Ecological Risk Assessment of the impacts of Climate Change on Peruvian key species

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PERÚ Ministerio de la Producción

INSTITUTO DEL MAR DEL PERÚ · CIENCIA Y TECNOLOGÍA

BID Mejorando vidas

1. Welcome and introduction to the content of the course

2. Introduction to Climate Change

Climate Change

“A statistically significant variation in the mean state of the climate or its variability, persisting for an extended period (typically decades or longer)”

+

Anthropogenic Climate Change

“A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”

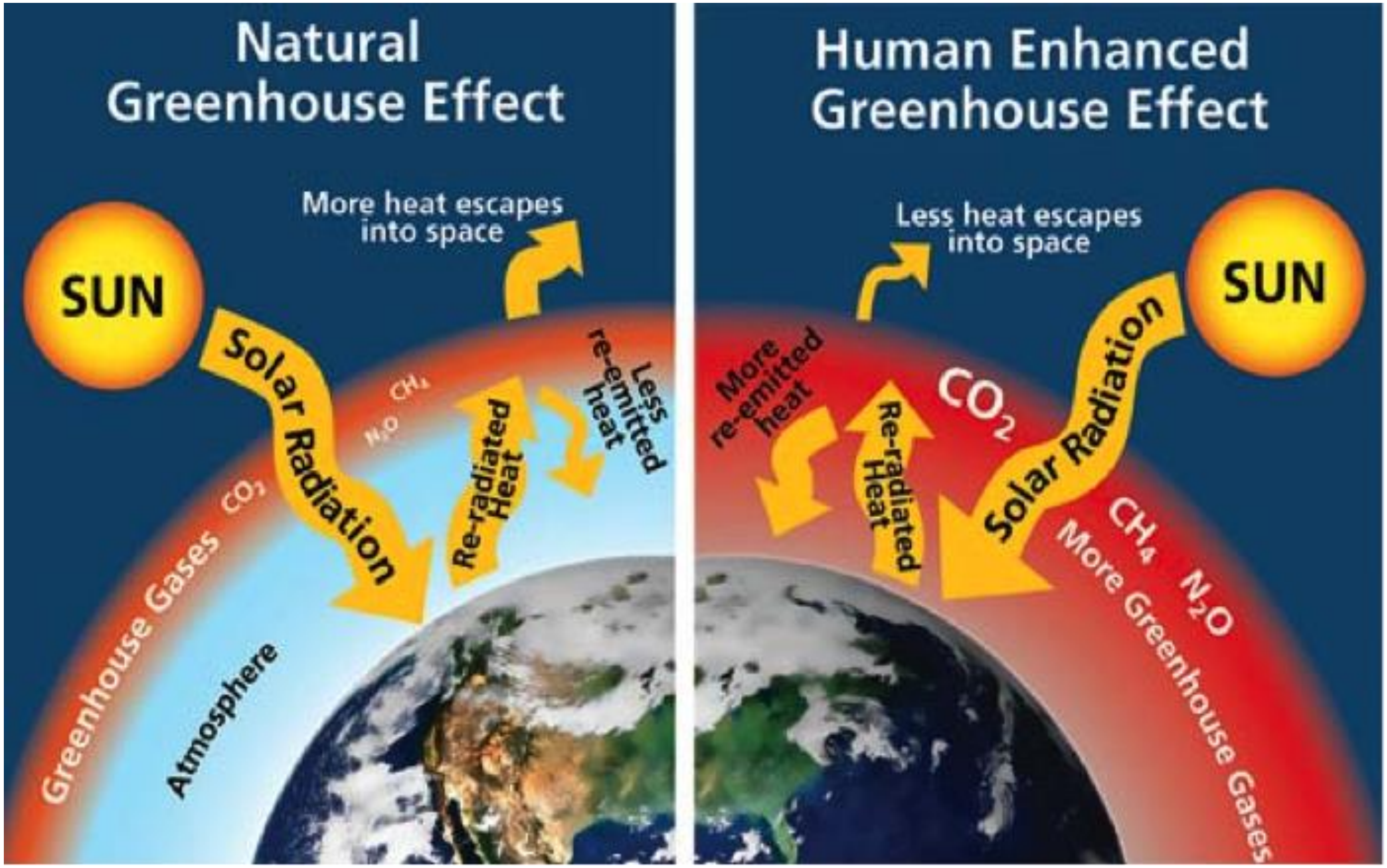
http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=663

CO_2 sources

Non anthropogenic

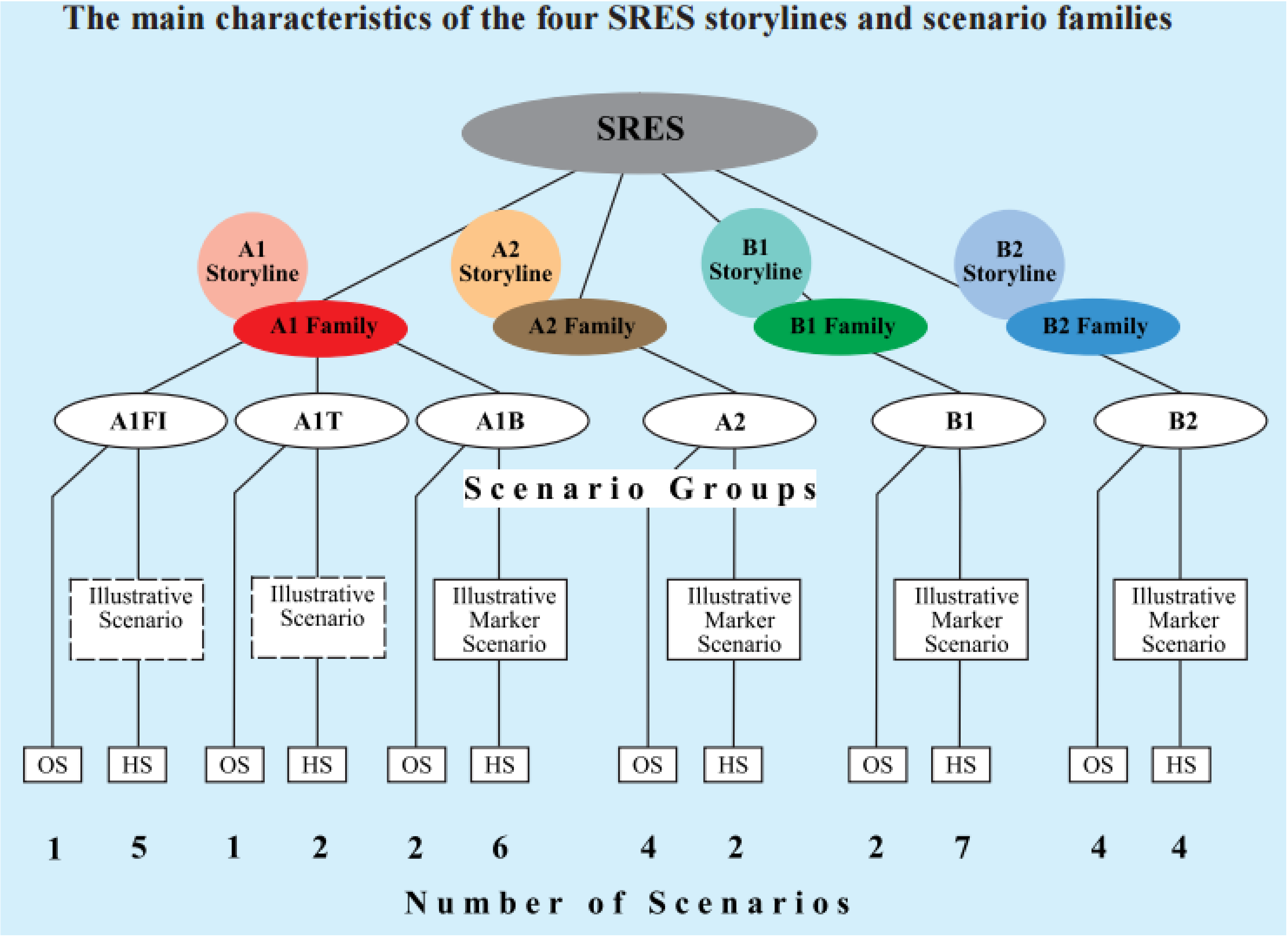
Anthropogenic

The mechanism behind



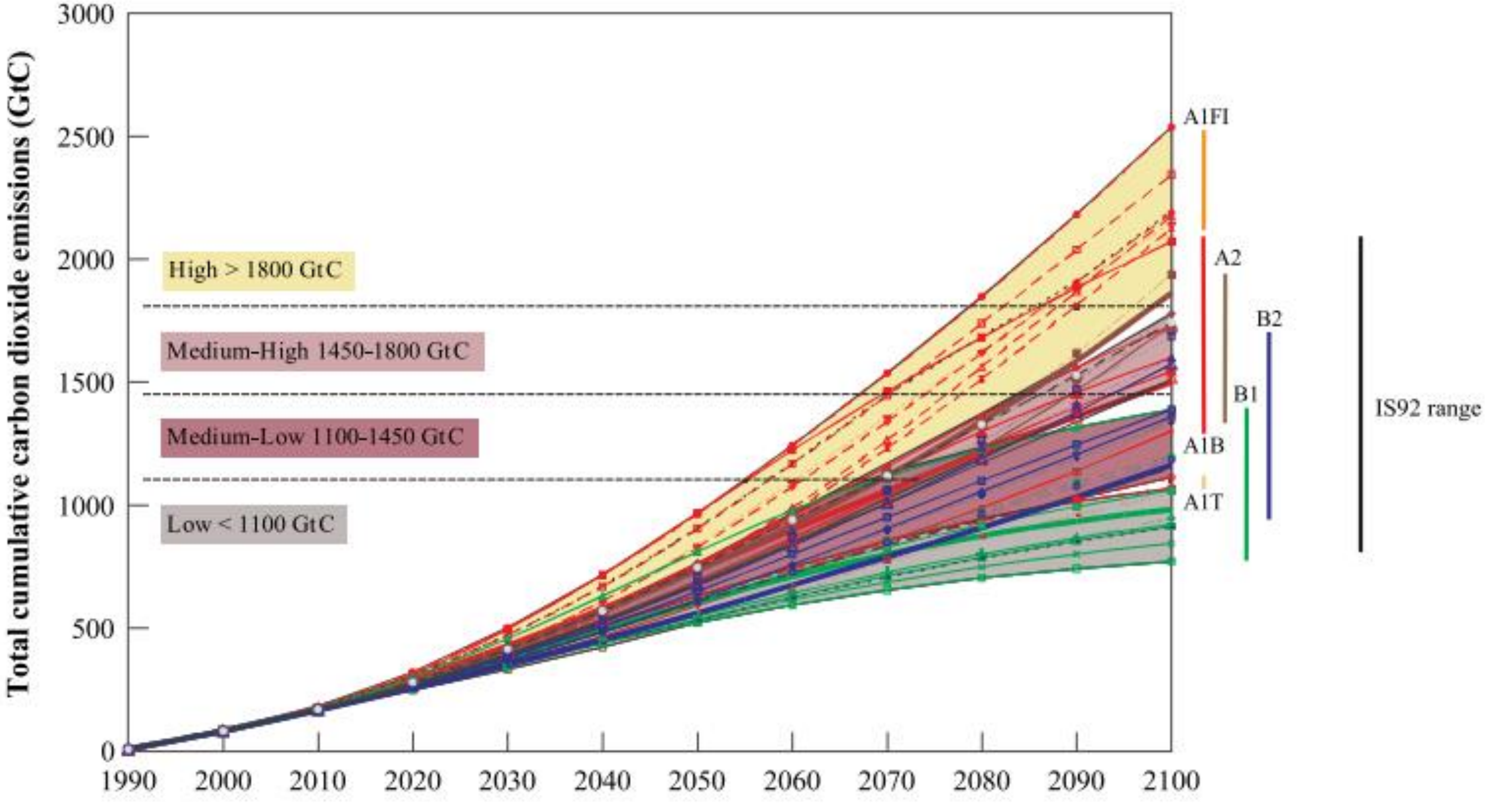
http://www.c2es.org/science-impacts/basics/kids

IPCC scenarios



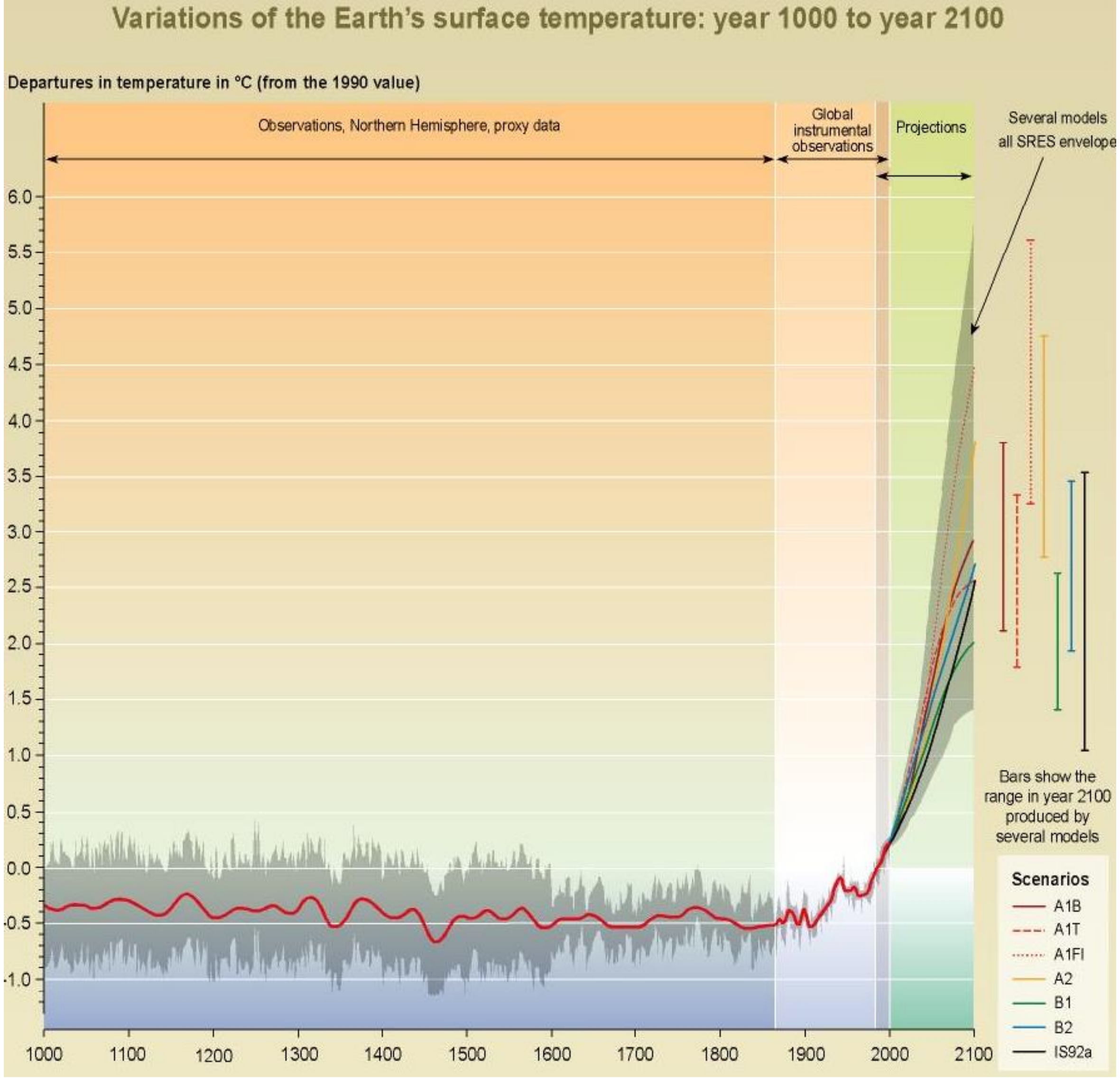
IPCC, 2007

IPCC scenarios



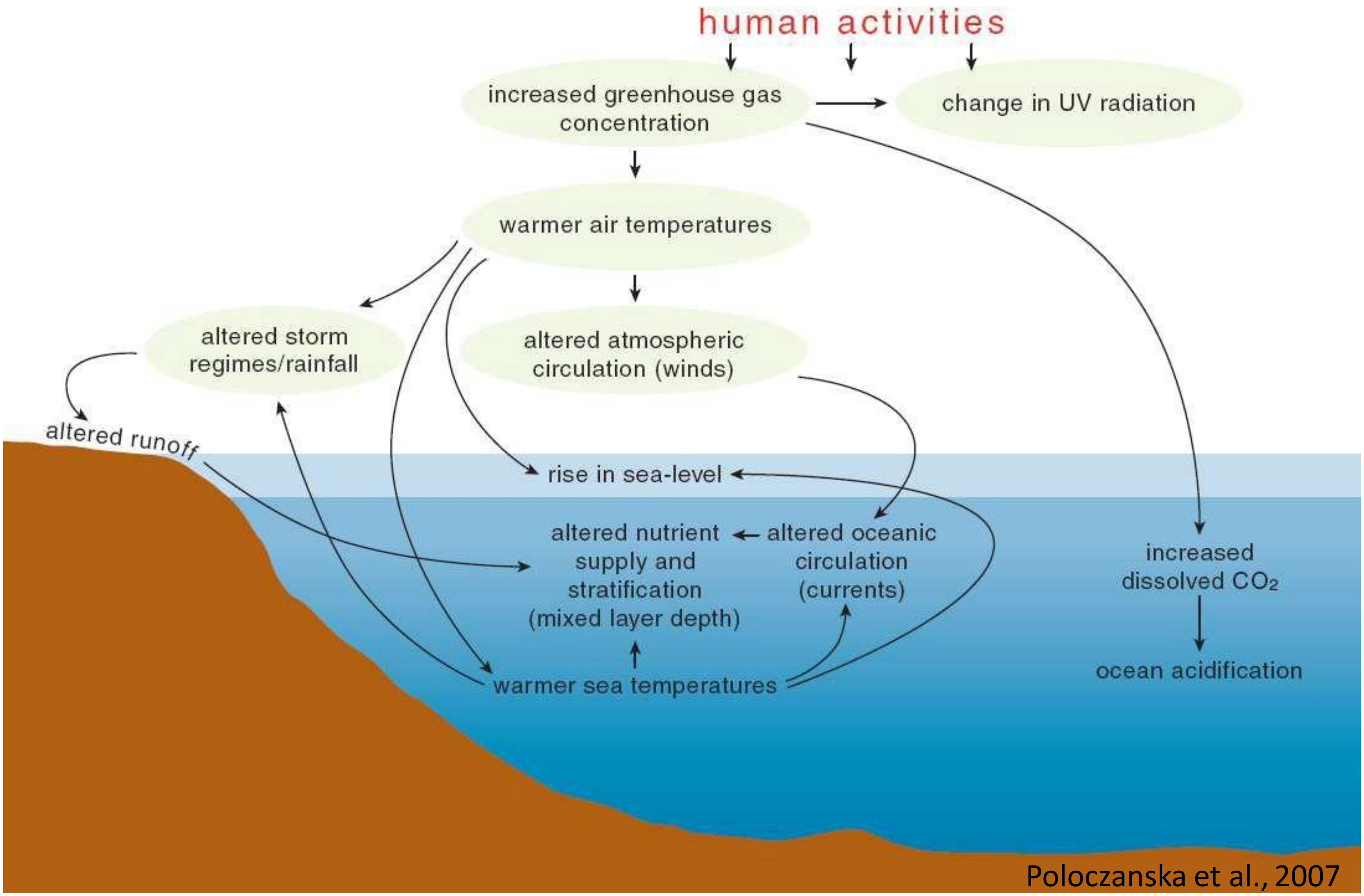
IPCC, 2007

IPCC scenarios



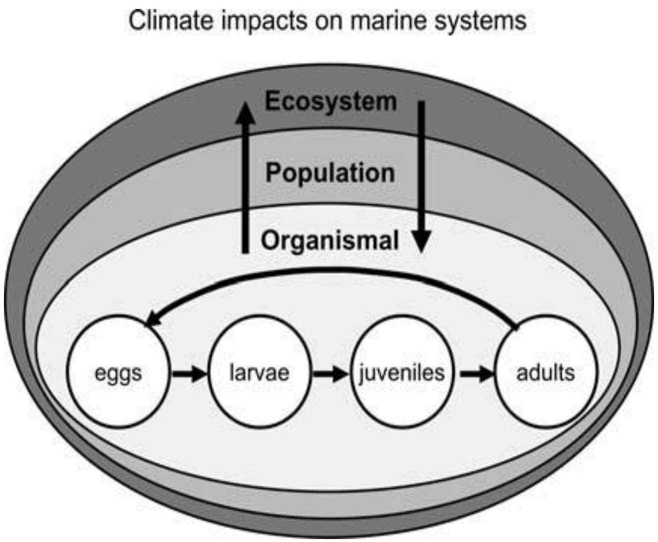
IPCC, 2007

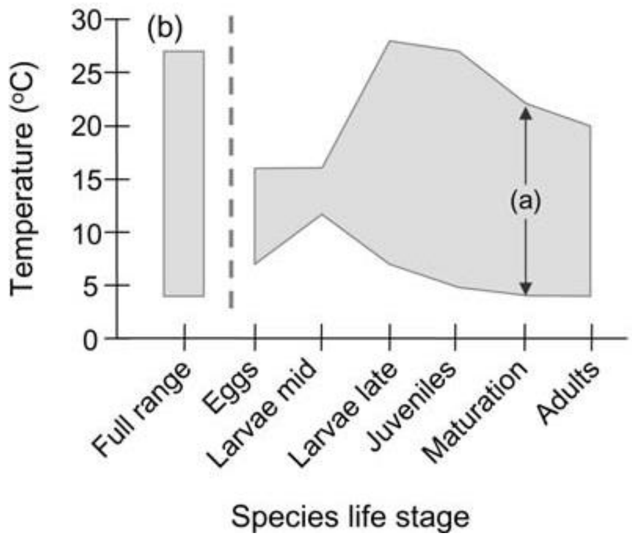
Impacts of Climate Change



Poloczanska et al., 2007

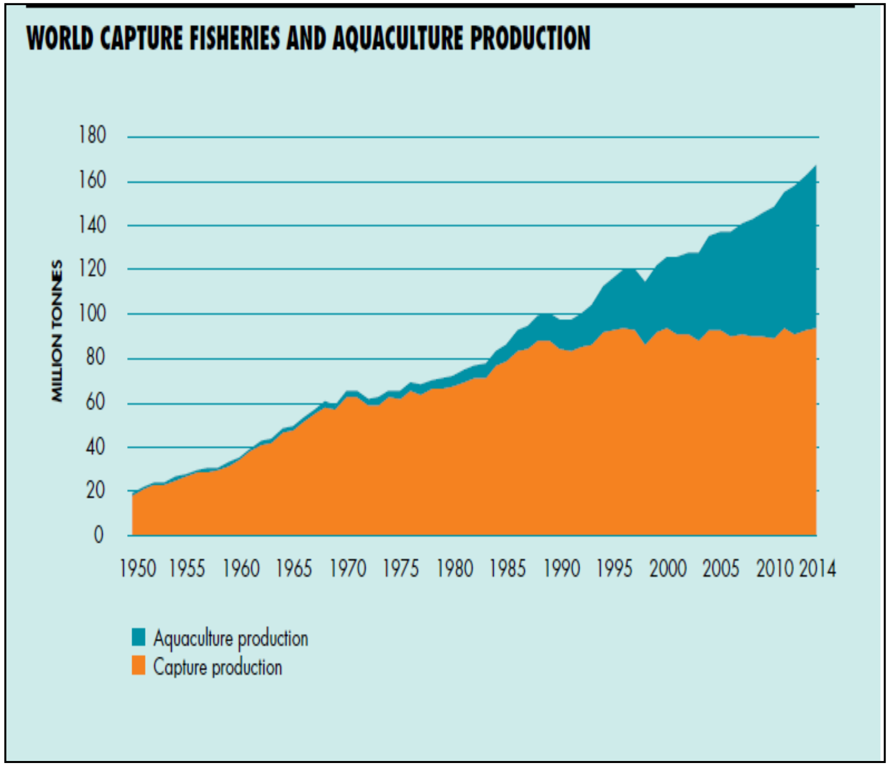
Impacts on marine life

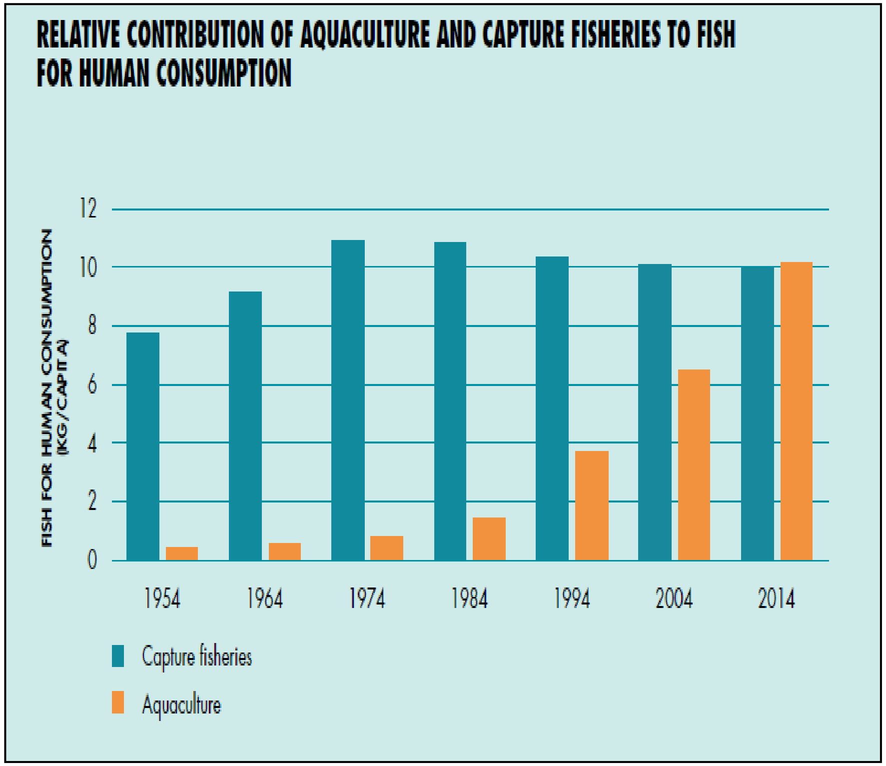




Rijnsdorp et al., 2009

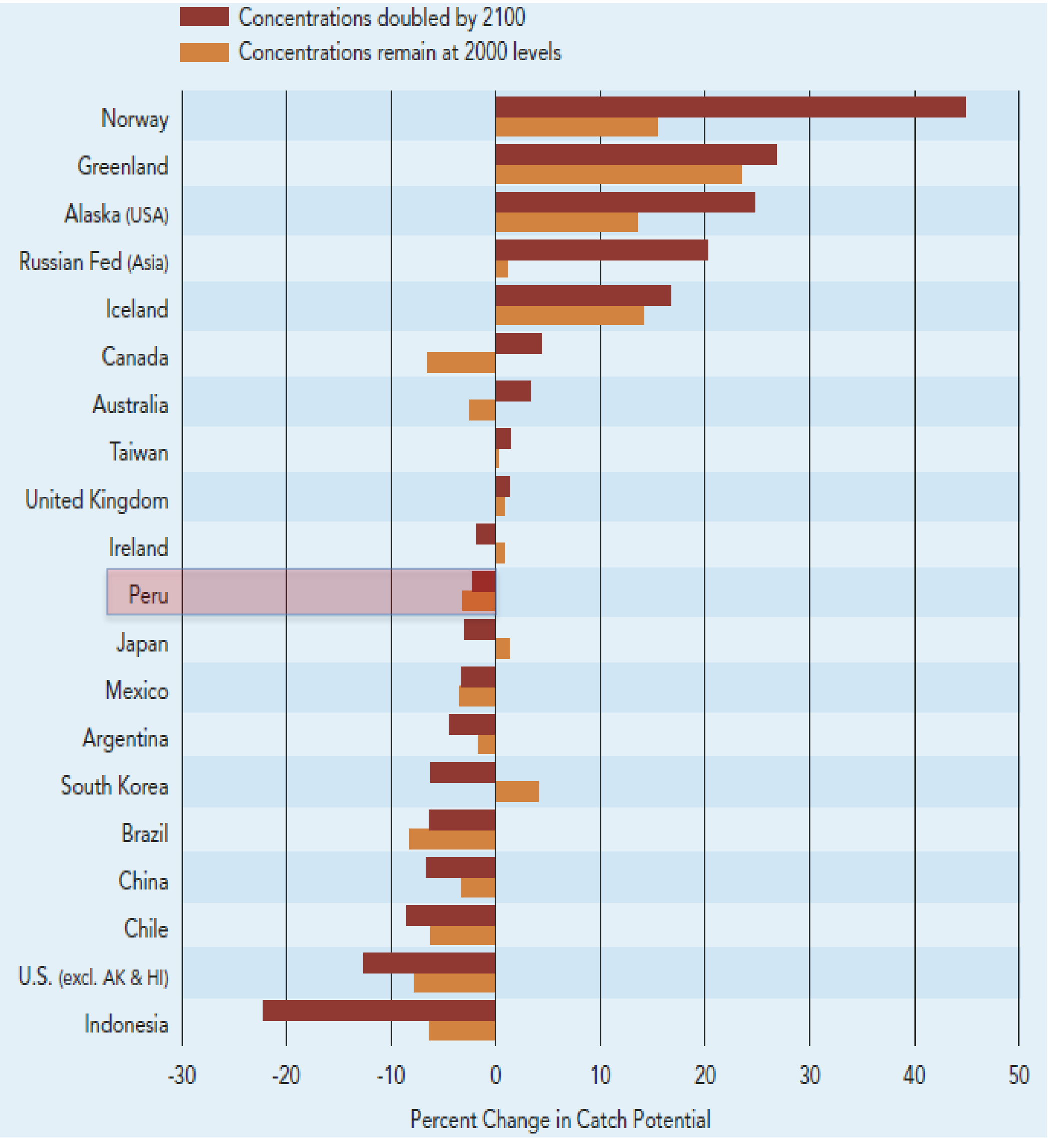
Importance of fisheries and aquaculture





FAO, 2016

Changes in fish landings

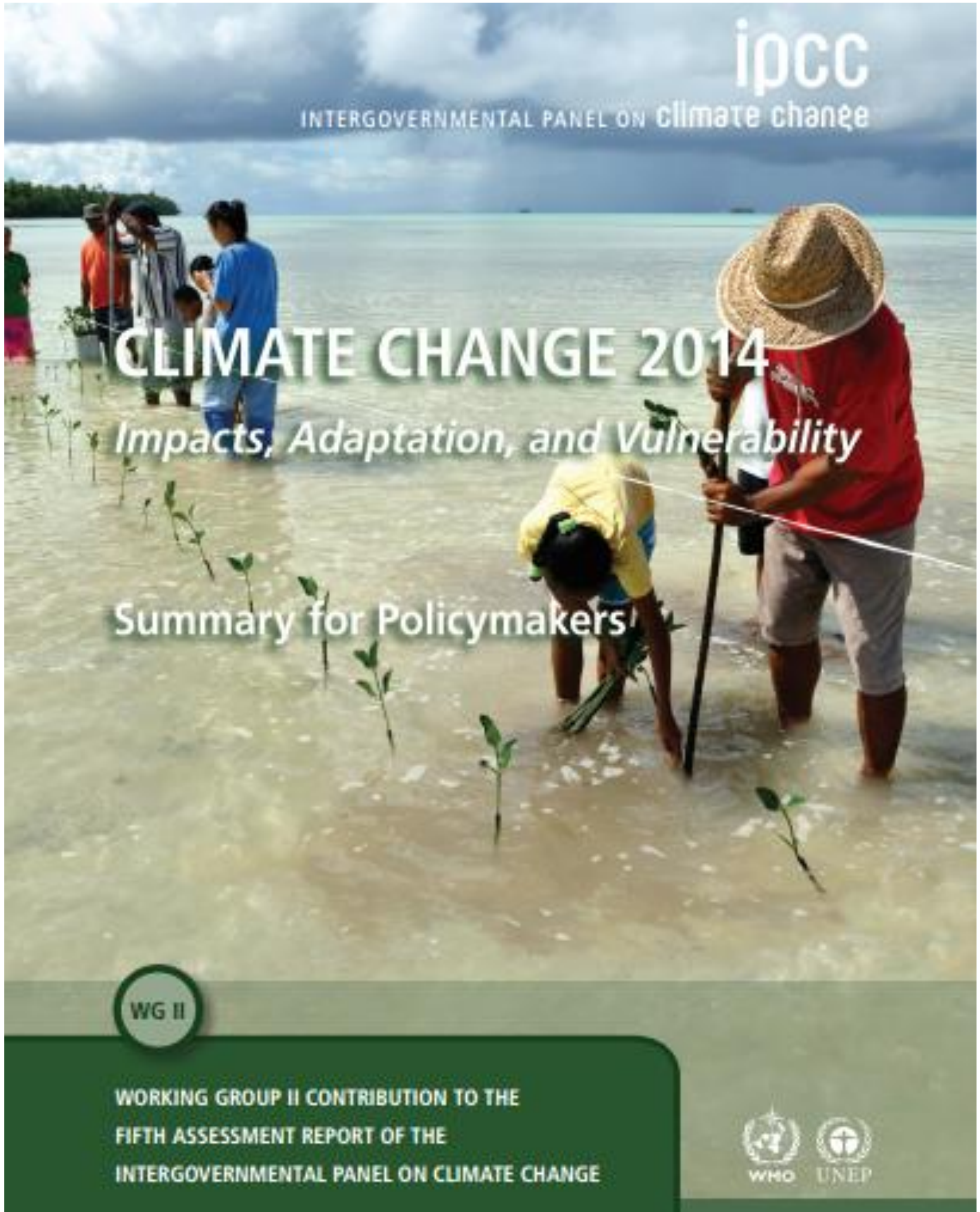


The two scenarios represent greenhouse gas emissions:

First scenario, emissions continue to grow in their current trajectory and will double by 2100.

Second scenario, assumes that greenhouse gas concentrations remain constant at 2000 levels.

Cheung et al., 2009

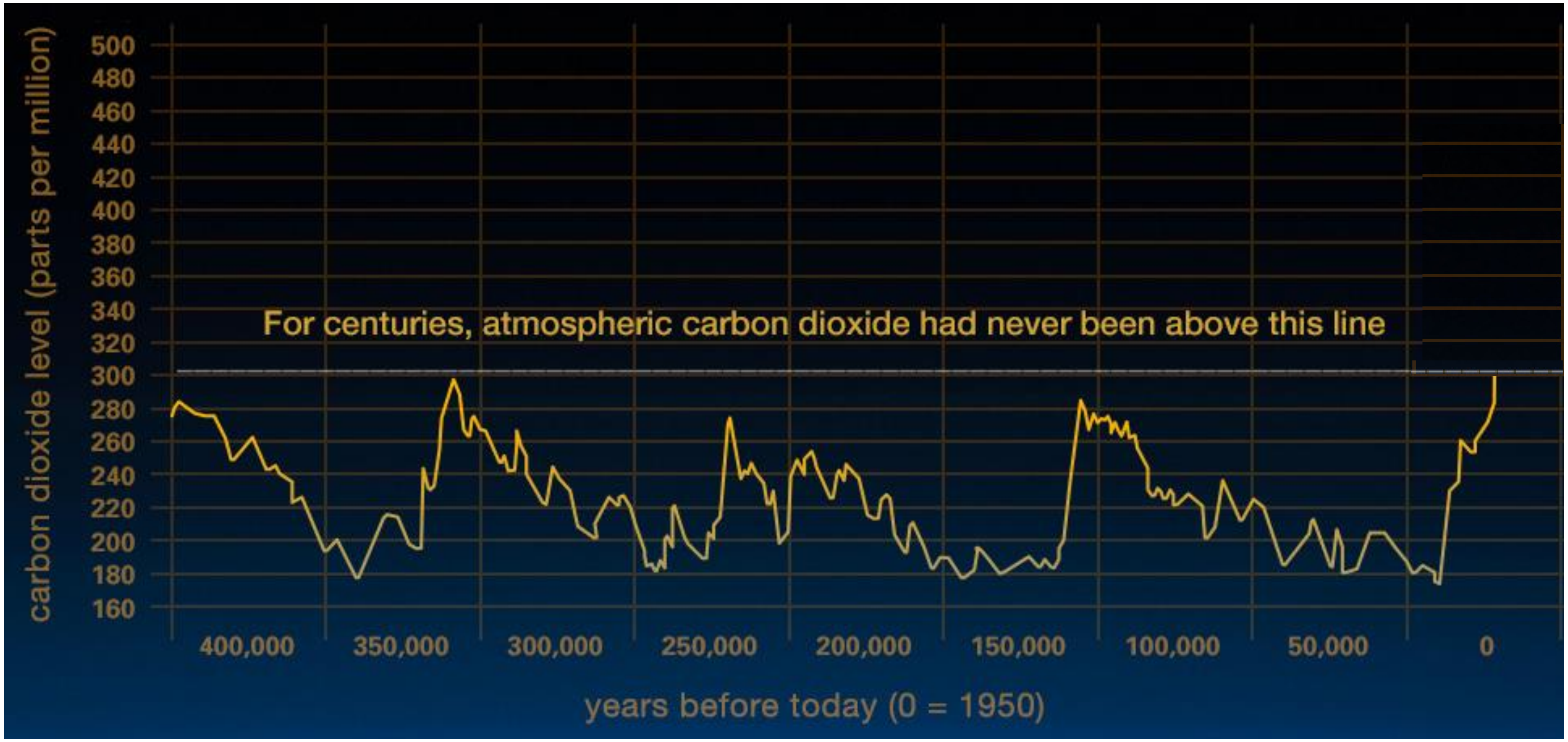

ipcc
INTERGOVERNMENTAL PANEL ON climate change
CLIMATE CHANGE 2014
Impacts, Adaptation, and Vulnerability
Summary for Policymakers
WG II
WORKING GROUP II CONTRIBUTION TO THE
FIFTH ASSESSMENT REPORT OF THE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO
UNEP

IPCC, 2014

3. Global physical changes associated with Climate Change

CO_2 emissions

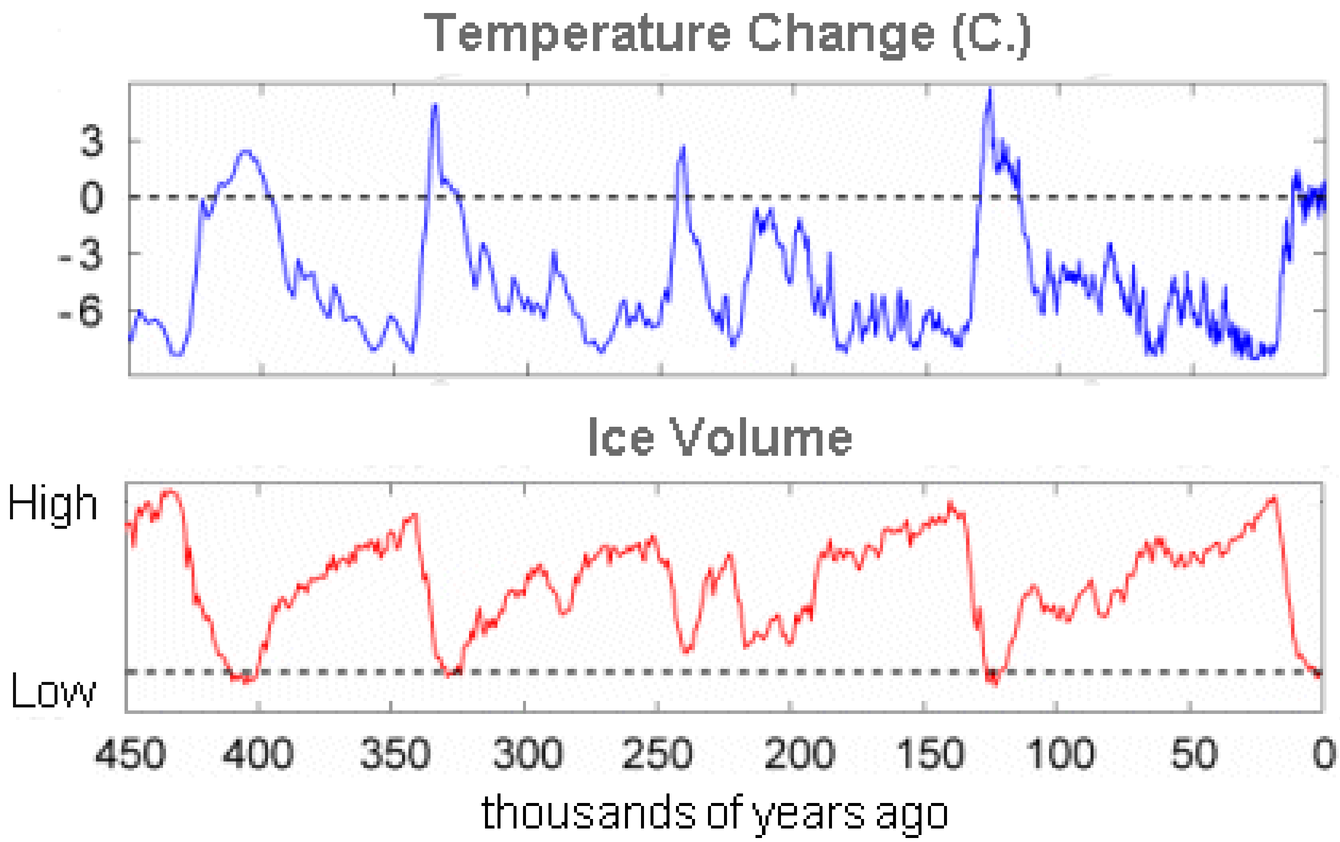
Climate has always been changing, e.g. natural CO_2 oscillations.



http://climate.nasa.gov/evidence/

Our changing climate

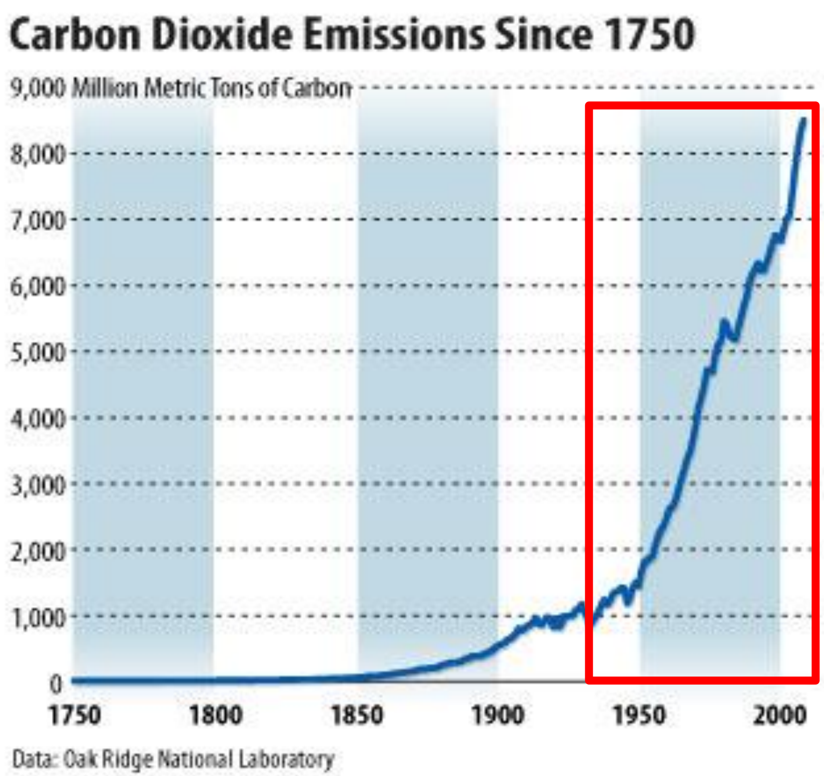
Climate has always been changing, e.g. several glaciations through the history of earth.

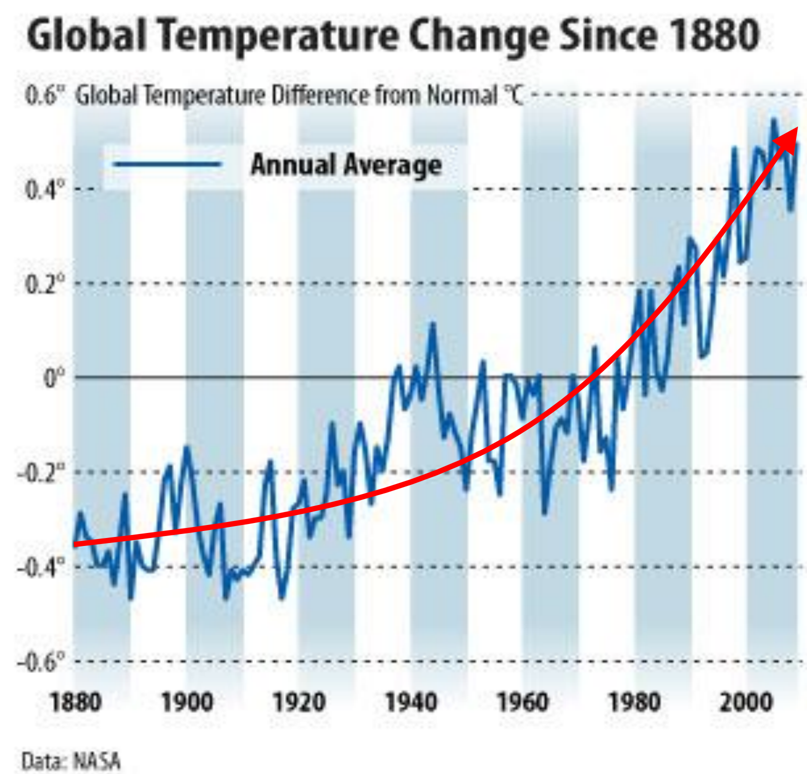


http://anthro.palomar.edu/homo/homo_3.htm

Our changing climate

Climate has always been changing BUT… pace of current changes is 10x more rapid than in the past.

