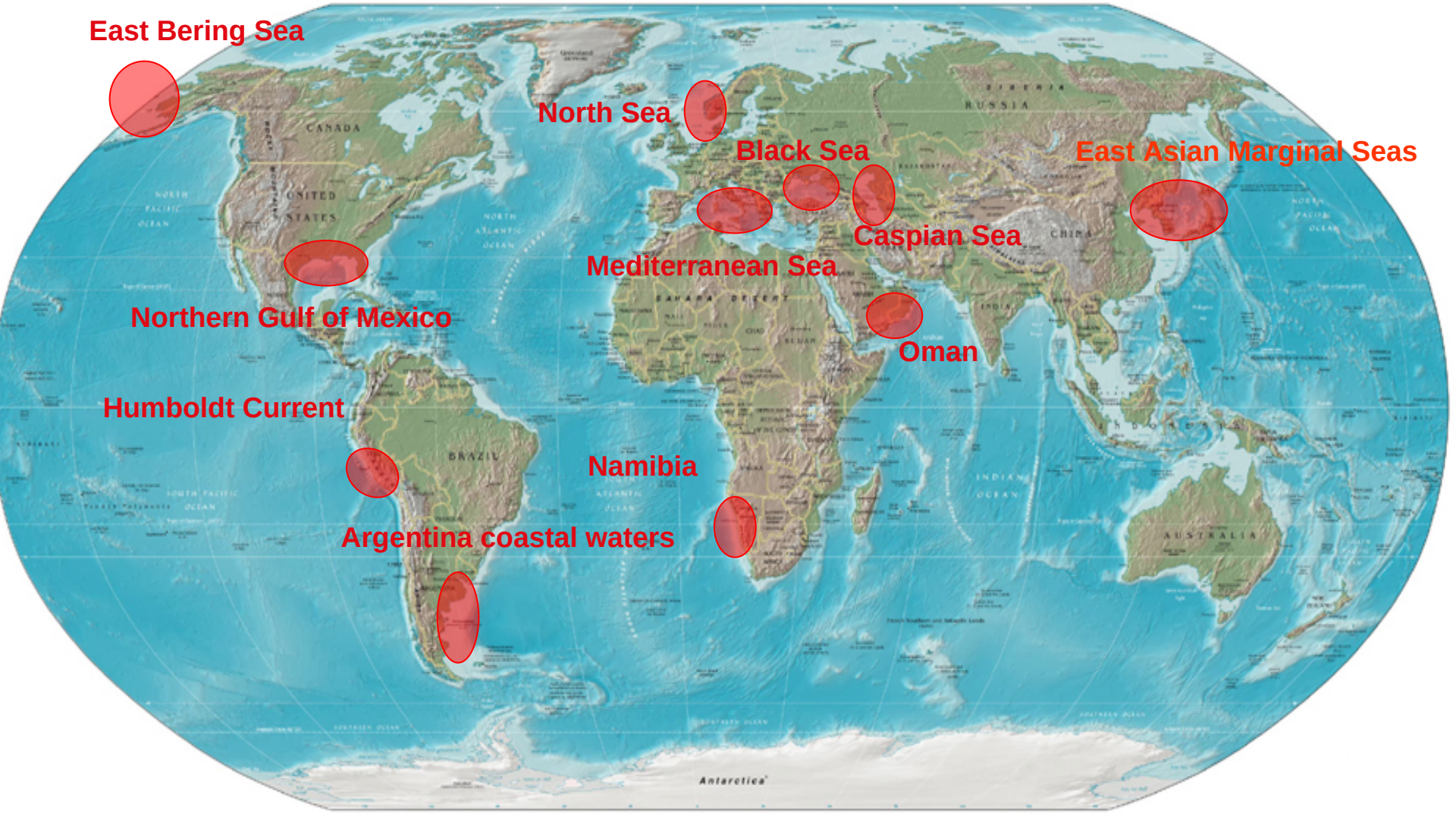
- **Stinging – health + reduced tourism**

Many effects on fish

- **Interfere with fishing – clog nets, ruin and reduce fish catches**
- **Kill fish in aquaculture pens**
- **Predators and competitors of fish**

- **Clog intake screens of power and desalination plants causing shutdowns (Israel and Scotland 2011)**

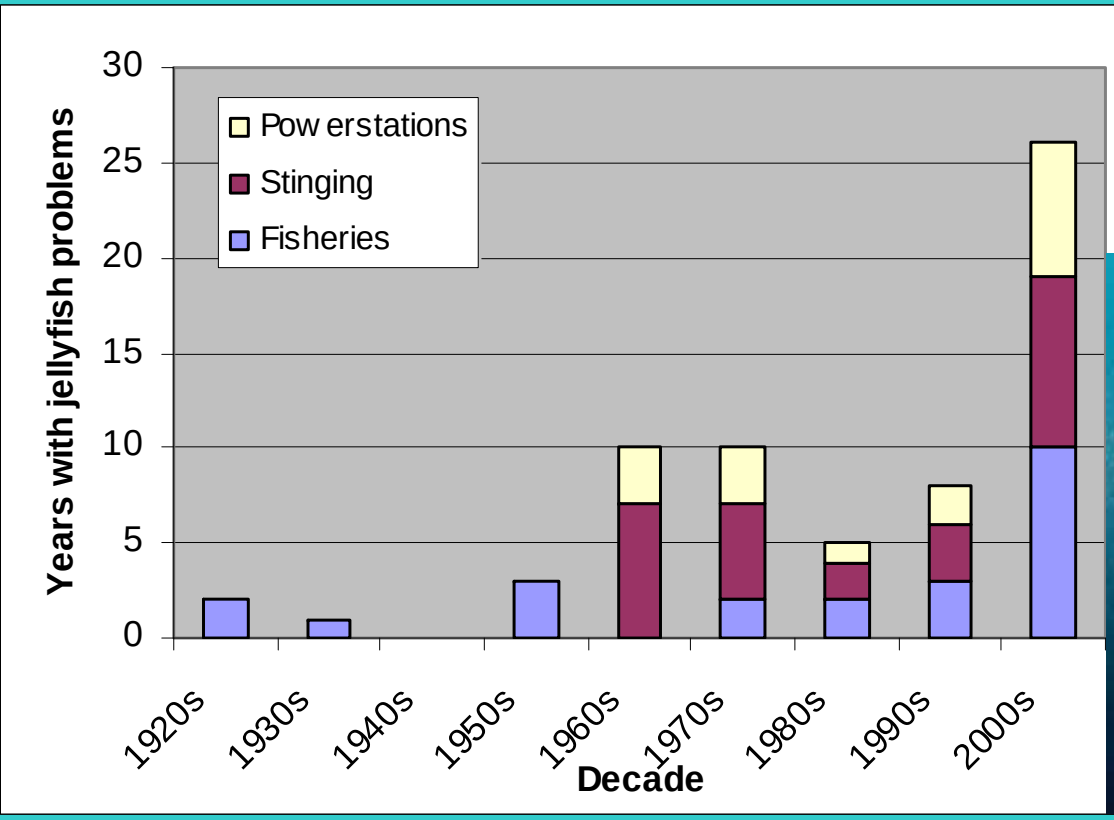
Recent jellyfish blooms worldwide



Problems with jellyfish are increasing

(Purcell et al. 2007; Purcell 2011)

Japan



Aurelia aurita

(@ Monterey Bay Aquarium)

Nemopilema normuri (@ Natl Geogr)