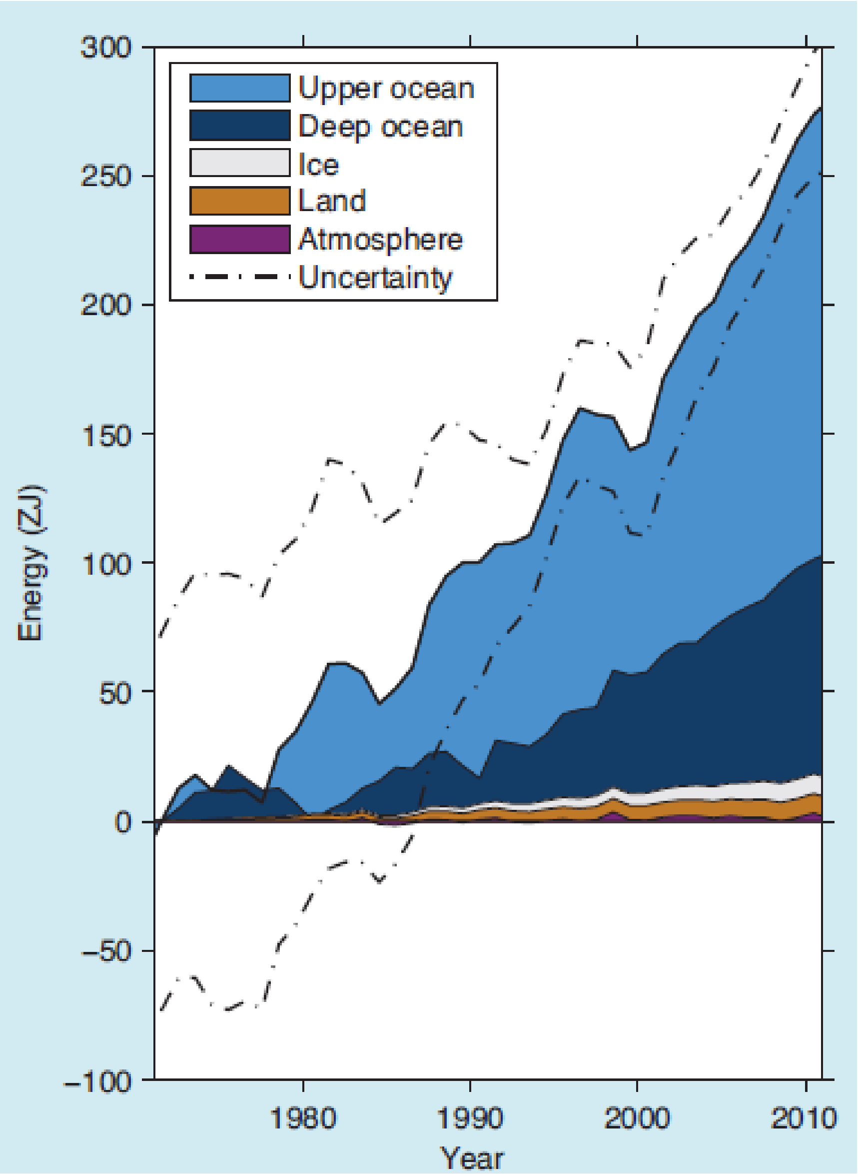




95% certainty that humans are the main cause of recent warming

IPCC, 2007

Oceanic warming



Oceans absorb 80% of heat

Global warming is mostly oceanic!!!!

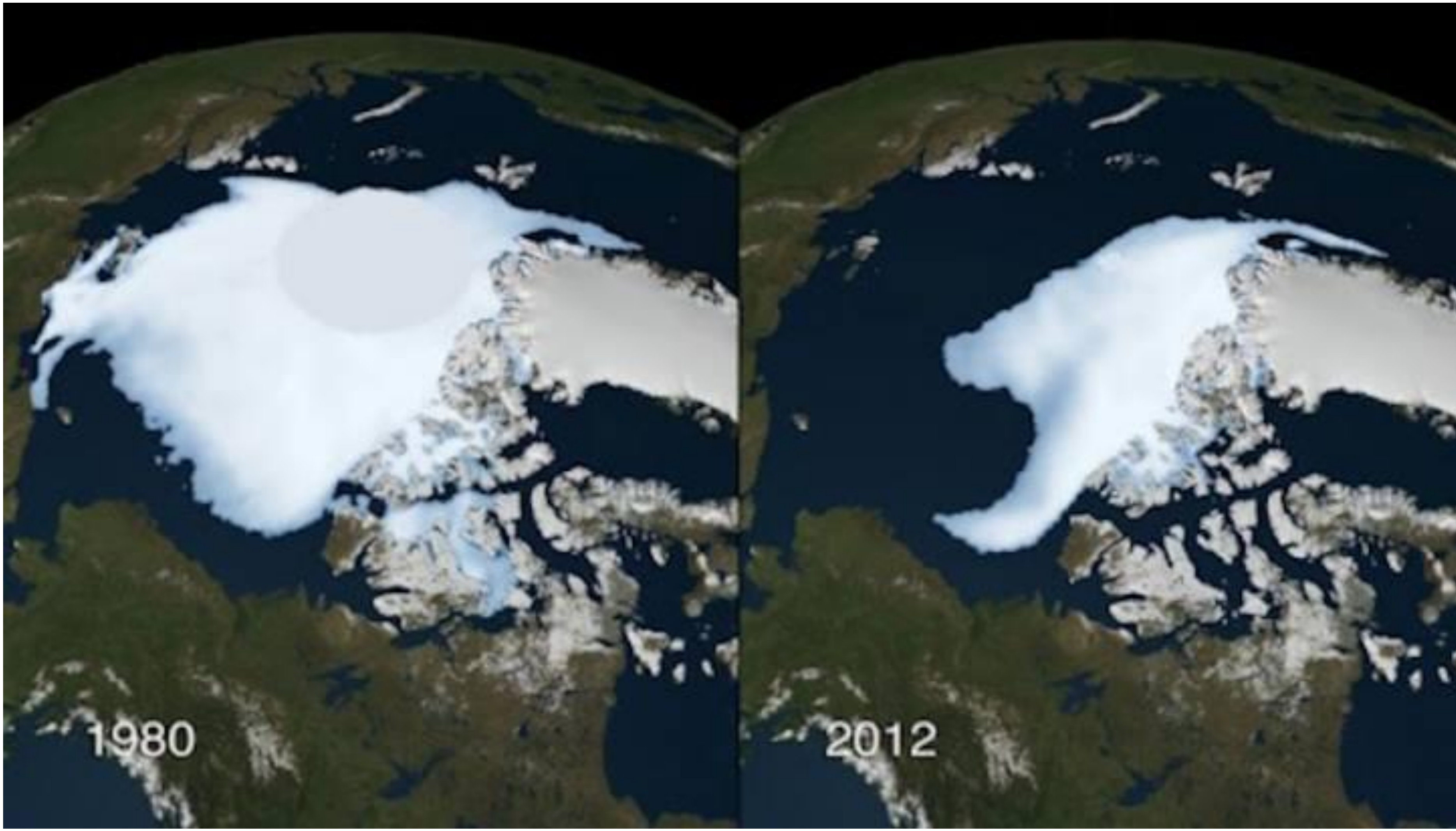
Rhein et al., 2013

A Global Network of MARINE • HOTSPOTS

- Areas of rapid ocean warming (top 10% ΔSST)
- Hotspots are the world's natural laboratories
- Useful to assess impacts, predict & develop/evaluate human adaptation options

Hobday & Pecl, 2014

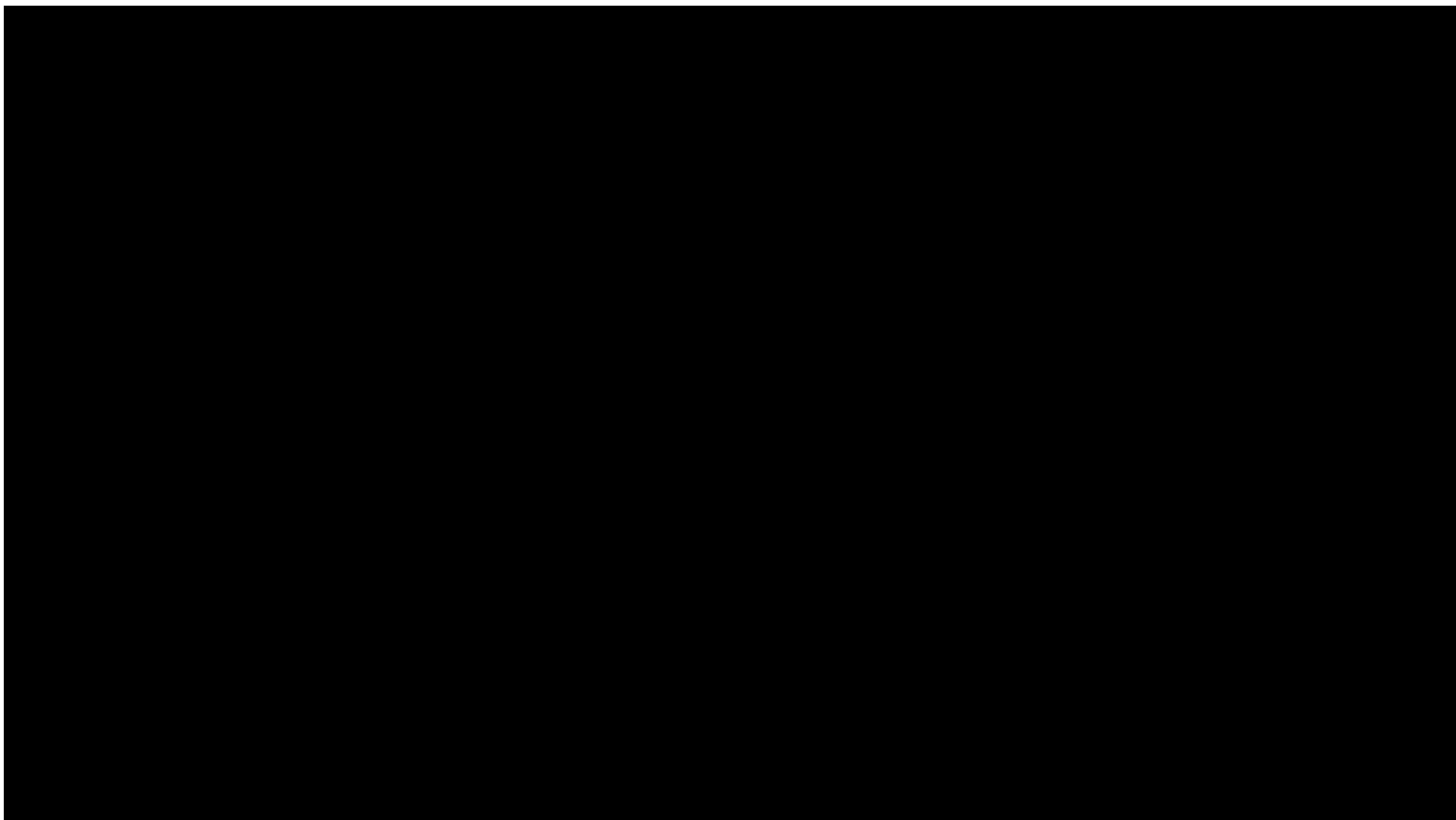
Artic sea ice melting



http://climate.nasa.gov/

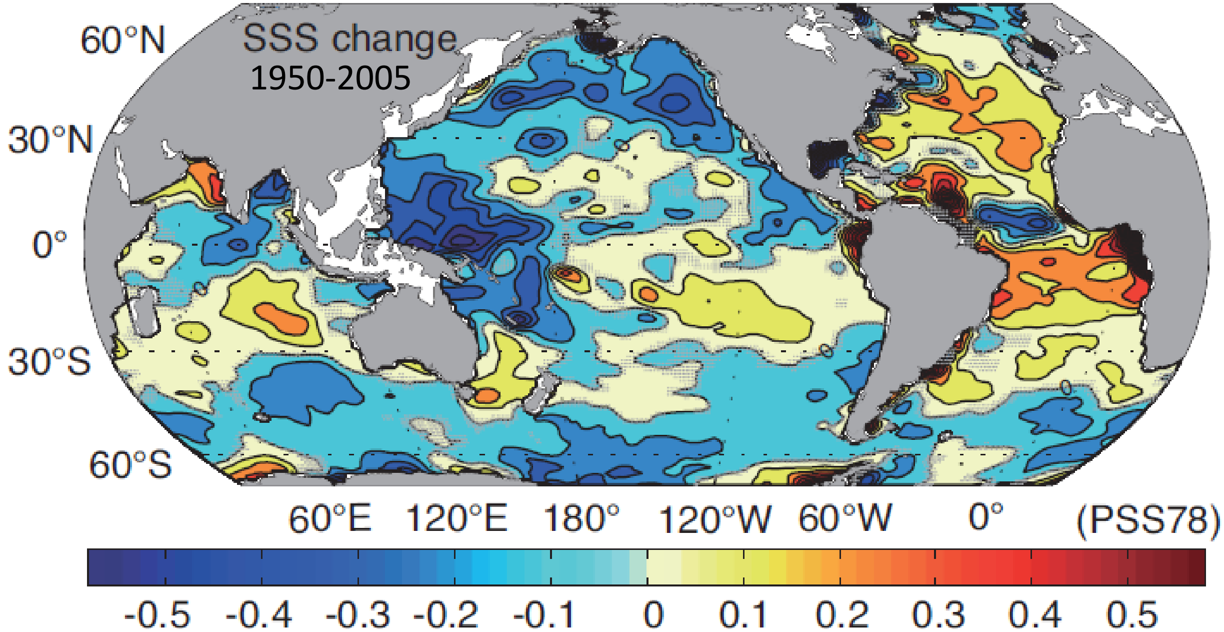
Changes in sea level

Globally averaged sea level has risen with a mean rate of 1.7 mm yr^{-1} between 1900 and 2010, and 3.2 mm yr^{-1} between 1993 and 2010.



https://sealevel.nasa.gov/resources/83/rising-seas-by-decade; Rhein et al., 2013

Changes in salinity

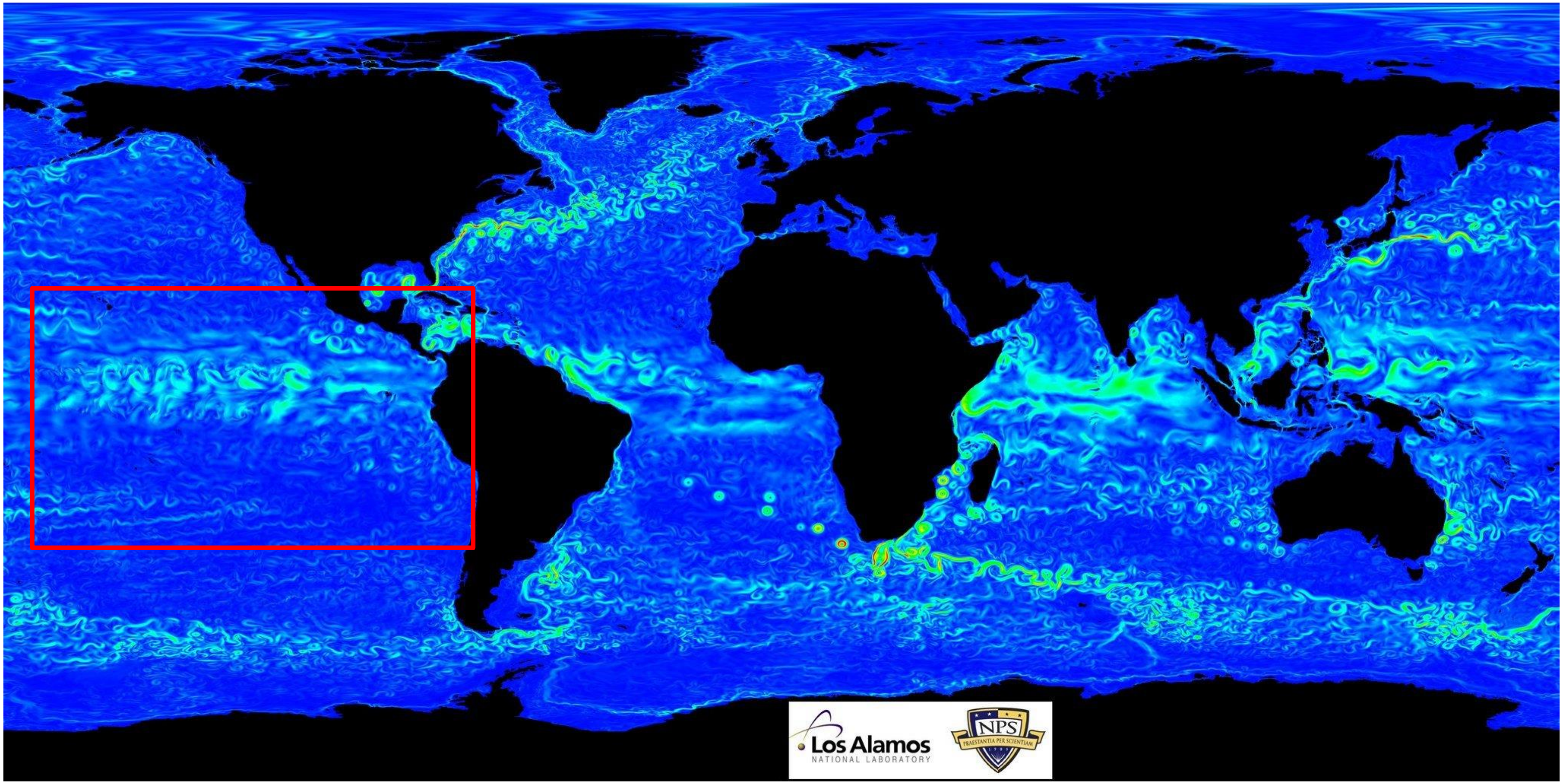


Patterns in salinity trends are caused by changes in evaporation and precipitation over the ocean as the lower atmosphere has warmed.

- Saline surface waters in the evaporation-dominated mid-latitudes have become more saline.
- Relatively fresh surface waters in rainfall-dominated tropical and polar regions have become fresher.

Rhein et al., 2013

Changes in oceanic circulation

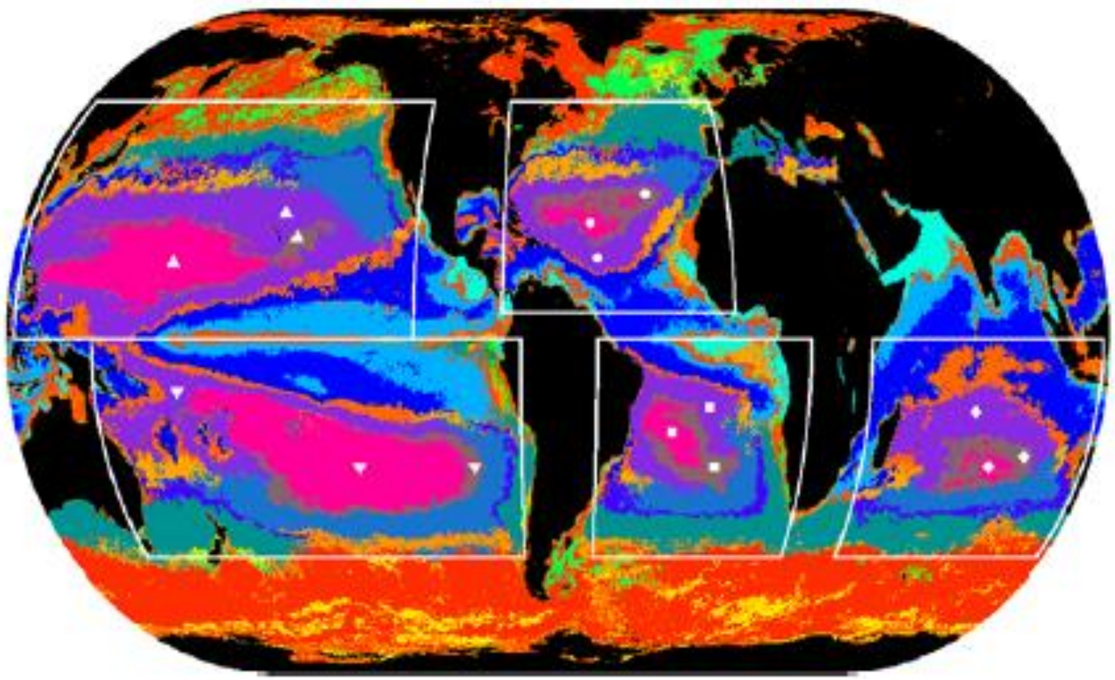


It is very likely that the subtropical gyres in the North Pacific and South Pacific have expanded and strengthened since 1993.

Rhein et al., 2013

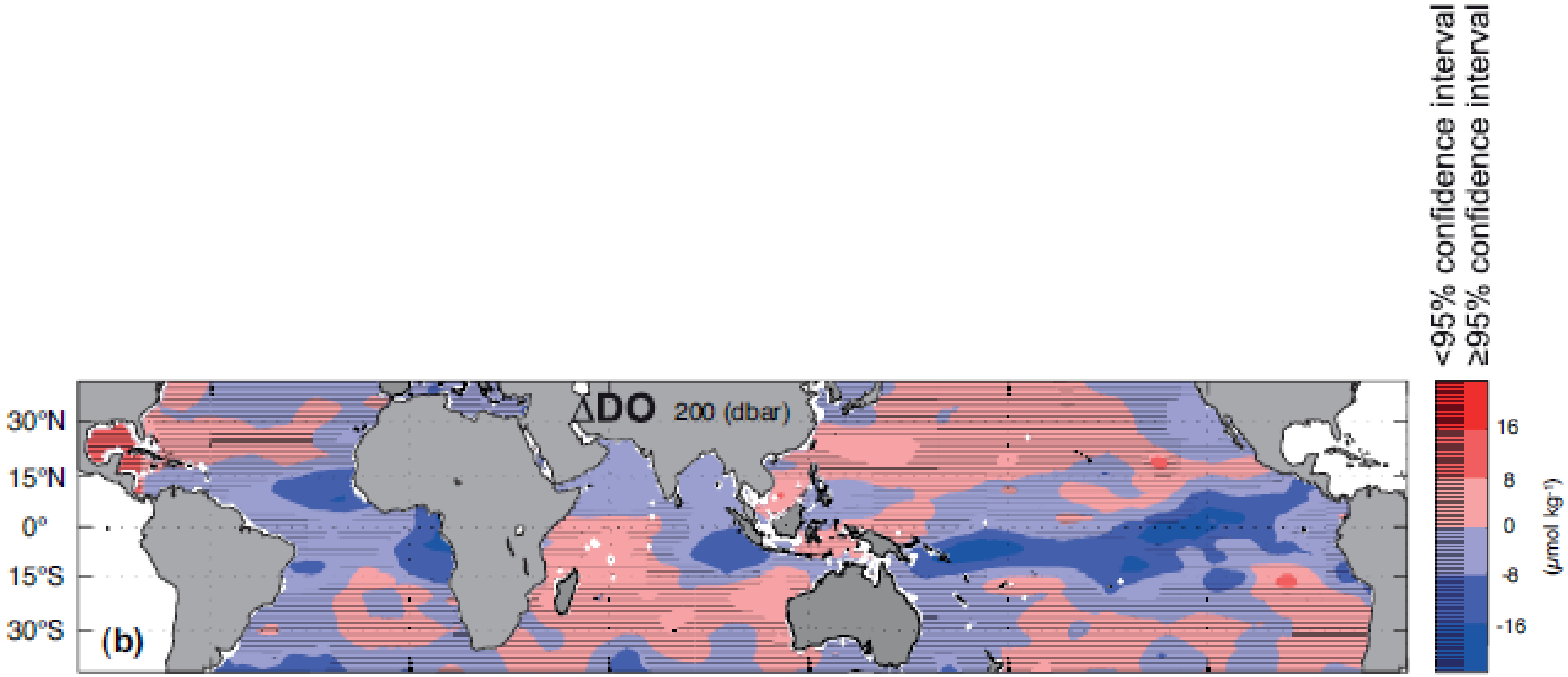
Changes in nutrients

Oligotrophic provinces in the North and South Pacific, and in the North and South Atlantic have expanded at average rates of 0.8 to 4.3% yr^{-1} from 1998 to 2007.



Polovina et al., 2008; Irwin & Oliver, 2009

Changes in dissolved oxygen concentration



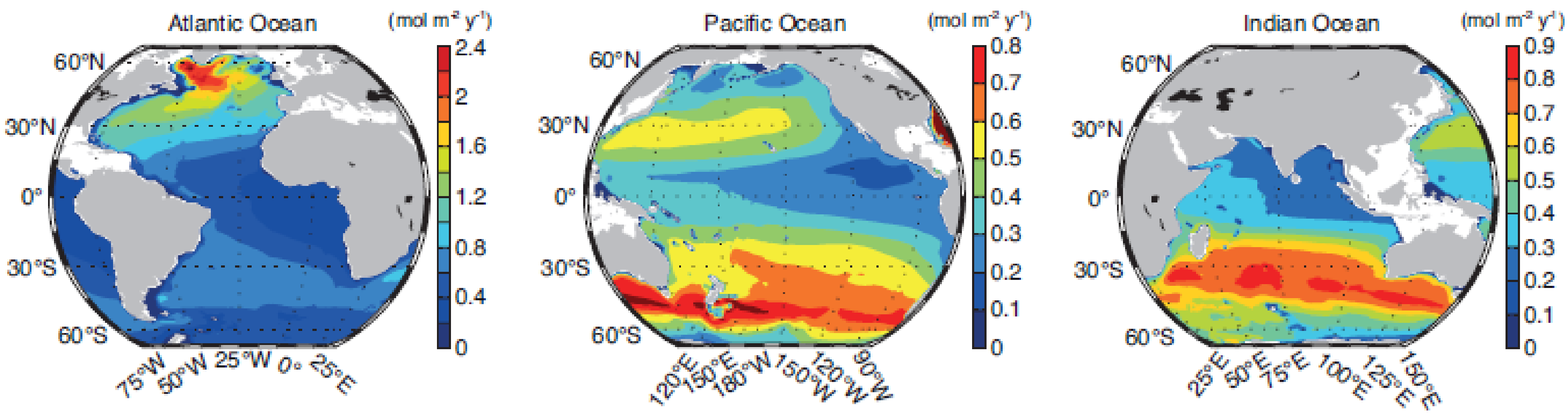
Changes between 1960 and 1974, and 1990 and 2008 of (b) dissolved oxygen (ΔDO) at 200 dbar. Increases are red and decreases blue.

Stramma et al., 2010

Ocean acidification

Mean pH of surface waters: 7.8 – 8.4 but decreasing

Oceans are 26% more acidic

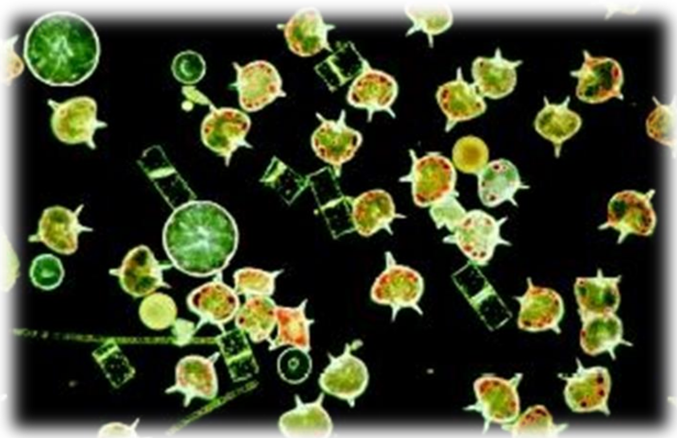


Storage rate distribution of anthropogenic carbon (mol m^{-2} yr^{-1}) for the three ocean basins averaged over 1980–2005.

Khatiwala et al., 2009; Rhein et al., 2013

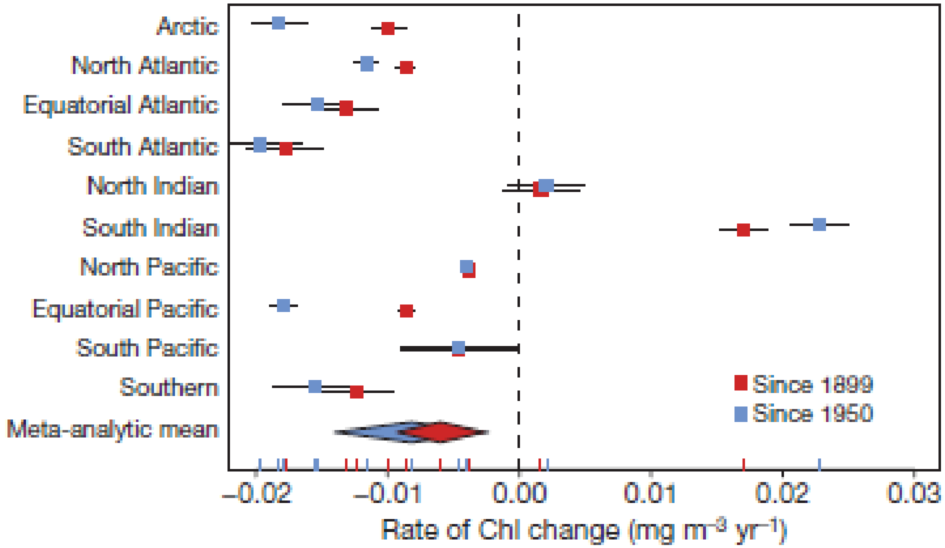
4. Global impacts of Climate Change on marine ecosystems

Primary producers



Phytoplankton produces 50% of the planet´s oxygen.

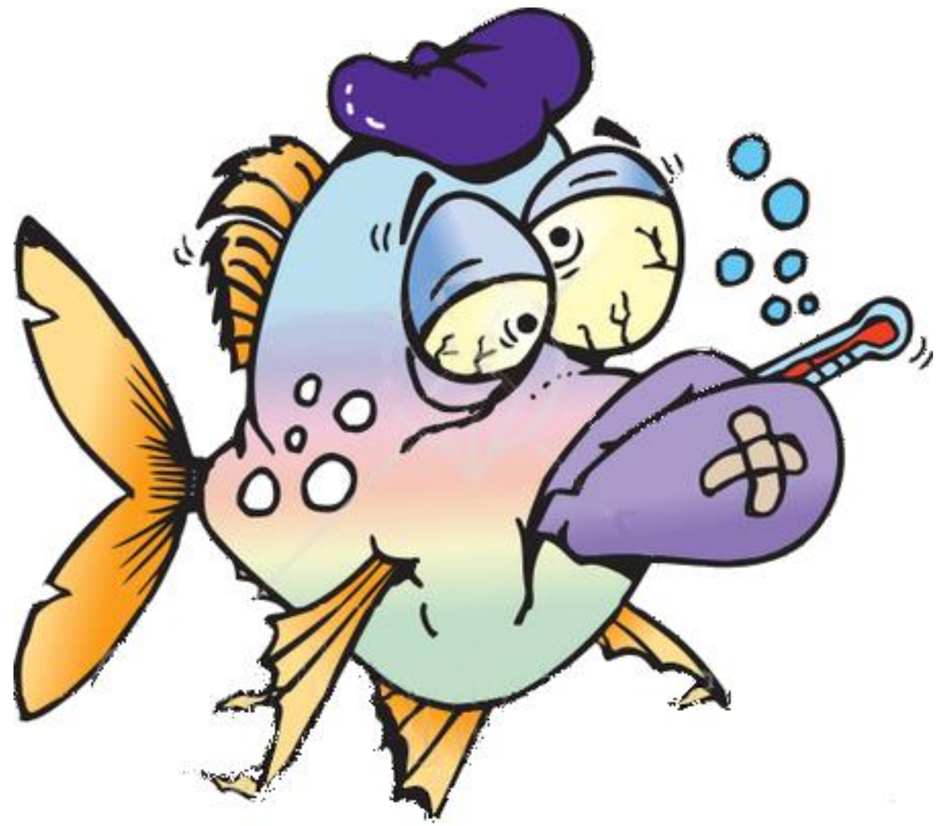
Phytoplankton abundance has declined in 40% since the 1950’s, very likely due to oceanic warming.

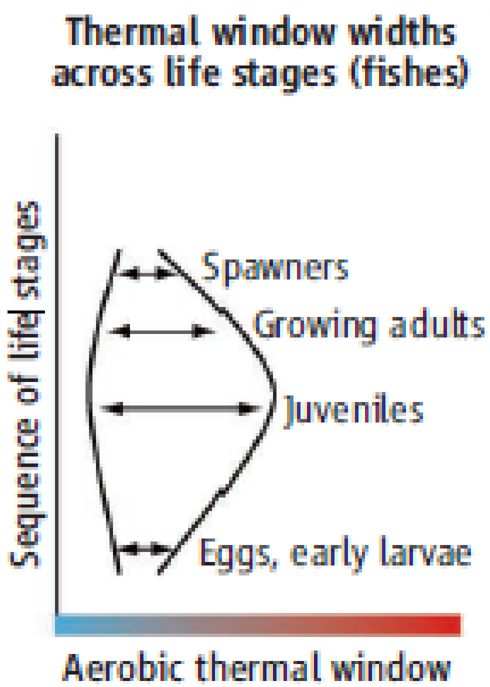


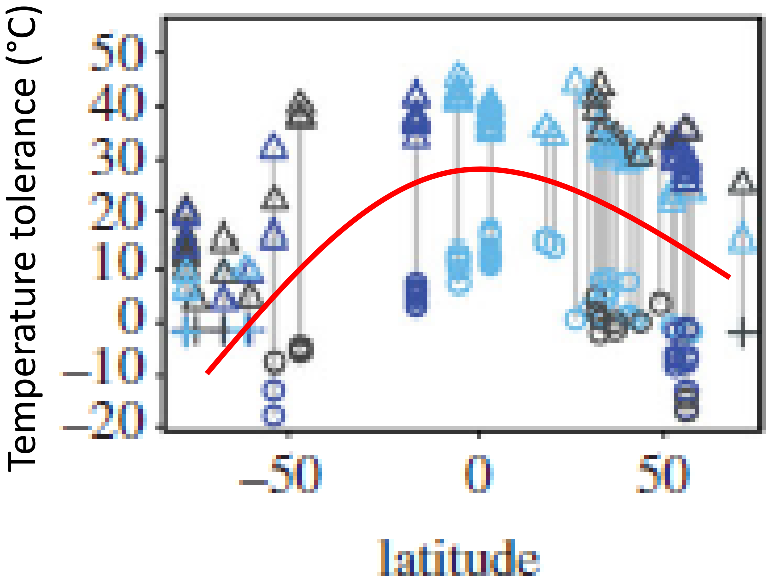
Boyce et al., 2010

As waters warm:

- There is less oxygen available
- Animals use more energy to breathe
- Greater stress on animals
- More stress makes animals more susceptible to disease
- Less energy available to reproduce







Eggs, early larvae and spawners are more vulnerable to oceanic warming

Thermal tolerance limits of marine species through a latitudinal gradient

Pörtner & Farrell, 2010; Sunday et al., 2011

Effects on growth

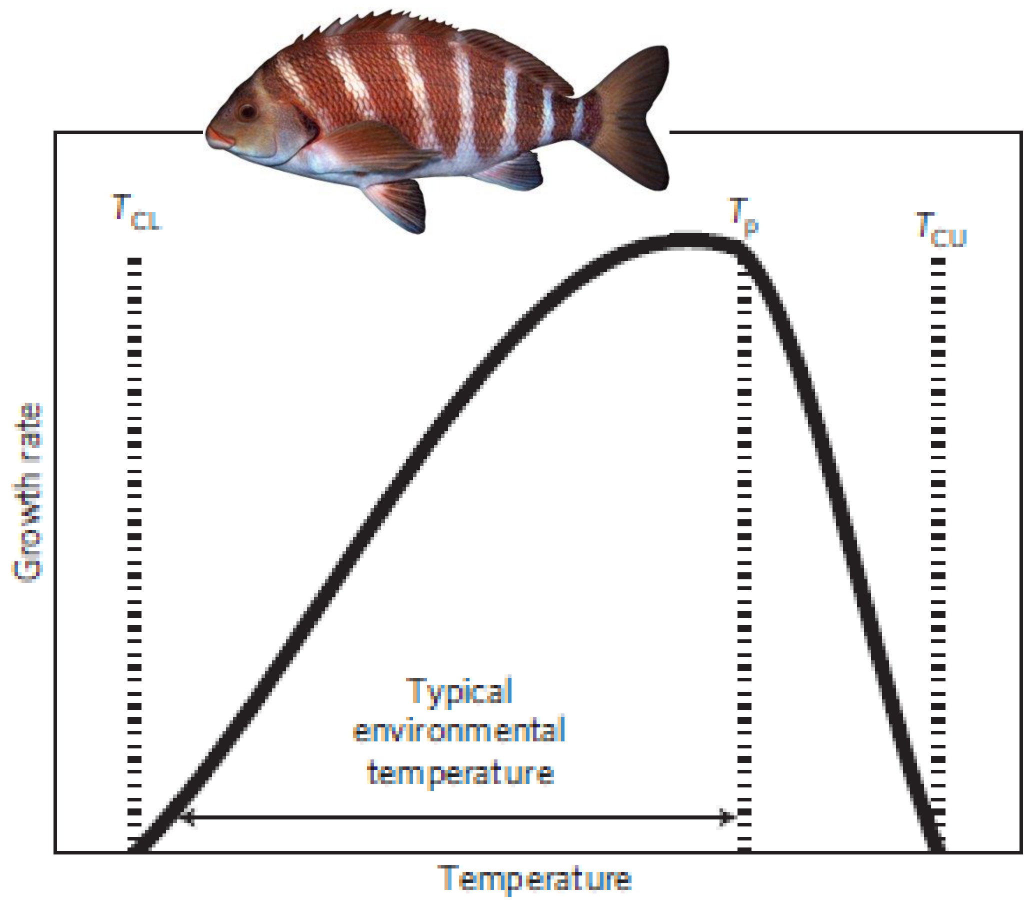
Depend on where the animal is within its range of distribution.

Increasing temperatures result in:

Increased growth at the **middle of the species range**

Reduced growth at the warm **equatorward** edge of the species range

Temperatures may have already reached levels associated with increased metabolic costs



TCL) Lower critical temperature; TP) Pejus temperature; TCU) Upper critical temperature.

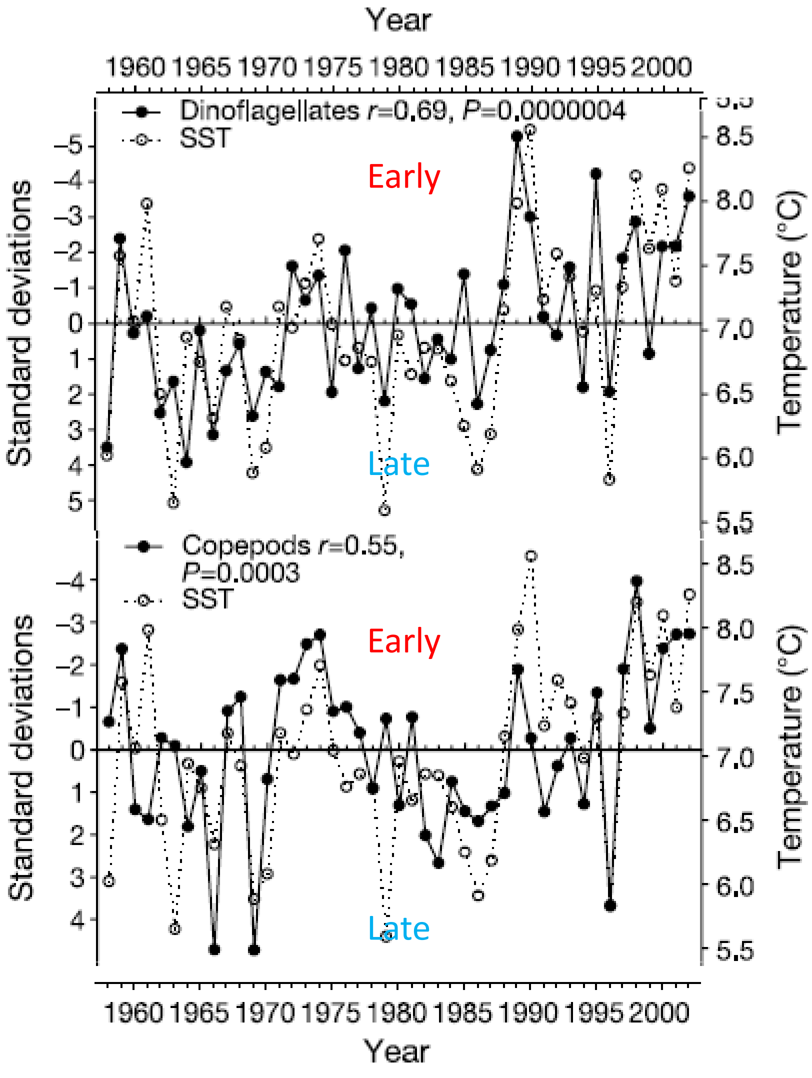
Neuheimer et al., 2011

Changes in phenology

The level of response to climate change may vary across functional groups and trophic levels.

The decoupling of phenological relationships will cause changes in:

- trophic interactions,
- food-web structures,
- the ecosystem.