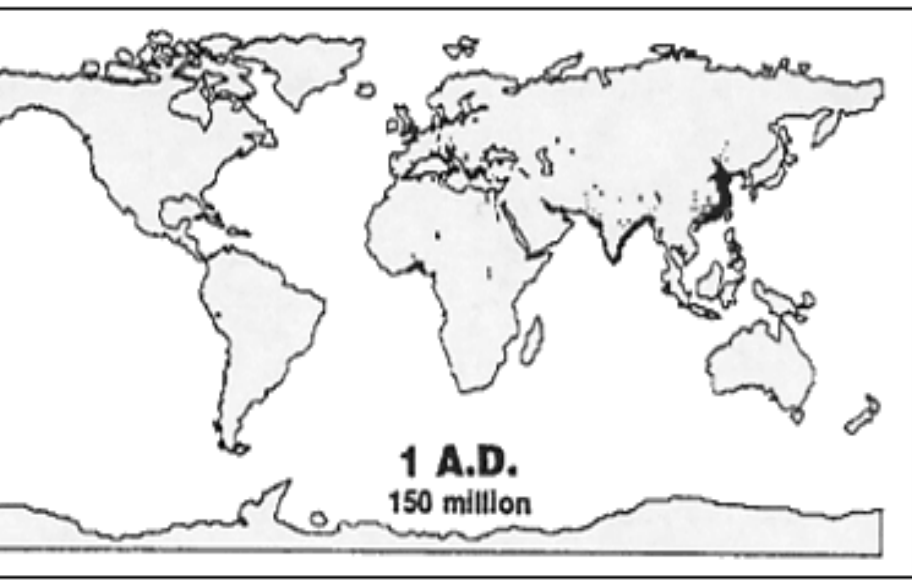
Possible causes of jellyfish increases

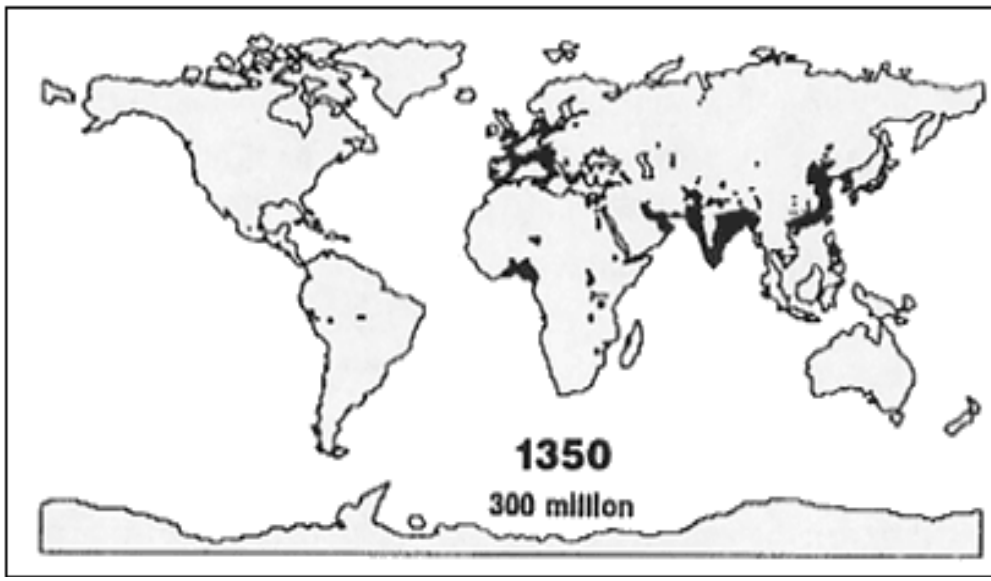
- Fishing – removes predators + competitors
- Eutrophication – high nutrients, low silica, flagellate-based food web; hypoxia
- Climate change – warming etc.
- Species introductions
- Aquaculture – habitat and nutrients added

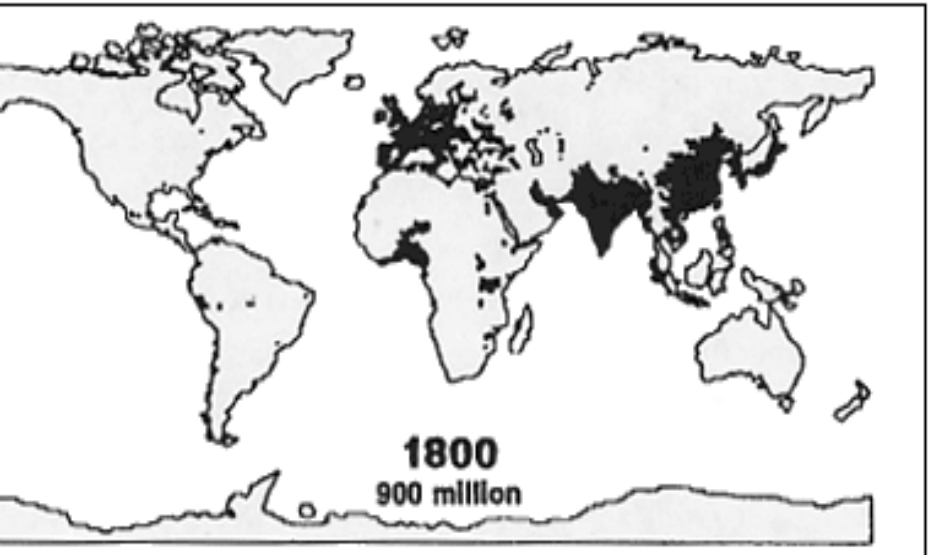
Examine the evidence that problems with jellyfish have occurred where the most humans have lived for the longest time

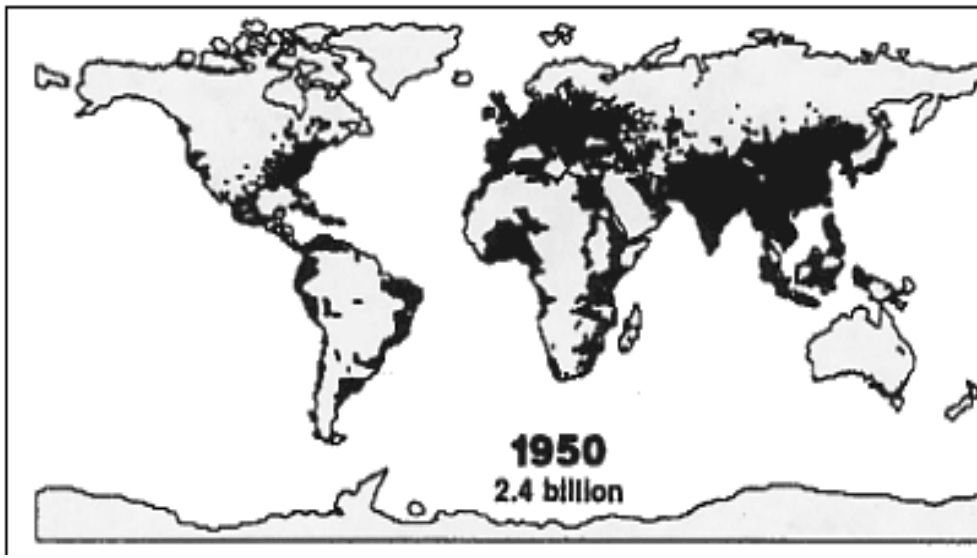
Human population growth (Tanton 1995)

each dot = 1 million humans



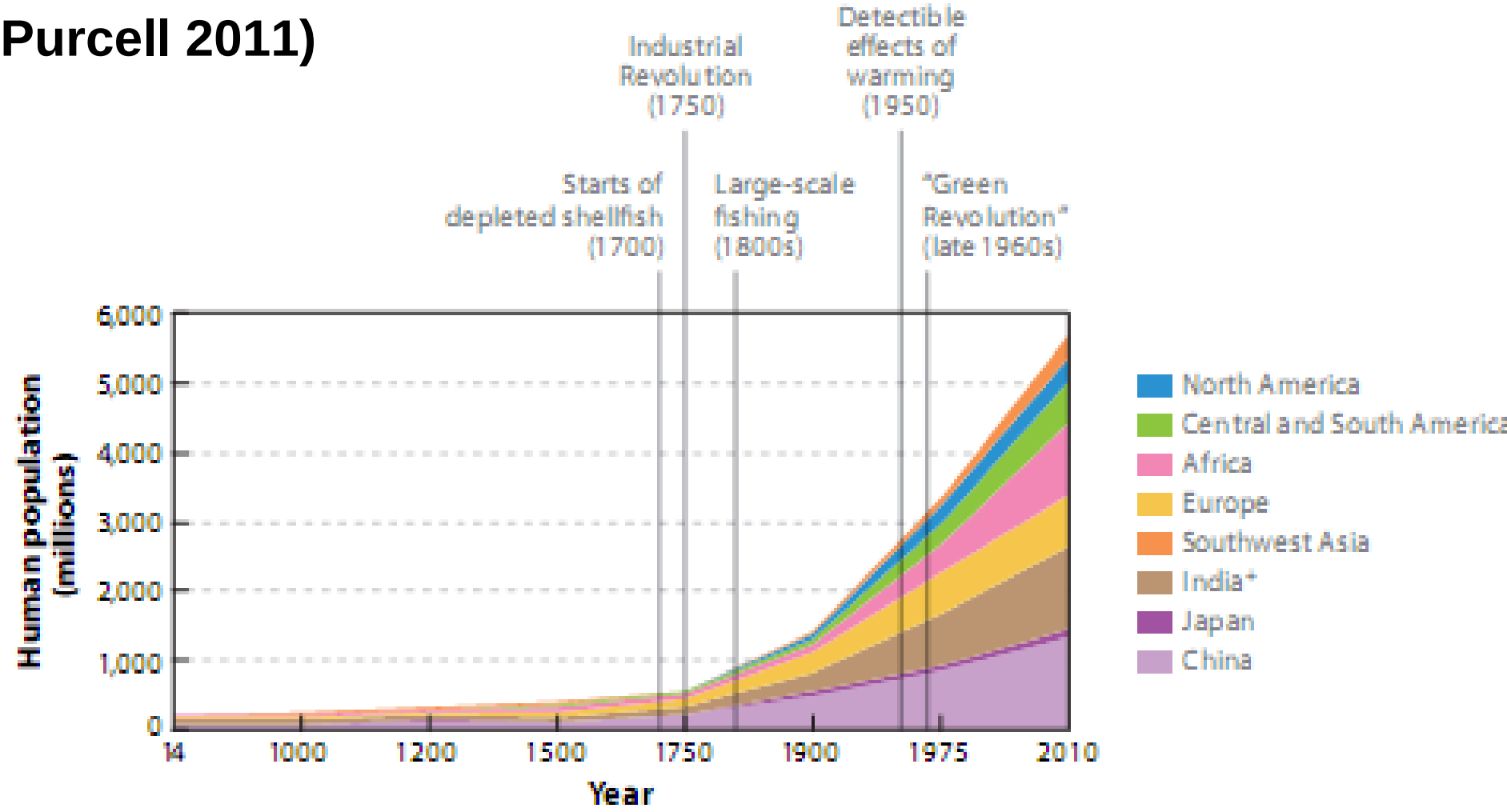






Human population and acceleration of environmental damage

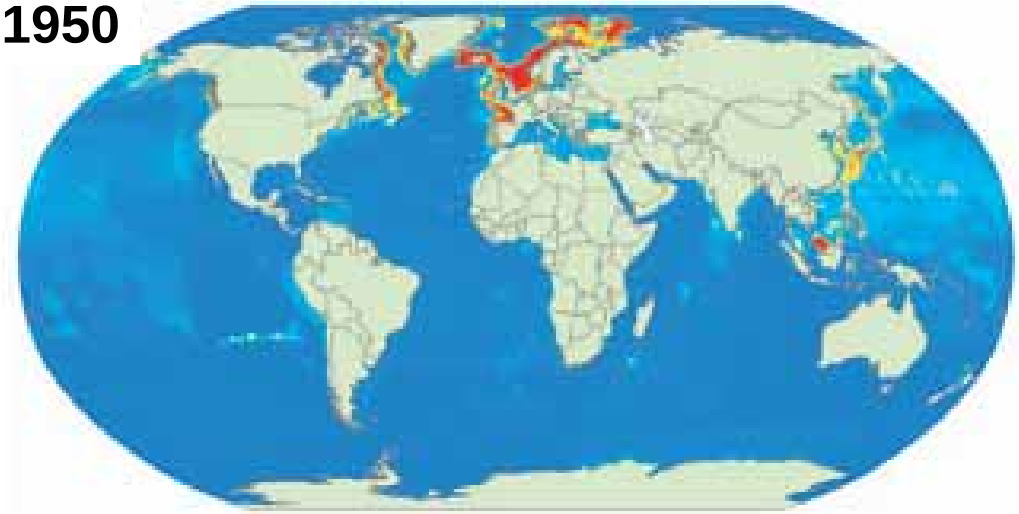
(Purcell 2011)



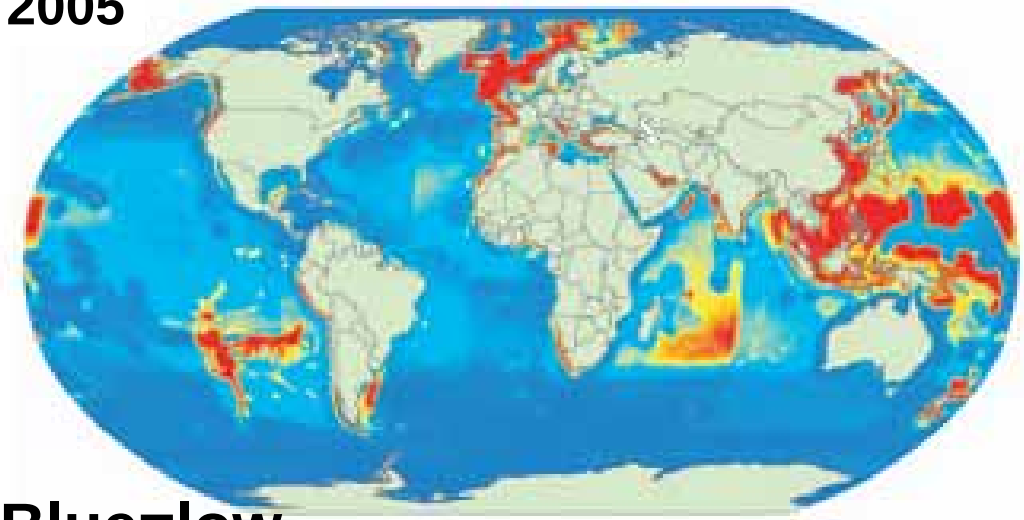
Fishing pressure 1950 vs. 2005

(Swartz et al. 2010)