Edwards & Richardson, 2004

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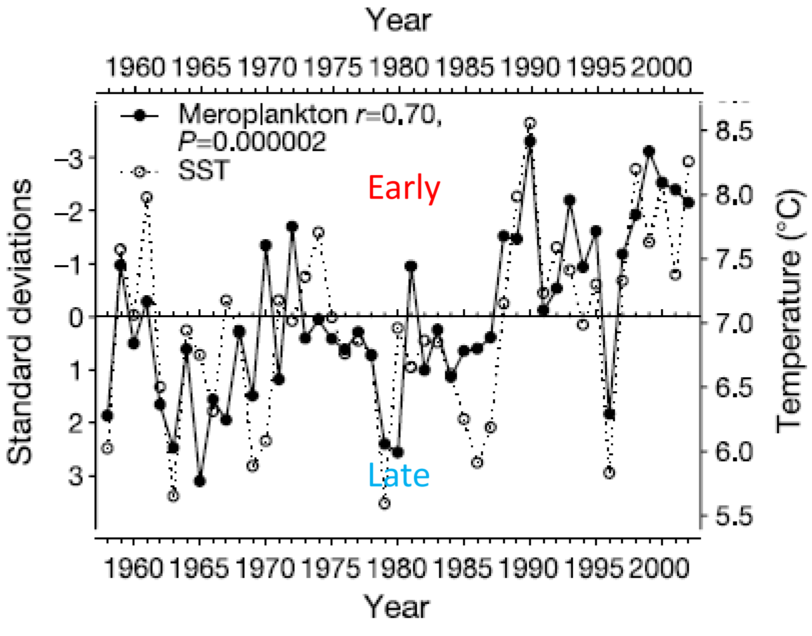


Edwards & Richardson, 2004

Changes of distribution – ‘range shifts’

If species are to persist in the face of rapid environmental change, they must:

- adjust in situ or, where able
- shift their geographic distribution

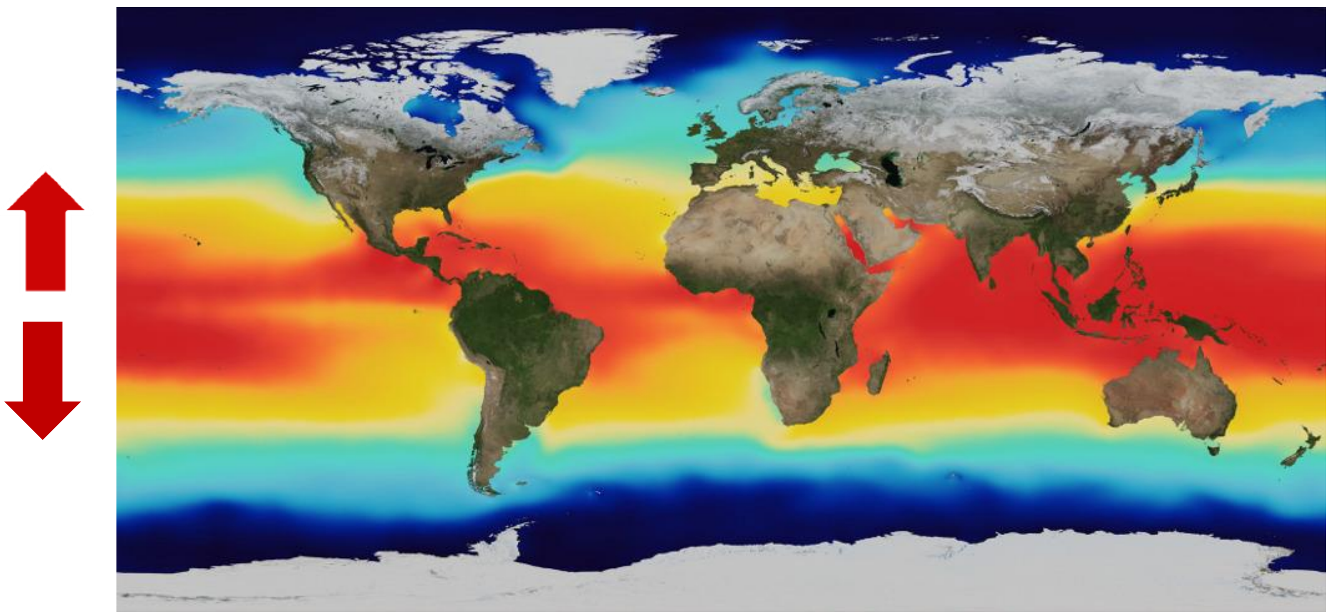
Consequently, one of the most widely documented impacts of Climate Change is a shift in species distributions

– effectively a redistribution of the planet’s species

Pinsky et al., 2013; Poloczanska et al., 2013, 2016; Burrows et al., 2014; Sunday et al., 2015

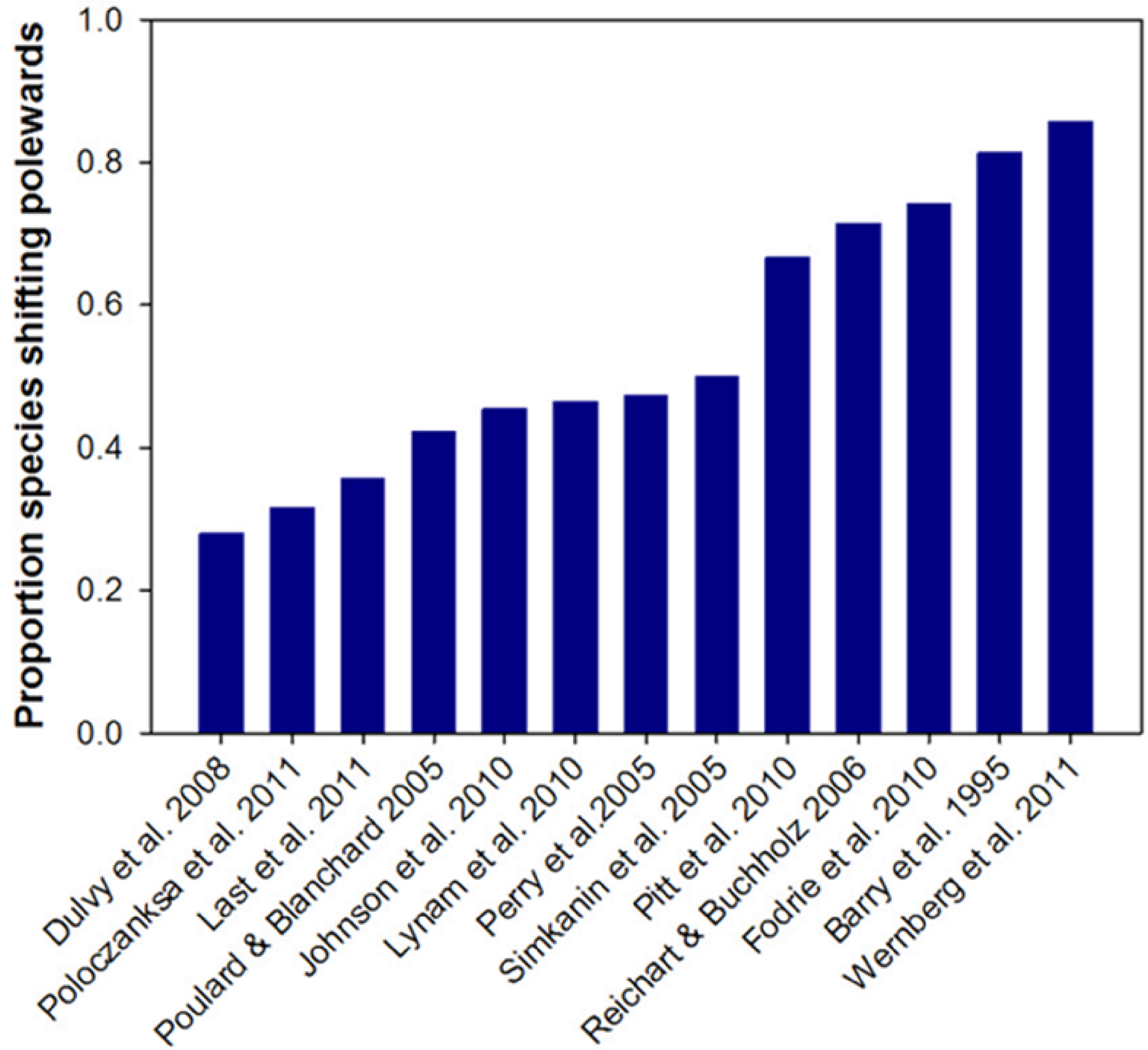
Species on the move all over the globe

- Species have a preferred range of temperatures they like to live in
- Species' distributions shifting polewards
- 'Range shifts' are greatest where climate has warmed the most



Pinsky et al., 2013; Poloczanska et al., 2013, 2016; Burrows et al., 2014; Sunday et al., 2015

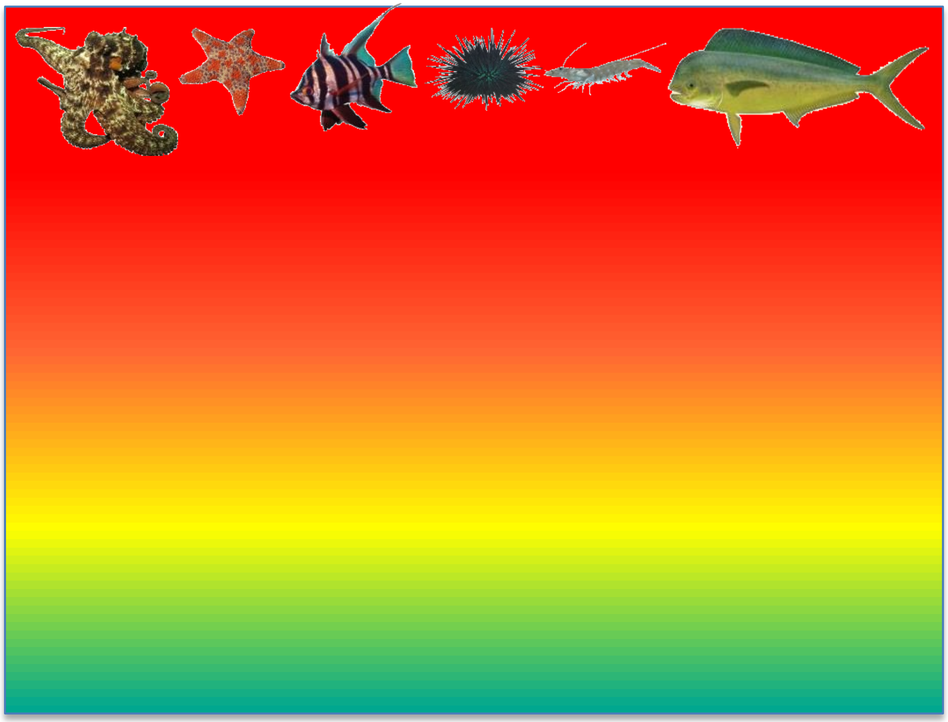
Between 25–85% of animals monitored are changing where they live



Variation in timing & pace of species shifts

- Not all species can/will shift
- Species shift at different rates
- General poleward movement - but lots of variation

Equator/North (warmer)



Polewards/South (cooler)

On average leading range edges shifting at 72 km $decade^{-1}$

Poloczanska et al., 2013

Variation in timing & pace of species shifts

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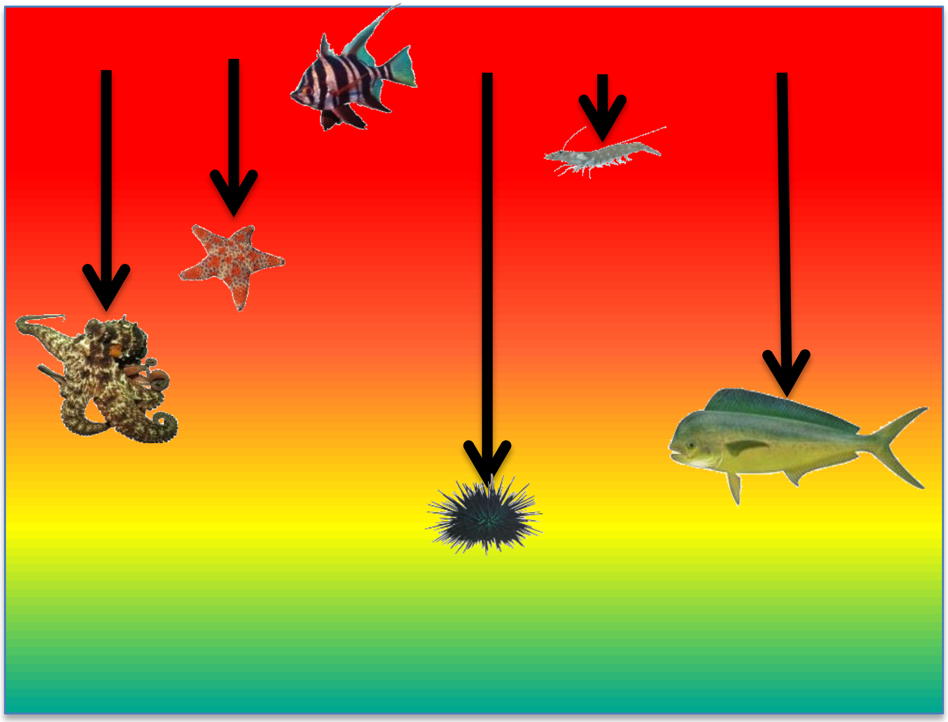
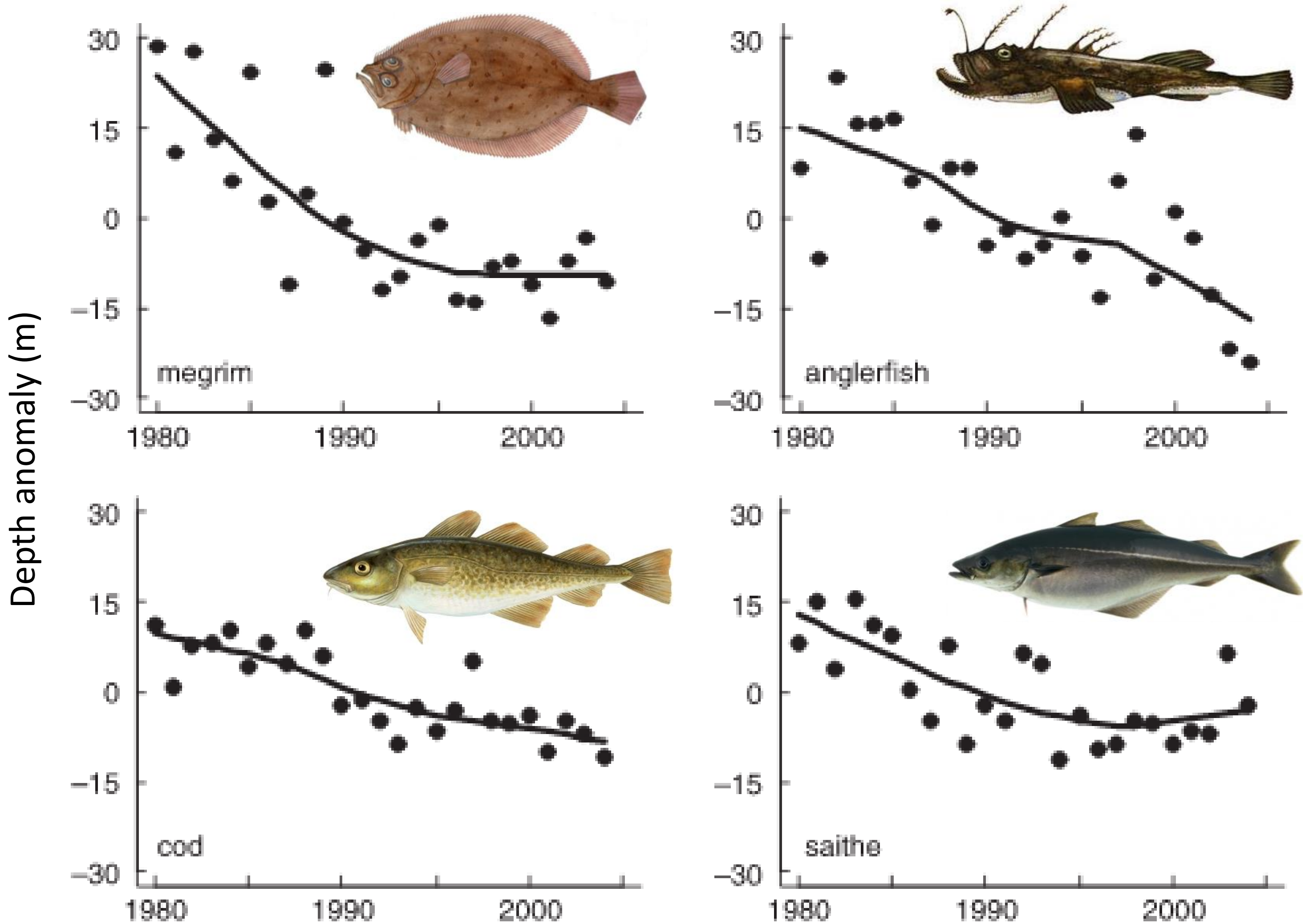


On average leading range edges shifting at 72 km decade^{-1}

Poloczanska et al., 2013

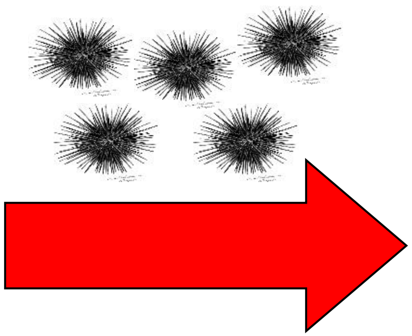
Deepening of North Sea fishes (UK)



Dulvy et al., 2008

Harmful species

Oceanic warming and the invasive sea urchin *Centrostephanus rodgersii* have caused 95% decline of Tasmanian kelp forests in South-east Australia

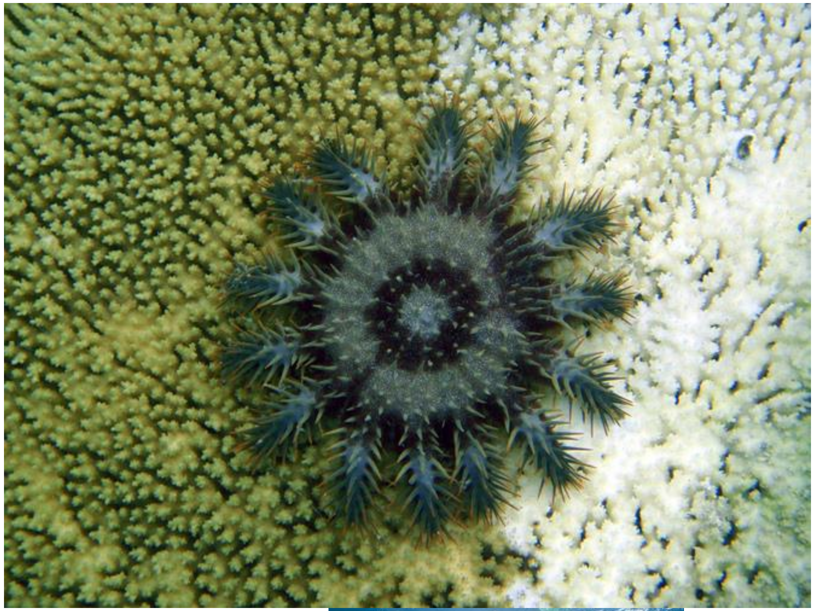


Ling et al., 2009

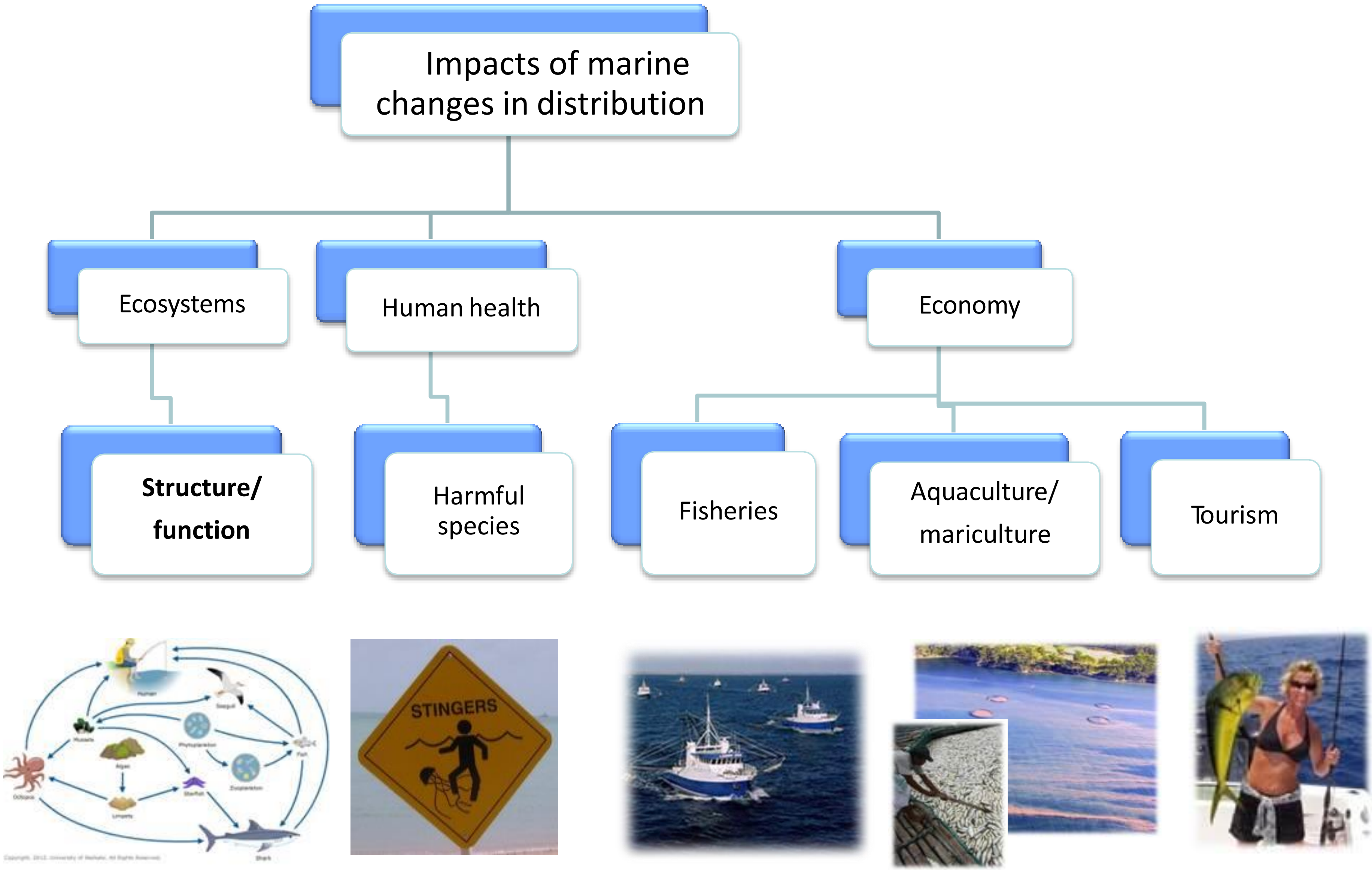
Harmful species

The crown of thorns starfish *Acanthaster planci* has caused extensive damage to coral reefs by eating coral

This species caused the 50–70% decline in soft coral reefs in the Great Barrier Reef



Fabricius, 1997; Hock et al., 2015



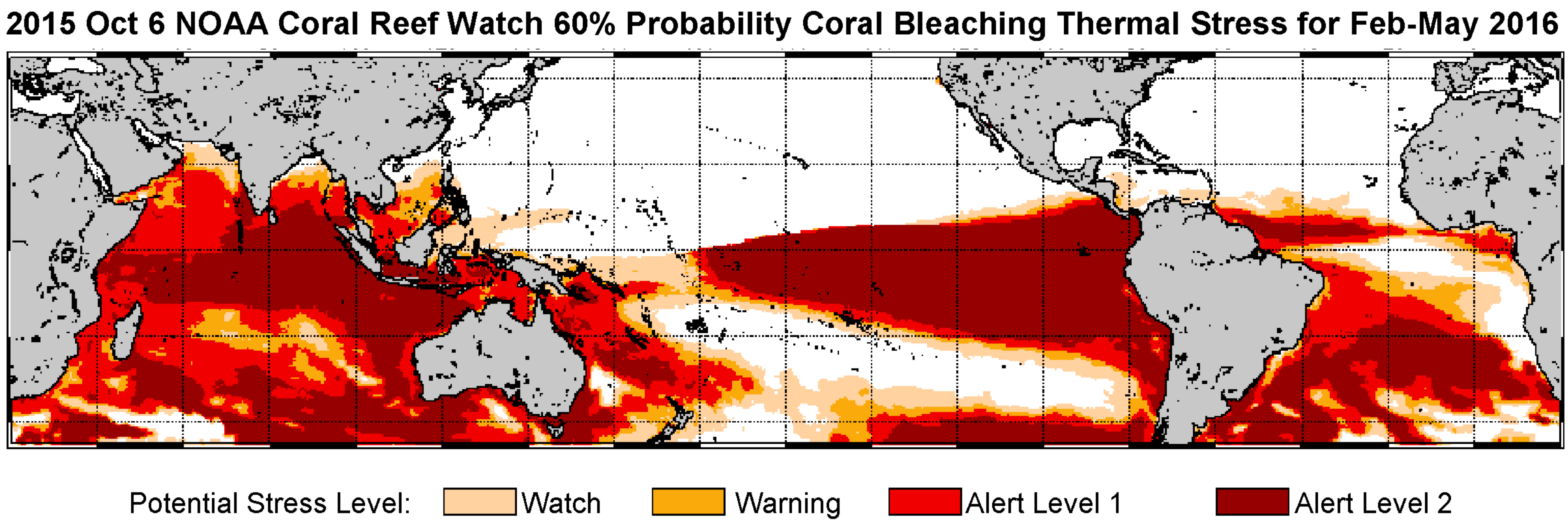
Madin *et al.* 2012

Coral bleaching

Combined effect of temperature and acidification

Orr et al., 2005; Ainsworth et al., 2016

Currently in midst of third major global bleaching event



https://theconversation.com/coral-bleaching-comes-to-the-great-barrier-reef-as-record-breaking-global-temperatures-continue-56570

Before

Now

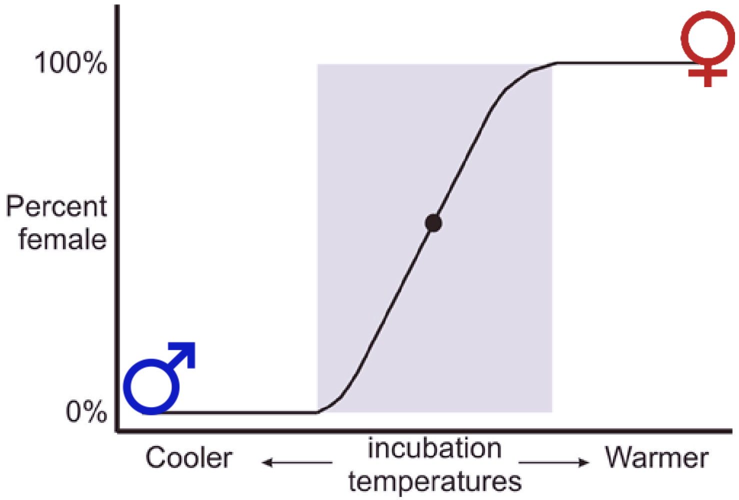
Sea level rise

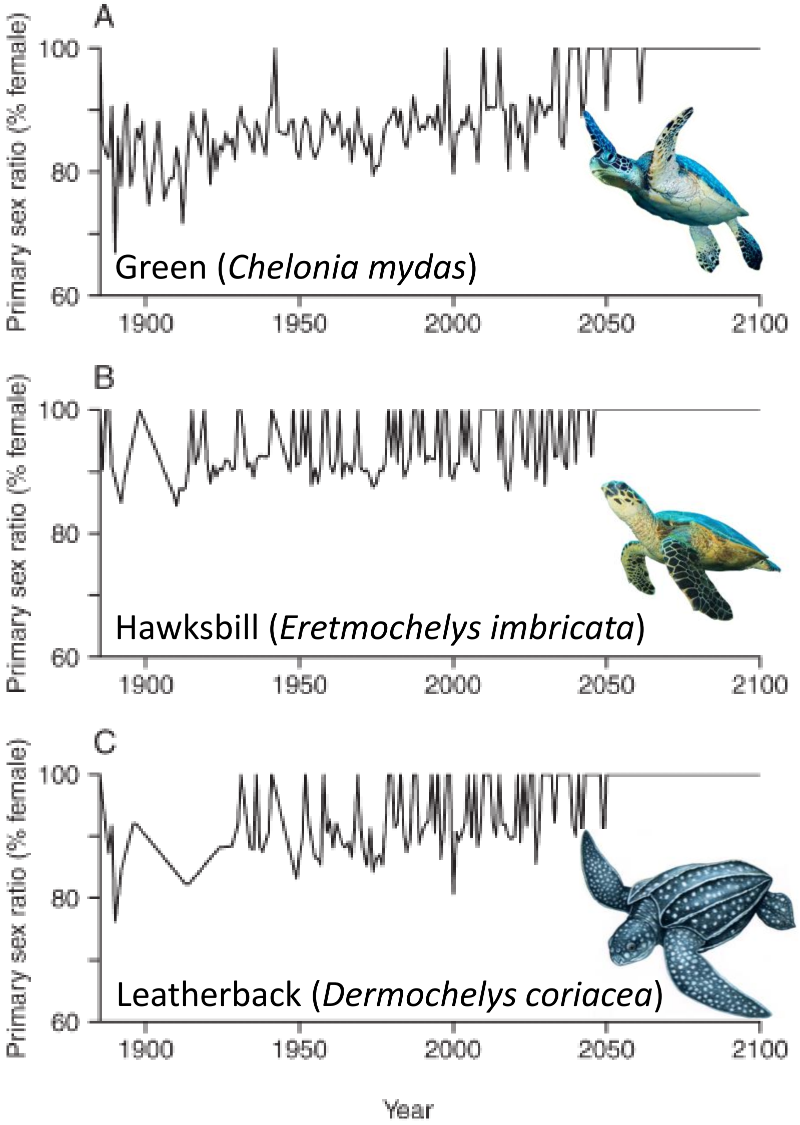
Sea level rise may cause:

- Coastal erosion
- Saltwater intrusion
- Flood risk
- Habitat loss
- Changes of distribution of associated species

Bergkamp & Orlando, 1999; Barros & Albernaz, 2013

Temperature-dependent sex determination

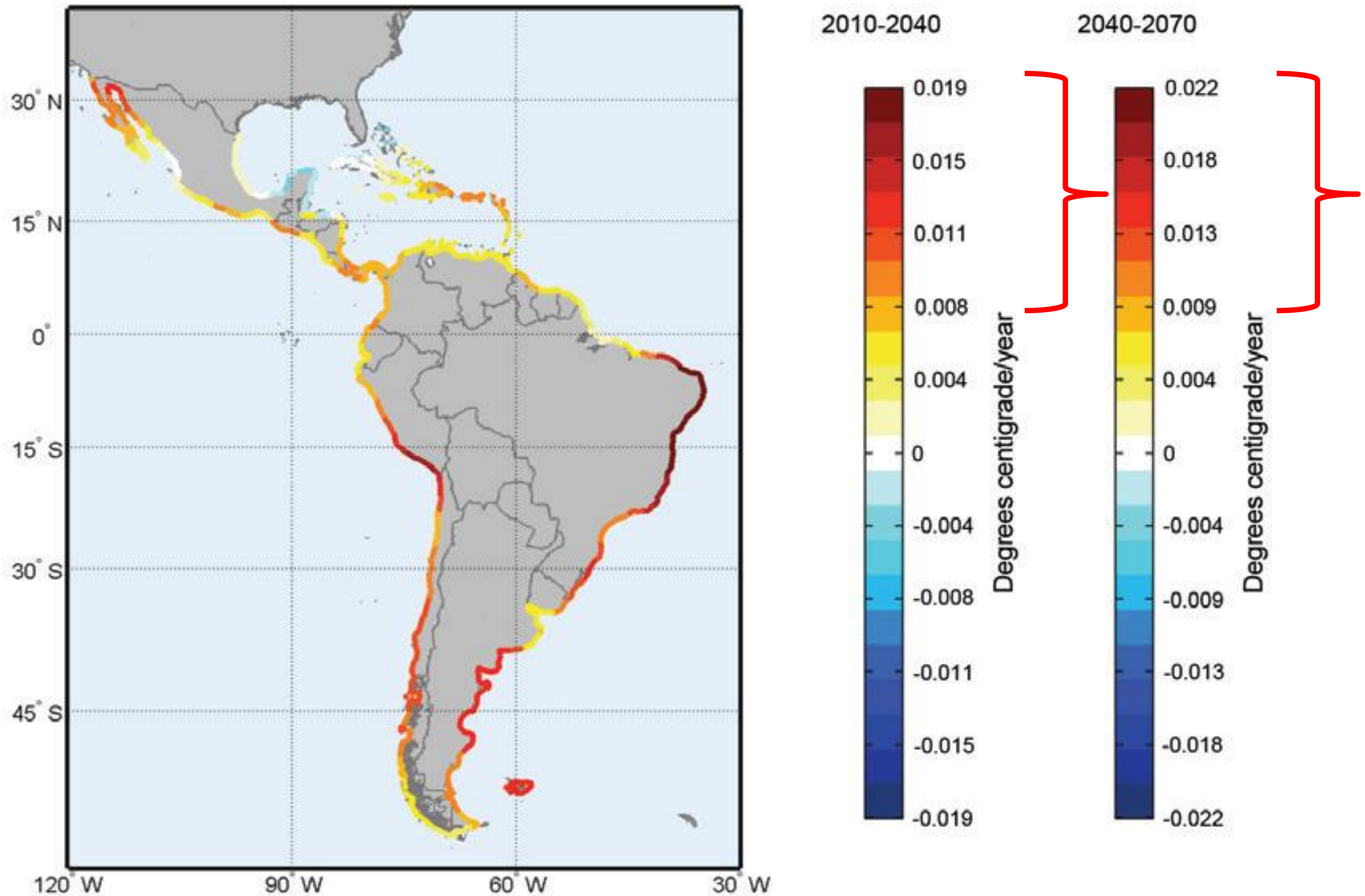




http://www.seaturtle.org/mtn/archives/mtn128/mtn128p7.shtml; Laloë et al., 2016

5. Regional physical changes associated with Climate Change

Mean sea surface temperature projections



Greater sea surface temperature increase (°C/year) towards the south of Peru

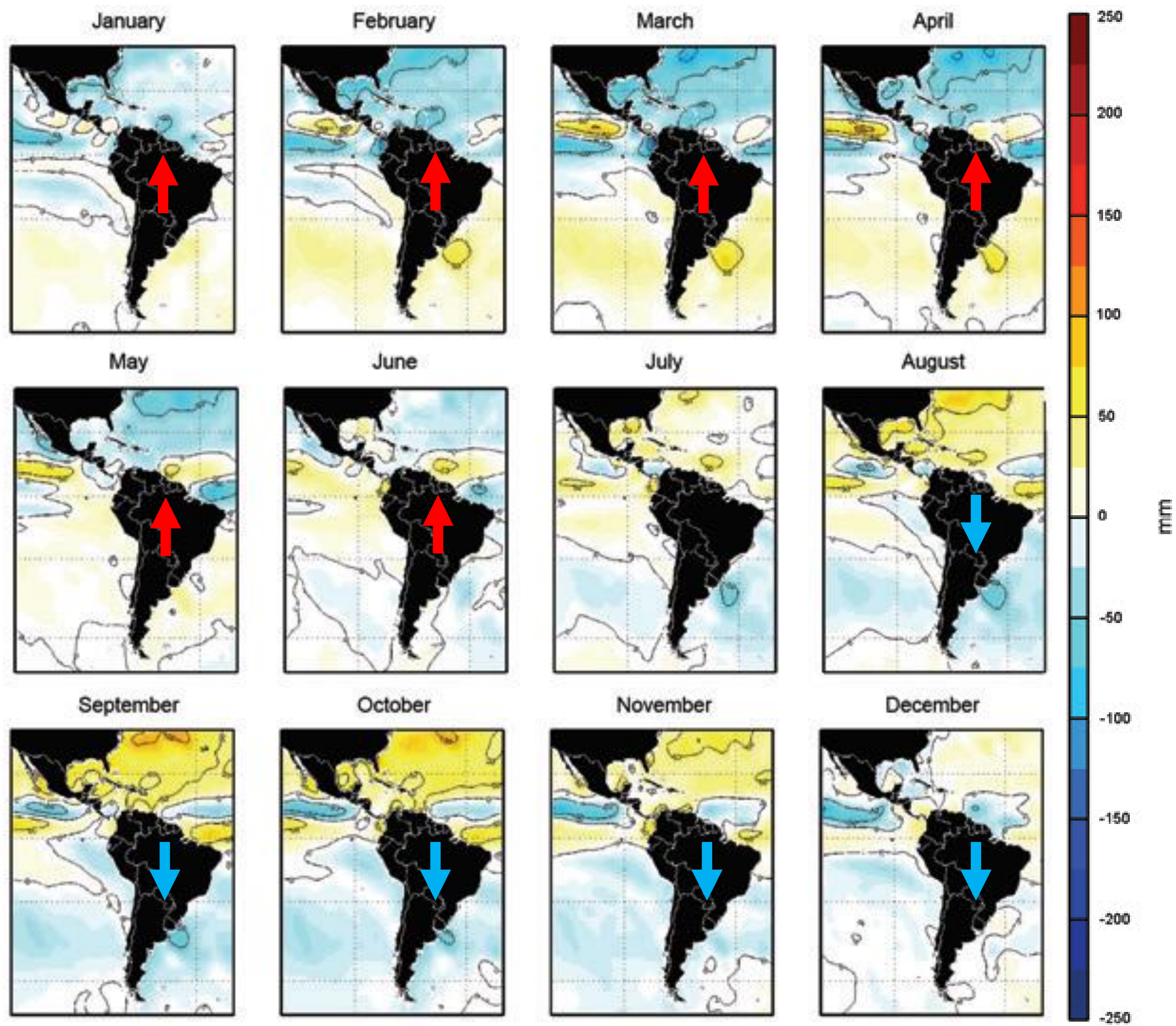
UN-CEPAL 2015

Seasonal mean sea level

Sea level in Peru

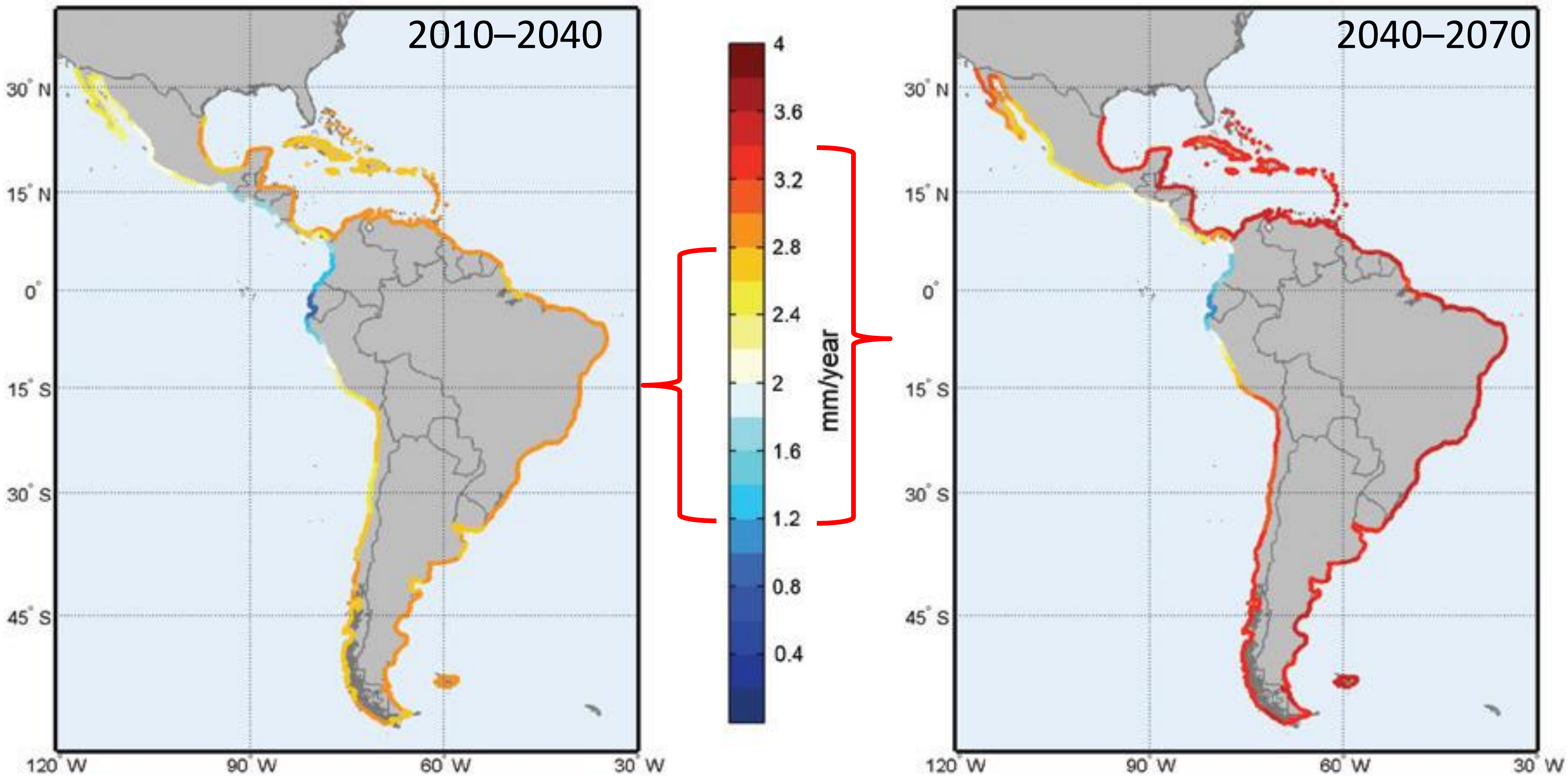
Increase in sea level:
- Jan through June

Decrease in sea level:
- Aug through Dec



UN-CEPAL 2015

Mean sea level projections



Greater sea level rise towards the south of Peru

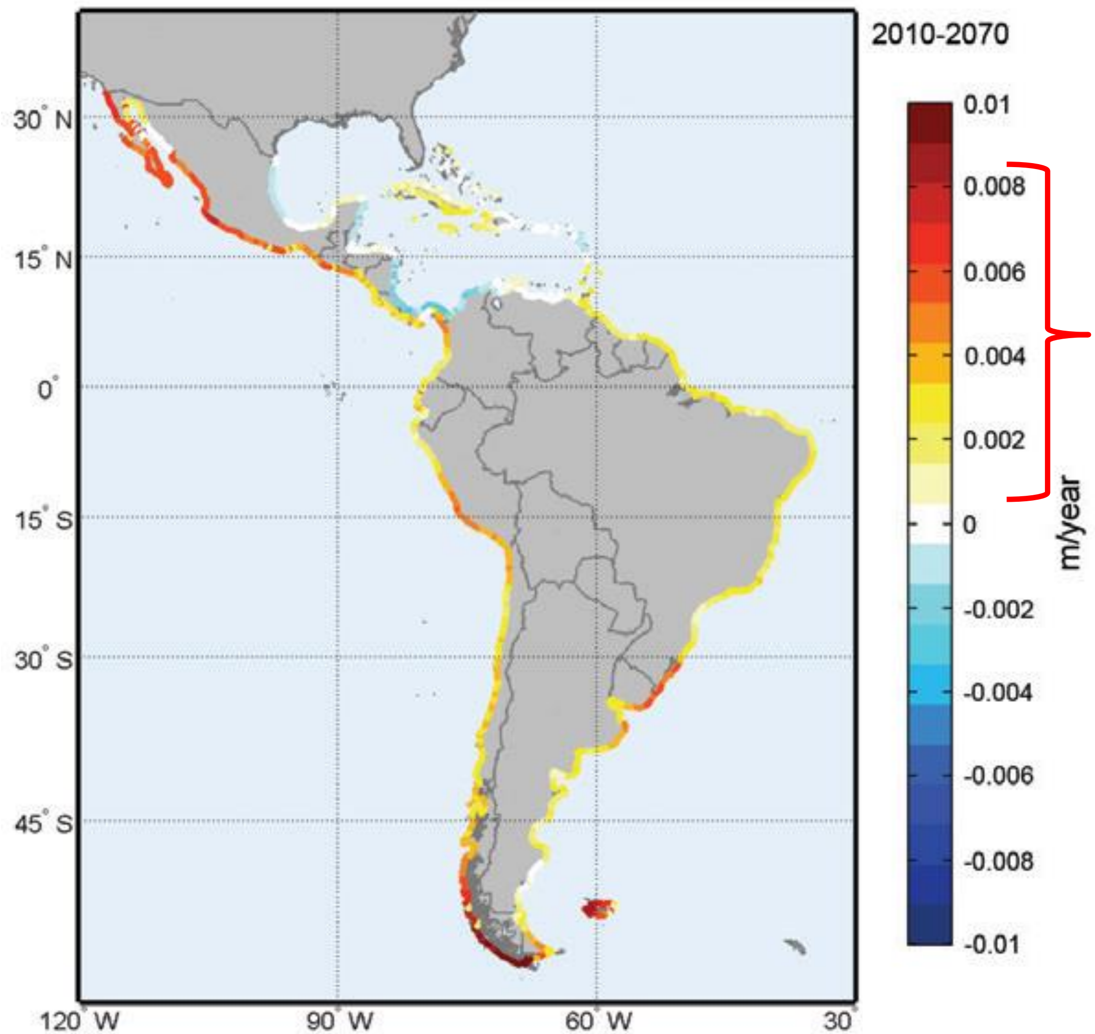
Soto & Quiñones, 2013

Mean wave height projections

Greater mean wave height increase towards the centre and south of Peru

Mean wave height increase of 1–8 mm/year off the coast of Peru

Up to 45 cm wave height in 2070

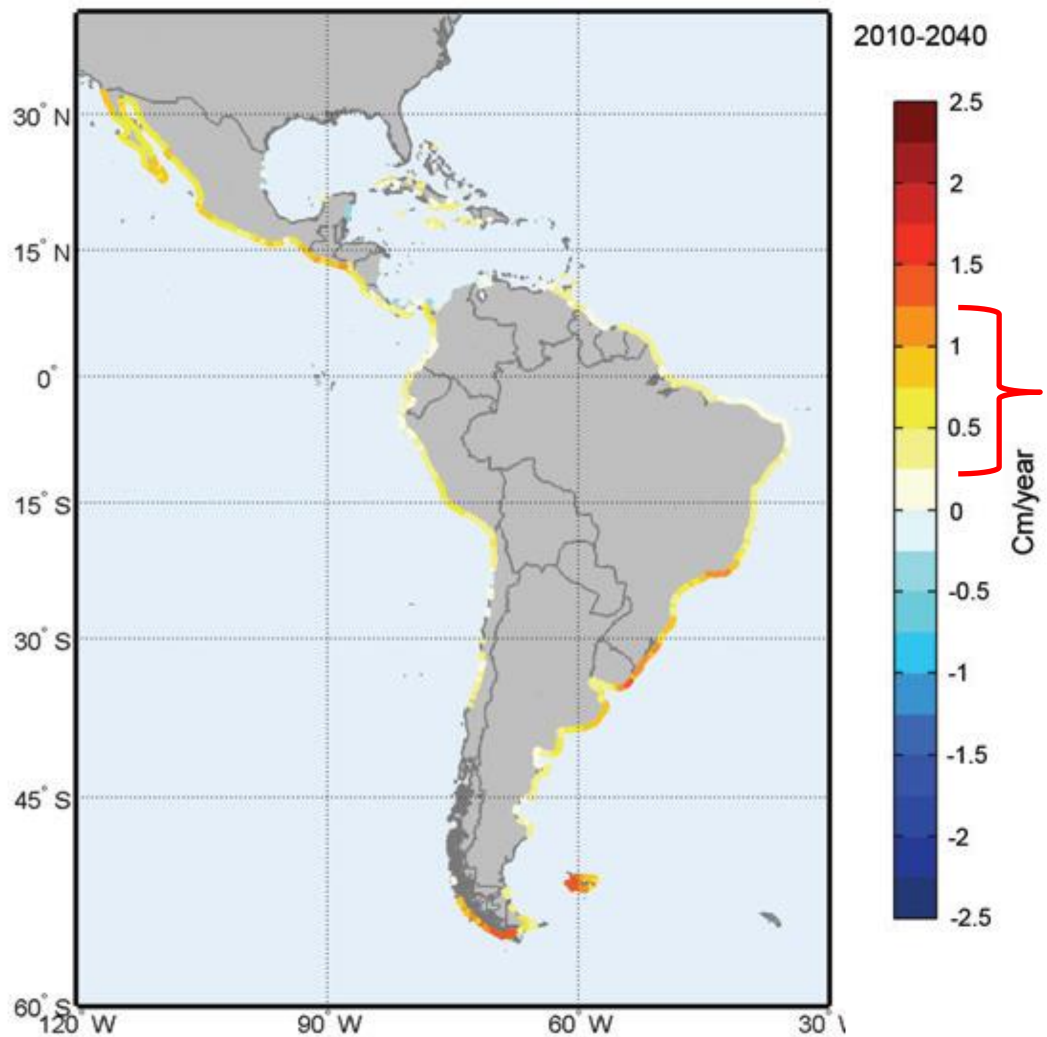


UN-CEPAL 2015

Extreme wave height projections

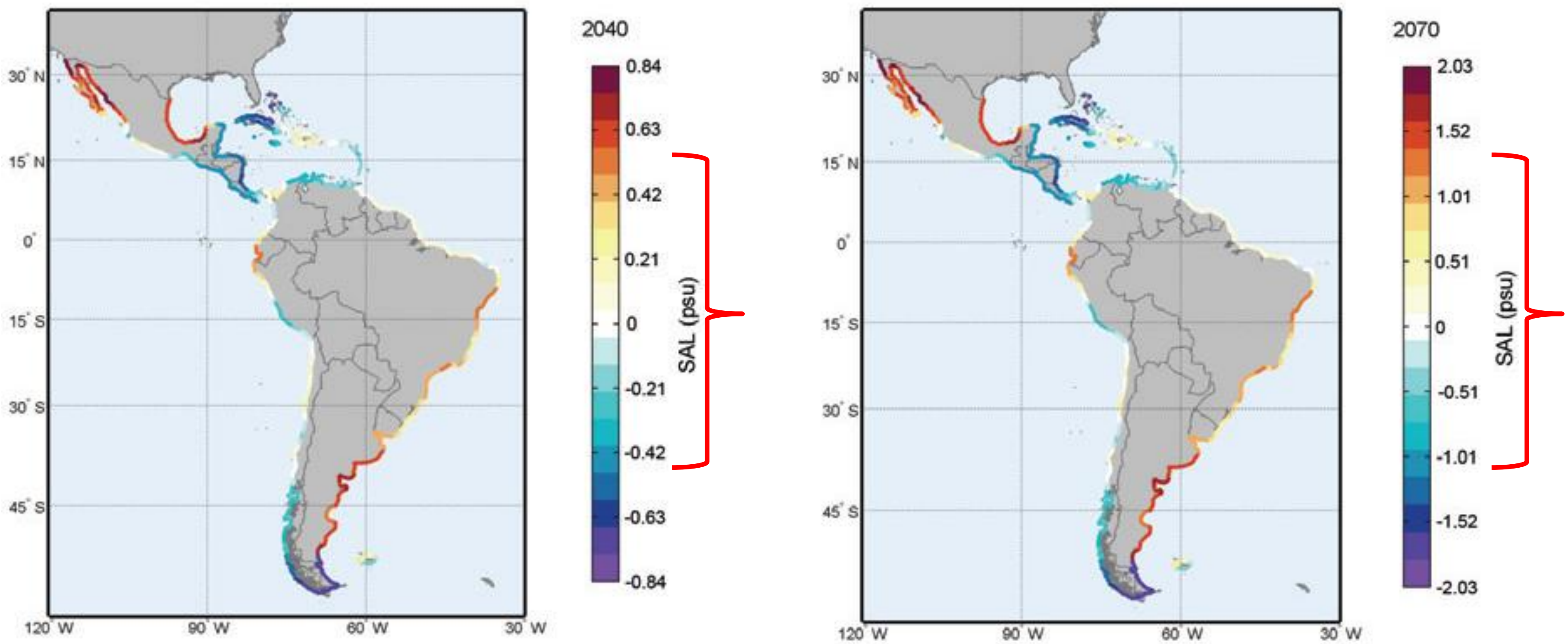
Extreme wave height increase of 2.5 mm–1.25 cm/year off the coast of Peru

Up to 67 cm wave height in 2070



UN-CEPAL 2015

Mean salinity projections



Greater increase in salinity from the centre towards the north of Peru by 2040 and 2070

UN-CEPAL 2015

El Niño Southern Oscillation

http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

Summary

- Greater **increase in sea surface temperature towards the south of Peru**, with mean increases of 0.008–0.022 °C/year from 2010–2070.

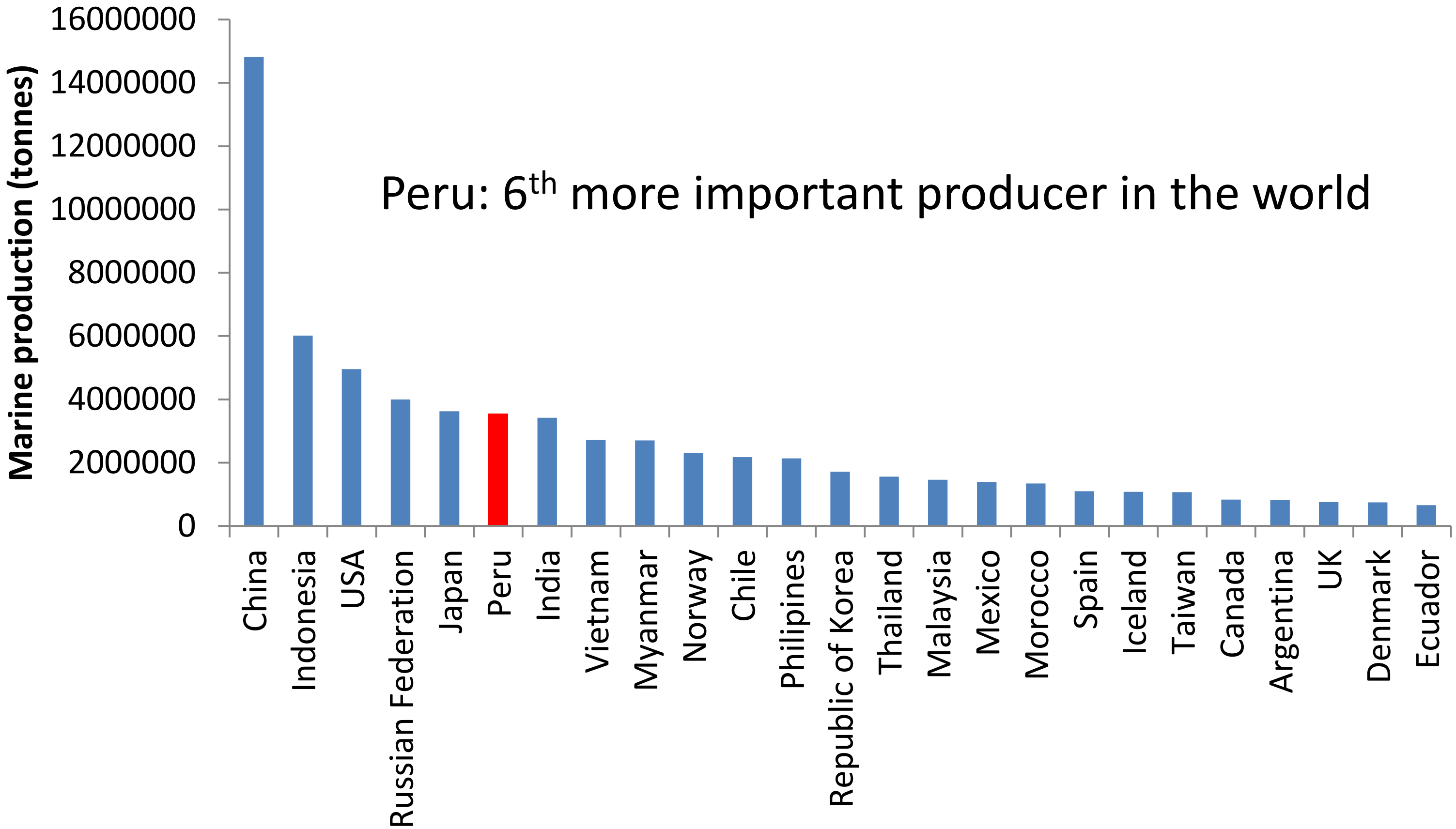
- Greater **sea level rise from Jan–June towards the south of Peru**, with 1.2–3.4 mm/year from 2010–2070. El Niño is also correlated to sea level rise.

- Greater **increase in wave height towards the centre and south of Peru**, with maximums of 2.5 mm–1.25 cm/year.

- **Greater increase in salinity towards the north**, with up to 1.25 psu by 2070. **Greater decrease in salinity towards the centre and south**, with -1 psu by 2070.

6. Regional impacts of Climate Change on fisheries

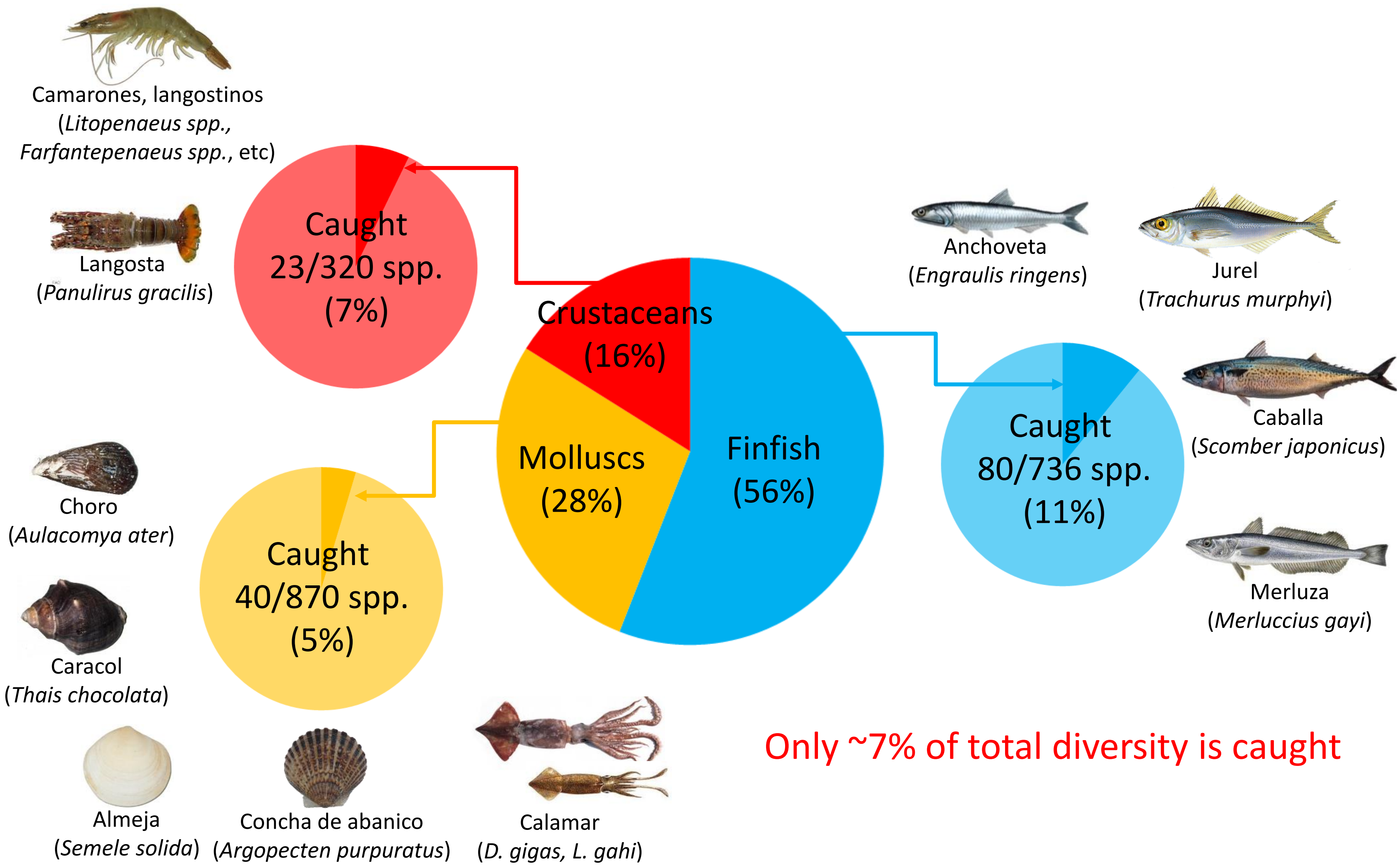
Peru fisheries statistics



~10% of the world's fish catch!

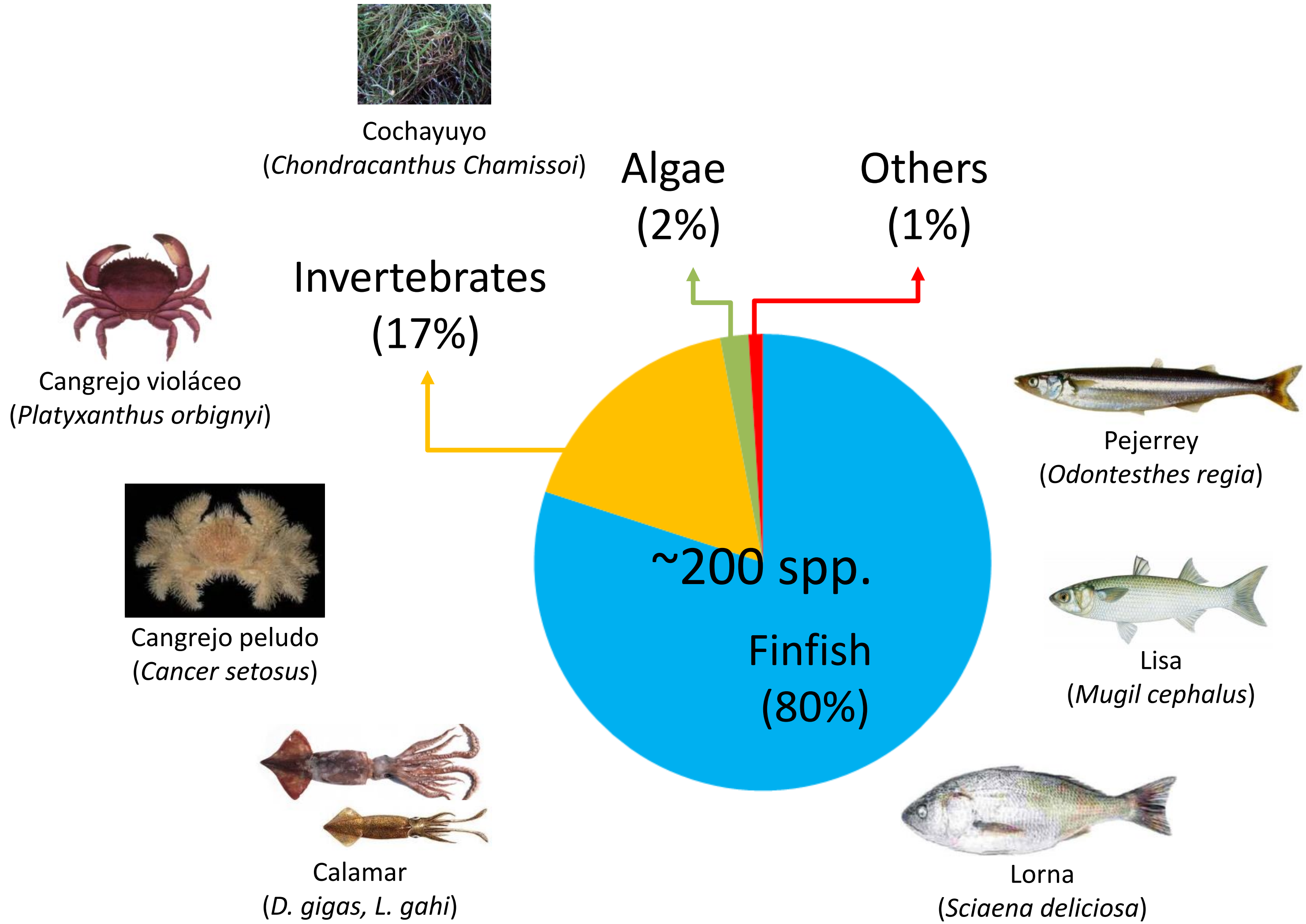
http://www.fao.org/fishery/facp/PER/en; FAO, 2016

Peru fisheries statistics



FAO, 2016

Artisanal fleet



721,000 tonnes landed in 2008

http://www.fao.org/fishery/facp/PER/en

Peru fisheries statistics

Estimated employment (2007)	
Primary sector (including aquaculture)	145,232
Gross value of fisheries output (trade 2008):	
Value of fisheries imports	USD 73.7 million
Value of fisheries exports	USD 2.43 billion

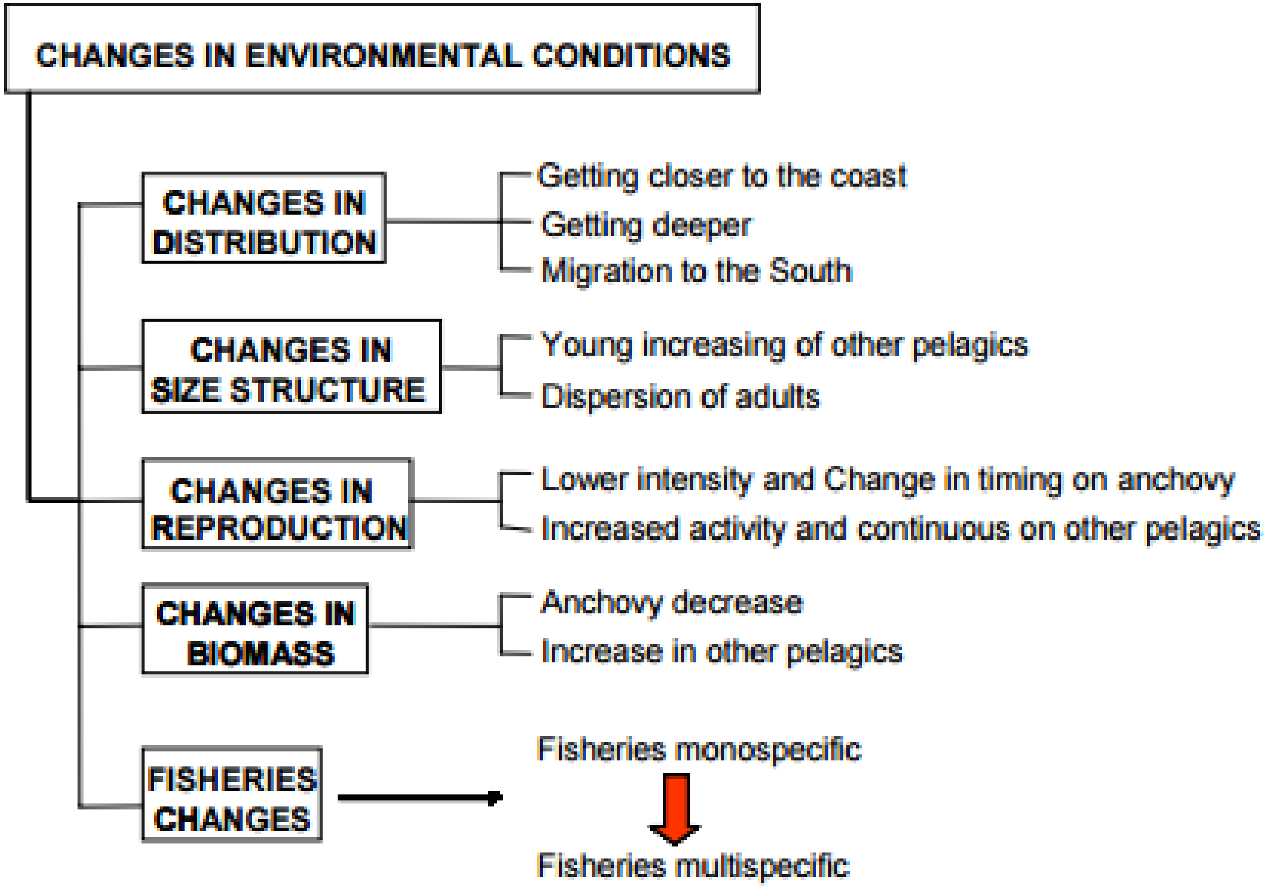



http://www.fao.org/fishery/facp/PER/en

Latin America's coastal areas are highly vulnerable to Climate Change due to:

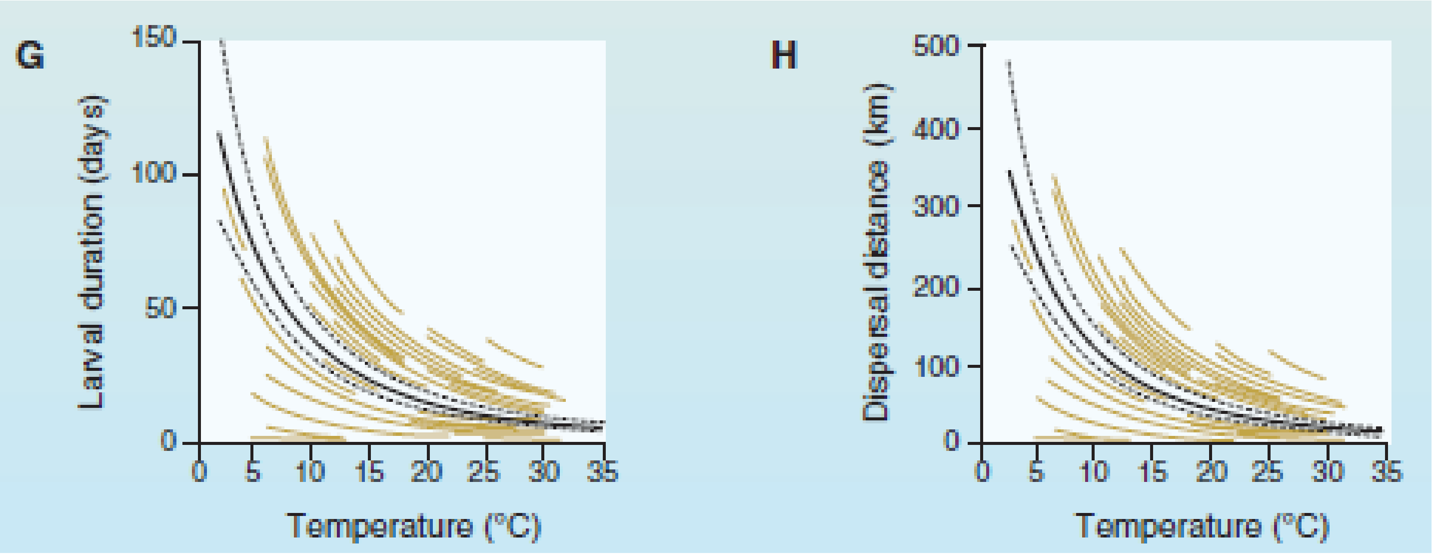
- Increase of population.
- Increase of socio-economic activities, e.g. fisheries and aquaculture.
- Maritime infrastructure.
- Other shorter term climatic events, e.g. ENSO.

El Niño effect on Peruvian fisheries



Ñiquen & Bouchon, 2004

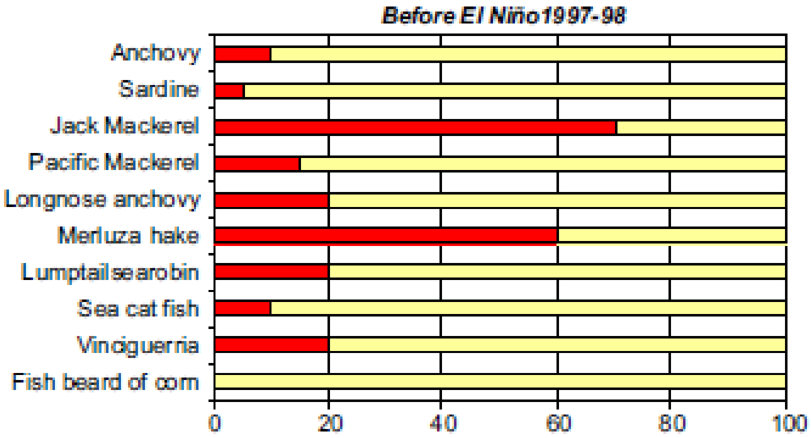
Altered recruitment and dispersal

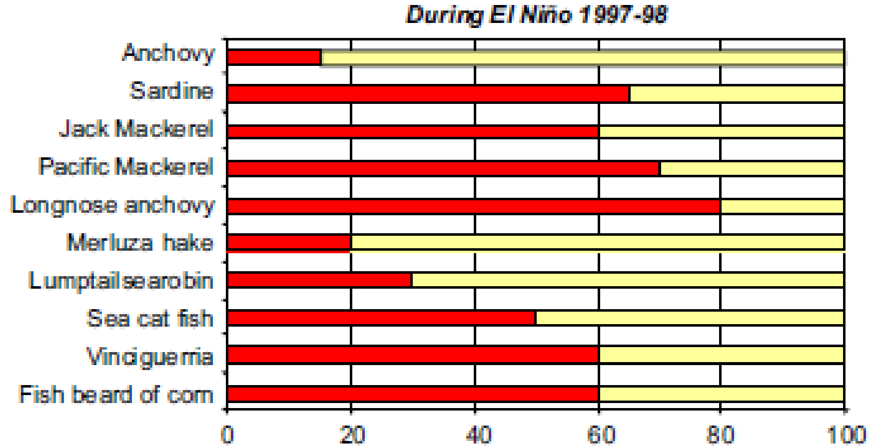


Increasing temperatures result in decreasing larval duration and dispersal of 72 marine species

Hoegh-Guldberg & Bruno, 2010

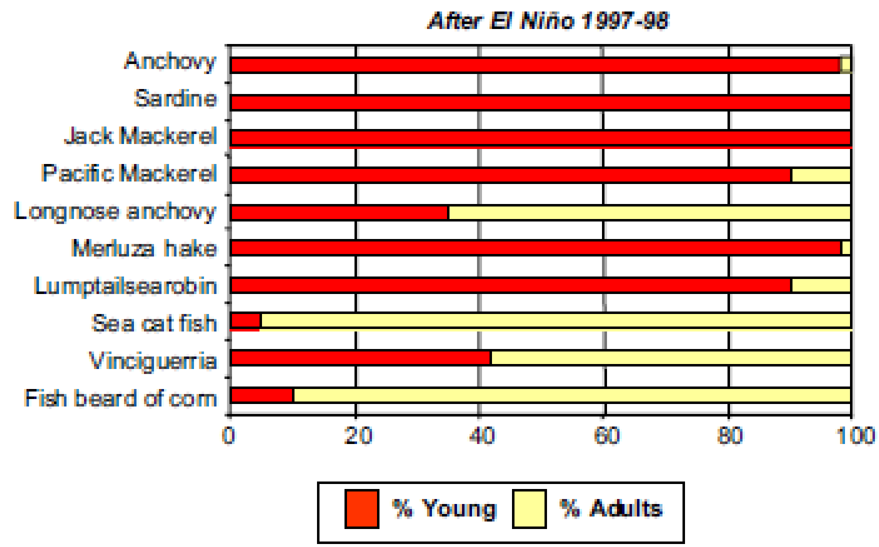
Changes in size structure





Pelagic biomass before, during and after El Niño events.

- Recovery of stocks?
- Smaller individuals because of decreased abundance of food

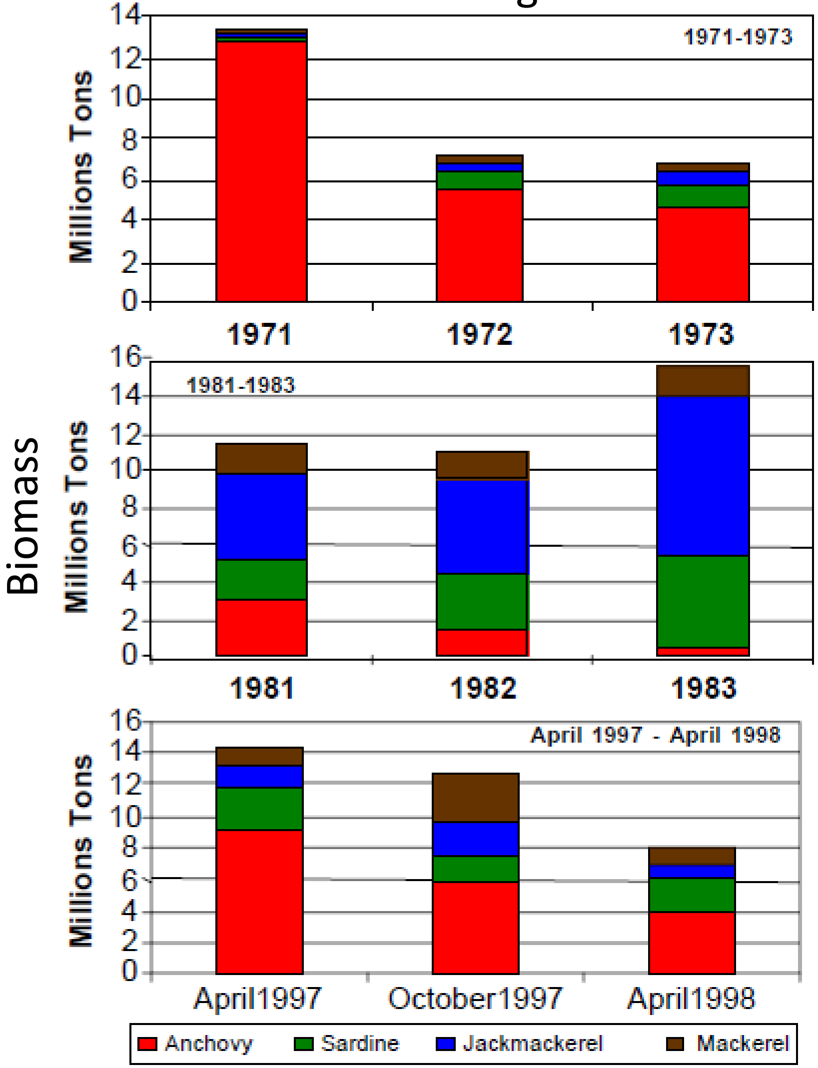


Ñiquen & Bouchon, 2004

Changes in biomass

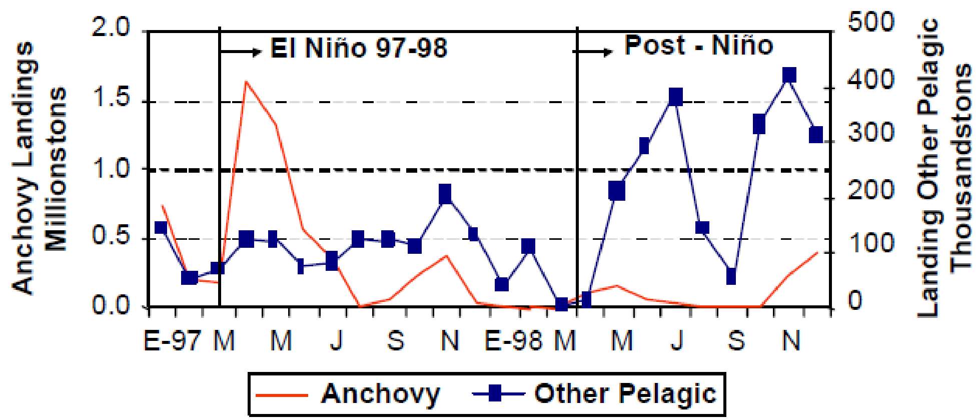
El Niño

Before During After



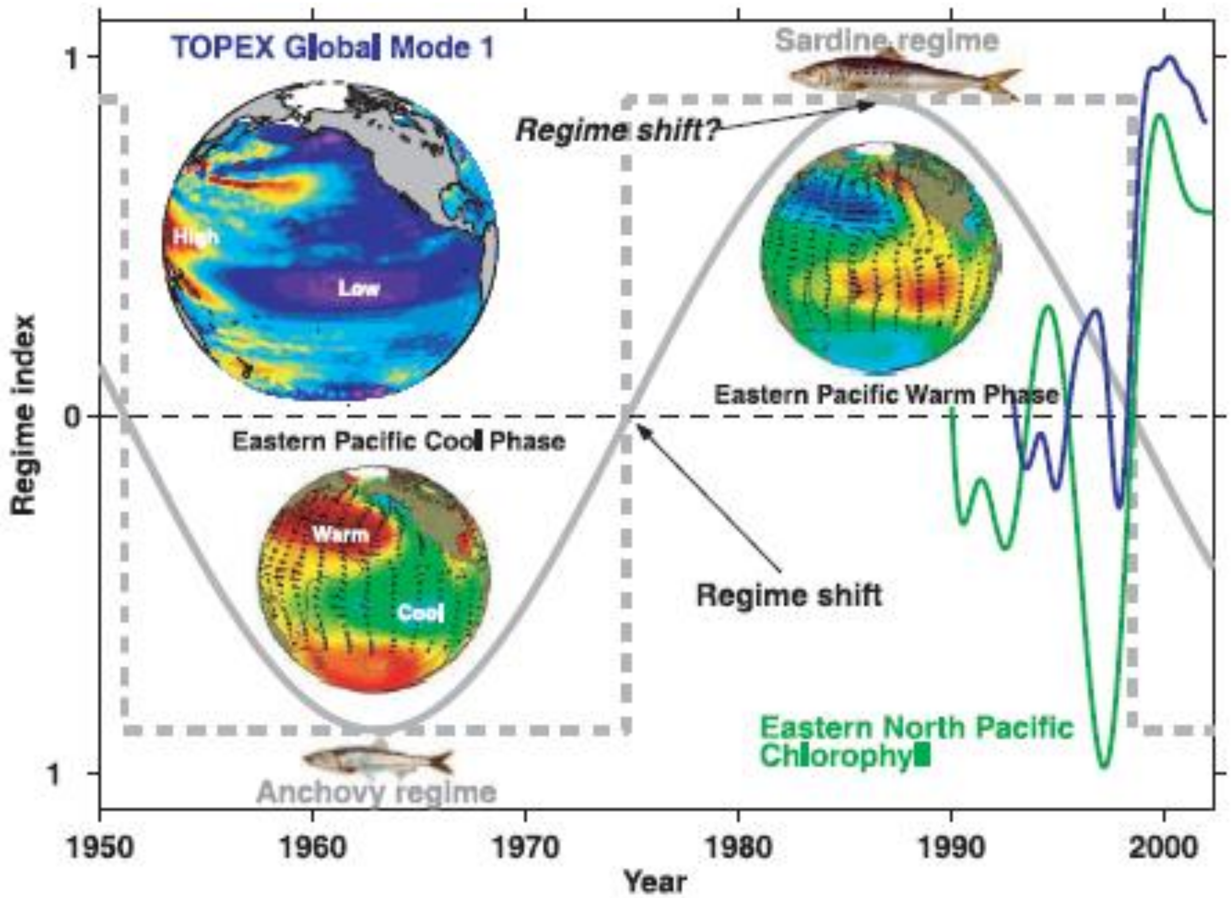
Less anchovy, more of other pelagic species.

Diversification of the fishery



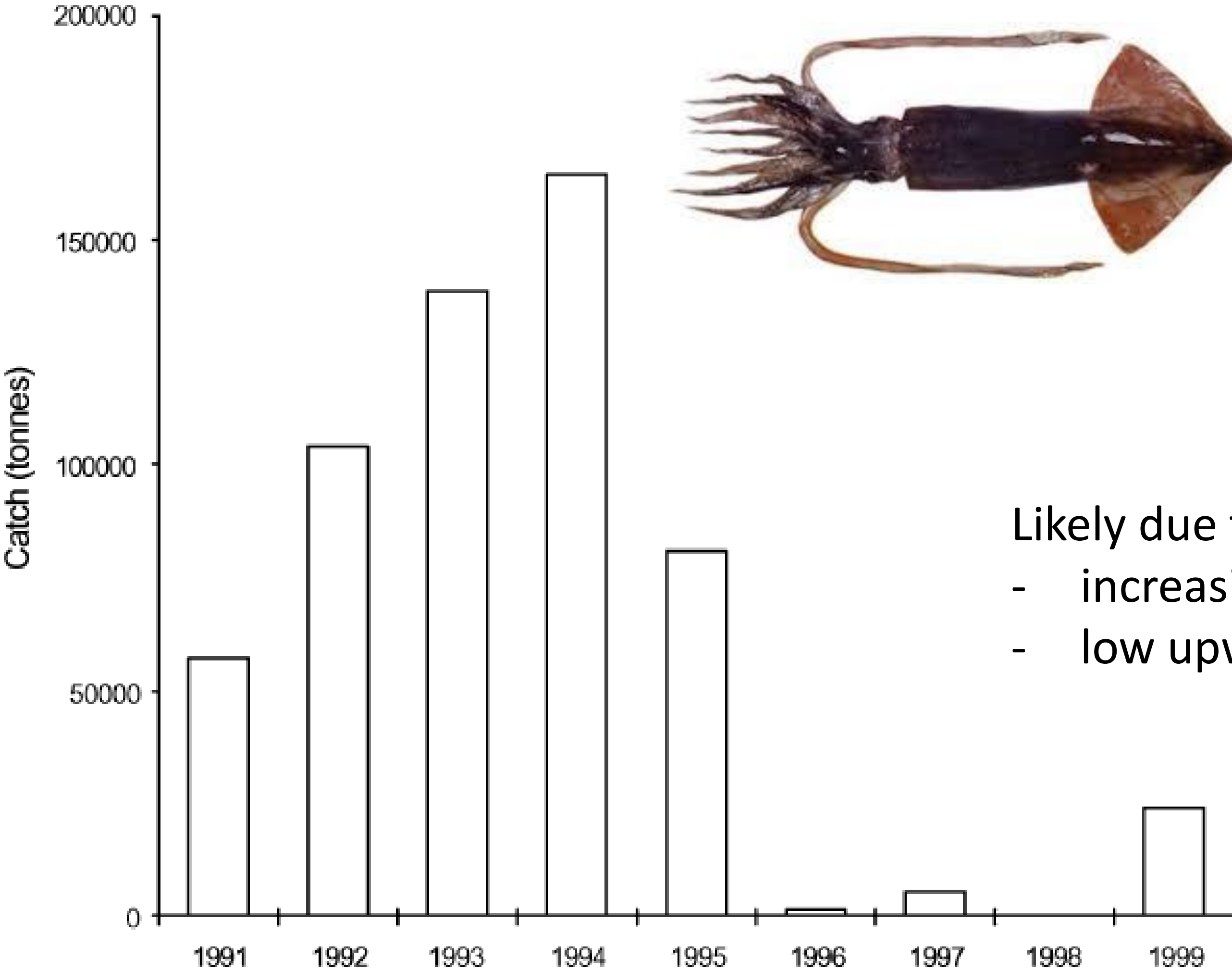
Ñiquen & Bouchon, 2004

Effect of inter-decadal oscillation on Peruvian fisheries



Chávez et al., 2003

Temperature and catches



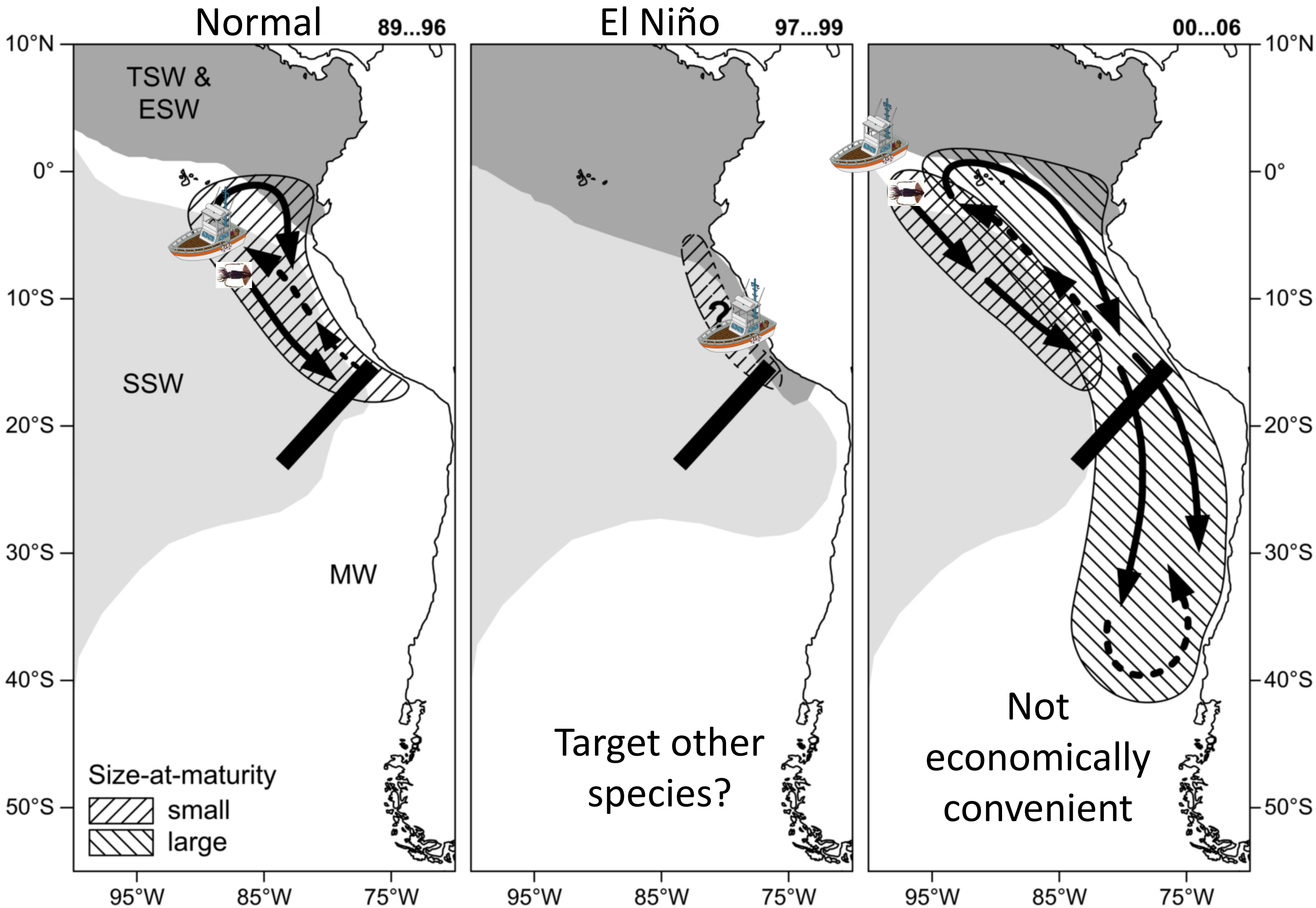
Annual catches of *Dosidicus gigas* off the Peruvian coast

Likely due to El Niño conditions:

- increasing temperatures
- low upwelling

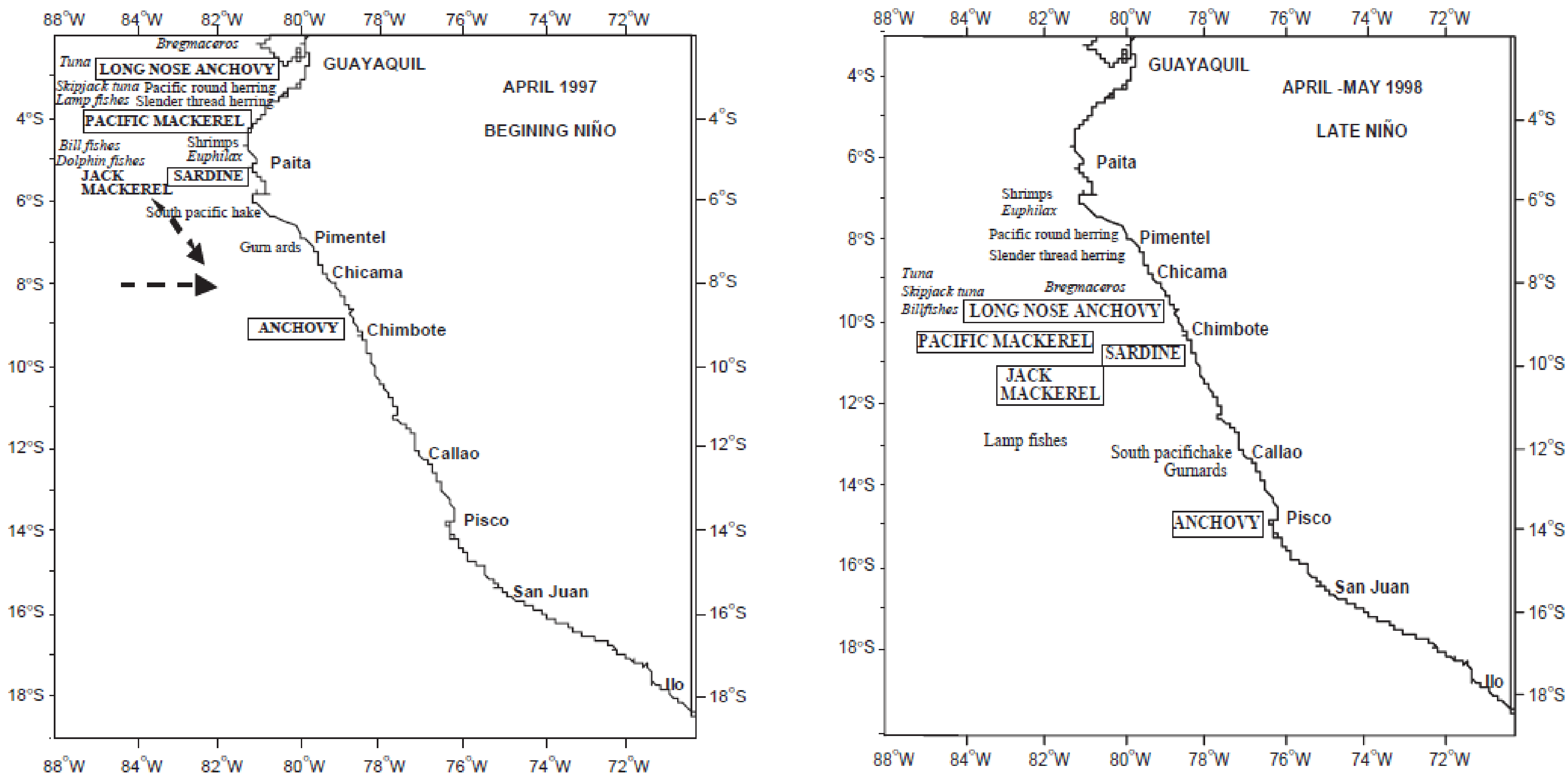
Taipe et al., 2001

Range shift



Keyl et al., 2008

Range shift

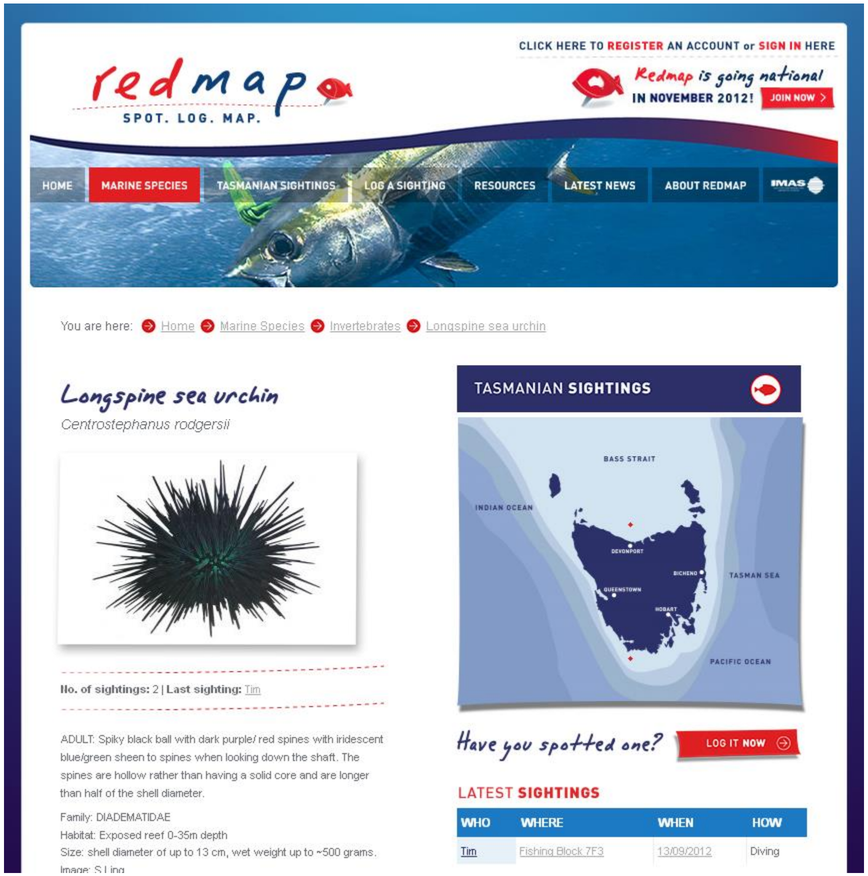


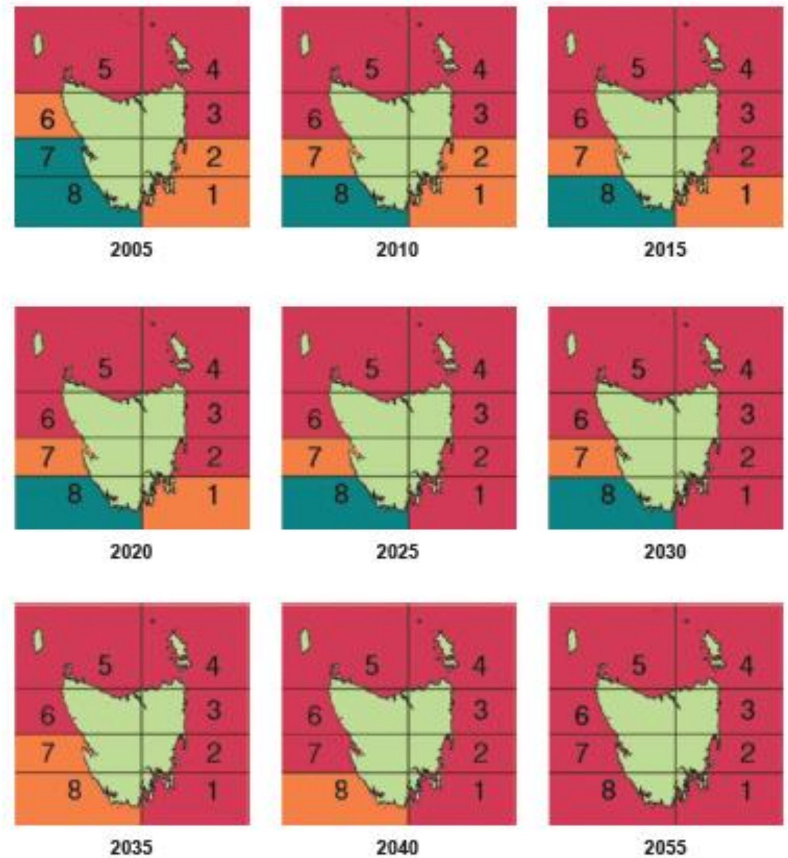
Species migration associated to El Niño 1997–98 event along the Peruvian coast