1950



2005



Blue=low

Red=high

Fishing removes

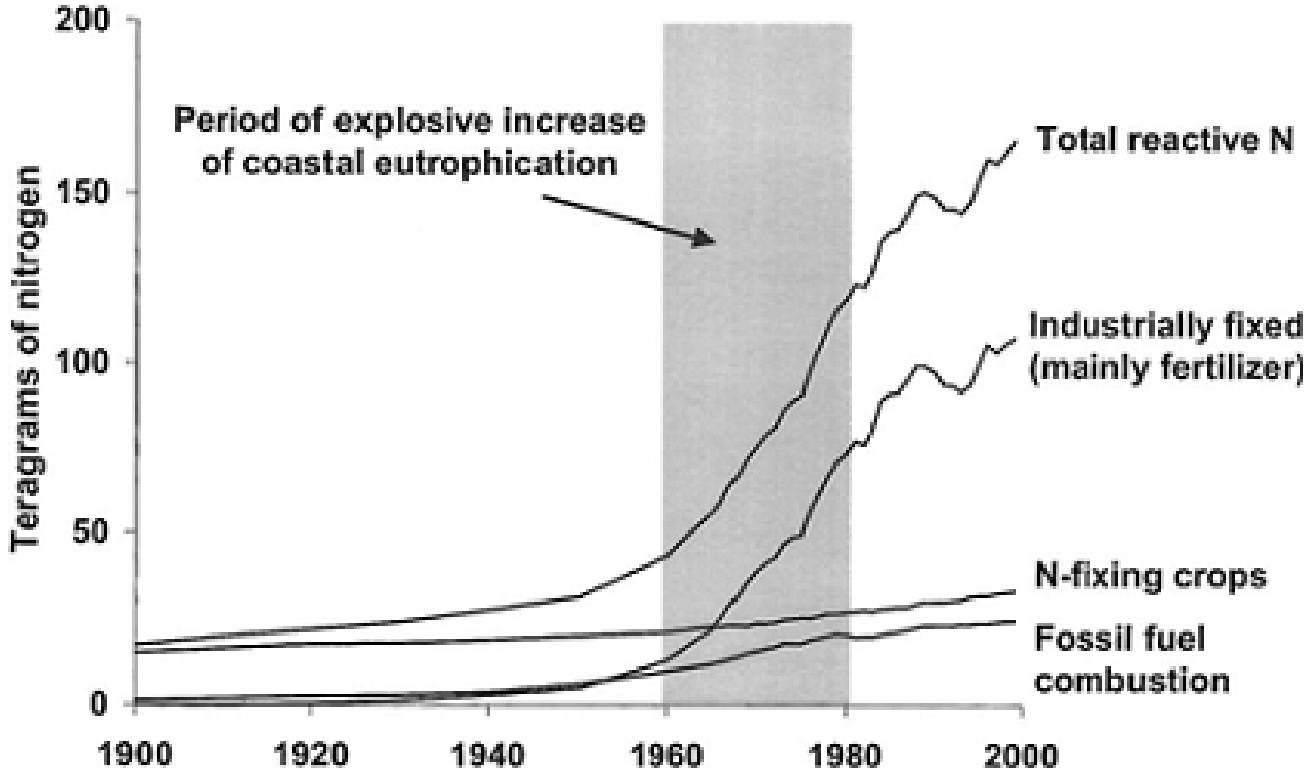
•competitors of jellyfish

•predators of jellyfish

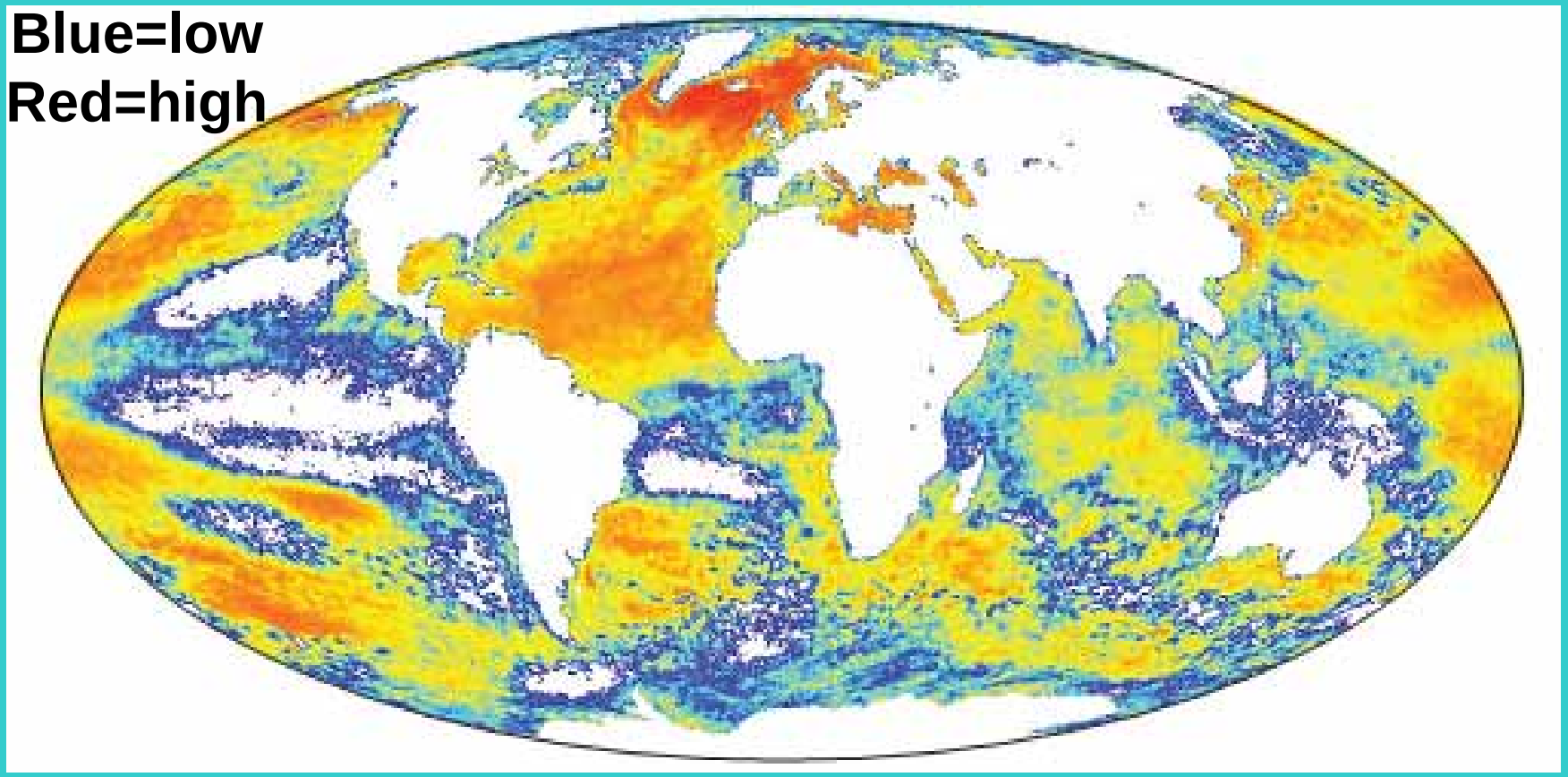
Eutrophication

- Increases food available
- Planktonic foods become smaller, nutrient ratios changed
- Hypoxia

(Boesch et al. 2002)



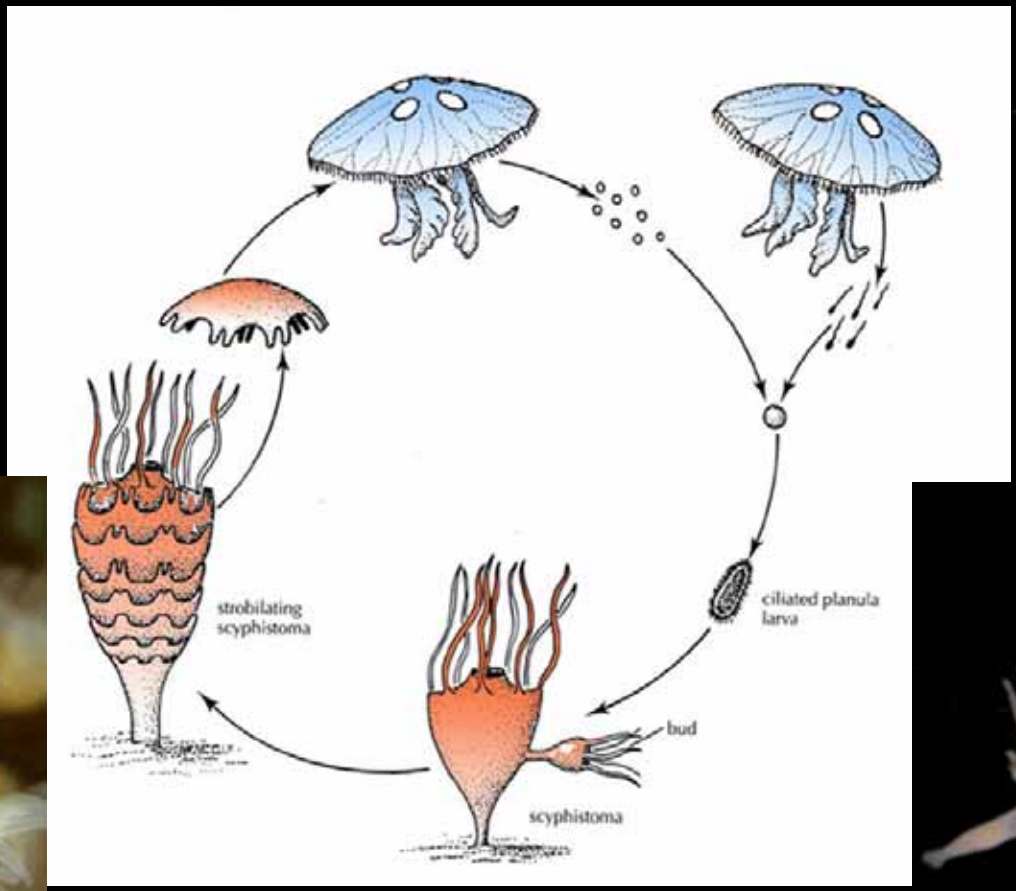
Sea temperature warming
(Halpern et al. 2008)



- Directly affects jellyfish growth and reproduction
- Changes ocean productivity
- Correlations of warming with abundant jellyfish

Jellyfish life cycle

ephyra



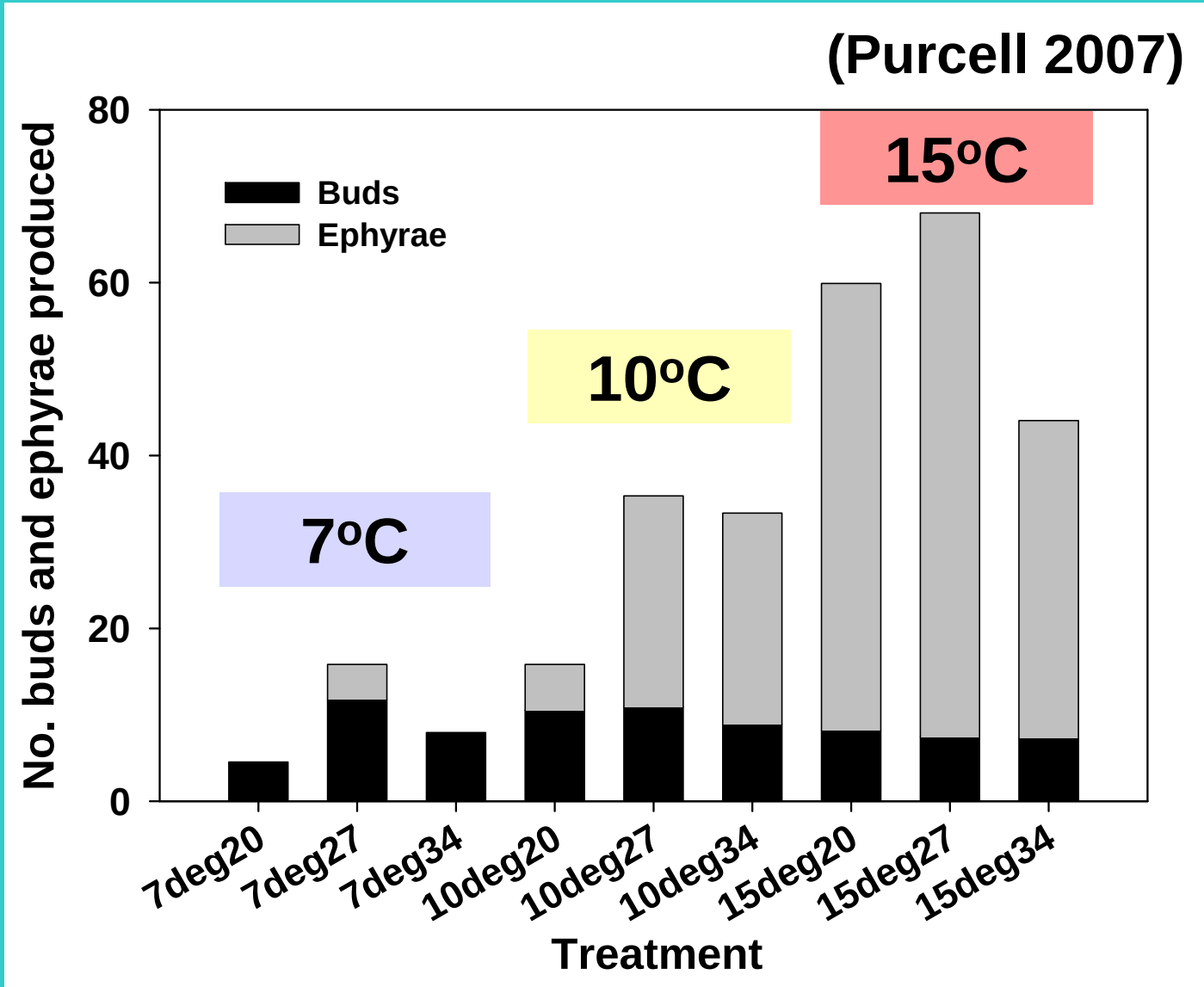
medusa

strobilation

Polyp budding polyps

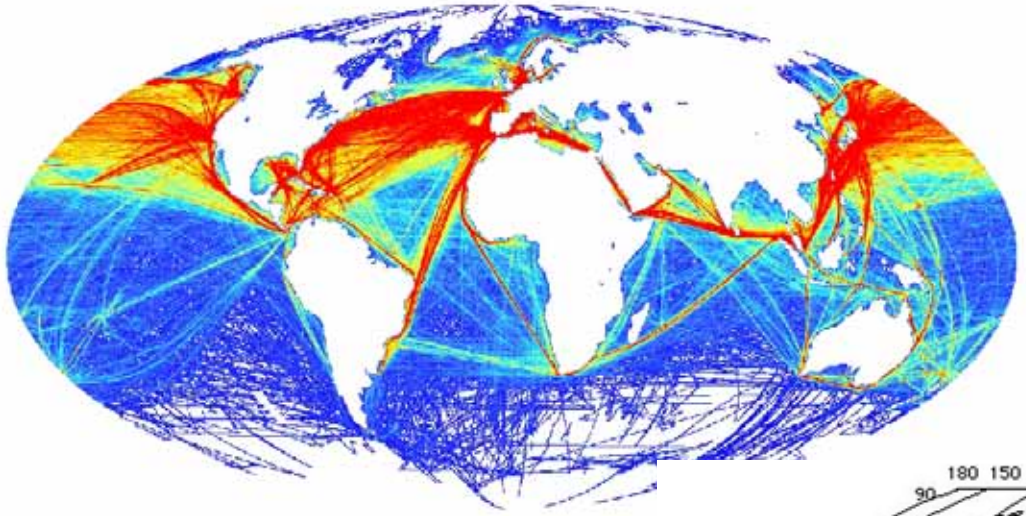
http://jellieszone.com/scyphomedusae.htm

Moon jellyfish total polyp & ephyra production 104 d
Temperature 7, 10, 15°C; salinity 20, 27, 34
More jellyfish were produced more quickly



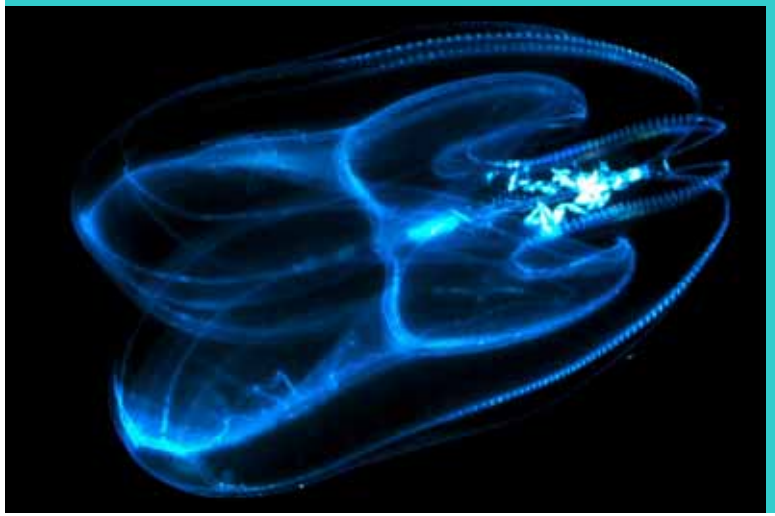
Species introductions -- shipping

(Halpern et al. 2008)

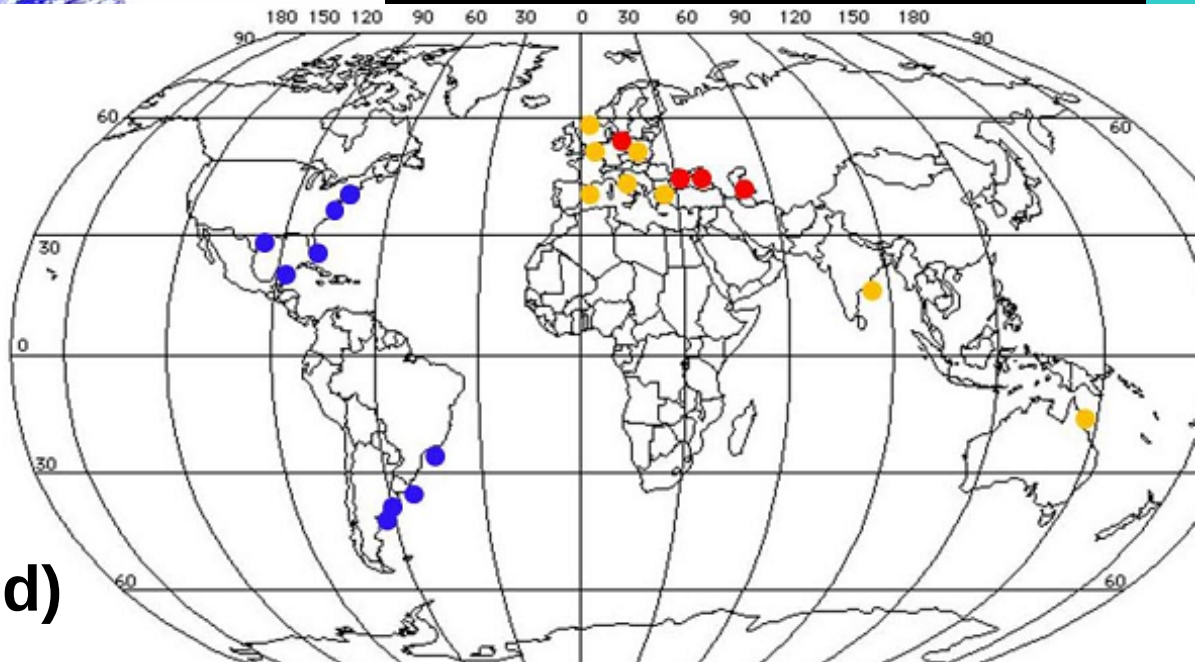


Blue=low
Red=high

Comb jelly *Mnemiopsis*



Blue dots = native
Orange = introduced

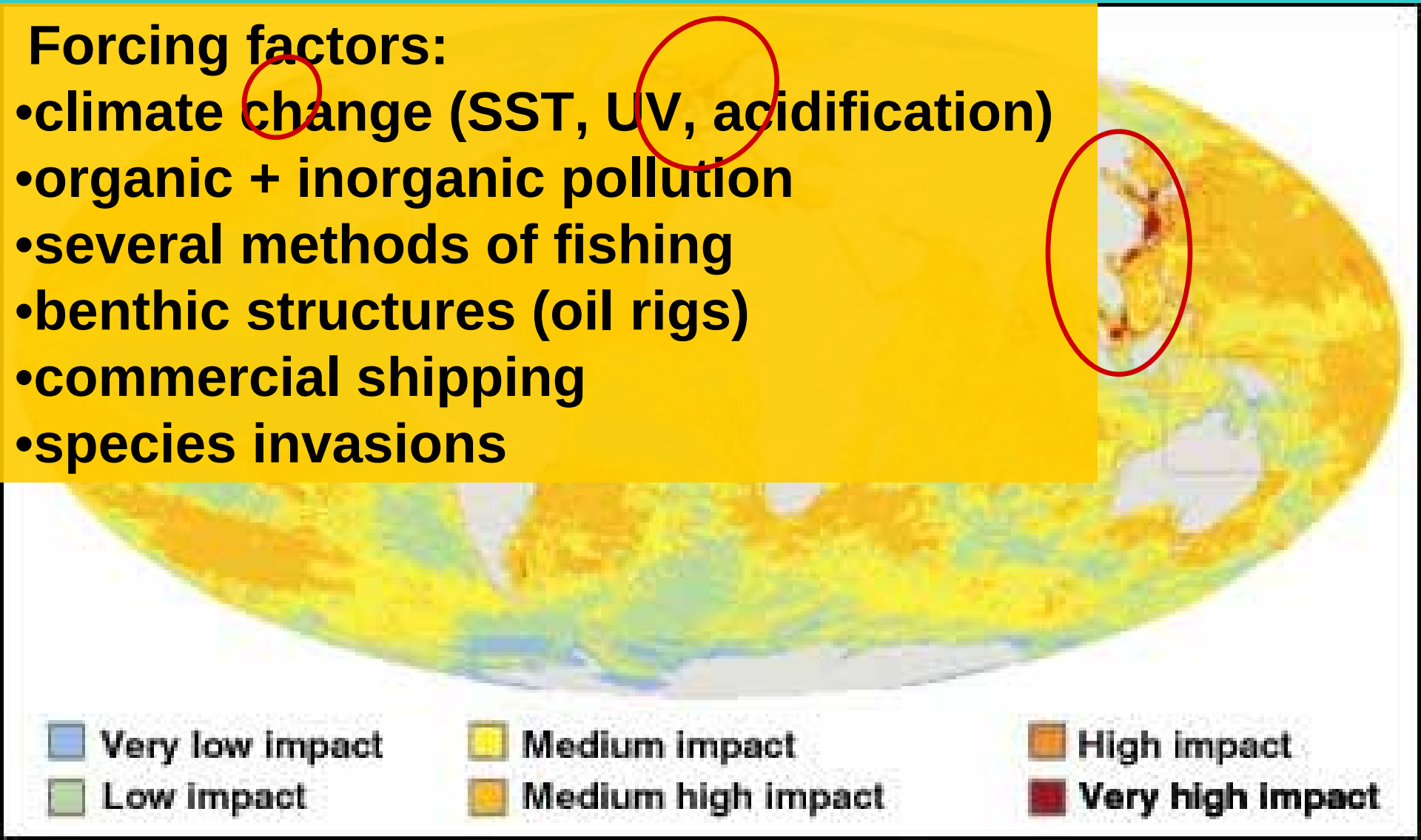


(Costello et al. submitted)