Up to 7° latitude southward = 800 km southward

Ñiquen & Bouchon, 2004

The range shift of *Centrostephanus rodgersii*

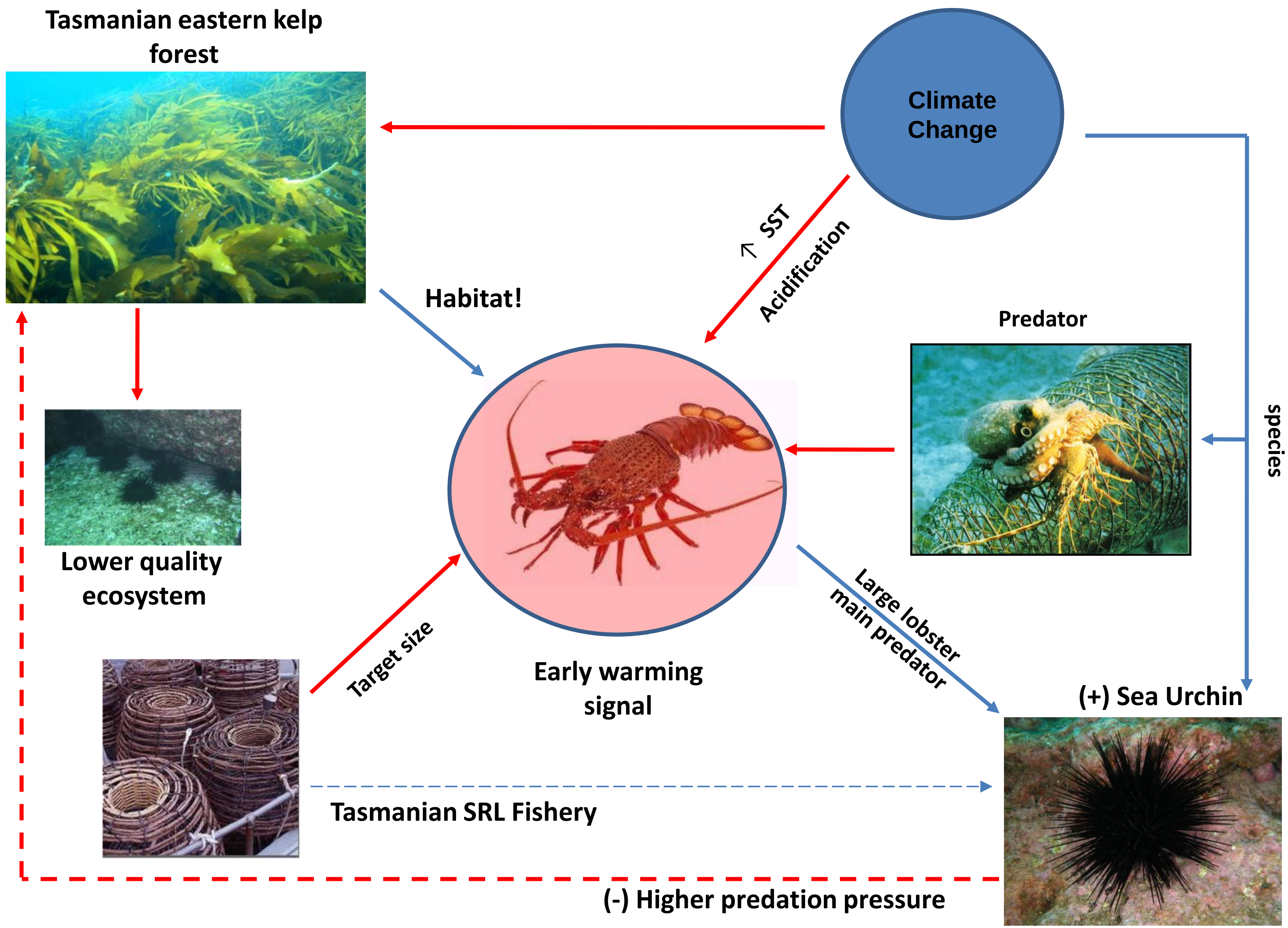




Centrostephanus rodgersii habitat suitability.
C. *rodgersii* do not develop below 12°C.
Red > 12.5°C; Orange = 12-12.5°C; Green < 12°C.

http://www.redmap.org.au/species/2/34/

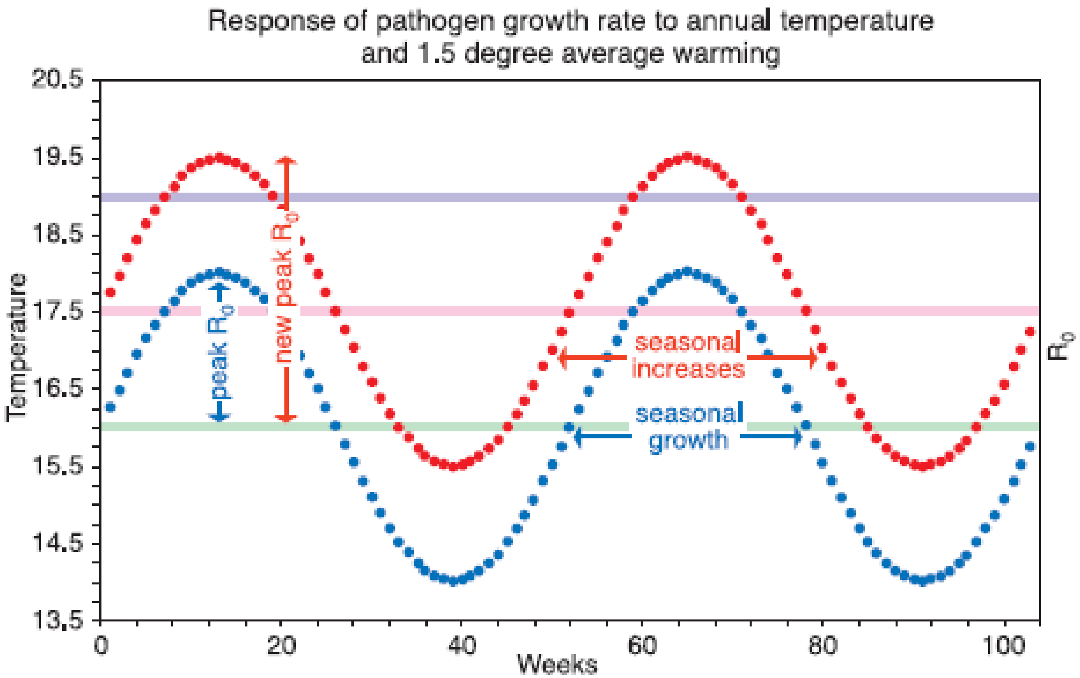
Cascade effect on Tasmanian kelp forest



Increased susceptibility to disease, parasites

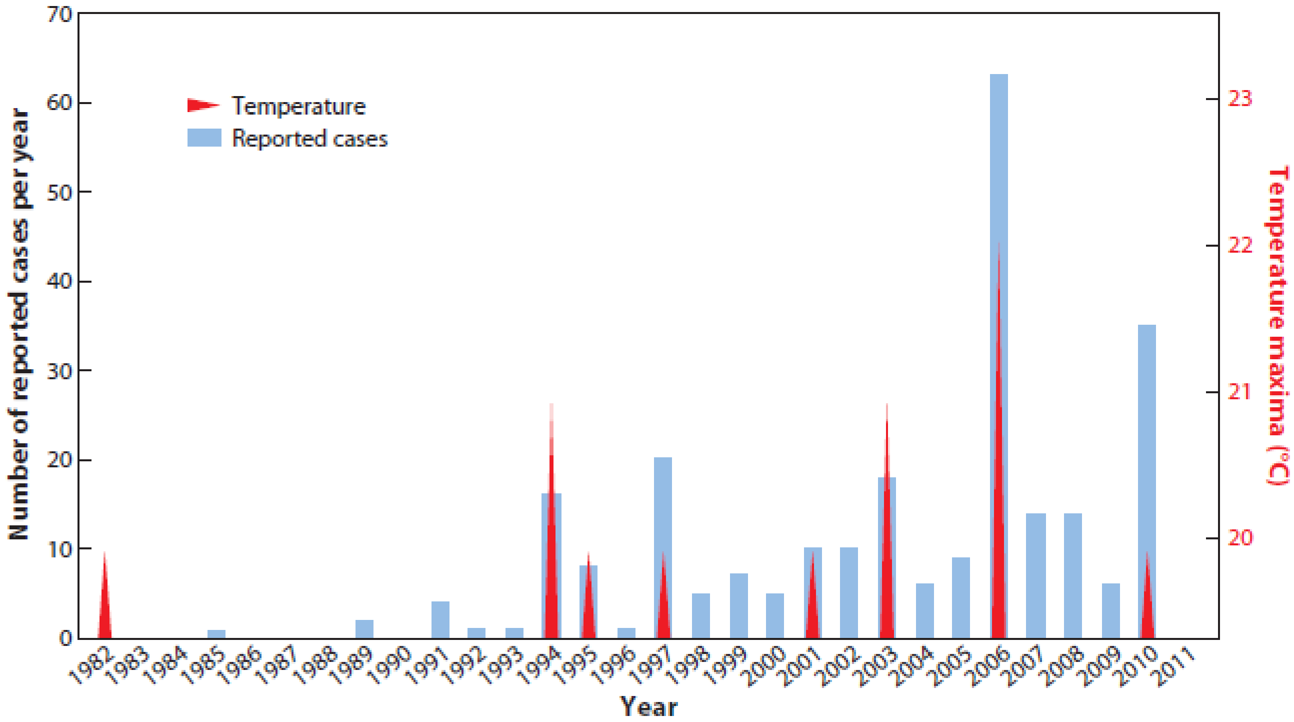
Climate warming may:
1. increase pathogen development rates, transmission, and number of generations per year; and
2. modify host susceptibility to infection.

These changes may cause pathogen range expansions and host declines.



Harvell et al., 2002;Burge et al., 2014

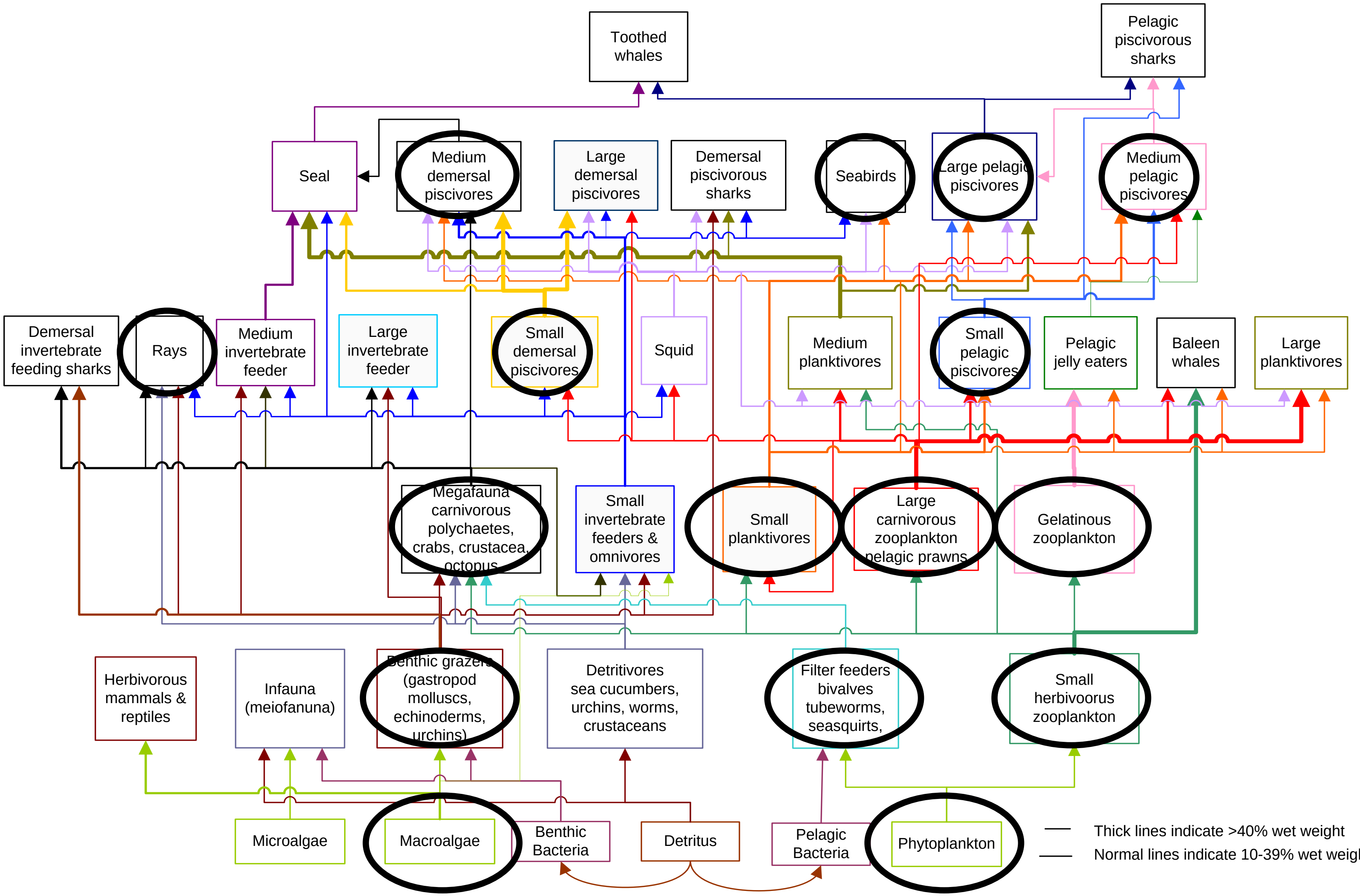
Increased susceptibility to disease, parasites



Number of reported *Vibrio* cases in the Baltic Sea area from 1982 to 2010.

Burge et al., 2014

Changes throughout the food web



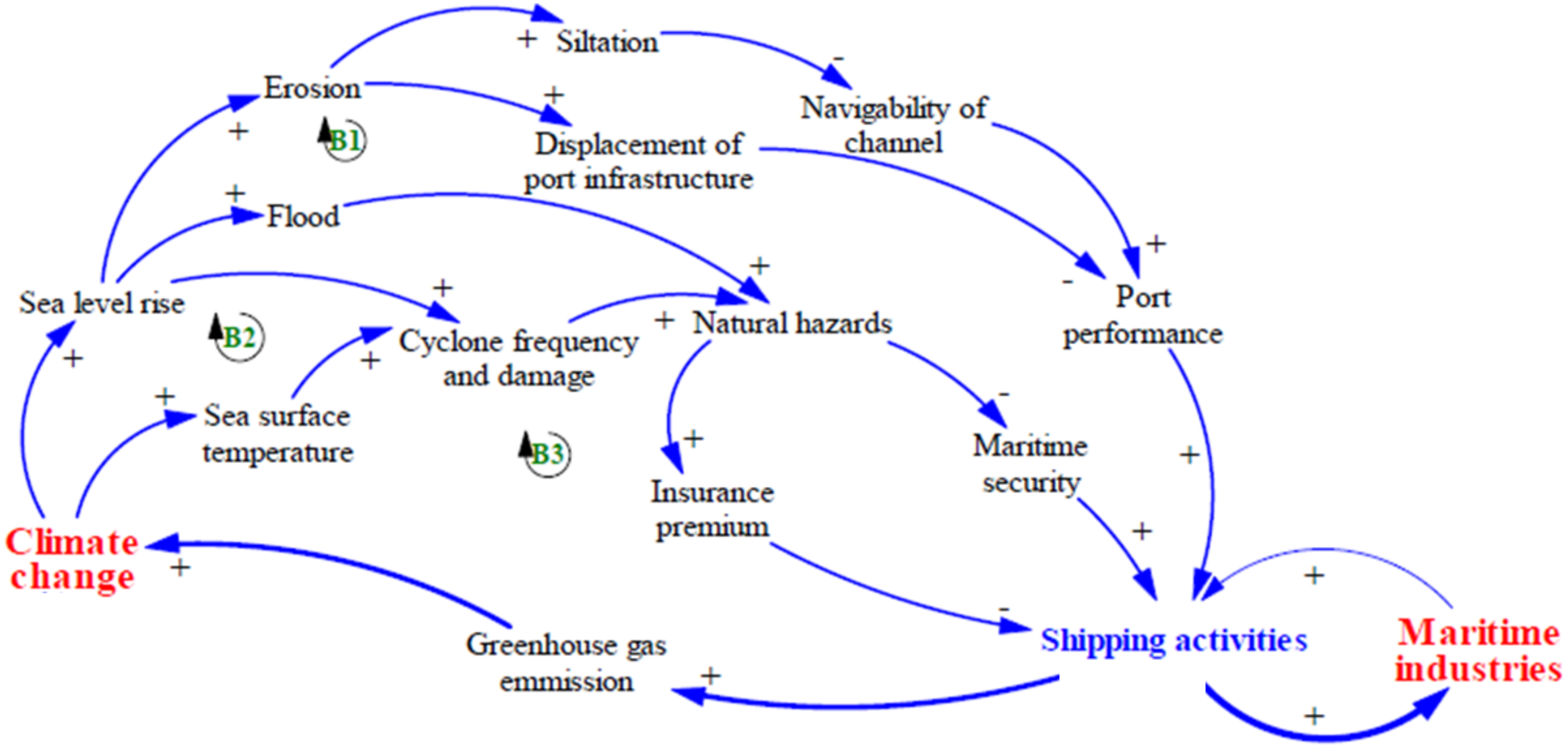
Frusher et al ., 2014

Risk to the population due to a 1m sea level rise

Damage to maritime facilities

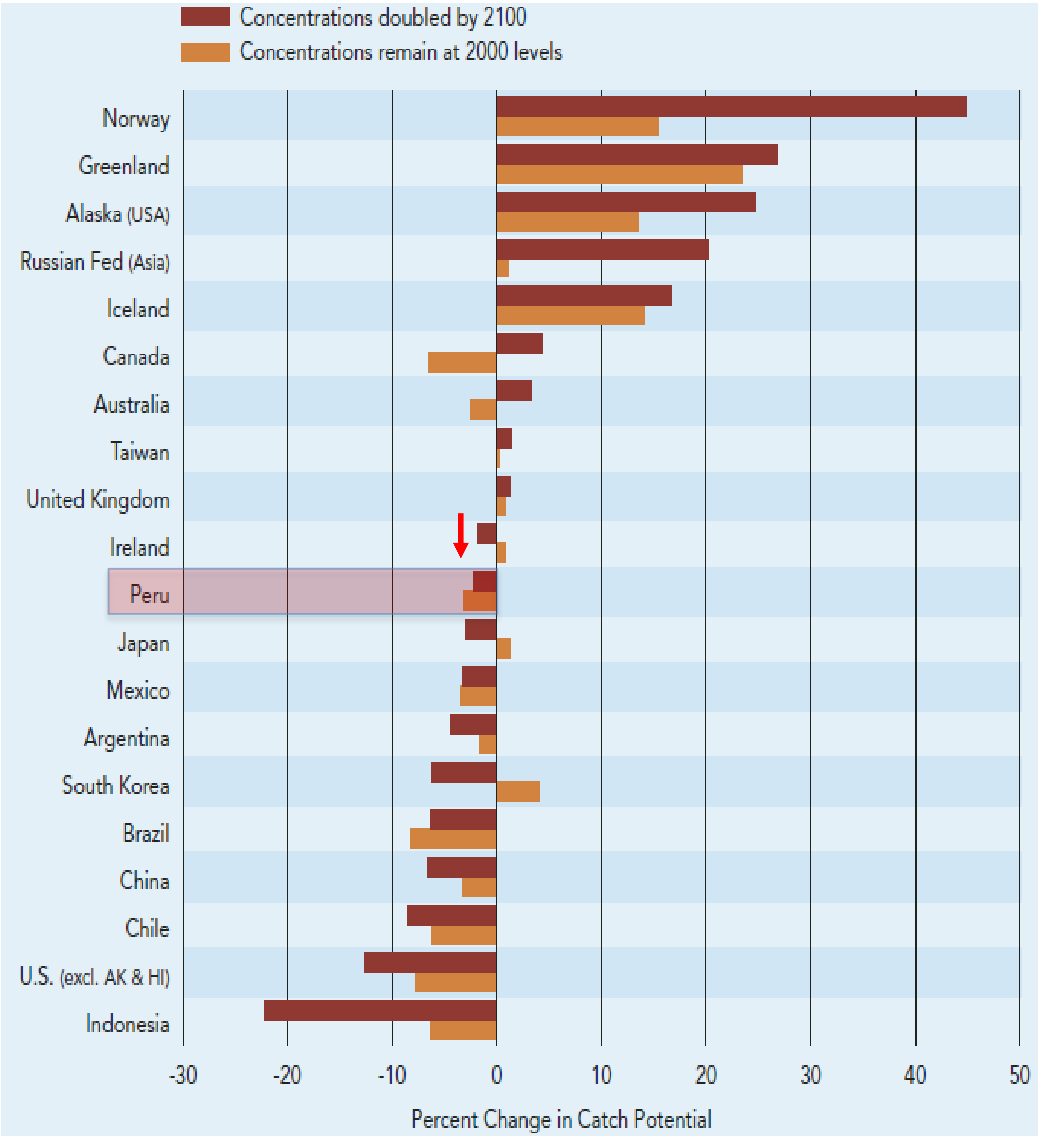
UN-CEPAL 2012

Maritime structures



Sarwar, 2006

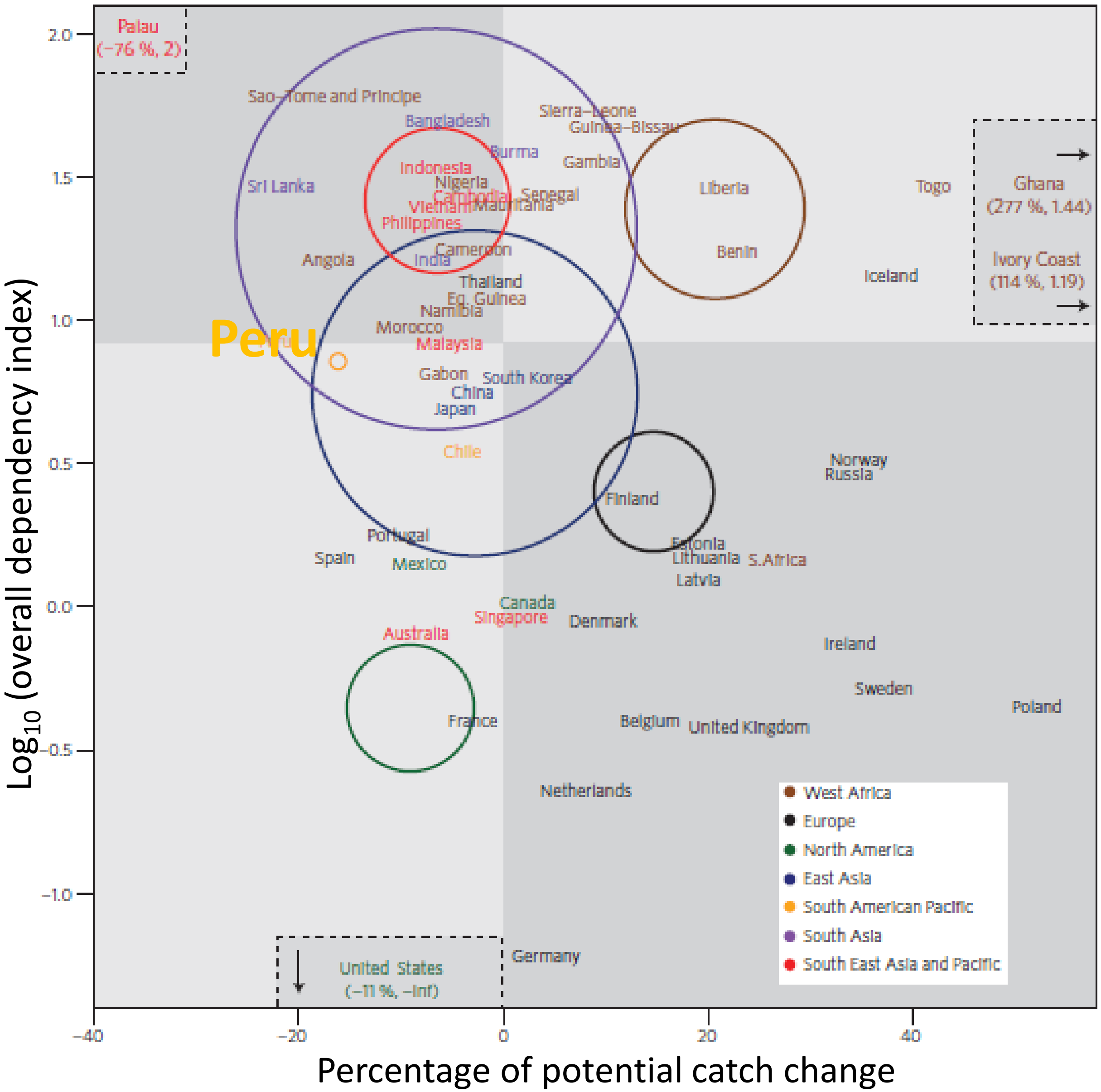
Change in catch potential



Projected changes in 10-year averaged maximum catch potential from 2005 to 2055.

Cheung et al., 2010

Change in catch potential



Combining dependency with the projected impact of climate change on fish catches suggests that these impacts will be of great concern to Peru.

At the EEZ level, the Peruvian potential catch is predicted to decrease significantly.

Barange et al., 2014

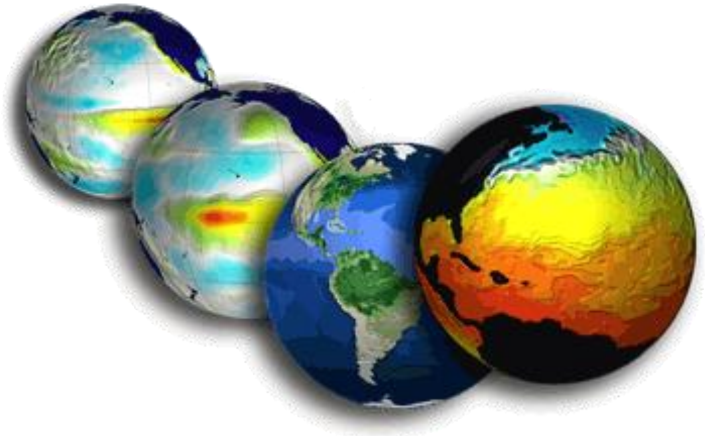
Summary

- Altered recruitment and dispersal (currents, temperature, and larval duration).
- Increased susceptibility to disease, parasites and physiological stress.
- Altered productivity (upwelling).
- Changes to food web structure.
- Distribution shifts of habitat forming organisms (coral, seagrass, kelp, etc.).
- Impacts on productivity, distribution and abundance of commercial and recreational fishery resources.
- Climate change impacts in Peruvian ecosystems are likely to be considerable and to have ecological and economic consequences.

7. Impacts of Climate Change on Aquaculture

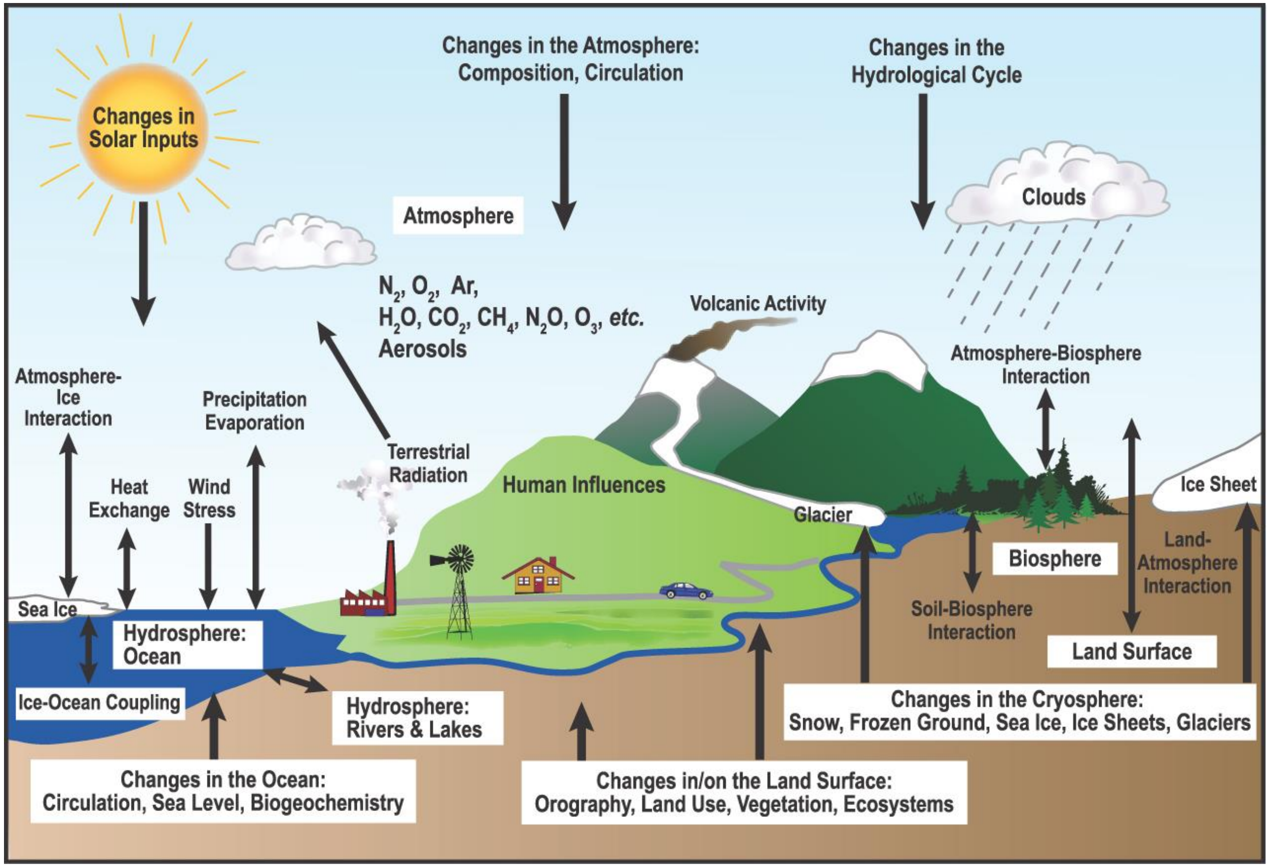
Outline

- Overview on climate change: physical impacts.
- Global impacts and major challenges for fresh water and marine aquaculture.
- Physiological challenges for aquaculture species.
- Examples from Latin-America, i.e. Peru.



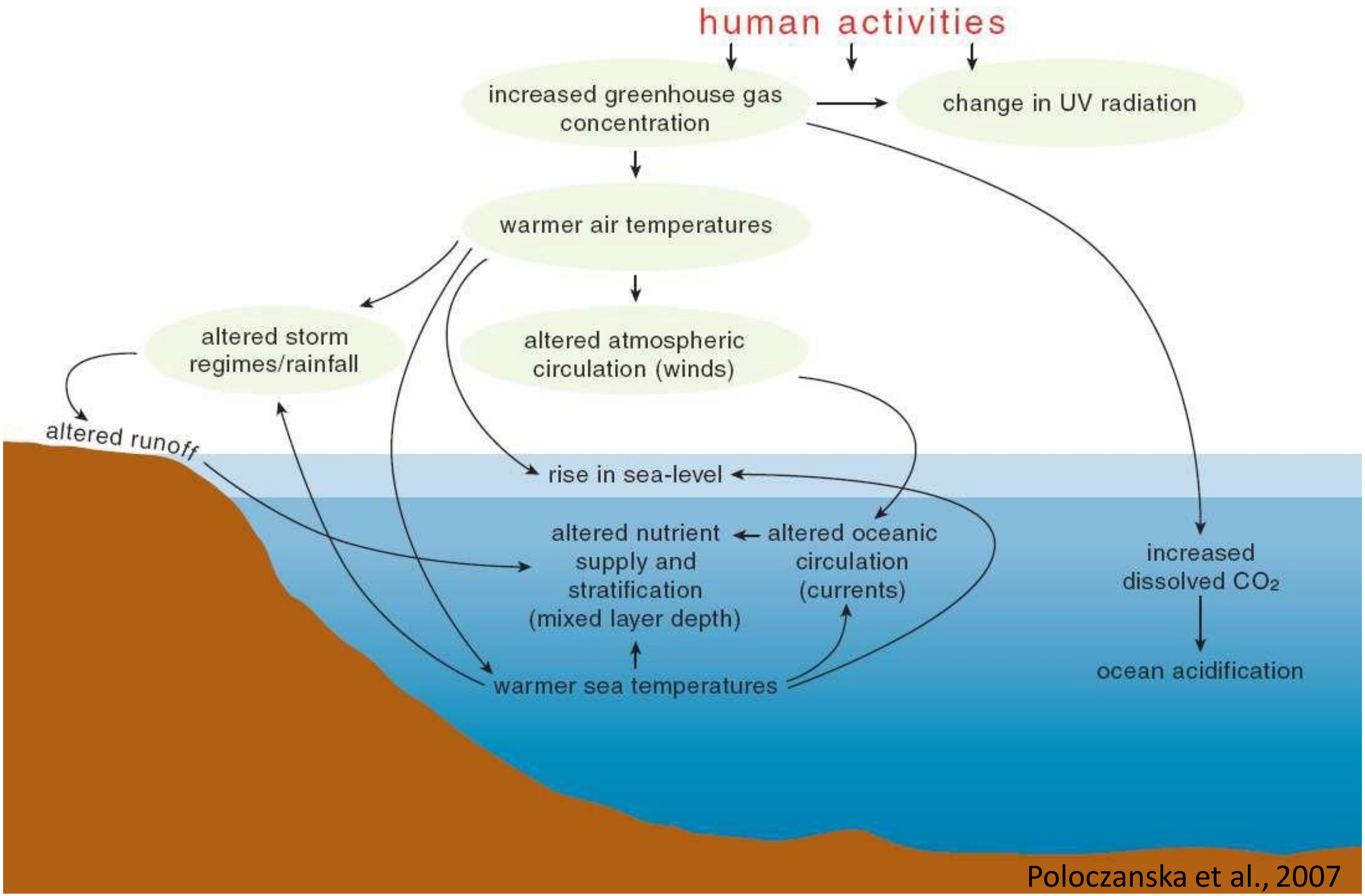
Climate Change

"A statistically significant variation in the mean state of the climate or its variability, persisting for an extended period (typically decades or longer)"

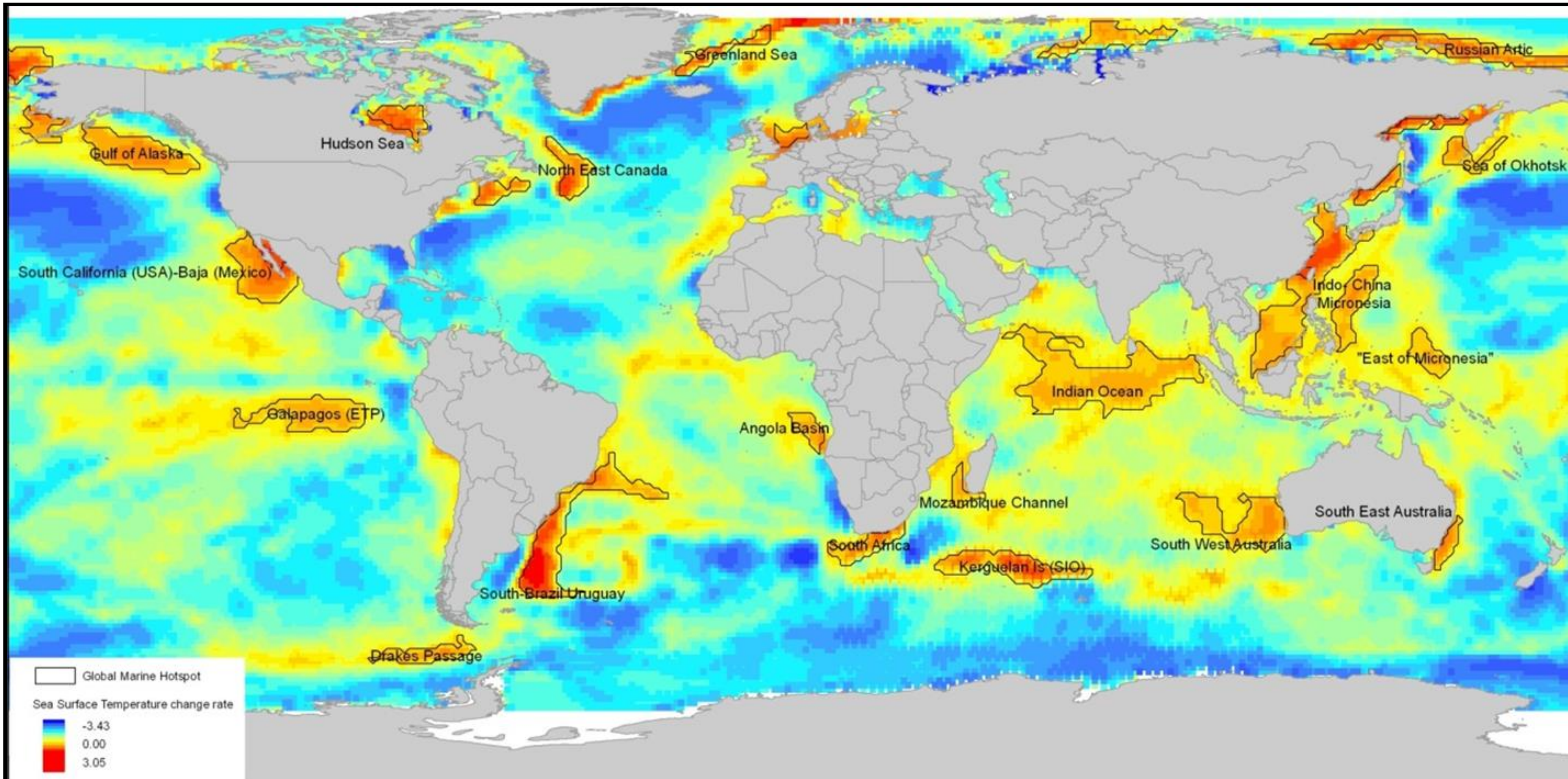


http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=663

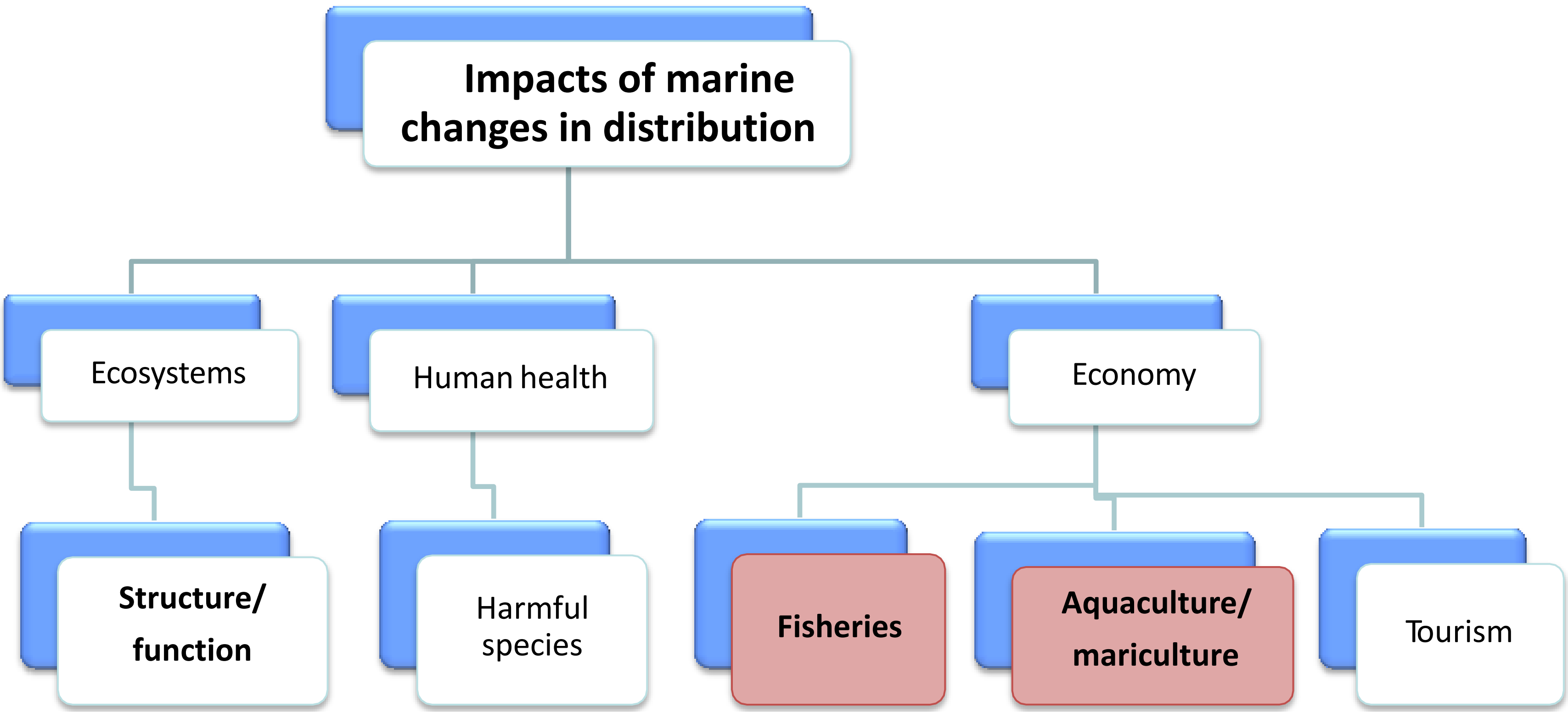
Impacts of Climate Change



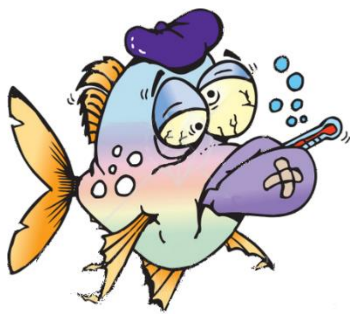
Ocean warming hotspots areas in the top 10% for rate of warming



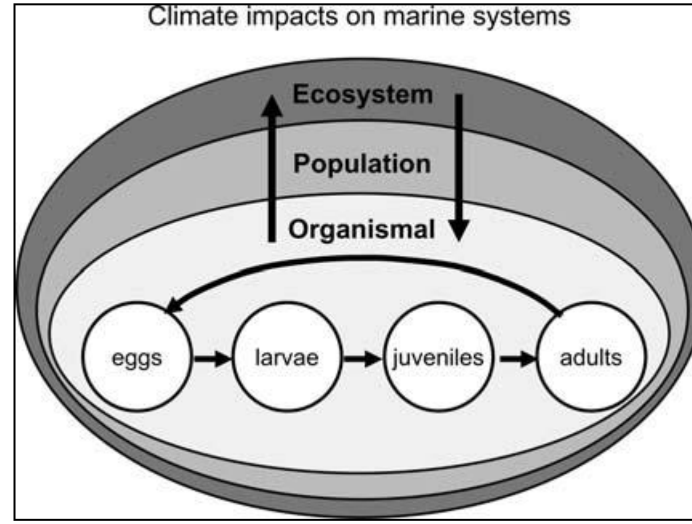
Hobday & Pecl, 2014


Impacts of marine changes in distribution
Ecosystems
Human health
Economy
Structure/ function
Harmful species
Fisheries
Aquaculture/ mariculture
Tourism

As waters warm:



- There is less oxygen available.
- Animals use more energy to breathe.
- Greater stress on animals.
- More stress makes animals more susceptible to disease.
- Less energy available to reproduce.