Combined human impacts
(Halpern et al. 2008)

Forcing factors:

- **climate change (SST, UV, acidification)**
- **organic + inorganic pollution**
- **several methods of fishing**
- **benthic structures (oil rigs)**
- **commercial shipping**
- **species invasions**



Combined human impacts
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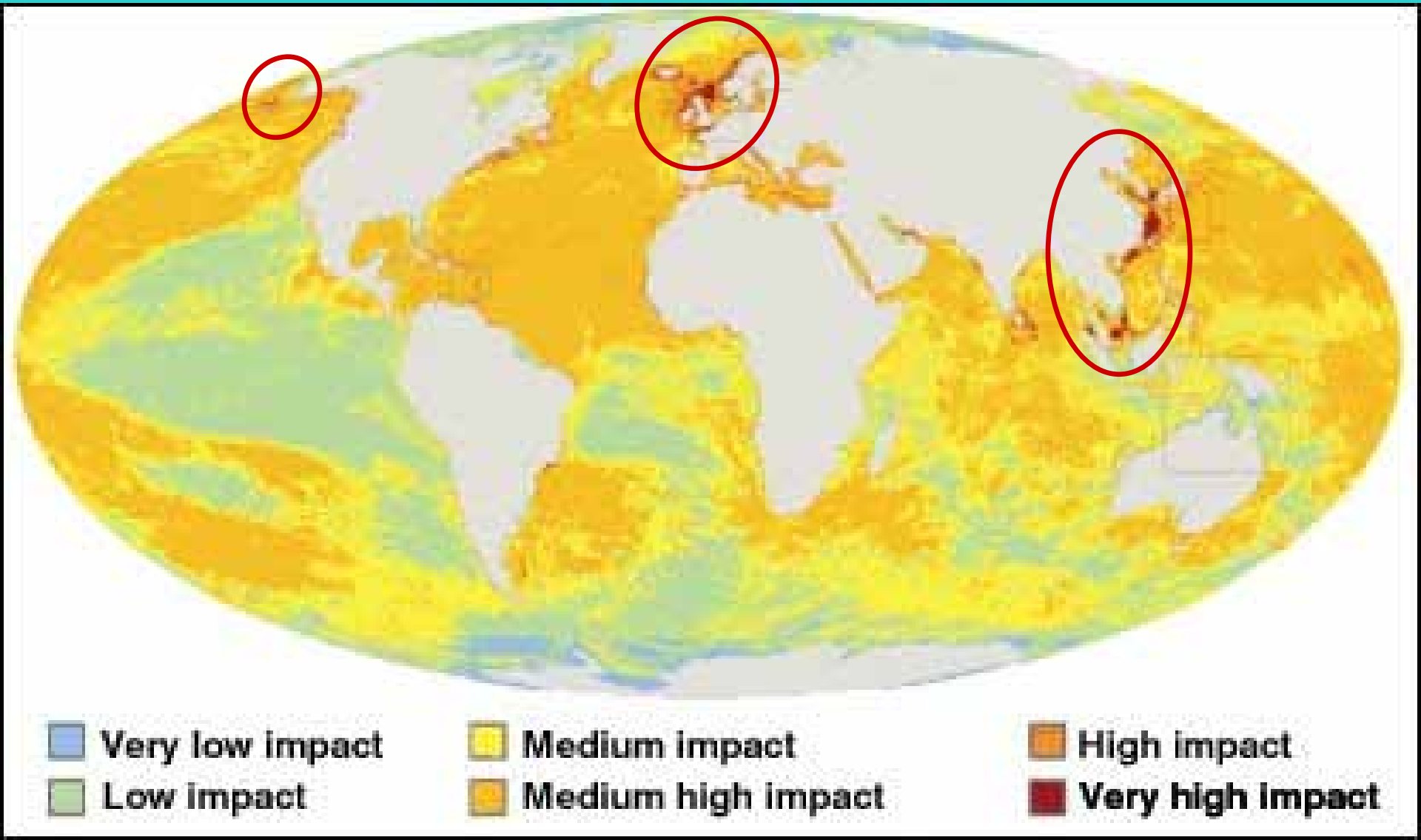


Human impacts in regions with jellyfish problems -- rankings of 180 regions

(from Halpern et al. 2008)

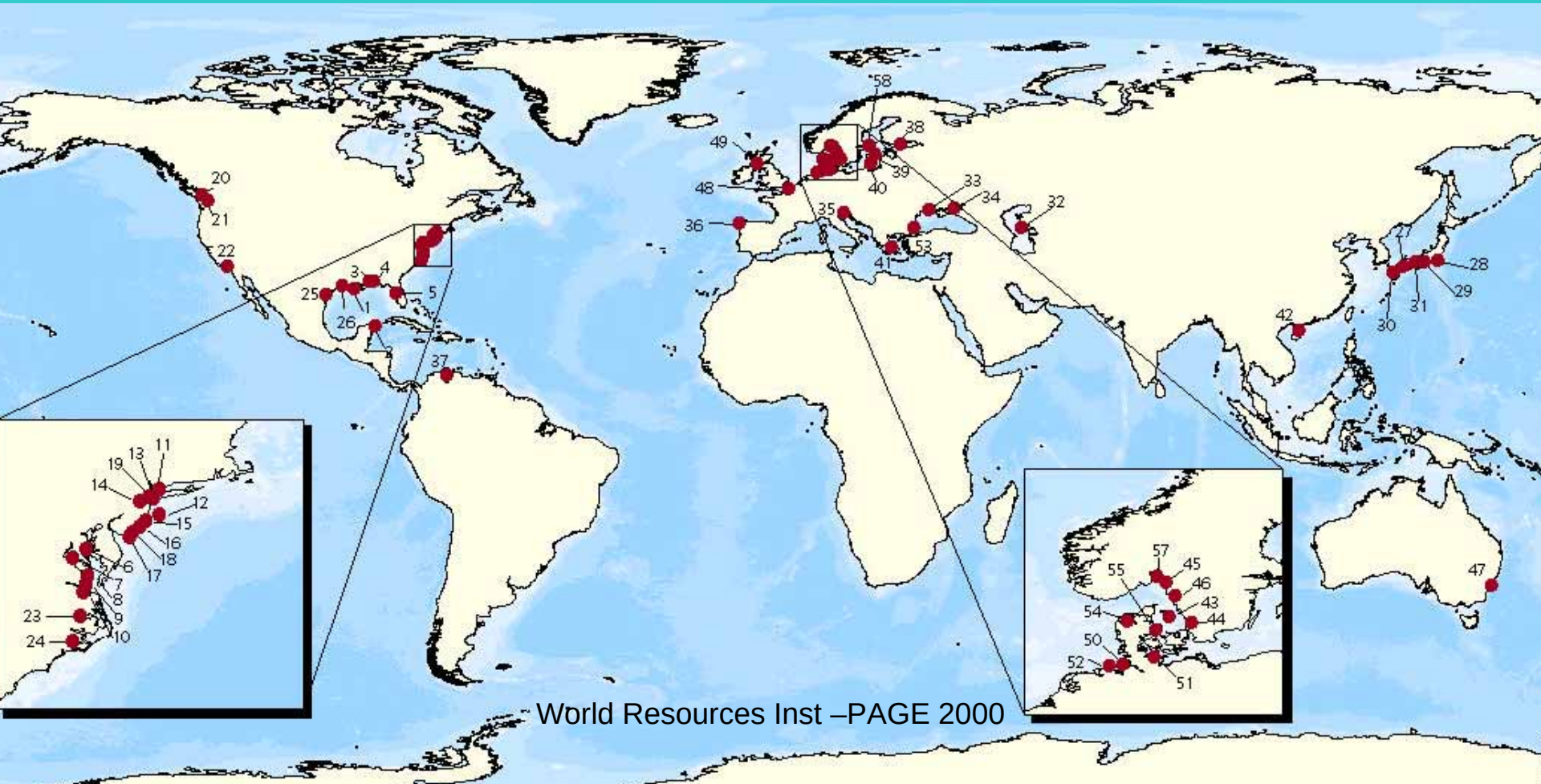
Location	Score millions	Rank	Humans km^{-2}	FiB	N load	DO
E Bering Sea	9.1	2	0.1	1.5	< 0.1	---
EastChinaSea	8.7	3	214	1.7	3.0	S
North Sea	8.7	4	482	-0.04	4.1	M
Celtic Sea	6.8	5	464	1.8	3.2	M
Yellow Sea	4.6	6	156	1.6	5.6	S
Baltic Sea	3.7	9	49	0.24	6.2	WP