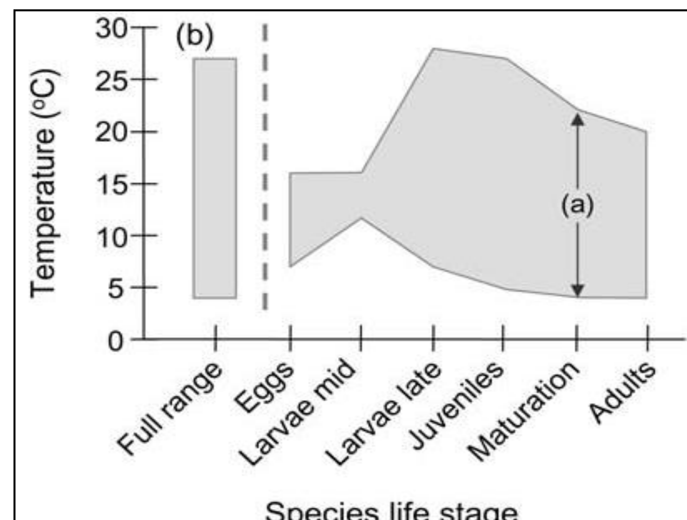
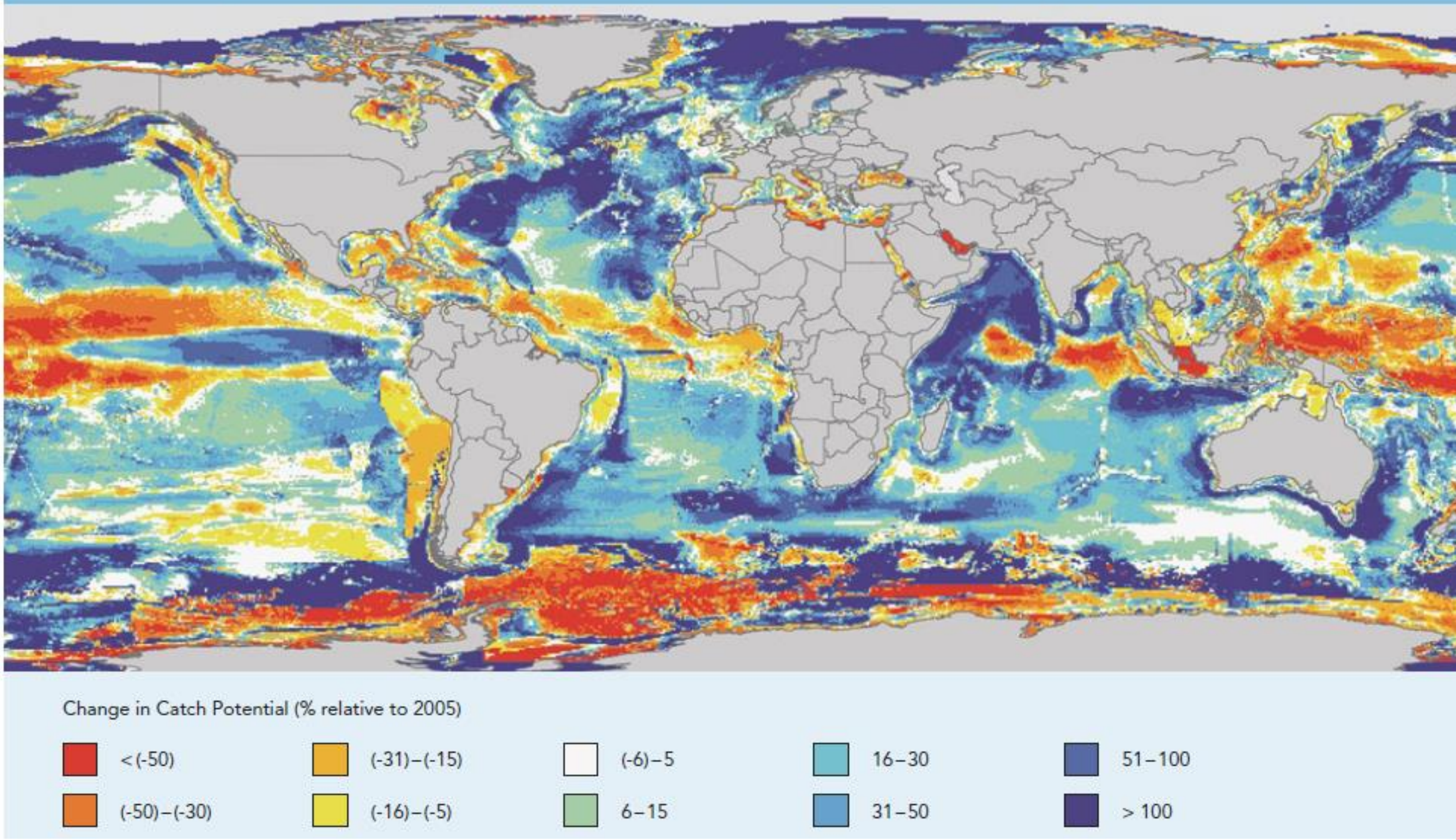
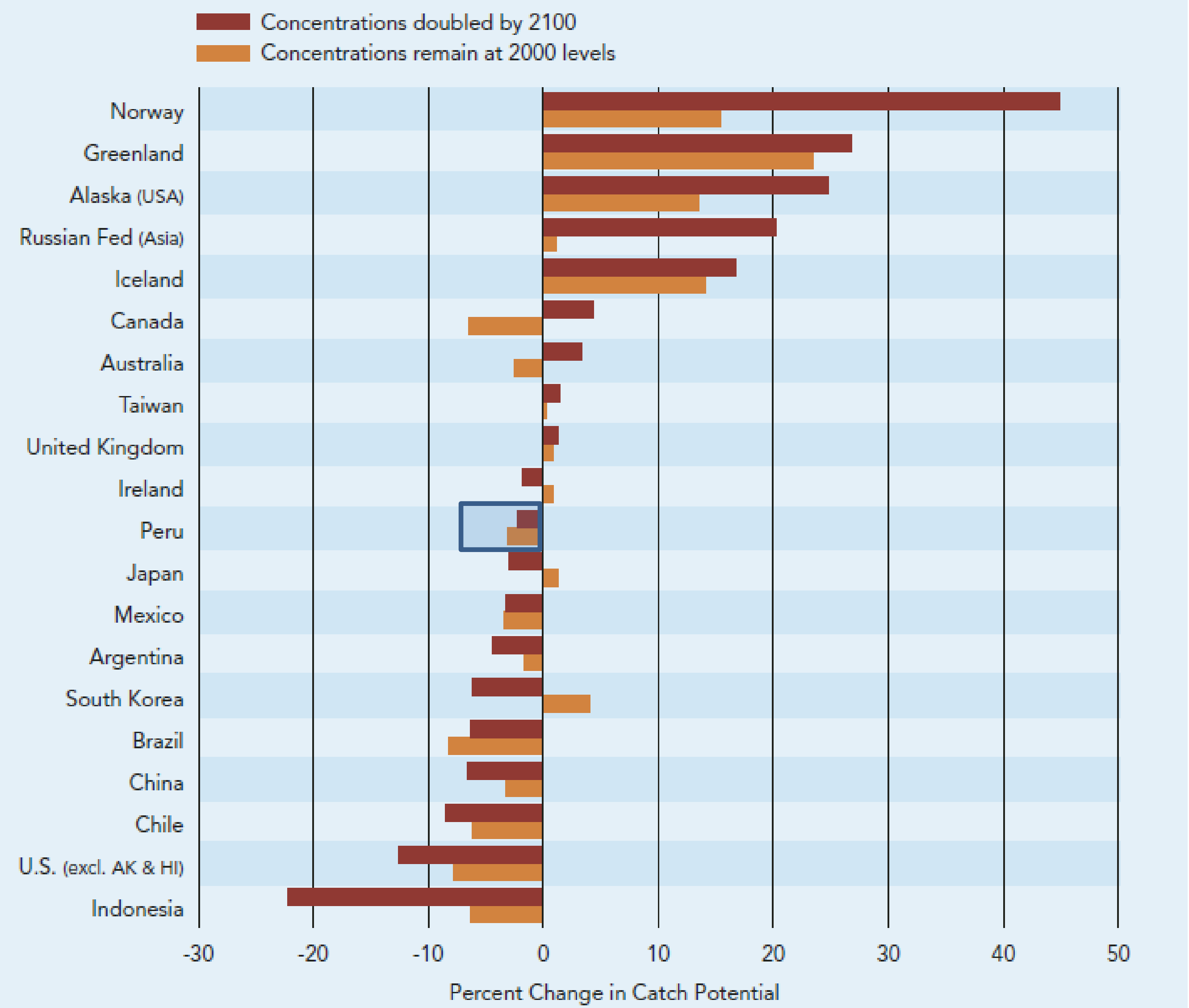


FIGURE 1. CHANGE IN MAXIMUM CATCH POTENTIAL FROM 2005 TO 2055 under the climate change scenario where greenhouse gas concentration is doubled by the year 2100.

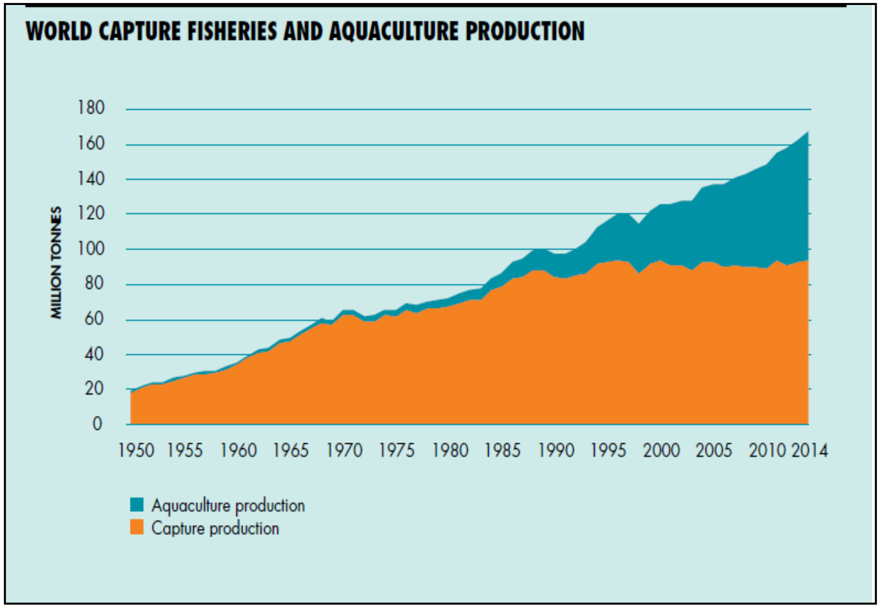


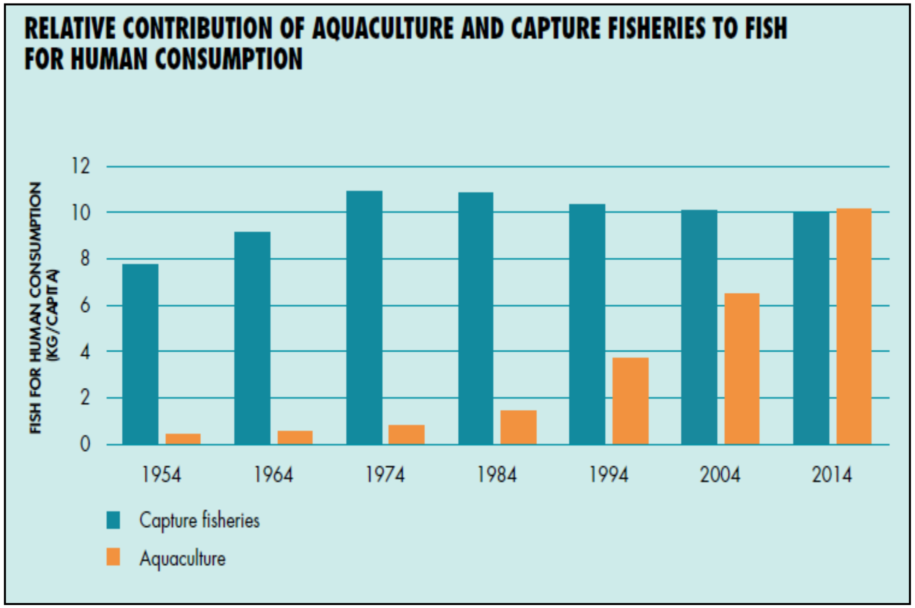
Cheung et al,, 2009



The two scenarios represent possible greenhouse gas emissions. In the first scenario, emissions continue to grow in their current trajectory and will double by 2100. The second scenario assumes that greenhouse gas concentrations remain constant at 2000 levels.

Cheung et al,, 2009


WORLD CAPTURE FISHERIES AND AQUACULTURE PRODUCTION
180
160
140
120
100
80
60
40
20
0
MILLION TONNES
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2014
Aquaculture production
Capture production


RELATIVE CONTRIBUTION OF AQUACULTURE AND CAPTURE FISHERIES TO FISH FOR HUMAN CONSUMPTION
12
10
8
6
4
2
0
FISH FOR HUMAN CONSUMPTION (KG/CAPITA)
1954 1964 1974 1984 1994 2004 2014
Capture fisheries
Aquaculture

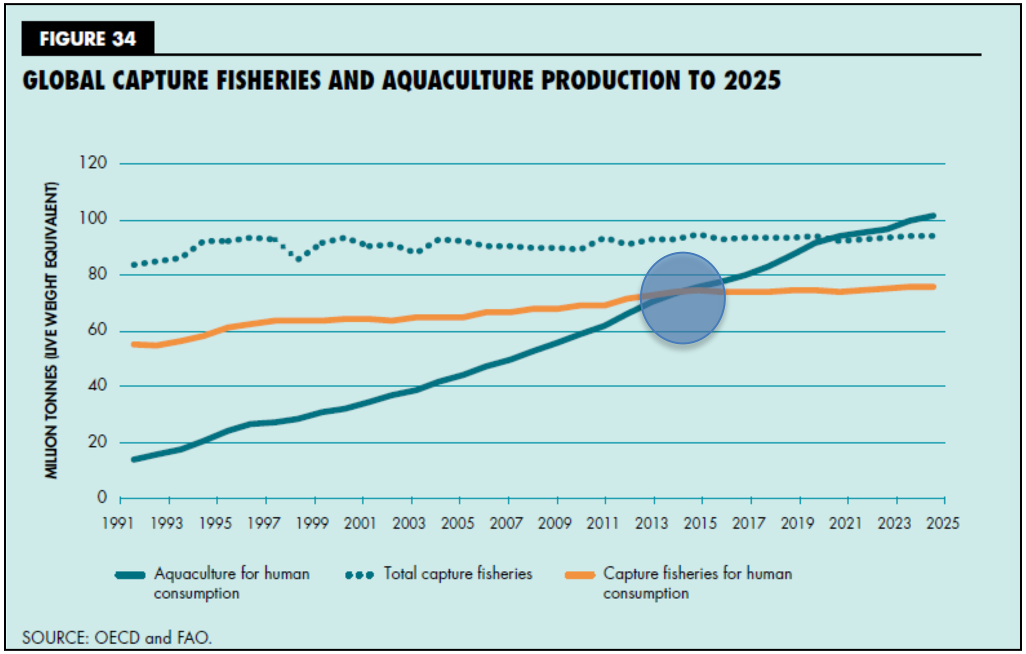
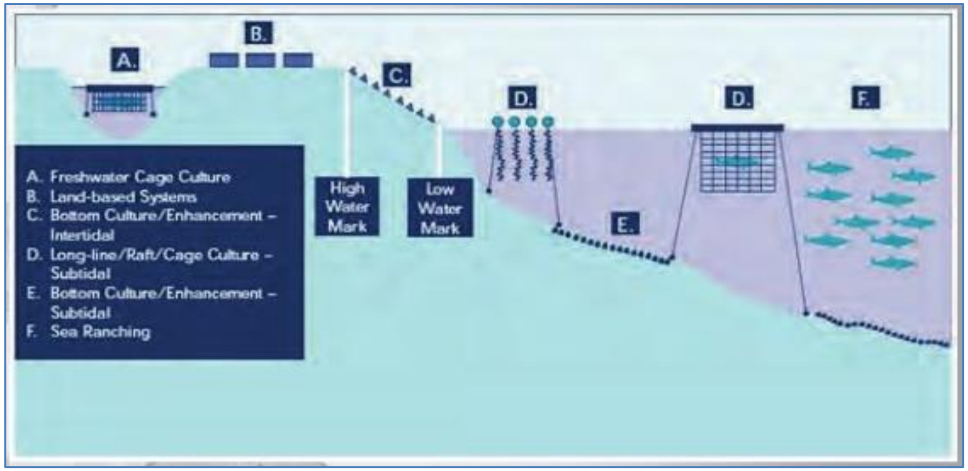
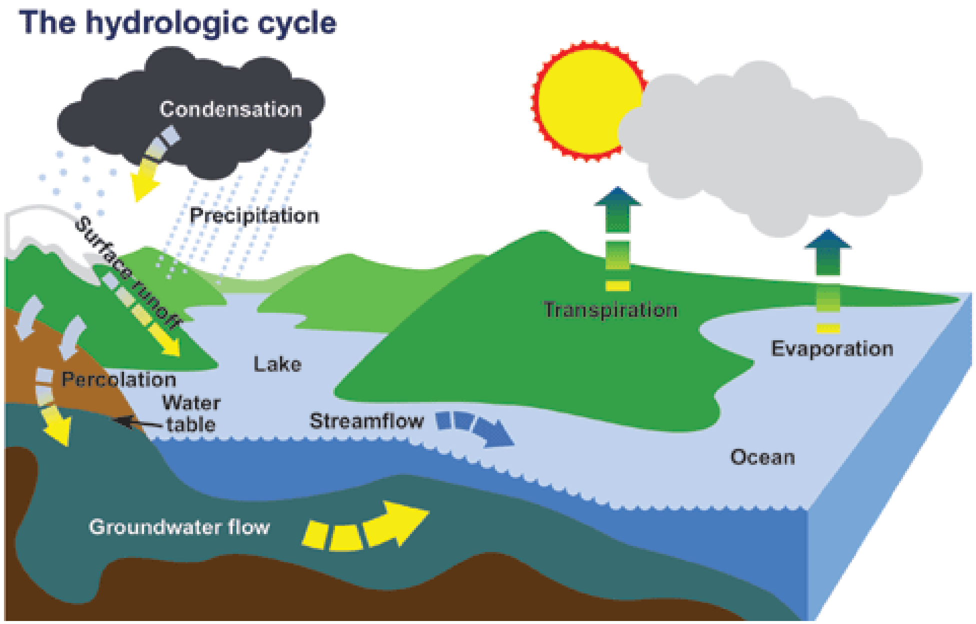


FIGURE 34
GLOBAL CAPTURE FISHERIES AND AQUACULTURE PRODUCTION TO 2025
120
100
80
60
40
20
0
MILLION TONNES (LIVE WEIGHT EQUIVALENT)
1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021 2023 2025
Aquaculture for human consumption
Total capture fisheries
Capture fisheries for human consumption
SOURCE: OECD and FAO.

FAO, 2016

Aquaculture production depends on climate zone and habitat





Climate change on world and regional aquaculture

Climate change and aquaculture: potential impacts, adaptation and mitigation

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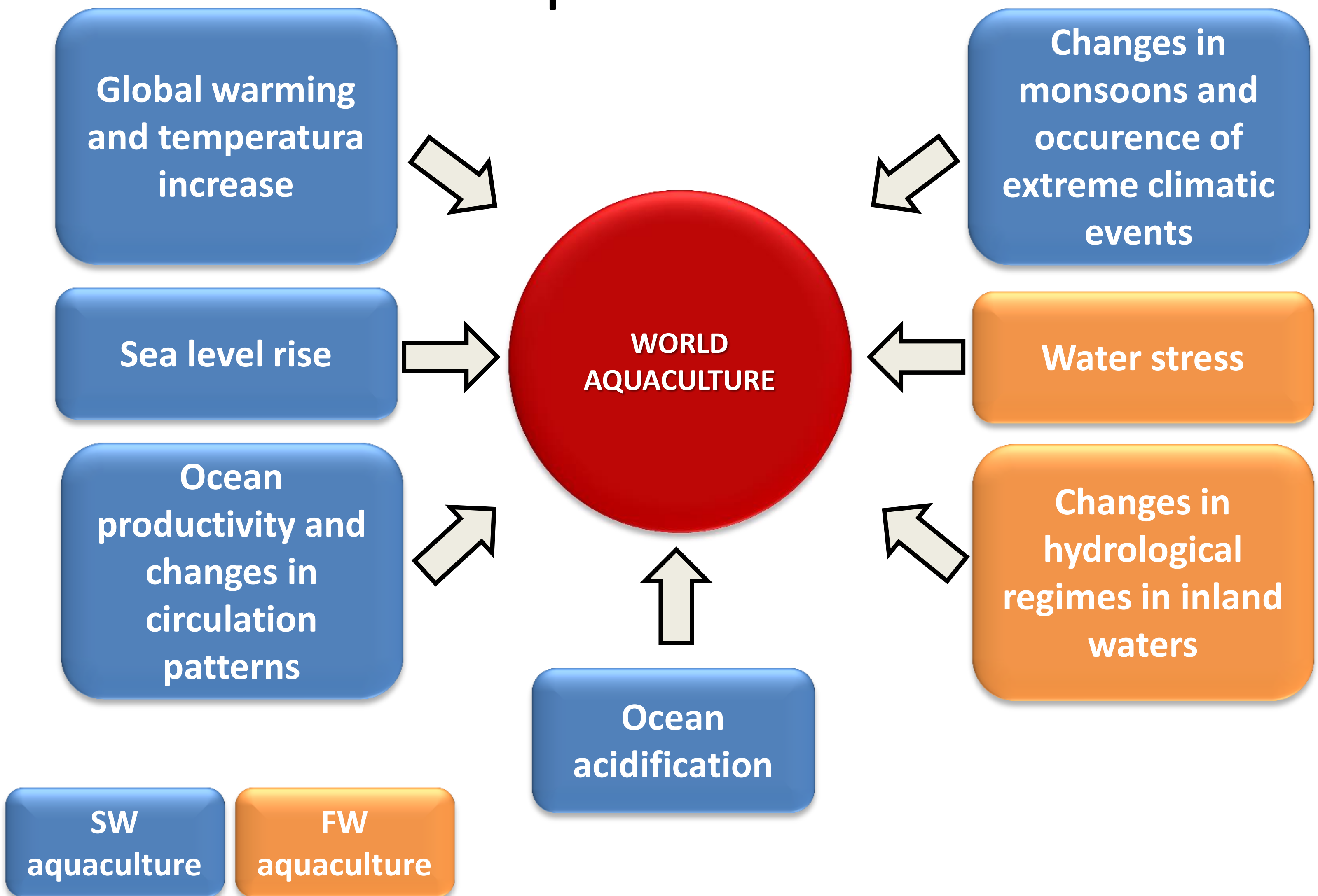
- Not all climatic changes will equally impact aquaculture, either directly or indirectly.
- The potential impacts on farming activities cannot be attributed to one single factor of climatic change.
- All cultured aquatic animal species for human consumption are <u>poikilothermic.</u>
- Impacts will depend on environments:

(1) Fresh water
(2) Brackish water
(3) Marine water.

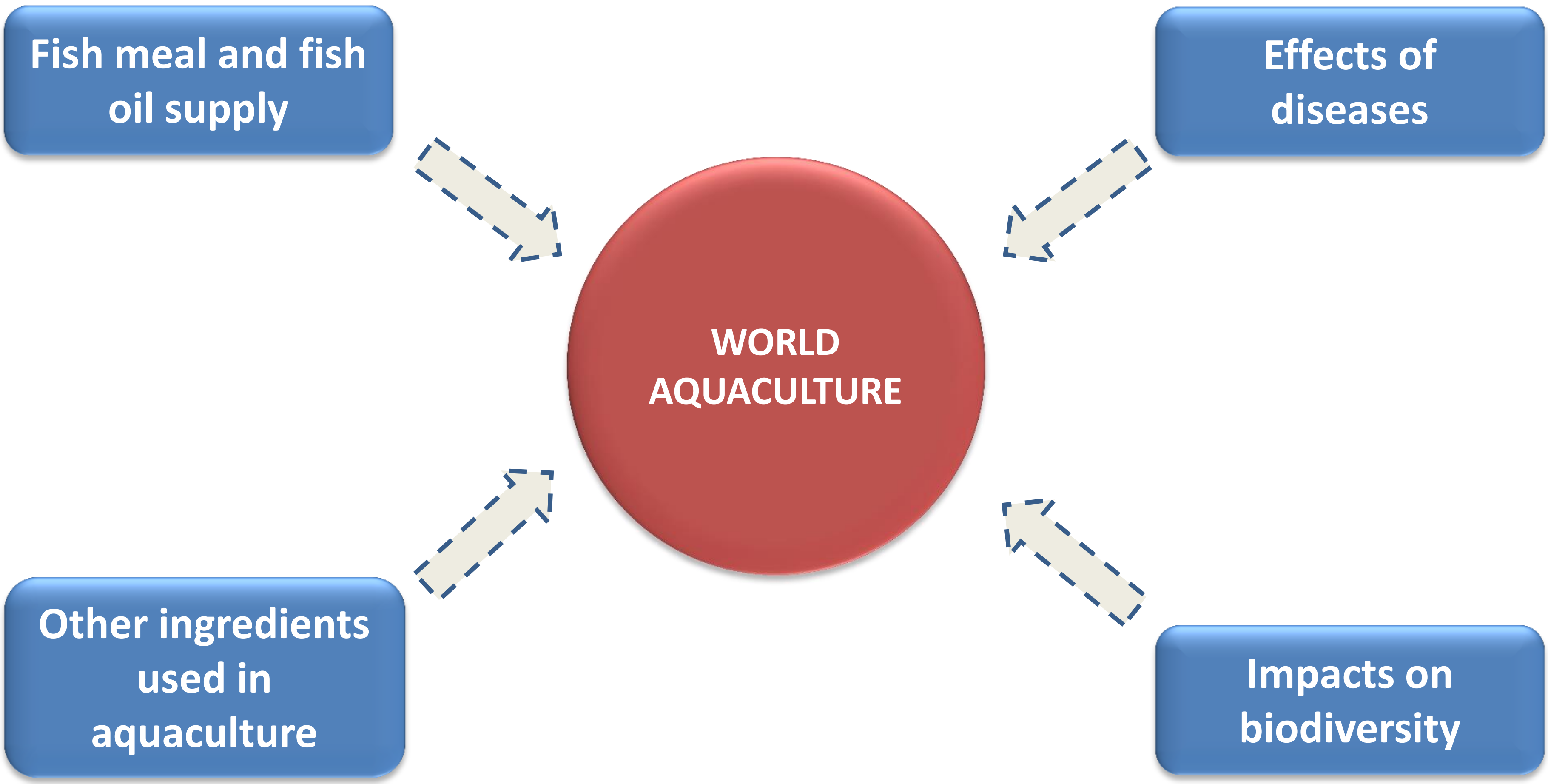
Da Silva & Soto, 2009 in Cochrane et al., 2009

Physical impacts of climate change on wolrd aquaculture



FAO, 2006

Indirect impacts of Climate Change on world aquaculture



FAO, 2006

Rising of temperature – Impacts on aquaculture

TABLE 6

Temperature tolerances of selected, cultured species of different climatic distribution

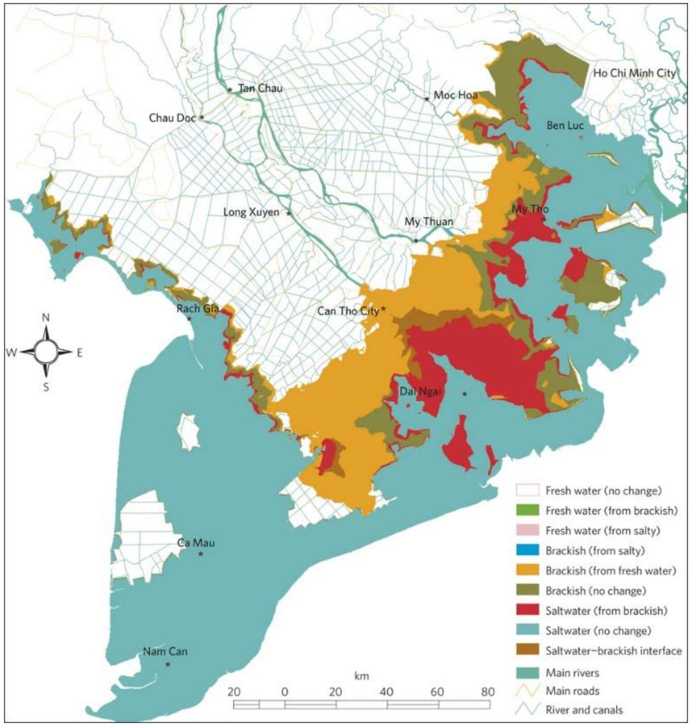
Climatic/temperature guild/Species	Incipient lethal temp. (°C) Lower	Incipient lethal temp. (°C) Higher	Optimal range (°C)
Tropical			
Redbelly tilapia (*Tilapia zillii*)	7	42	28.8–31.4
Guinean tilapia (*Tilapia guineensis*)	14	34	18–32
Warm water (subtropical)			
European eel (*Anguilla anguilla*)	0	39	22–23
Channel catfish (*Ictalurus punctatus*)	0	40	20–25
Temperate/polar			
Arctic charr (*Salvelinus alpinus*)	0	19.7	6–15
Rainbow trout (*Oncorhynchus mykiss*)	0	27	9–14
Atlantic salmon (*Salmo salar*)	-0.5	25	13–17

Source: modified after Ficke, Myrick and Hansen, 2007.

FAO, 2006

Sea level rise

- Shrimp/finfish farming in the Mekong delta as case study.
- Physiological challenges for shrimp species.
- Upstream translocation of aquaculture facilities.
- Impacts on rice culture.



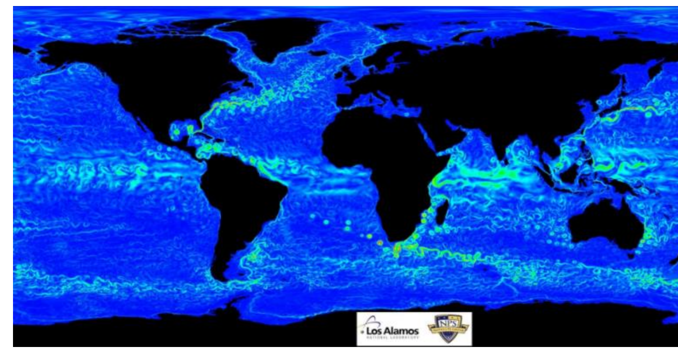
Mekong delta, Vietnam

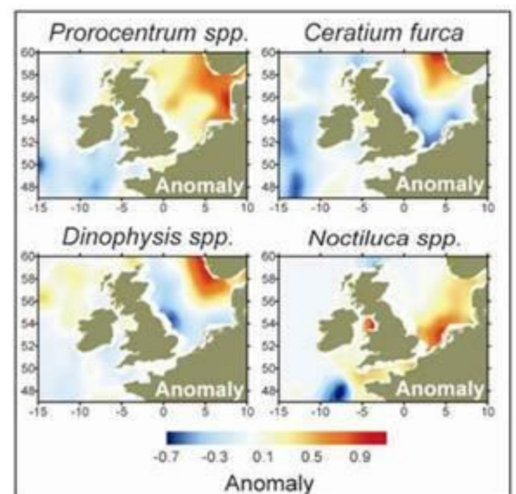
Changes in ocean productivity and circulation patterns

- Aquaculture can be affected by changes in nutrient supply due to changed vertical stability and exchange.

- Harm algal blooms (HABs) and jellyfish blooms can increase due to ocean warming.

- Changes in runoff patterns also increase nutrient supply to coastal areas.





Changes in monsoon patterns and occurrence of extreme events

- **Impacts on aquaculture:**
- Physical destruction of facilities.
- Loss of stocks.
- Scape of cultured exotic species.
- Spread of diseases.

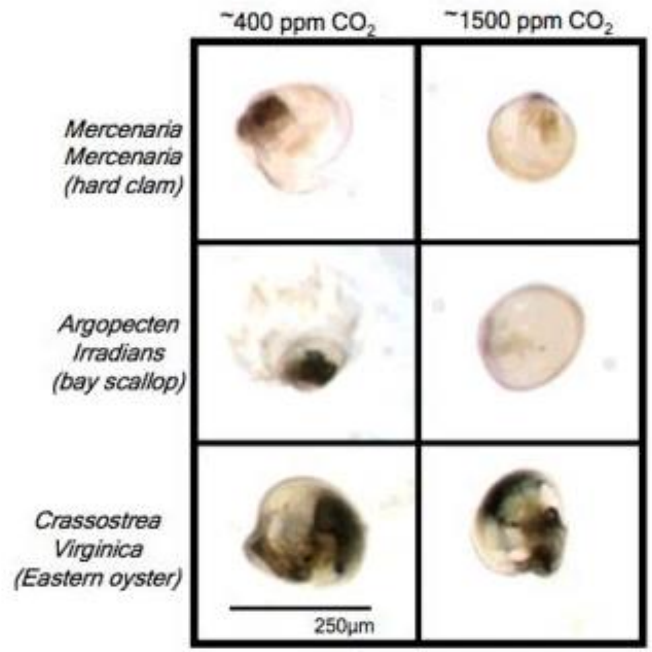
Damaged inshore cages after a typhoon in China

Open salmon pen after post-tropical storm Arthur, Nova Scotia, Canada

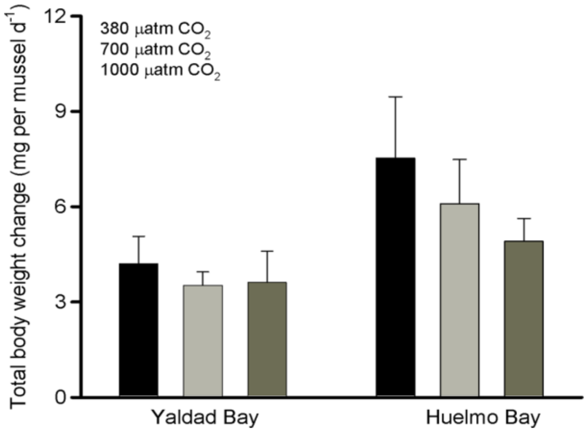
(http://thechronicleherald.ca/opinion/1226208-what-open-pen-salmon-can-learn-from-landlubber-lobster

Ocean acidification

- Shellfish are considered among the most vulnerable organisms in a more acidic ocean due to their reliance on calcium carbonate ($CaCO_3$) shell.
- Increasing mortality risk by current changes in pH conditions (North America), as well as risk of disease and parasite.
- Physiological challenges to compensate for low pH by upregulating calcification internally, impacting growth, reproduction and other processes.
- Oyster farming in North America as a case study.



https://www.eurekalert.org/pub_releases/2009-10/sbu-oam102609.php

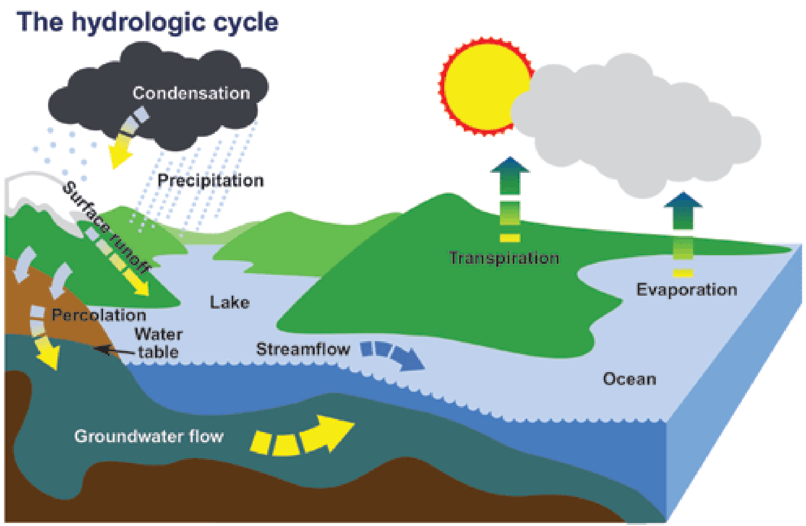


Mytilus chilensis

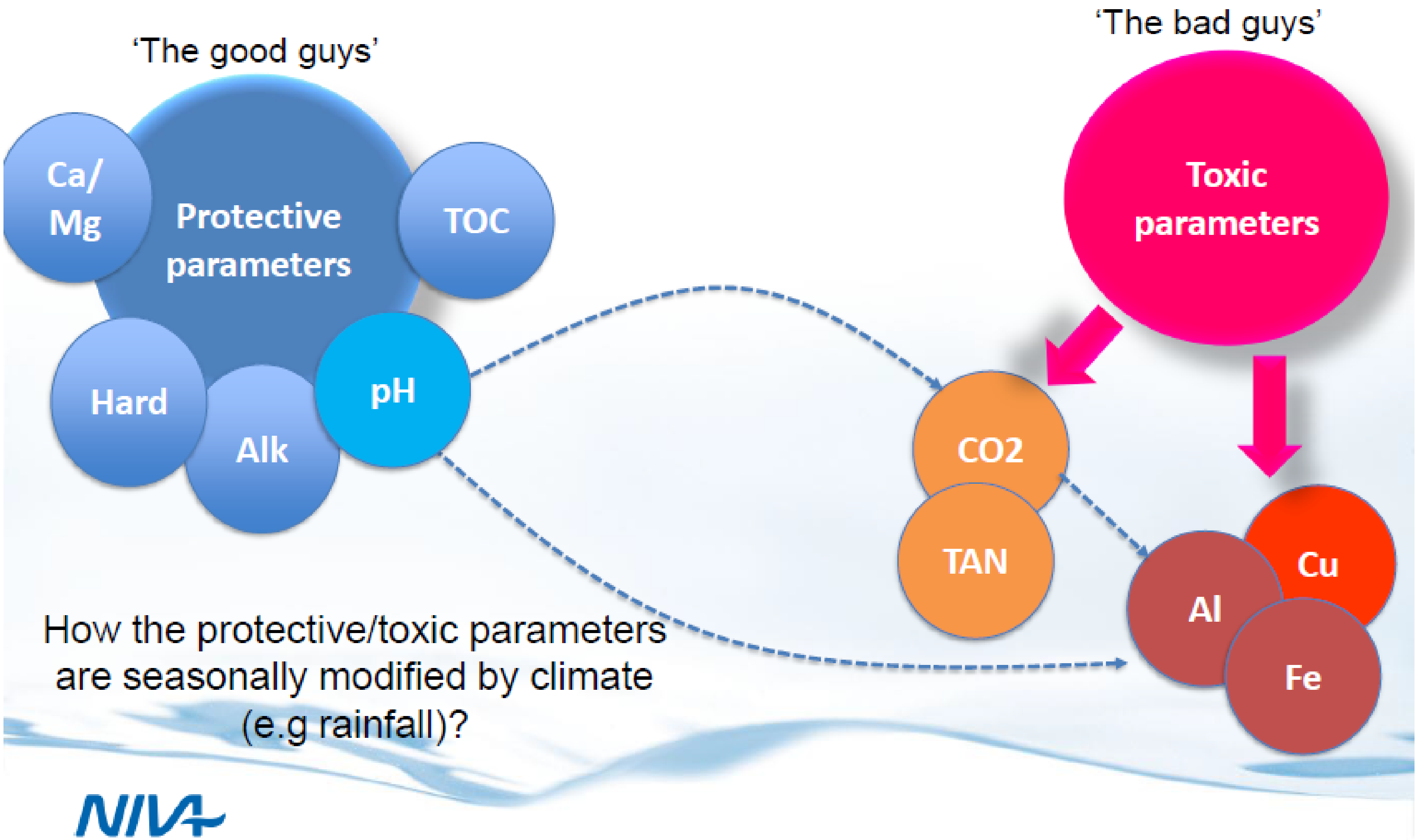
Duarte et al., 2014; Clements et al., 2016

Water stress and changes in hydrological regimes in inland waters

- Changes in water quantity and quality for freshwater and brackish water aquaculture.
- Saline intrusion and changes in precipitation patterns.
- Gross changes in habitats where extensive aquaculture occurs (e.g. wetlands).
- Saline intrusion and physiological and reproductive challenges of species.
- Intensive farming such as salmon farming can be highly impacted given high demands of water quality and quantity.



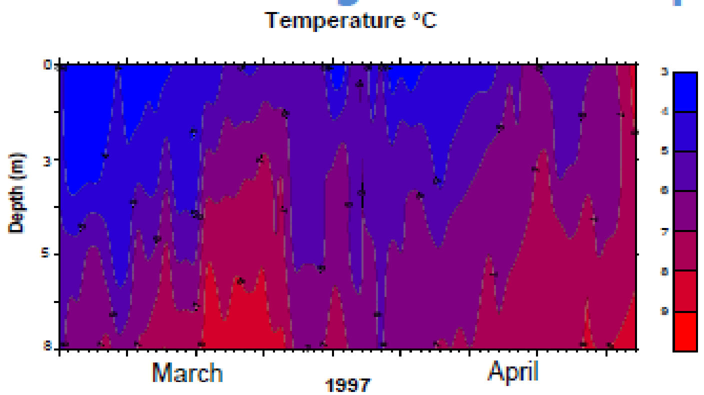
Water quality and fish welfare

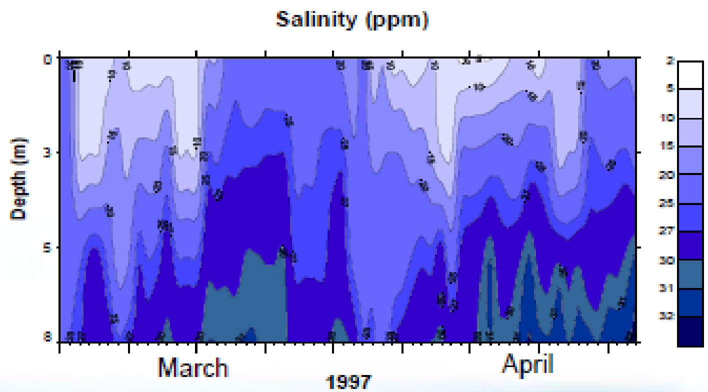


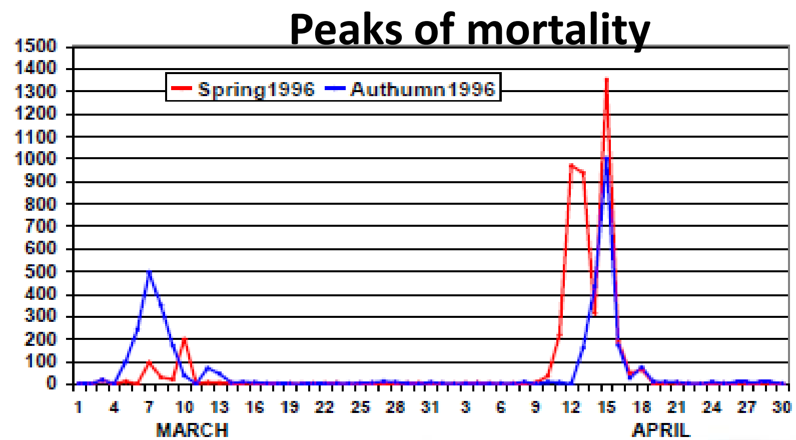
Changes in water quality can impact salmon farming production in Norway and Chile

Mixing zones and its effect on salmon farming in Norway – toxicity by heavy metals

Mortality in salmon farms in the Osterfjorden spring 1997



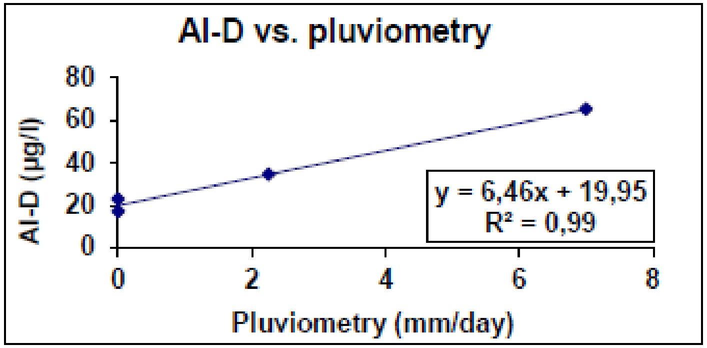




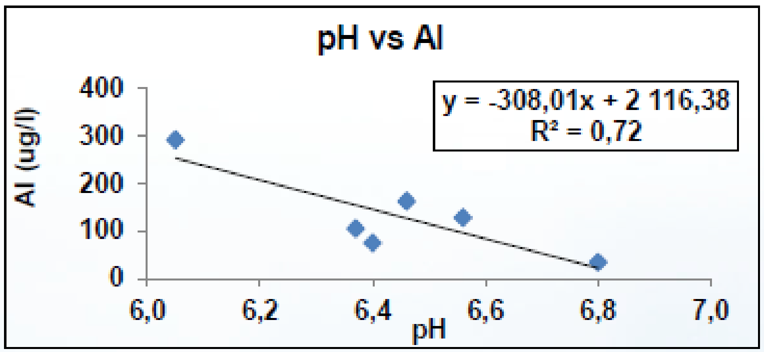
From Bjerknes et al. 2003
In: Marine Chemistry

Slide from Aase Aatland, NIVA

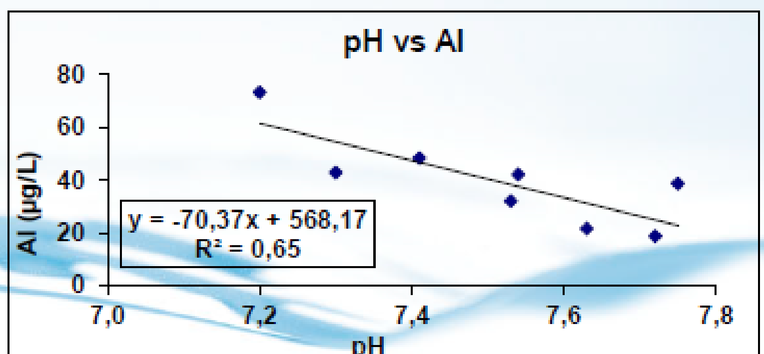
Effects of floods in rivers of Southern Chile.



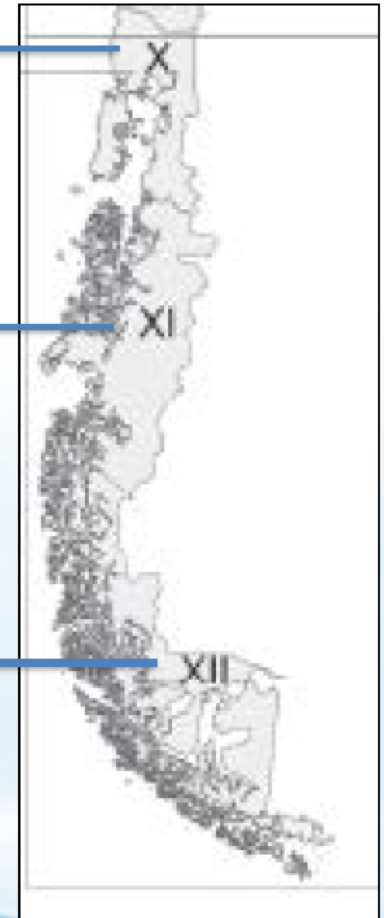
Source: River. Región: X.



Source: River. Región: XI.



Source: River. Región: XII.

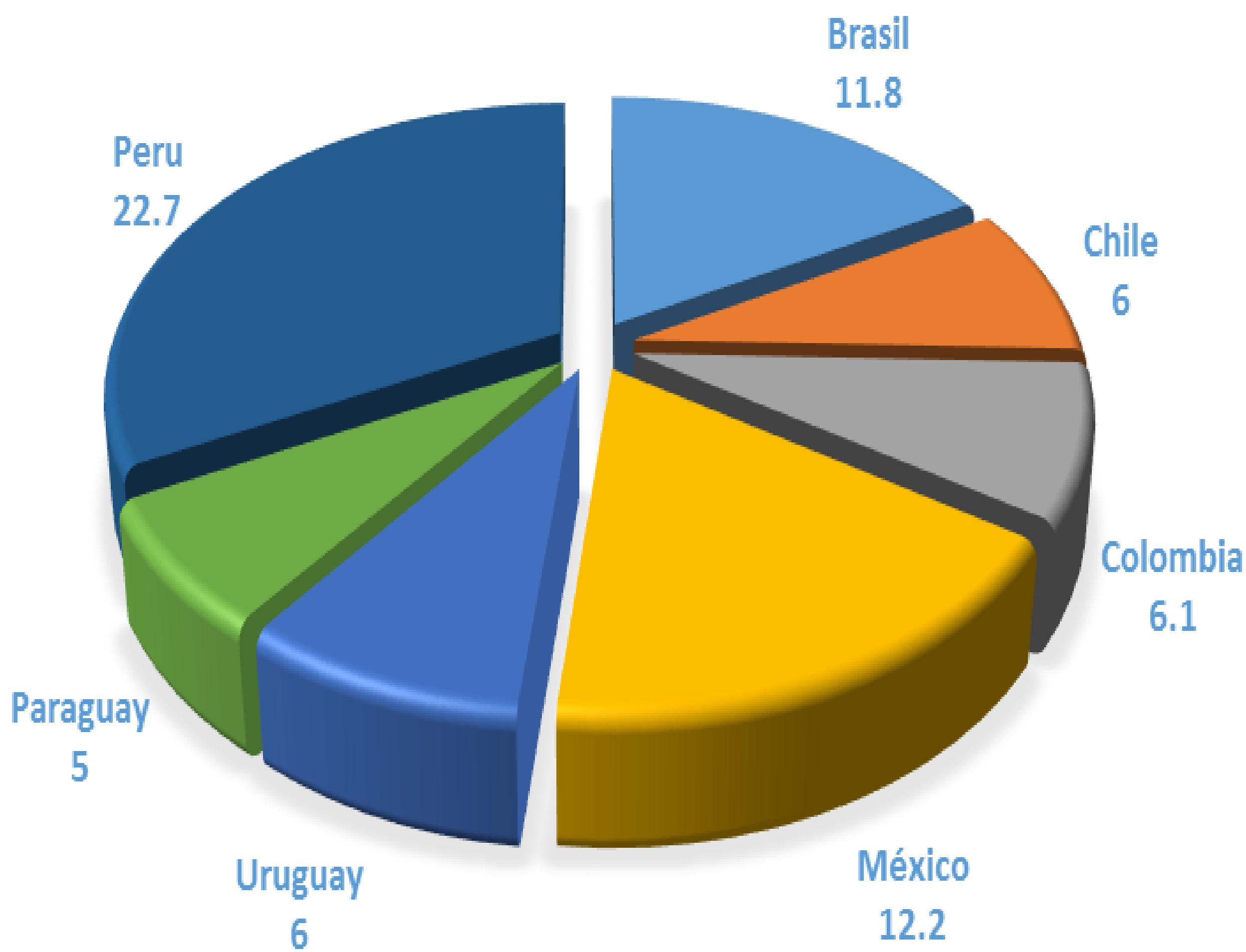


NIVA Chile. Unplublished

Slide from Xavier Gutierrez, NIVA Chile

Aquaculture in Peru

Fish consumption (kg per capita) in Latin American countries



Main aquaculture species in Peru

MARINE SPECIES

Langostino

Litopeneus vannamei

Concha de Abanico

Argopecten purpuratus

FRESHWATER SPECIES

Trucha

Oncorhynchus mykiss

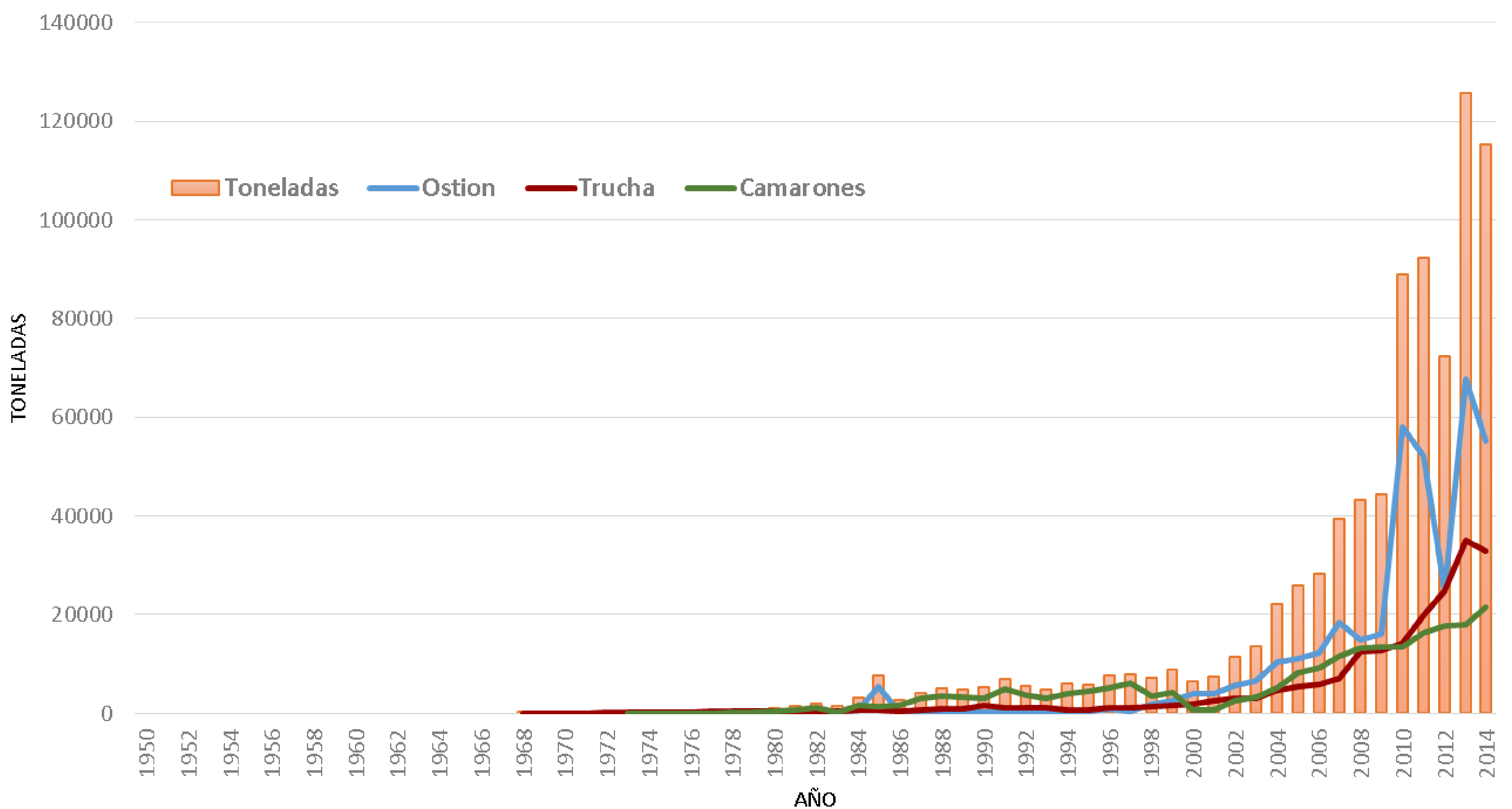
Tilapia

Oreochromis niloticus

Paiche

Arapaima gigas

Aquaculture production in Peru (1950-2014)



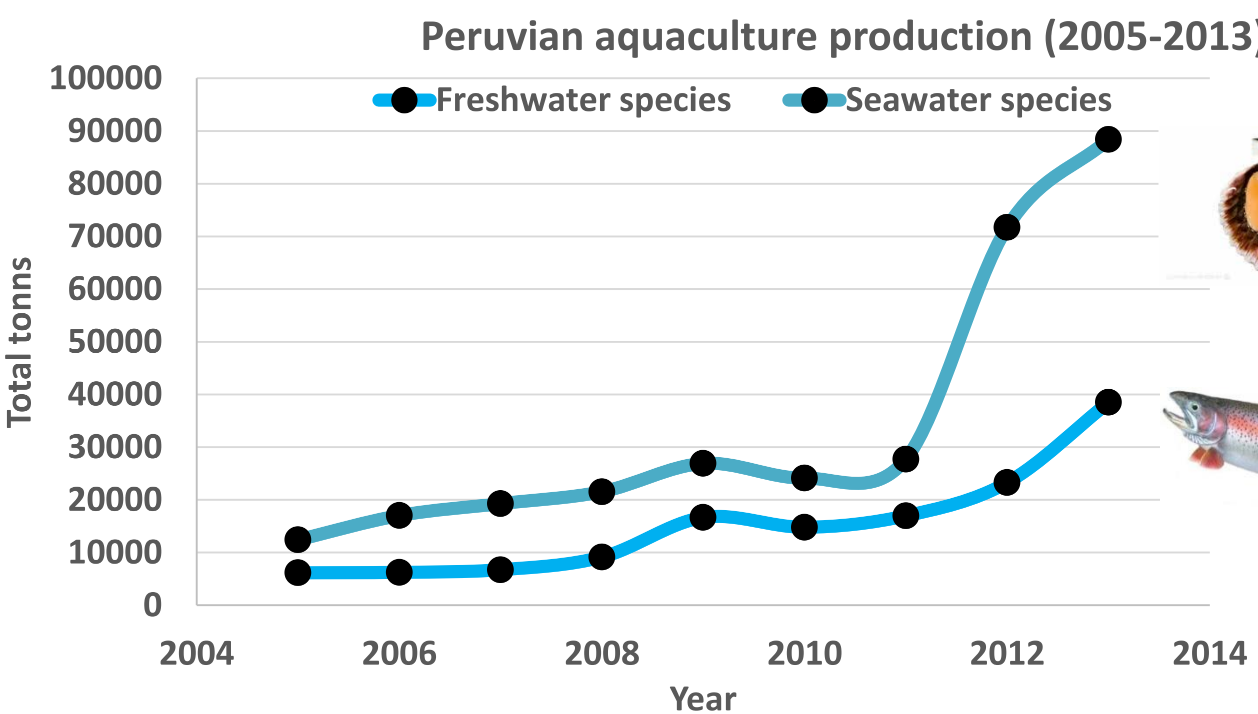
Source: PRODUCE

- There are three aquaculture production levels in Peru for farming site permits:

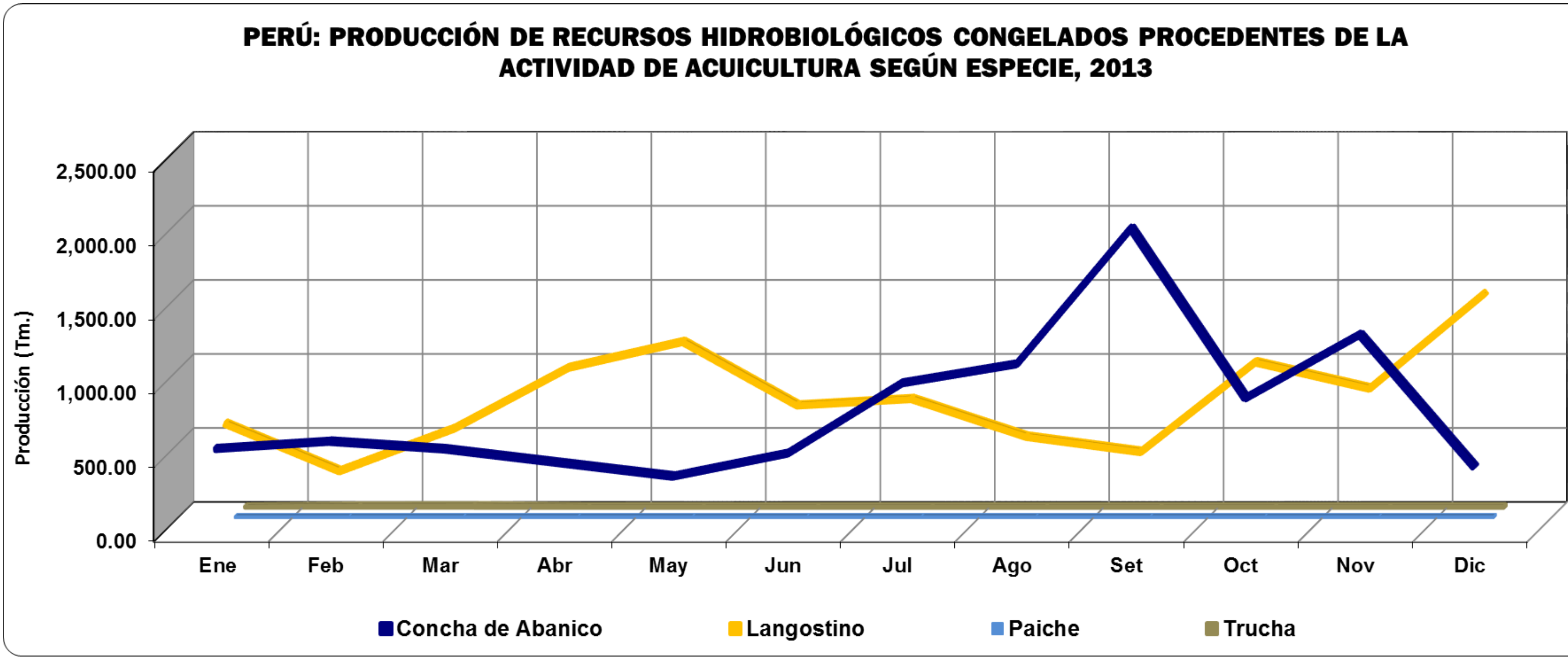
- **Subsistence aquaculture:** < 2 tons per year, with 10 years of permit.

- **Small scale aquaculture:** 2-50 tons per year, with 15 years of permit. Alevin production farms are included in this category.

- **Large scale aquaculture:** > 50 tons per year, with 30 years of permit.

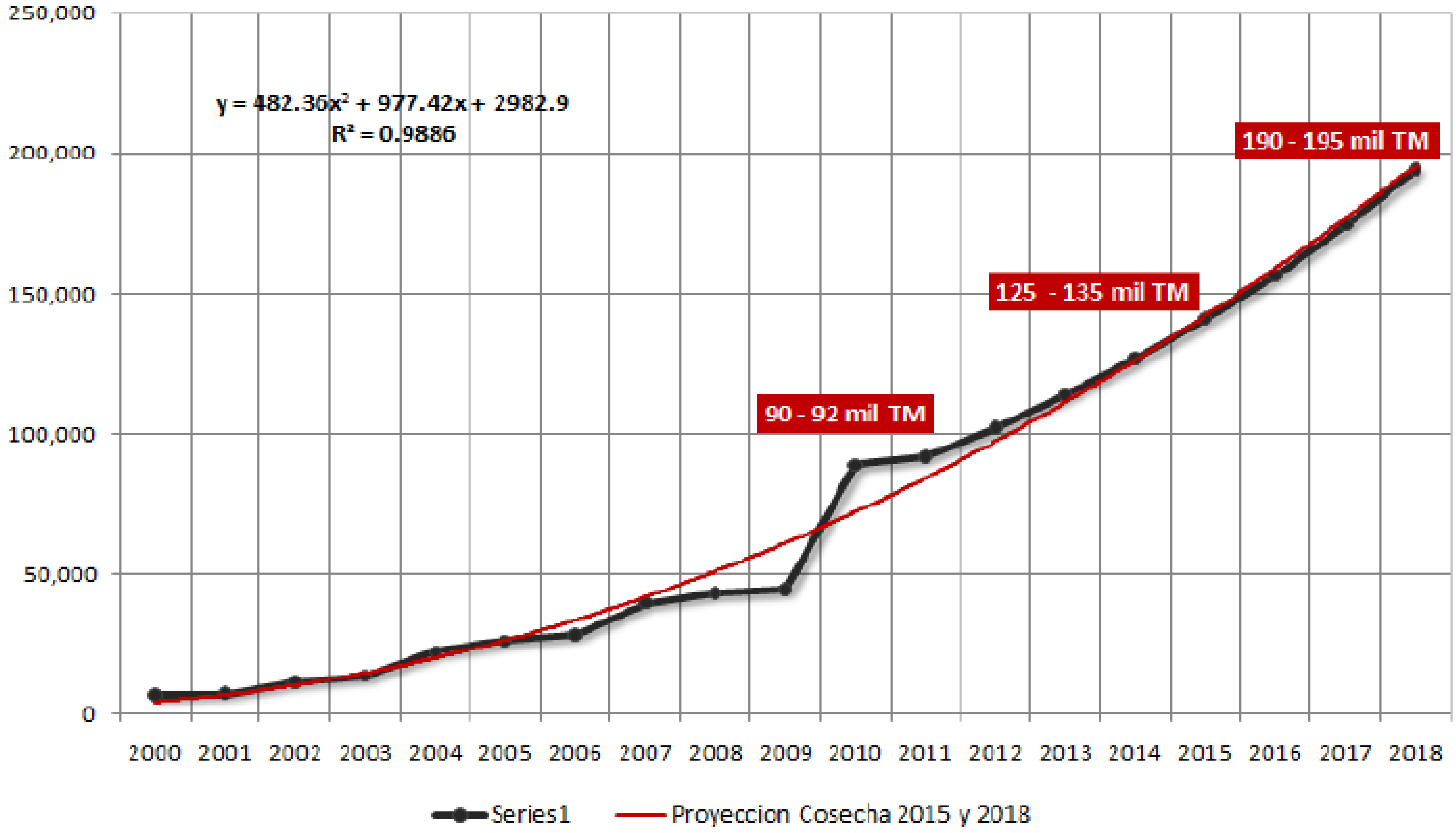


Seasonal trends in aquaculture production in Peru, 2013



Fuente: Produce

Projections of Peruvian aquaculture (2000-2018)



Fuente: Informe: Panorama de la Acuicultura Mundial, en América Latina y el Caribe y en el Perú
DGCHD-Dirección de Acuicultura – Ministerio de la Producción

Marine aquaculture in Peru

Langostinos
Tumbes

Concha de Abanico
Sechura

Concha de Abanico
Samanco y Casma

Concha de Abanico
Pisco

61.35 %

Argopecten purpuratus

38.65 %

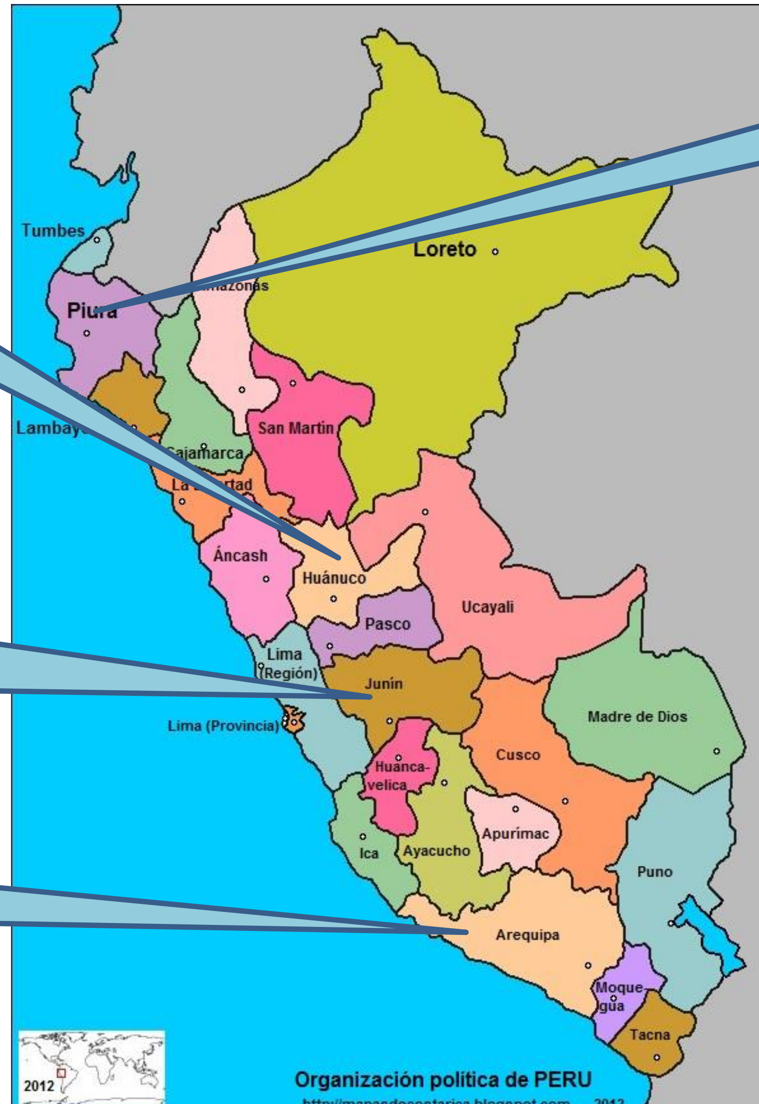
Litopenaeus vannamei

Freshwater aquaculture in Peru

Tilapia
San Martin

Trucha
Junín, Huancavelica, Lima and Pasco

Trucha
Puno



Tilapia
Sullana

18.62%

Oreochromis niloticus

74.85%

Oncorhynchus mykiss

Minor freshwater species

Gamitana, Paco, Sábalo, Paiche and Ornamental fishes

Loreto, Ucayali, M. de Dios and San Martin

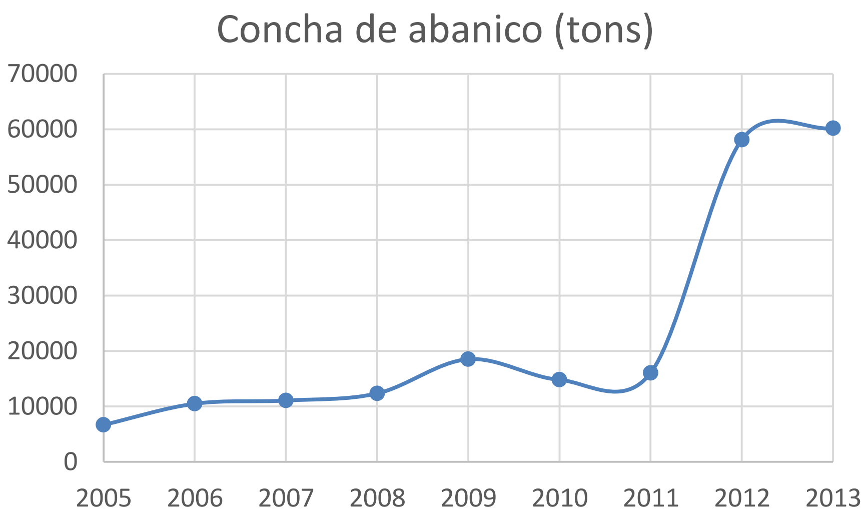
Arapaima gigas

Concha de abanico

- Two culture systems: on-bottom and off-bottom (suspended, pearl nets).
- Seeds from natural banks and hatchery.
- Production depends on key factors such as food, temperature and dissolved oxygen (DO).
- ENSO events can impact scallop productivity by modifying these key factors.

Impacts from climate change are unclear, but it could be expected (*):

- Physiological challenges from rising of SST, lowering of DO and salinity changes.
- Morphological challenges from ocean acidification (e.g. shell structure/shape).
- Infrastructure damage from extreme events, changes in winds, waves and currents.



- Risk of spreading diseases and plagues from extreme events, increasing risk of mortality.

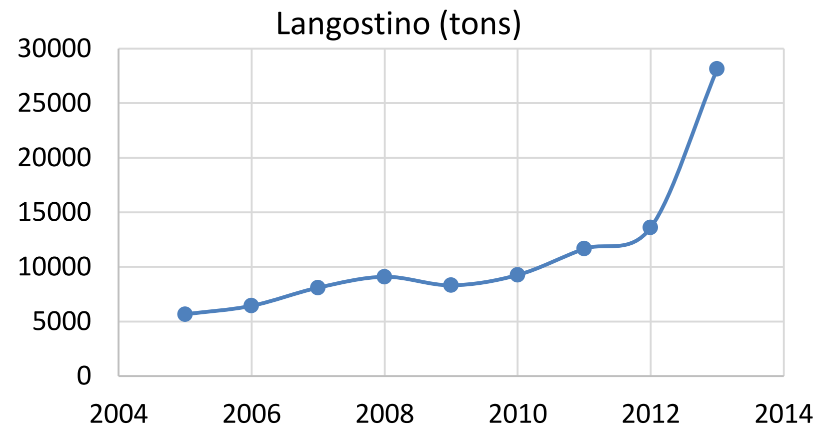
González et al., 2011

Langostino

- ‘Seeds’ imported from Equator
- Two hatcheries in Peru (post-larval stage)
- Extensive, semi-intensive and intensive production

Impacts from climate change are unclear, but we could expect:

- Physiological challenges from rising SST, decreasing DO, and salinity changes.
- Infrastructure damage from extreme events, changes in winds, waves and currents.
- Risk of spreading diseases and plagues from extreme events, increasing risk of mortality.



Trucha

- Semi-intensive and intensive production systems.
- FW land-based facilities and floating cages.
- Format: mostly pan size, but also ‘Truchon’.
- Trout farming occurs mainly in Andean lakes (e.g. Titicaca).
- Inlet waters from rivers and mountain snow.
- Egg (‘ovas’) importation from EEUU (80%), Denmark and other countries.
- Over the last years trout production has rapidly increased.
- Trout production in Puno has been preliminary examined as case study of climate change effects.

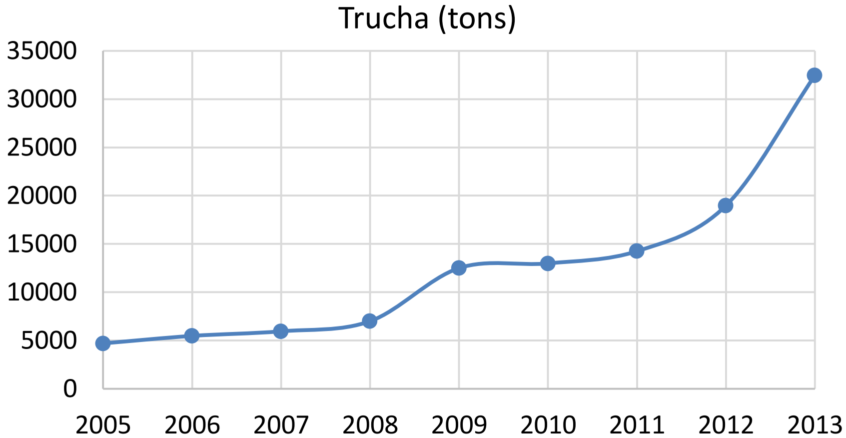


Tabla 8. Caracterización y análisis del riesgo para la acuicultura en Puno

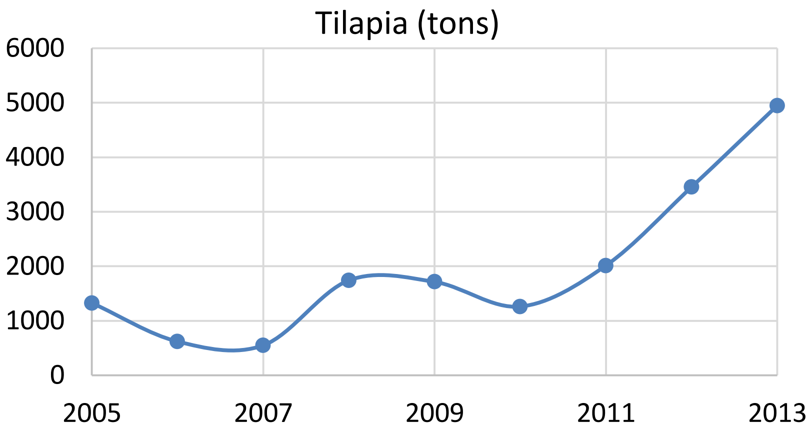
AMENAZAS		VULNERABILIDAD: EXPOSICIÓN	VULNERABILIDAD: SENSIBILIDAD	VULNERABILIDAD: CAPACIDAD ADAPTATIVA	ANÁLISIS DEL RIESGO ACTUAL (cadena de impactos potenciales)			VALORACIÓN DEL RIESGO
CLIMÁTICA	Eventos extremos (heladas, vientos)	Volumen de cosecha: 83% de la producción acuícola nacional de trucha Alto número de personas que se dedican a la acuicultura: 732 acuicultores, de los cuales 59 tienen la acuicultura como su única actividad económica	Derechos de menor escala: 92% de los derechos acuícolas otorgados de la región Autoconsumo: 13.35% de la cosecha para autoconsumo Diversificación productiva (no es única actividad) Baja diversificación de especies Sensibilidad de la trucha	Existencia de un marco institucional para acuicultura Interés político en la promoción de la actividad Asociatividad: 117 asociaciones Acceso a extensión y capacitación Acceso a financiamiento: 23% ROPA del Lago Titicaca	Impactos a los medios de vida del acuicultor		Empobrecimiento de acuicultores y déficit nutricional	Medio
CLIMÁTICA	Alteraciones en la temperatura (polarización) y precipitación							
NO CLIMÁTICA	Presión de múltiples actividades en el Lago Titicaca				Impactos en la calidad del agua	Menor cantidad / calidad de producción		
NO CLIMÁTICA	Contaminación del Lago Titicaca							

Fuente: Elaboración propia

DIAGNÓSTICO DEL SECTOR PESQUERO Y ACUÍCOLA frente al cambio climático y lineamientos de adaptación - Produce

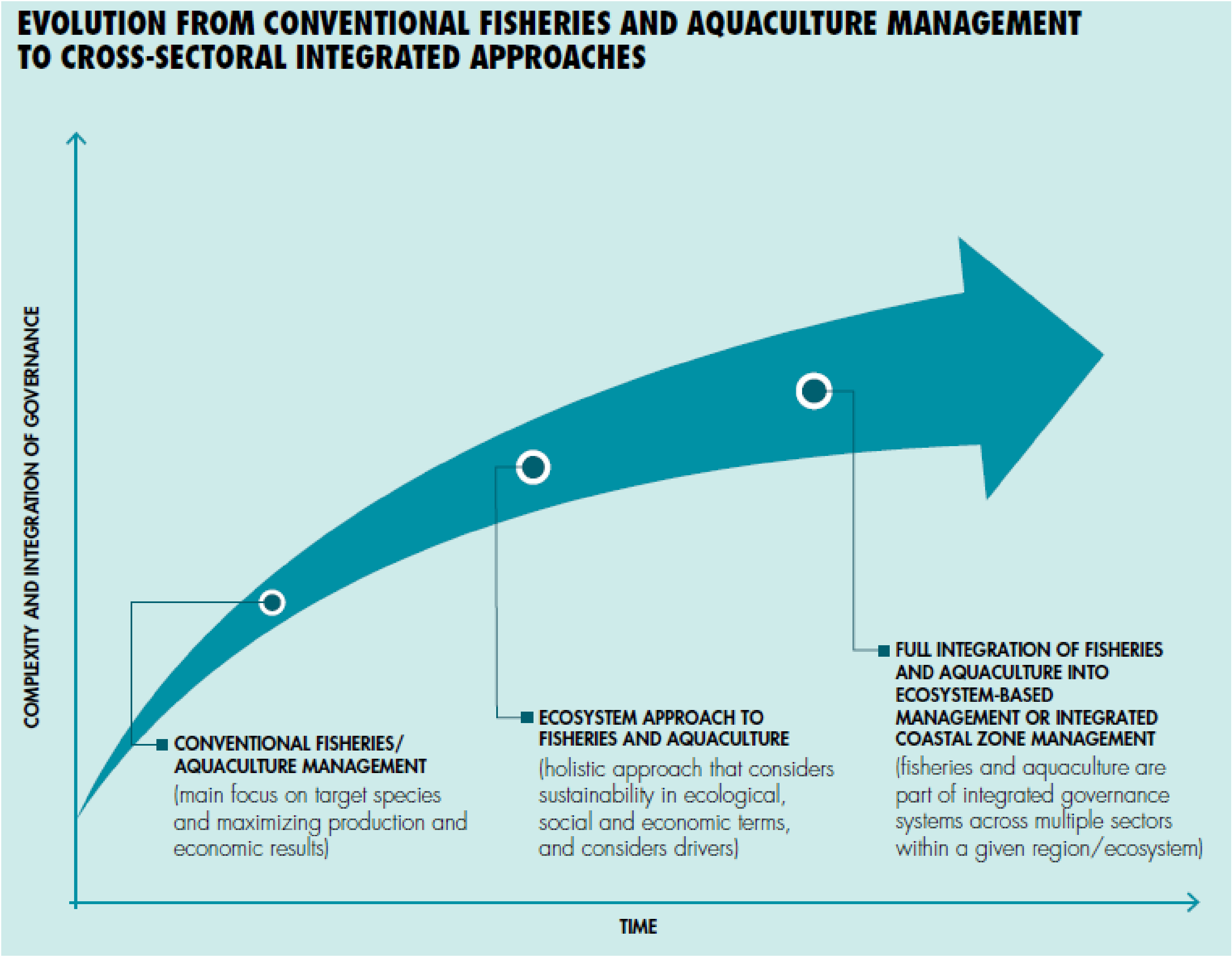
Tilapia

- Introduced in Peru in 1970's.
- Production in extensive, semi-intensive and intensive systems (tanks and floating cages).
- Total farms: 668 (476 are from subsistence).
- Monoculture, but also polyculture (paco, gamitana and paiche).
- Water inlets of FW land-based farms include rivers and dams.
- Technology has improve local production.

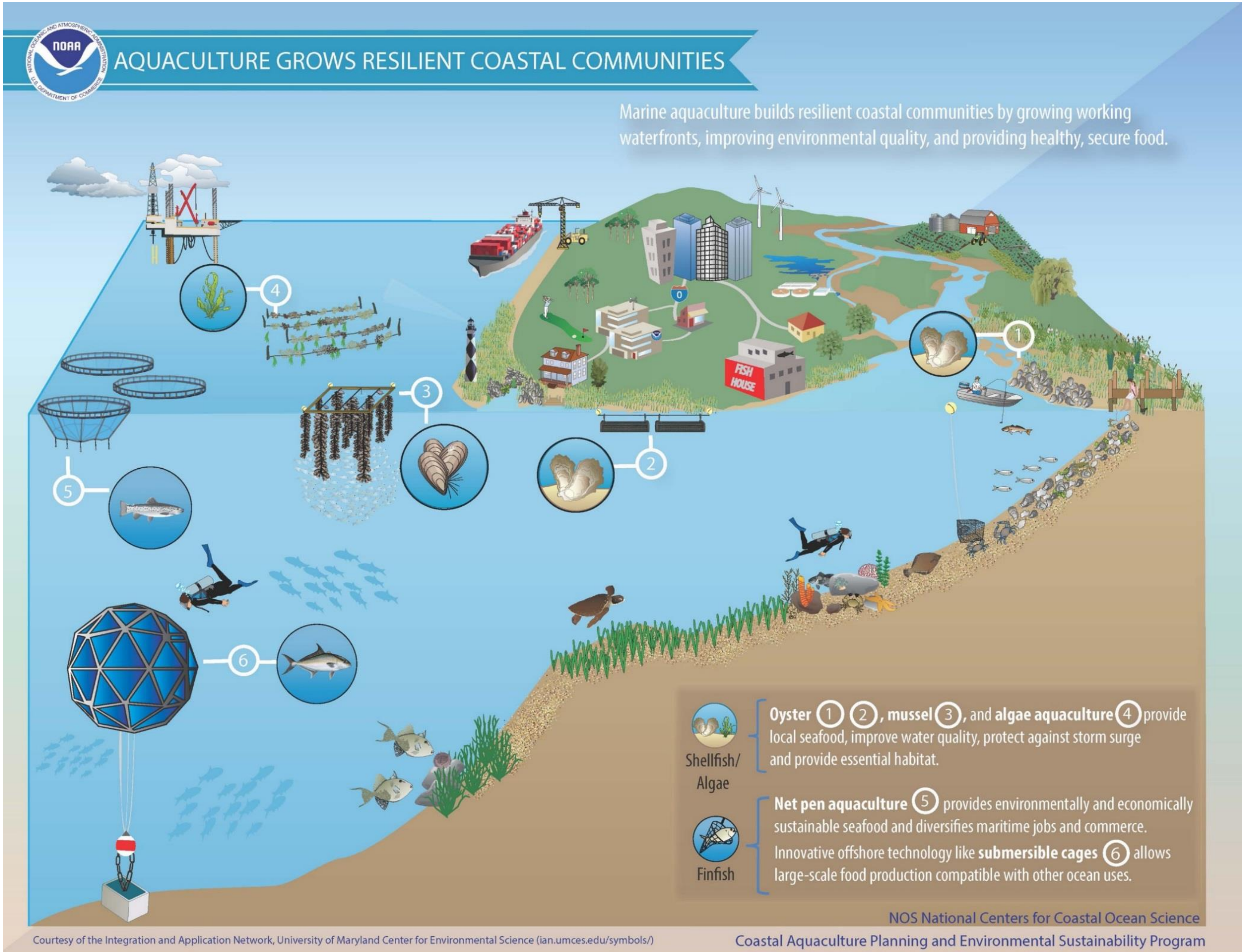


Impacts from climate change are unclear, but we could expect:

- Water supply for inland farms by changes in water quantity/quality.
- Key water quality parameters (DO, pH, alkalinity) can be altered, impacting tilapia physiology and productive outputs.


EVOLUTION FROM CONVENTIONAL FISHERIES AND AQUACULTURE MANAGEMENT TO CROSS-SECTORAL INTEGRATED APPROACHES
COMPLEXITY AND INTEGRATION OF GOVERNANCE
CONVENTIONAL FISHERIES/ AQUACULTURE MANAGEMENT
(main focus on target species and maximizing production and economic results)
ECOSYSTEM APPROACH TO FISHERIES AND AQUACULTURE
(holistic approach that considers sustainability in ecological, social and economic terms, and considers drivers)
FULL INTEGRATION OF FISHERIES AND AQUACULTURE INTO ECOSYSTEM-BASED MANAGEMENT OR INTEGRATED COASTAL ZONE MANAGEMENT
(fisheries and aquaculture are part of integrated governance systems across multiple sectors within a given region/ecosystem)
TIME

FAO 2016


AQUACULTURE GROWS RESILIENT COASTAL COMMUNITIES
Marine aquaculture builds resilient coastal communities by growing working waterfronts, improving environmental quality, and providing healthy, secure food.
FISH HOUSE
Shellfish/ Algae
Oyster 1 2, mussel 3, and algae aquaculture 4 provide local seafood, improve water quality, protect against storm surge and provide essential habitat.
Finfish
Net pen aquaculture 5 provides environmentally and economically sustainable seafood and diversifies maritime jobs and commerce.
Innovative offshore technology like submersible cages 6 allows large-scale food production compatible with other ocean uses.
NOS National Centers for Coastal Ocean Science
Coastal Aquaculture Planning and Environmental Sustainability Program
Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

Summary

- Current aquaculture production is greater than fishery production
- Aquaculture can be impacted by climate change in different ways:
- Physiological challenges of species
- Infrastructure damage
- Changes in productivity and coastal currents
- Aquaculture in Peru includes continental and marine species
- Impacts of Climate change on Peruvian aquaculture are unclear, but some advances have been done in specific locations (Puno)
- Ecosystem-based approach is requested to face main impacts from

climate change

8. Adaptation to Climate Change

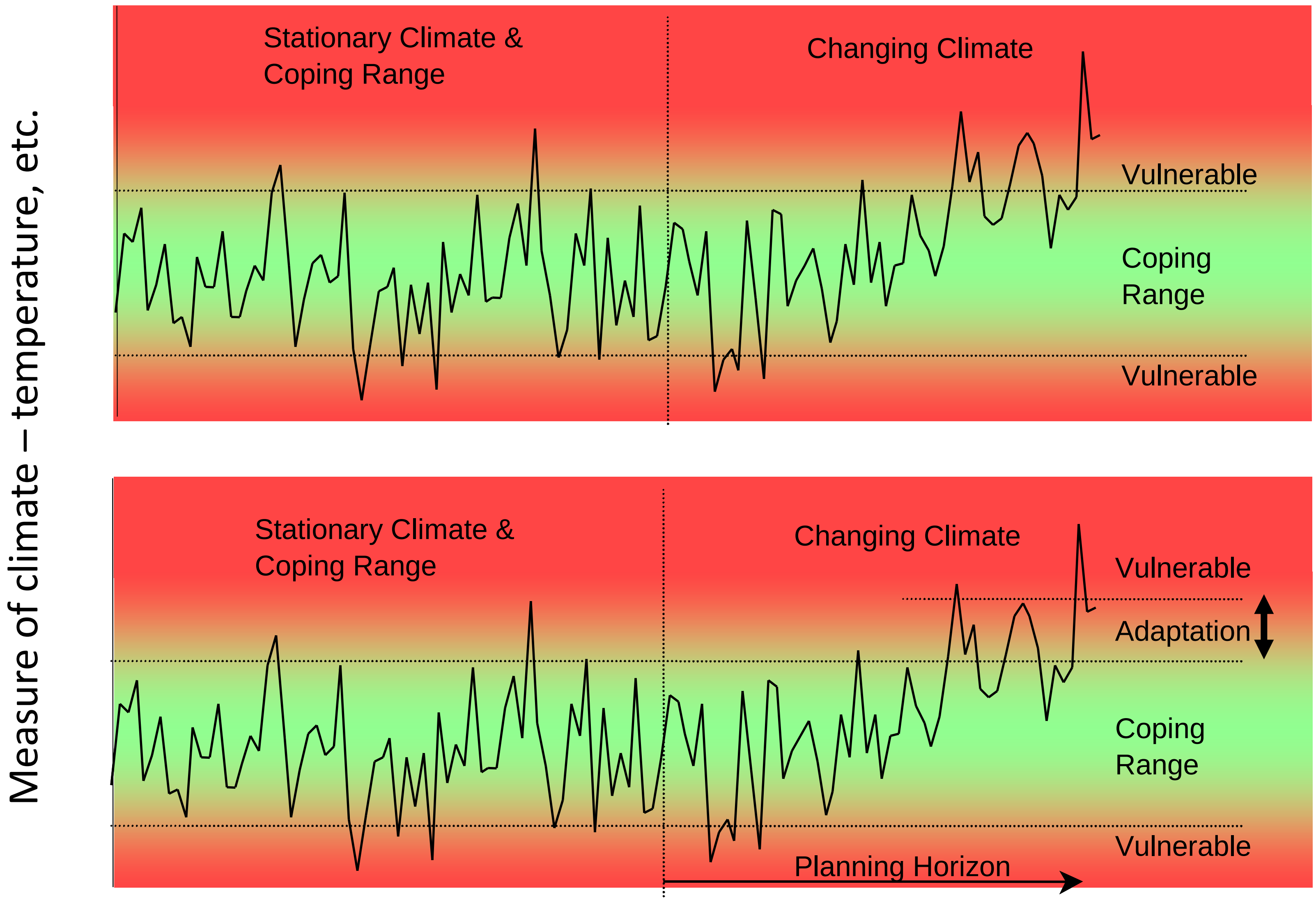
What is adaptation?