Some impacts important for jellyfish blooms were not in Halpern et al. (2008)

- **hypoxia**
- **shoreline hardening provides habitat for jellyfish polyps**
- **aquaculture provides habitat for polyps, adds food**

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

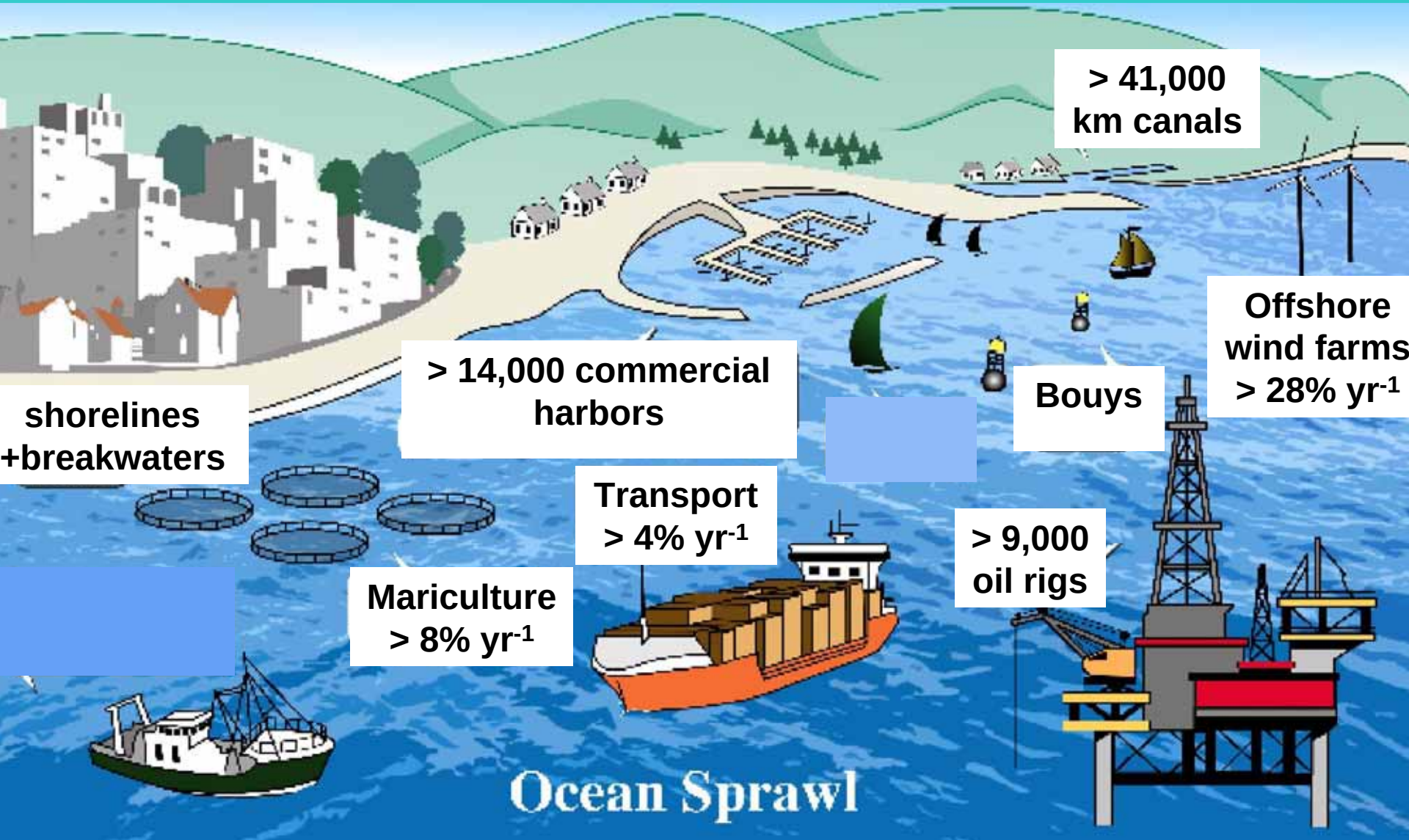
- **Added nutrients cause more phytoplankton to be produced than consumed. Excess decomposes**



Jellyfish are more tolerant of hypoxia than fish

- Fish avoid or die in waters < 2 mg O_2 l^{-1}
- *Mnemiopsis* ctenophores live for > 72 h at 0.5 mg O_2 l^{-1} (Purcell et al. 2001)
- *Chrysaora quinquecirrha* medusae lived > 96 h at 1 mg O_2 l^{-1}; their polyps can live and reproduce at 0.5 mg O_2 l^{-1} (Purcell et al. 2001)
- *Aurelia aurita* polyps inhabit the bottom of harbor pilings in hypoxic Tokyo Bay where no other fouling occurs; planulae settled and polyps reproduced at 2 mg O_2 l^{-1} (Ishii et al. 2008; Ishii & Katsukoshi 2010)
- Several other jellyfish species are very tolerant of hypoxia (Purcell et al. 2001; Rutherford & Thuesen 2005)

Human impacts ("hardening") not included in Halpern et al. (2008) from Duarte et al. (submitted)

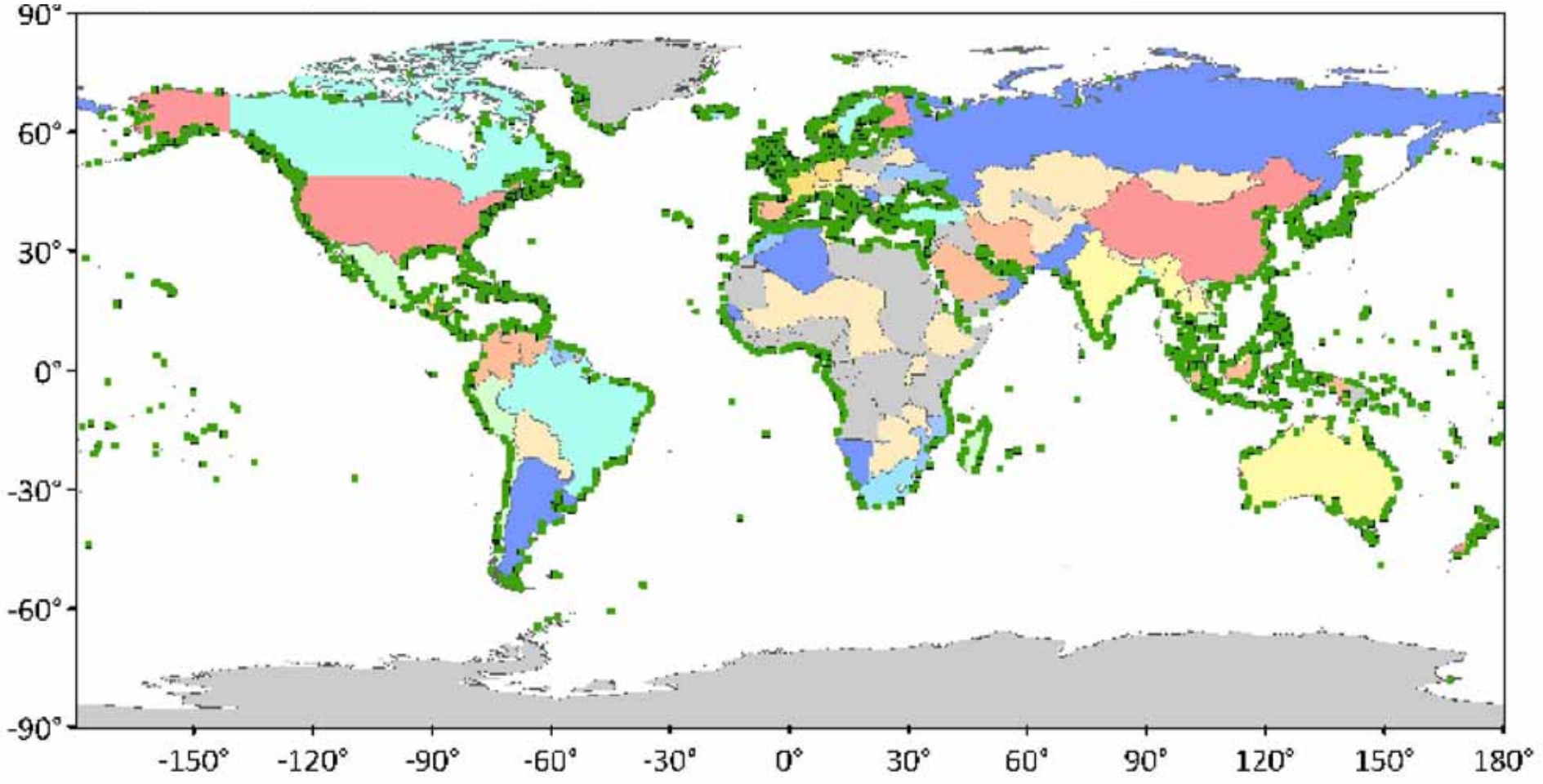


Human impacts (ports & aquaculture) not included in Halpern et al. (2008)

Aquaculture production (mtons / km coast)

Blue = low
Pink = high
Green dots = ports

Duarte et al. (submitted)



Cornet Bay Marina **17 Jan 04**

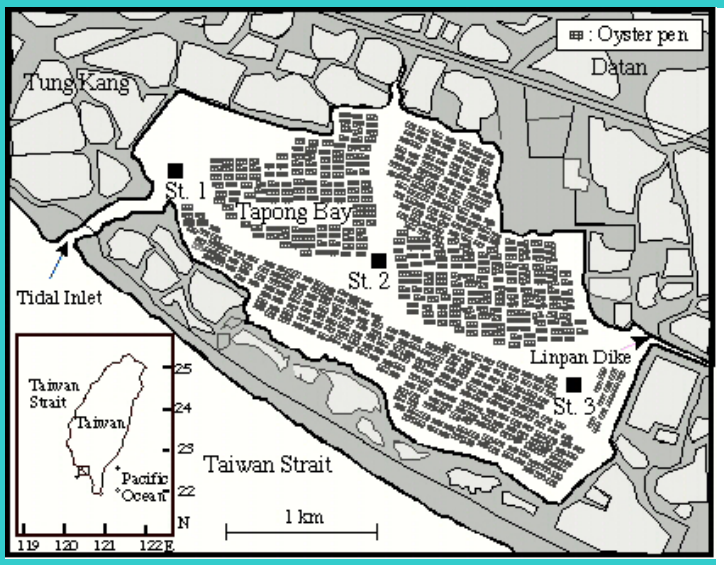
Moon jellyfish
10 polyps cm^{-2}
685 m^2

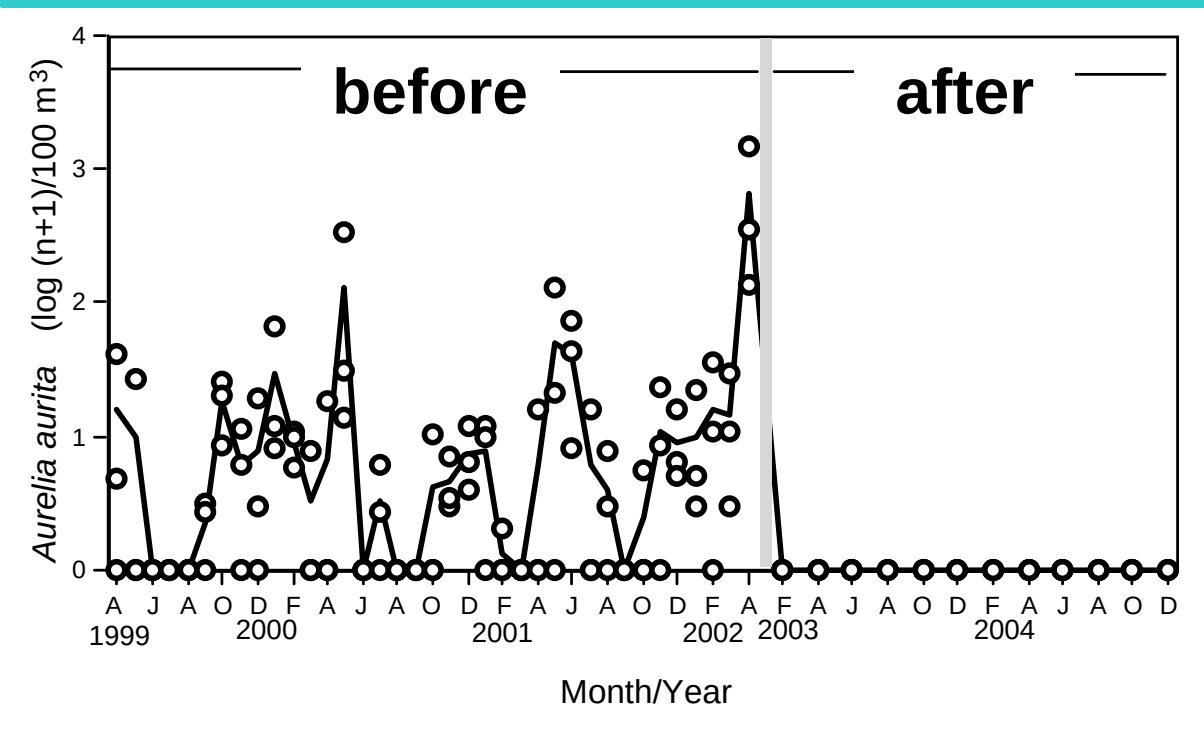
17 Feb 04

13.4 disks $polyp^{-1}$
≈ 918 million moon jellies produced in marina

(Purcell et al. 2009)

Jellyfish in Tapong Bay 1999-2005 before and after oyster rack removal (Lo et al. 2008)



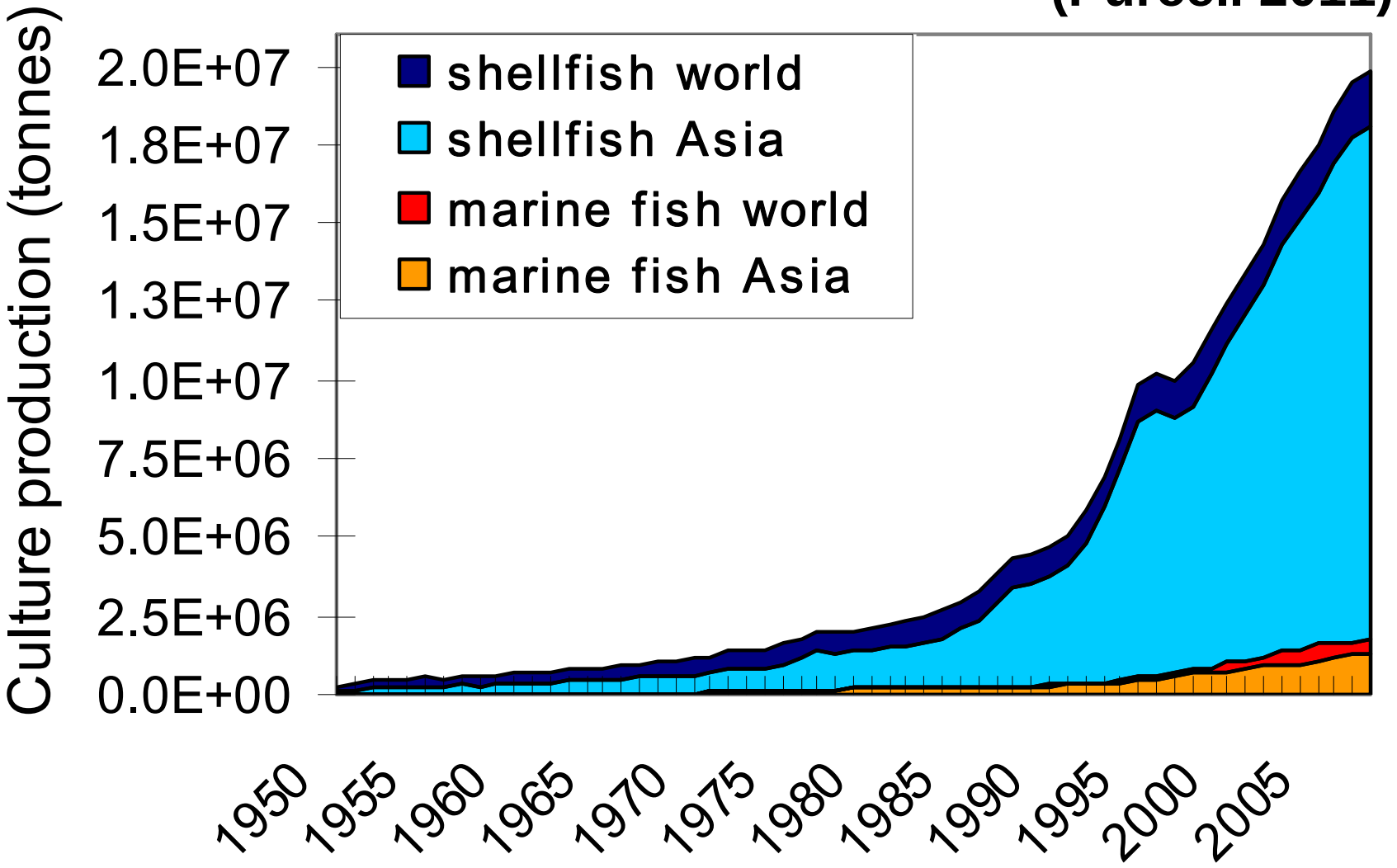


Removal of racks

- **removed polyp attachment sites**
- **removed shading**
- **increased water transport from bay**

Aquaculture trends 1950-2008

(Purcell 2011)



Summary

- **All probable causes of jellyfish increases are occurring together and increasing on coasts globally**
  - **Fishing – removes predators+competitors**
  - **Eutrophication – high nutrients, low silica, flagellate-based food web; hypoxia**
  - **Climate change – warming etc.**
  - **Species introductions**
  - **Aquaculture – habitat and nutrients added**
- **Human problems with jellyfish are likely to increase**