Process to enhance, develop, and implement strategies to moderate, increase the resilience, and take advantage of the consequences of climatic events.

↓

Manage risks – Minimise losses – Maximise opportunities

Adapting to a future climate



Jones & Mearns, 2005

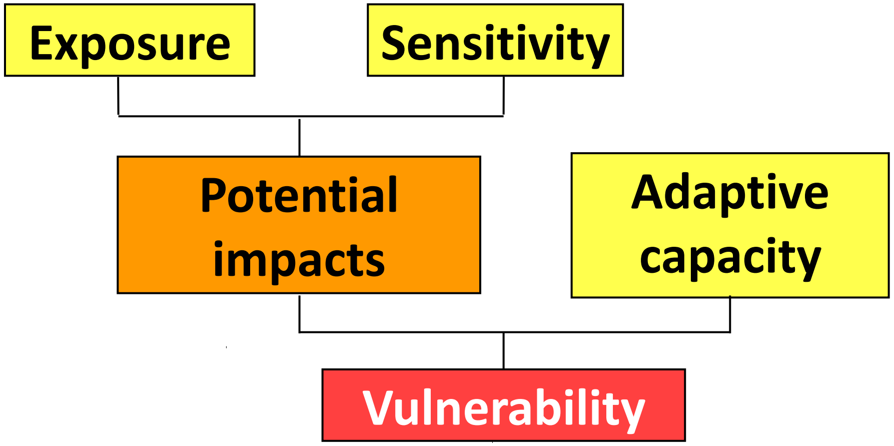
Key concepts

Exposure: Stimuli that have an impact on species or systems, e.g. climatic conditions.

Sensitivity: Degree to which a system is affected by the climate stimuli.

Adaptive capacity: Capability of a system to adapt to climatic stimuli, their effects or impacts.

Vulnerability: Degree to which a system is susceptible to damage (the detrimental part of sensitivity).



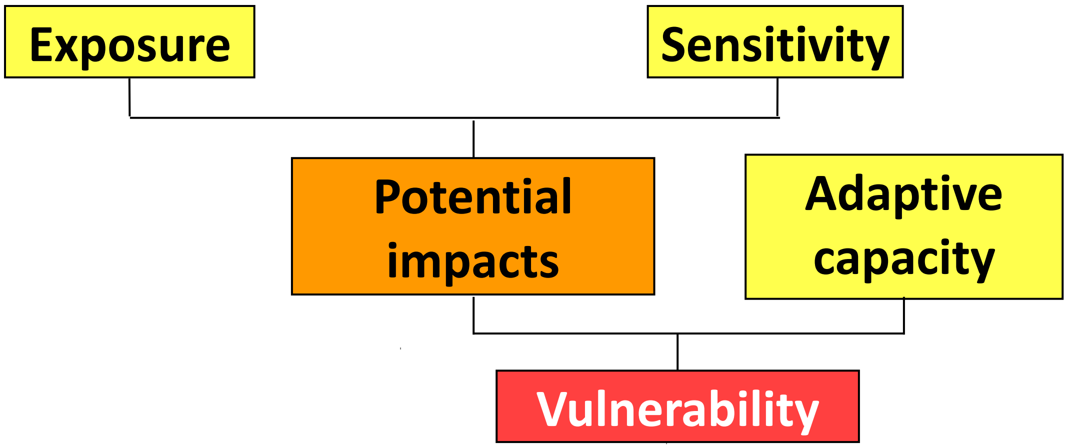
http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=650; Soto & Quiñones, 2013

Understanding the system

Adaptation planning requires an understanding of those systems that are most at risk—and why.

- Sea level rise
- Temperature
- Currents
- Upwelling
- ENSO

- Responsiveness to climatic influences
- Degree affected
- Thresholds
- Reversibility of changes



Ability to change in a way that better equips the system to deal with external influences.

Soto & Quiñones, 2013

Identifying key vulnerabilities

IPCC list of criteria to aid in identifying key vulnerabilities:

- **Magnitude:** Impacts are of large scale and/or high-intensity.
- **Persistence/Reversibility:** Impacts result in persistent damage or reversible damage.
- **Likelihood/Certainty:** Projected impacts are likely, with a high degree of confidence. The higher the likelihood, the more urgent the need for adaptation.
- **Importance:** Systems at risk are of great importance or value to society.

Factors to consider when developing adaptation options

- How different groups of stakeholders (or jurisdictions) weight objectives.

- Conflict which may act as barriers to implement adaptation actions.

1. Maximise wellbeing of communities
2. Maximise economic performance
3. Ensure environmental and ecosystem values
4. Strengthen management and governance

- Identifying weighted management objectives through workshops (managers, industry, scientists).

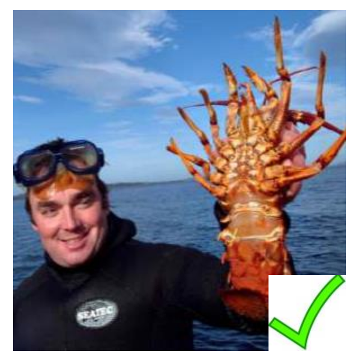
Jennings et al., in review

Factors to consider when developing adaptation options

For instance, Tasmanian Rock Lobster fishers have varying perceptions on reality of Climate Change:

- 80% believe Climate Change is not real
- 20% believe Climate Change is either happening or that 'something is up'

Fishers acknowledge changes BUT NOT Climate Change



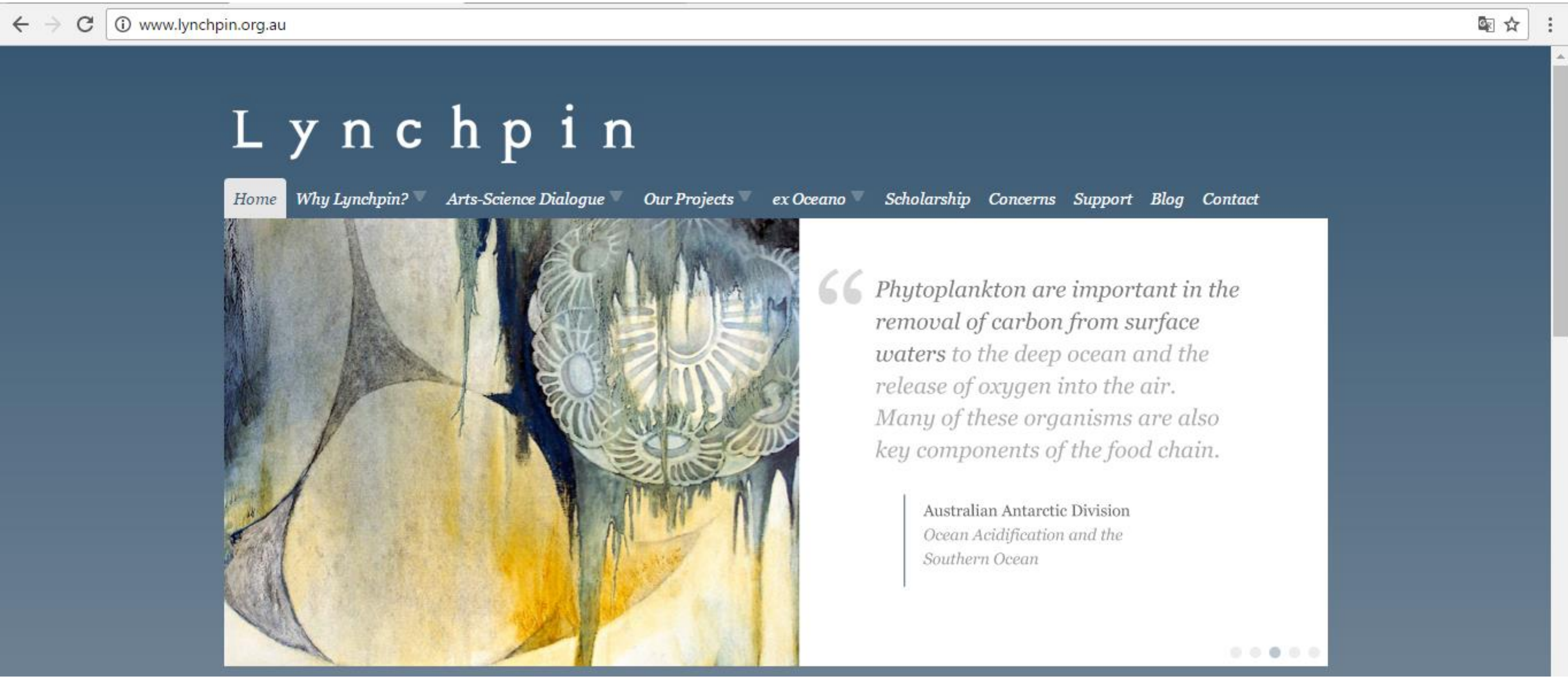
Communication and engagement is a priority

Nursey-Bray et al., 2012

Communication and trust is key

- Information sheets
- Industry and community presentations
- Papers/Reports
- Youtube
- Websites
- Industry newsletters
- Involvement in workshops
- TWO way communication!!!
- Regular & consistent communication

Science communication



http://www.lynchpin.org.au/our-projects/our-scholars/

Science communication

https://www.youtube.com/watch?v=UhM6QKGZd_s

Challenges & barriers to adaptation

- **Divergent expectations** from adaptation research
  - Managing agencies want information only (but no requirement to commit to change)
  - Public good funding agencies want management change
- **CC is not seen as an immediate threat** in contrast to other more immediate issues
- Fear of increased **costs of adaptation** to managing agencies and fishers
  - Need to highlight opportunities for improving efficiencies
- **Time involved** in doing interdisciplinary and participatory research is huge!
  - Challenge for all, including academics with pressures to ‘publish or perish’

Principles of “good” adaptation planning

1. Concrete adaptation actions.
2. Acknowledge that CC is one among many drivers of change and risks.
3. Acknowledge uncertainty.
4. Use an established robust approach – but allow flexibility for unique context.
5. Based on best available scientific information but also account/include perceptions and/or subjective info from stakeholders.
6. Transparent.
7. Acknowledge benefits/limitations of working at a particular scale.
8. Account for different needs of end users and use context relevant communication channels.
9. Be iterative, participatory and multi-stakeholder.

FAO, 2013

Examples of adaptation (Australia)

Sea urchin and rock lobster

Autonomous adaptation (lobster fishers)

- Commercial and recreational fishers move to regions of higher catch rates, offshore, change fishing gear.
- Recreational dive fishers move to non-impacted areas.

Possible adaptation actions

- Increase lobster size limits to increase numbers of large lobsters.
- Reduction of lobster catch in affected regions (e.g. temporal closures, reduce bag limits, etc.).
- Translocation of large lobsters into key areas to remediate urchin barrens.

- Development of commercial opportunities for harvesting the sea urchin.

Examples of adaptation (Australia)

Salmon farming

A. Reduce exposure through predictive modelling.

- What location might be suitable?
- What environment is expected at a range of time scales?

B. Improve salmon performance (at higher temperatures).

- Improve immune response and resistance to diseases.
- Reduce outbreak of diseases currently affecting salmon farming.
- Minimize impact of potential emerging pathogens and diseases.
- Improve growth and feed conversion at higher temperatures.

C. Select alternate species for local conditions.

- Determine attributes which make an alternative species attractive.

Battaglene et al., 2008

Terrestrial selective breeding advance

Breeds of chicken

Terrestrial selective breeding advance

Breeds of cattle

Hobday unpublished

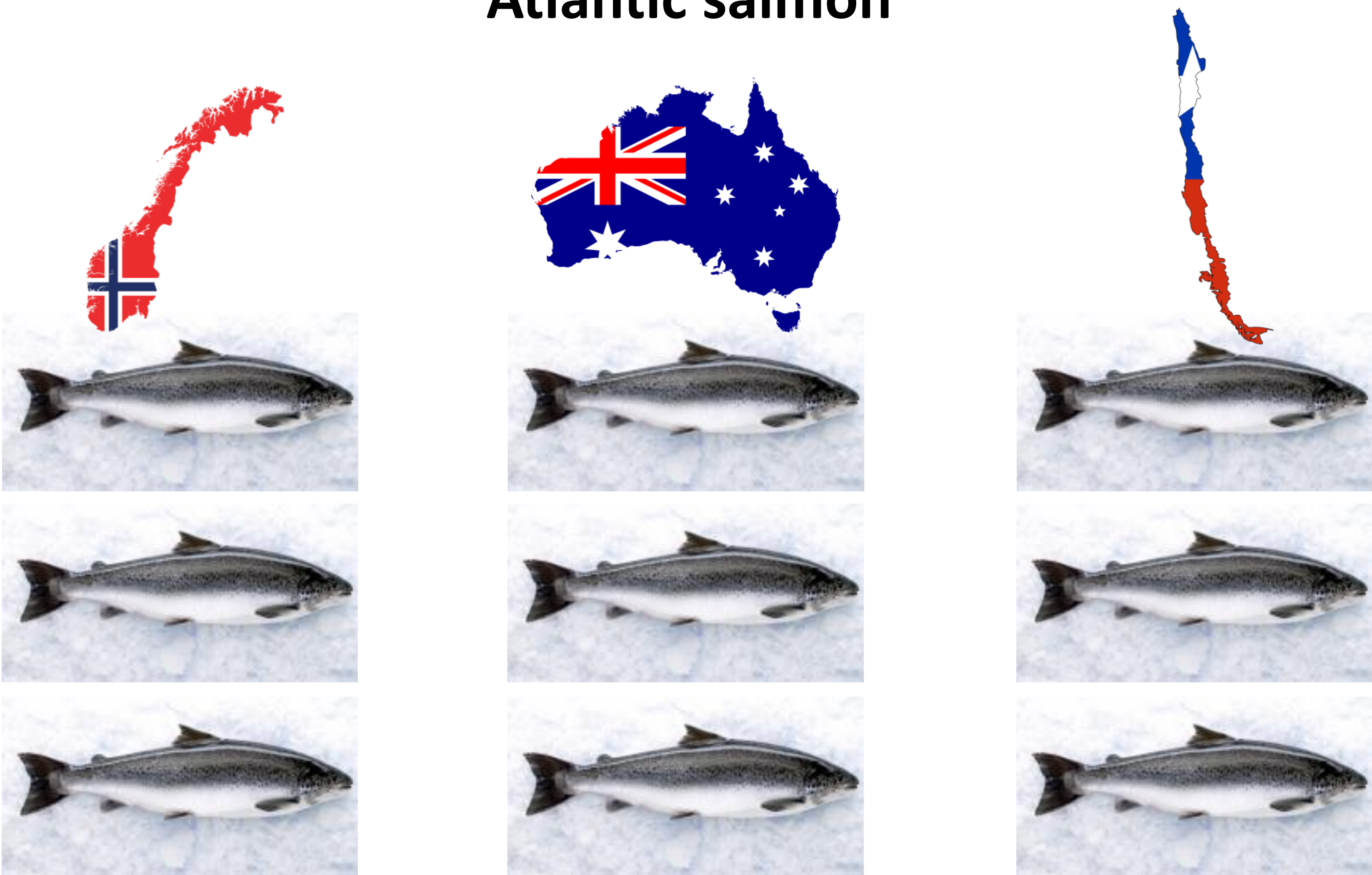
Terrestrial selective breeding advance

Breeds of dogs

Hobday unpublished

Marine selective breeding at its infancy

Atlantic salmon

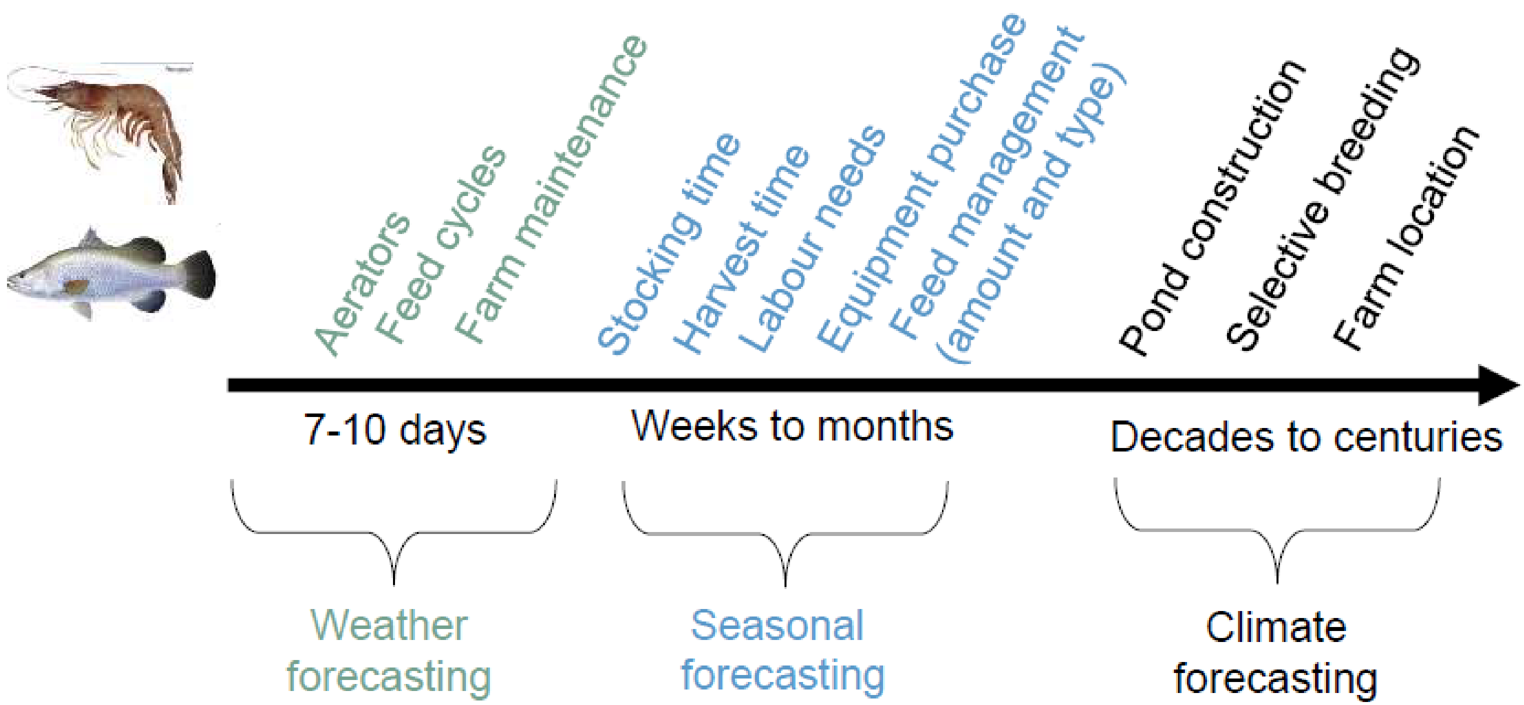


Hobday unpublished

Examples of adaptation (Australia)

Prawns and barramundi

Future environmental information can aid decision making

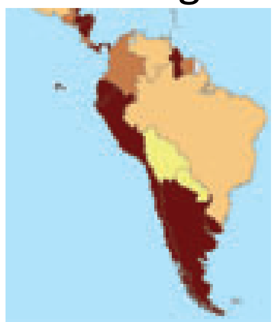


Hobday unpublished

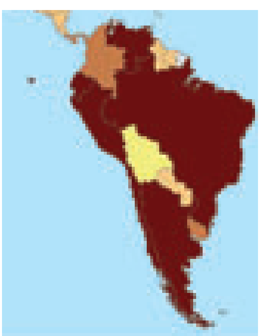
Dependency of Peru on fish and fisheries

Proportion of fishers

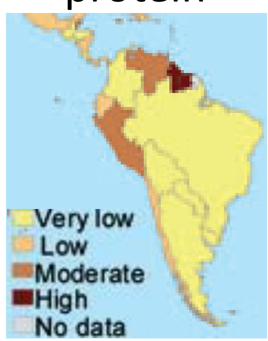
Fisheries landings

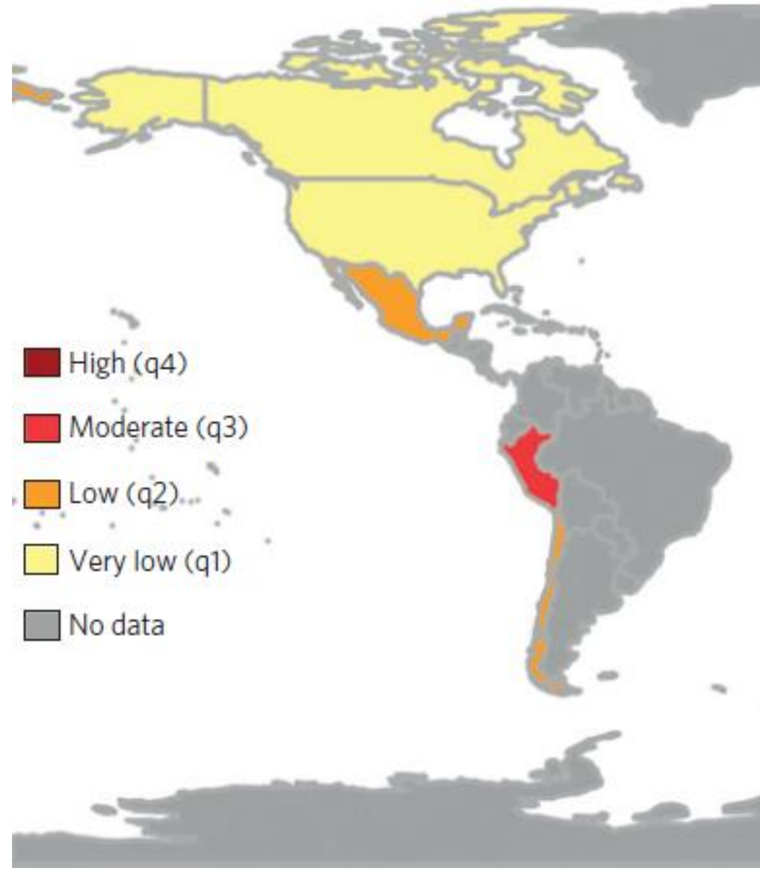


Fish export value



Fish protein





Peru has moderate to high dependency on fish and fisheries

Allison et al., 2009; Barange et al., 2014

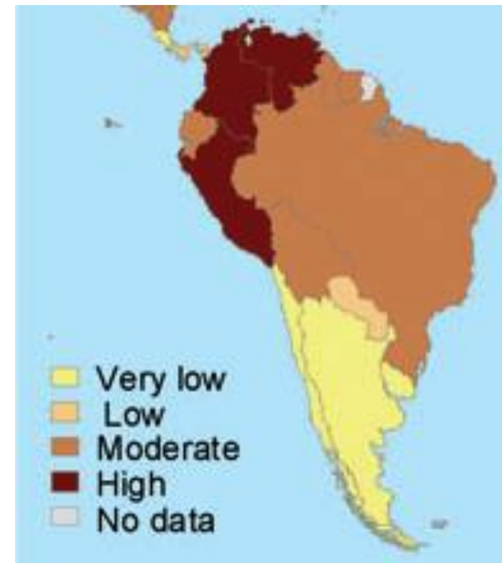
Impact of Climate Change on fisheries economy

Exposure

Sensitivity

Adaptive capacity

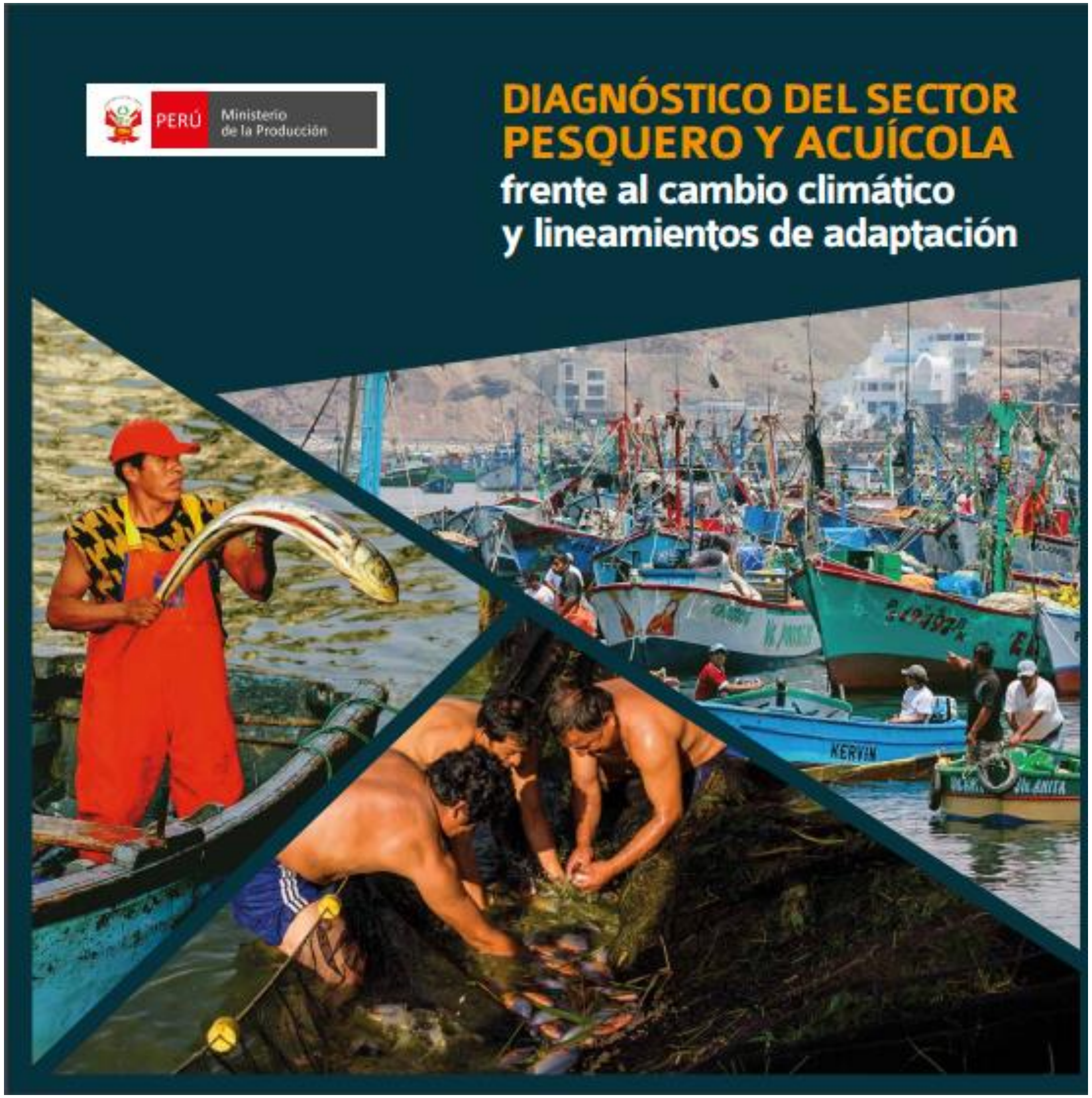
Vulnerability



World rank (of 132 countries)	Country	Exposure	Sensitivity	Adaptive capacity	Vulnerability
10	Peru	0.82	0.73	0.51	0.69

Allison et al., 2009

Adaptation (Peru)



http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

Tabla 2. Caracterización y análisis del riesgo para la pesca artesanal de consumo humano directo en Piura

AMENAZAS		VULNERABILIDAD: EXPOSICIÓN	VULNERABILIDAD: SENSIBILIDAD	VULNERABILIDAD: CAPACIDAD ADAPTATIVA	ANÁLISIS DEL RIESGO ACTUAL (cadena de impactos potenciales)			VALORACIÓN DEL RIESGO
CLIMÁTICA	Evento El Niño: • Inundaciones (↑PP) • Aumento TSM (↑ TSM) • Daños en la infraestructura (desembarcaderos, muelles, caminos, puentes)	Gran actividad de la industria de congelado y enlatado. Alto volumen de desembarque de especies hidrobiológicas	100% de los pescadores artesanales tiene la pesca artesanal como actividad principal	Existencia de un marco institucional para pesca artesanal	Daños en la infraestructura	Reducción del volumen de desembarque	Déficit nutricional y pérdidas de empleo	Alto
				Estrategia Regional de Cambio Climático Existencia de información climática				
NO CLIMÁTICA	Pesca ilegal		76% de los pescadores vende sus productos a mayoristas comercializadores en el desembarcadero	Acceso a créditos (19%)	Cambios en la distribución y abundancia de los recursos			
	Derrames petroleros			Existencia de regulación-ROP para algunos recursos (pota, jurel, caballa, atún, anchoveta para CHD)				
	Tráfico marítimo (agua de lastre)		Elevada informalidad de la actividad pesquera artesanal	Reglamentación de talla mínima de extracción y Porcentaje de Tolerancia Máxima de Juveniles (RM Nº 209-2001-PE)				
	Yacimiento de Bayovar		Alta diversidad de especies en los desembarques	PPR 0095 Fortalecimiento de la pesca artesanal				
	Contaminación							
	Exploración petrolera por el uso de la sísmica 2D y 3D			92% pescadores embarcados				

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

<table>
<tr><th colspan="9">Tabla 4. Caracterización y análisis del riesgo para la pesca industrial de consumo humano indirecto en Ancash</th></tr>
<tr><th colspan="2" rowspan="2">AMENAZAS</th><th colspan="3">VULNERABILIDAD</th><th colspan="3" rowspan="2">ANÁLISIS DEL RIESGO ACTUAL (cadena de impactos potenciales)</th><th rowspan="2">VALORACIÓN DEL RIESGO</th></tr>
<tr><th>EXPOSICIÓN</th><th>SENSIBILIDAD</th><th>CAPACIDAD ADAPTATIVA</th></tr>
<tr><td rowspan="3">CLIMÁTICAS</td><td>Eventos extremos</td><td rowspan="5">Gran presencia de plantas de procesamiento

Alto volumen de desembarque de anchoveta

Alto número de personas empleadas en actividades vinculadas a la pesquería de anchoveta</td><td rowspan="5">48% sólo cuenta con educación inicial o primaria

Exigencia de nuevos estándares de calidad

Pesquería mono específica (alta dependencia de la anchoveta)

Alta sensibilidad de la anchoveta a cambios de temperatura</td><td rowspan="5">Existencia de un marco institucional para pesca industrial

Marco regulatorio y monitoreo (cuotas)

Asociatividad alta

Instalación de emisor submarino Aproferrol</td><td rowspan="3">Daños a la infraestructura y embarcaciones</td><td rowspan="5">Disminución de desembarques</td><td rowspan="5">Pérdidas de empleo y pérdidas económicas</td><td rowspan="5">Alto</td></tr>
<tr><td>Oleaje anómalo</td></tr>
<tr><td>Evento El Niño</td></tr>
<tr><td rowspan="2">NO CLIMÁTICAS</td><td>Pesca ilegal</td><td rowspan="2">Cambios en la distribución y abundancia de los recursos</td></tr>
<tr><td>Contaminación</td></tr>
</table>

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

Tabla 8. Caracterización y análisis del riesgo para la acuicultura en Puno

AMENAZAS		VULNERABILIDAD			ANÁLISIS DEL RIESGO ACTUAL (cadena de impactos potenciales)	VALORACIÓN DEL RIESGO
		EXPOSICIÓN	SENSIBILIDAD	CAPACIDAD ADAPTATIVA		
CLIMÁTICA	Eventos extremos (heladas, vientos)	Volumen de cosecha: 83% de la producción acuícola nacional de trucha Alto número de personas que se dedican a la acuicultura: 732 acuicultores, de los cuales 59 tienen la acuicultura como su única actividad económica	Derechos de menor escala: 92% de los derechos acuícolas otorgados de la región Autoconsumo: 13.35% de la cosecha para autoconsumo Diversificación productiva (no es única actividad) Baja diversificación de especies Sensibilidad de la trucha	Existencia de un marco institucional para acuicultura Interés político en la promoción de la actividad Asociatividad: 117 asociaciones Acceso a extensión y capacitación Acceso a financiamiento: 23% ROPA del Lago Titicaca	Impactos a los medios de vida del acuicultor Impactos en la calidad del agua Menor cantidad / calidad de producción Empobrecimiento de acuicultores y déficit nutricional	Medio
	Alteraciones en la temperatura (polarización) y precipitación					
NO CLIMÁTICA	Presión de múltiples actividades en el Lago Titicaca					
	Contaminación del Lago Titicaca					

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

Tabla 9. Medidas de adaptación para la pesca artesanal para consumo humano directo en Piura	
LÍNEAS DE ACCIÓN	**MEDIDA DE ADAPTACIÓN**
POLÍTICAS	• Promover el uso de los planes de manejo para el uso sostenible de especies marinas vulnerables • Fortalecer la aplicación de normas para reducir la contaminación por efluentes y desechos sólidos en las áreas costeras y marinas • Fomentar la planificación espacial marino costera
INSTITUCIONALIDAD Y GOBERNANZA	• Fortalecer el seguimiento y control a los compromisos asumidos en los instrumentos de gestión ambiental de actividades productivas que se desarrollan en el medio marino y representan amenazas no climáticas
TECNOLOGÍA	• Fortalecer la infraestructura y equipamiento para reducir su vulnerabilidad frente a eventos climáticos extremos • Promover la implementación de artes y aparejos de pesca, y equipamiento en las embarcaciones artesanales para la extracción adecuada de especies potenciales y de oportunidad • Promover el desarrollo e implementación de tecnologías para el tratamiento de efluentes de las infraestructuras pesqueras
CONCIENCIA PÚBLICA	• Promover el control que oriente la extracción sostenible de los recursos pesqueros costeros así como adecuadas prácticas ambientales en los pescadores artesanales
INVESTIGACIÓN Y OBSERVACIÓN SISTEMÁTICA	• Fortalecer el monitoreo y manejo sostenible de los principales recursos explotados por la pesquería artesanal en la región • Fortalecer y dinamizar los Comités Regionales de Vigilancia Pesquera Artesanal (COREVIPAS) a fin de coadyuvar a la implementación y cumplimiento de las normas sectoriales

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

Tabla 10. Medidas de adaptación para la pesca industrial para consumo humano indirecto en Ancash	
LÍNEAS DE ACCIÓN	MEDIDA DE ADAPTACIÓN
POLÍTICAS	• Establecer incentivos a las buenas prácticas pesqueras y ambientales en la industria de harina y aceite de pescado • Promover el uso de instrumentos de gestión ambiental para las embarcaciones industriales pesqueras • Incentivar la entrada al sistema de emisores comunes por parte de las plantas industriales para evitar la contaminación de las bahías
TECNOLOGÍA	• Fortalecer los procesos de producción de harina de pescado para obtener productos de mejor calidad que al mismo tiempo reduzcan efluentes y emisiones • Promover la reconversión tecnológica para la captura de nuevas especies que pudieran presentarse por efecto de las condiciones climáticas
CONCIENCIA PÚBLICA	• Promover prácticas sostenibles de aprovechamiento del recurso hidrobiológico. • Capacitación de la tripulación sobre buenas prácticas a bordo y conservación del ecosistema marino
INVESTIGACIÓN Y OBSERVACIÓN SISTEMÁTICA	• Fortalecer el monitoreo de variables ambientales y oceanográficas mediante el uso de embarcaciones industriales

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

Regional risk assessments

Tabla 12. Medidas de adaptación para la acuicultura en Puno

LÍNEAS DE ACCIÓN	MEDIDA DE ADAPTACIÓN
POLÍTICAS	• Promover la investigación orientada a la adaptación de la acuicultura y la pesca artesanal al cambio climático para asegurar su sostenibilidad
INSTITUCIONALIDAD Y GOBERNANZA	• Fortalecer el rol del FONDEPES para promover, capacitar y financiar programas de acuicultura de pequeña escala • Asegurar la interacción del FONDEPES con el sector privado y con las asociaciones de acuicultores • Promover la asociatividad entre los acuicultores a fin de estandarizar la producción de trucha y poder acceder a diferentes mercados, a través de la venta de productos de mejor calidad • Fortalecer la coordinación interinstitucional que contribuya al desarrollo de la acuicultura y a la reducción del impacto generado por la contaminación en el lago
TECNOLOGÍA	• Implementar programas de investigación e innovación tecnológica, que sean una alternativa para el cultivo de trucha y otras especies cultivables (nativas e introducidas)
FORTALECIMIENTO DE CAPACIDADES	• Impulsar y fortalecer las modalidades asociativas que no limitan el desarrollo empresarial, mediante capacitaciones

http://www.produce.gob.pe/documentos/pesca/dgsp/publicaciones/diagostico-pesquero/Tomo-1.pdf

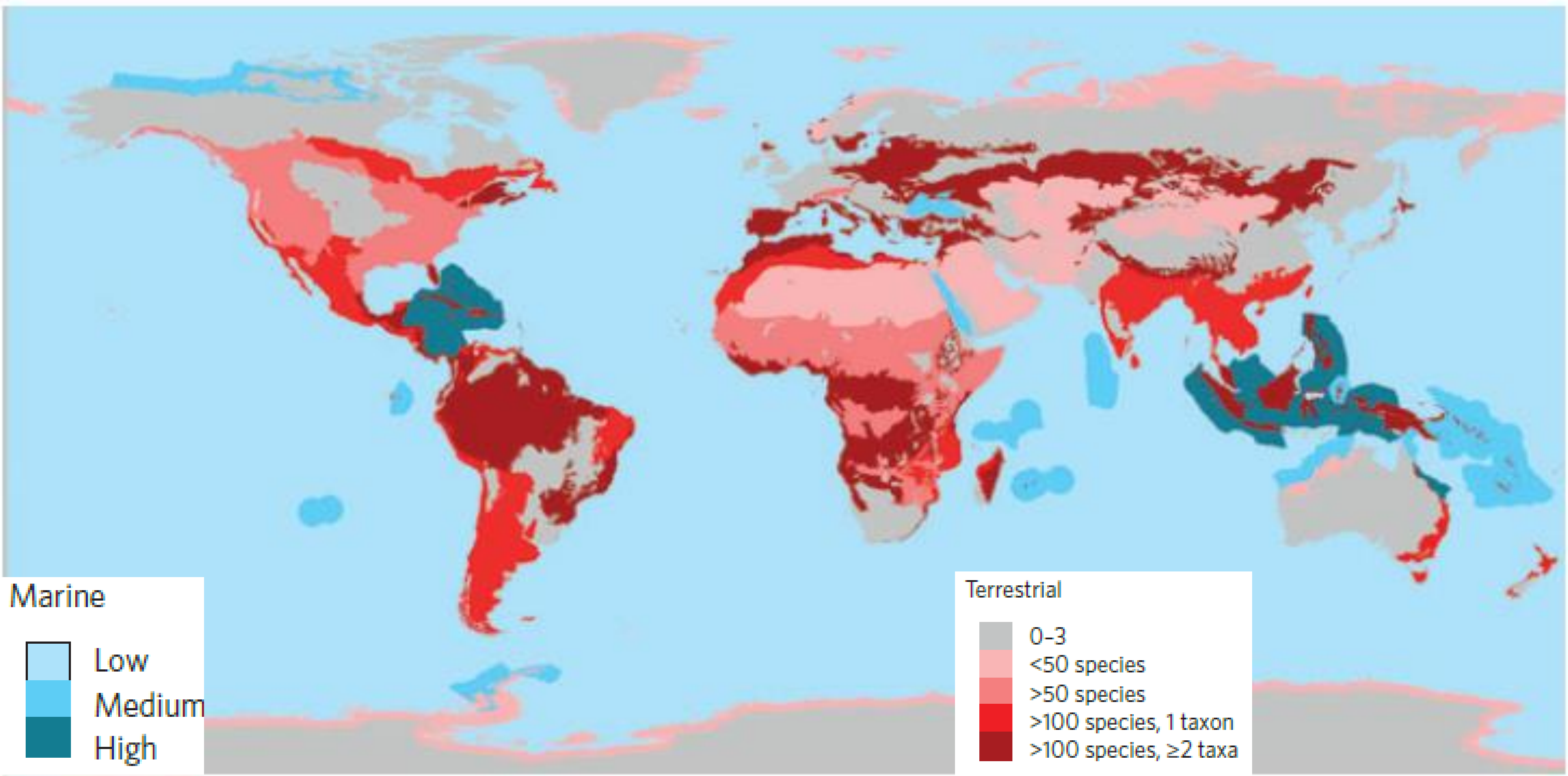
Summary

- Fishing, pollution, disease and habitat loss- likely to exacerbate Climate Change impacts.
- Understanding the response of species and ecosystems will be challenging but **we can’t wait for all the answers.**
- There are many examples of planned adaptations or responses that industries can start to think about that will minimise impacts and maximise opportunities.
- **Collaboration, engagement and good will is crucial.**
- **Industries that engage in adaptation will be ahead of the others!**

9. Local perception of change

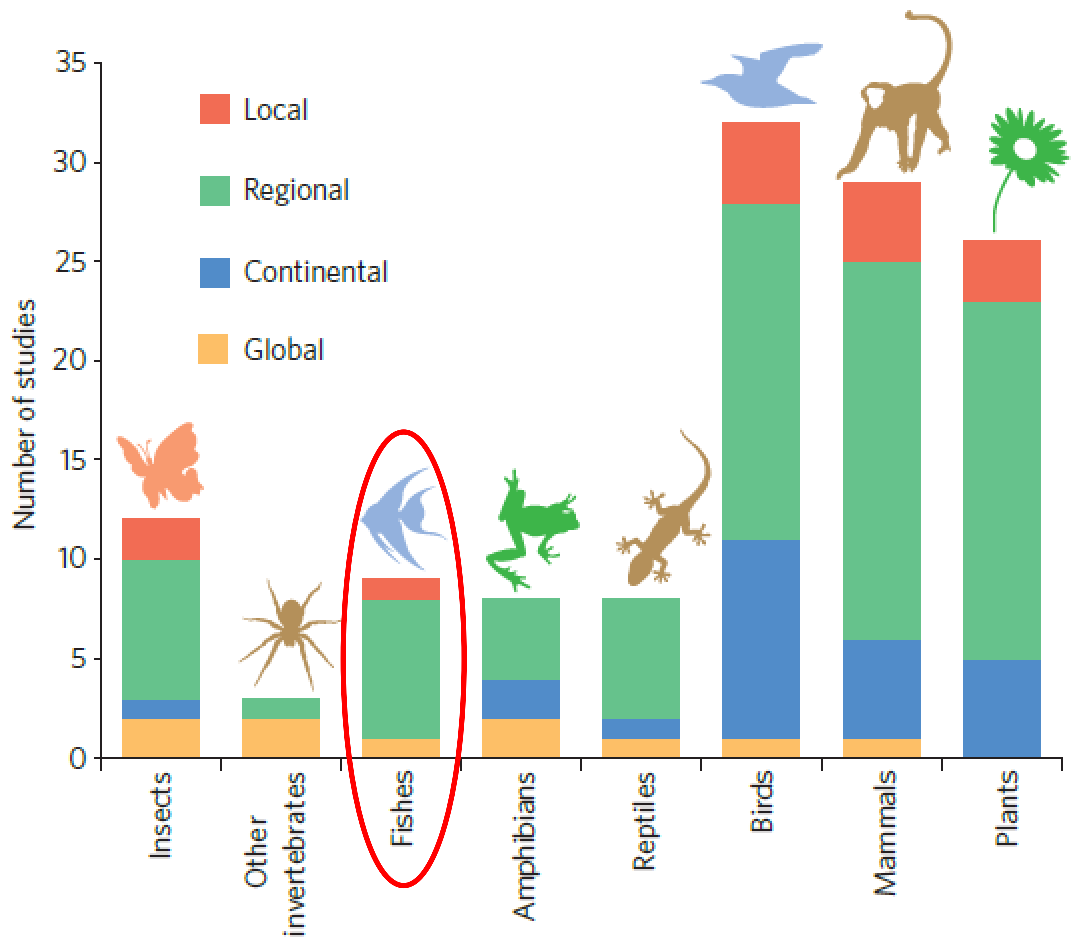
10. Overview of different risk assessment approaches to Climate Change

Marine Climate Change vulnerable species



Ecoregional global concentrations of marine Climate Change vulnerable species.

Pacifici et al., 2015



Not many marine species' vulnerability studies

Pacifici et al., 2015

Currency to assess vulnerability

Distributional changes

- Mechanistic models – relate environmental conditions to species' physiological data.
- Correlative niche models - relate environmental conditions to species' occurrence data.

Population changes
Predictions of population trends based on direct observations, indices of abundance, or from declines in extent of occupied/suitable area.

Extinction probability
Using population viability analyses, demographic models, or evolutionary models on known life history characteristics.

Vulnerability indices
Quantitative indicators of the relative vulnerability of species.

Pacifici et al., 2015

Species' vulnerability assessment approaches

Approach

Correlative

projecting future distributions based on niche models, etc.

Mechanistic

laboratory and field observations, detailed and data intensive models

Trait-based

use biological characteristics as predictors of risk

Pacifici et al., 2015

Comparison between approaches

Approach	Aim	Advantage	Disadvantage
Correlative	To represent the realized niche.	Applicable to a wide range of taxa at various spatial scales. Quick and cheap.	Climatic, algorithm, and biotic uncertainties. Not good for poorly known species.
Mechanistic	To represent the fundamental niche.	Provides a better approximation of the climatic space in which an organism can exist, compared with the correlative approaches. Can consider evolutionary changes and physiological responses.	Require detailed data that lack for most species. Uncertainty due to poor knowledge of model parameters (e.g. population abundance) and to combining data collected at different spatial resolutions. Do not account for non-climatic threats to dispersal or for biotic interactions

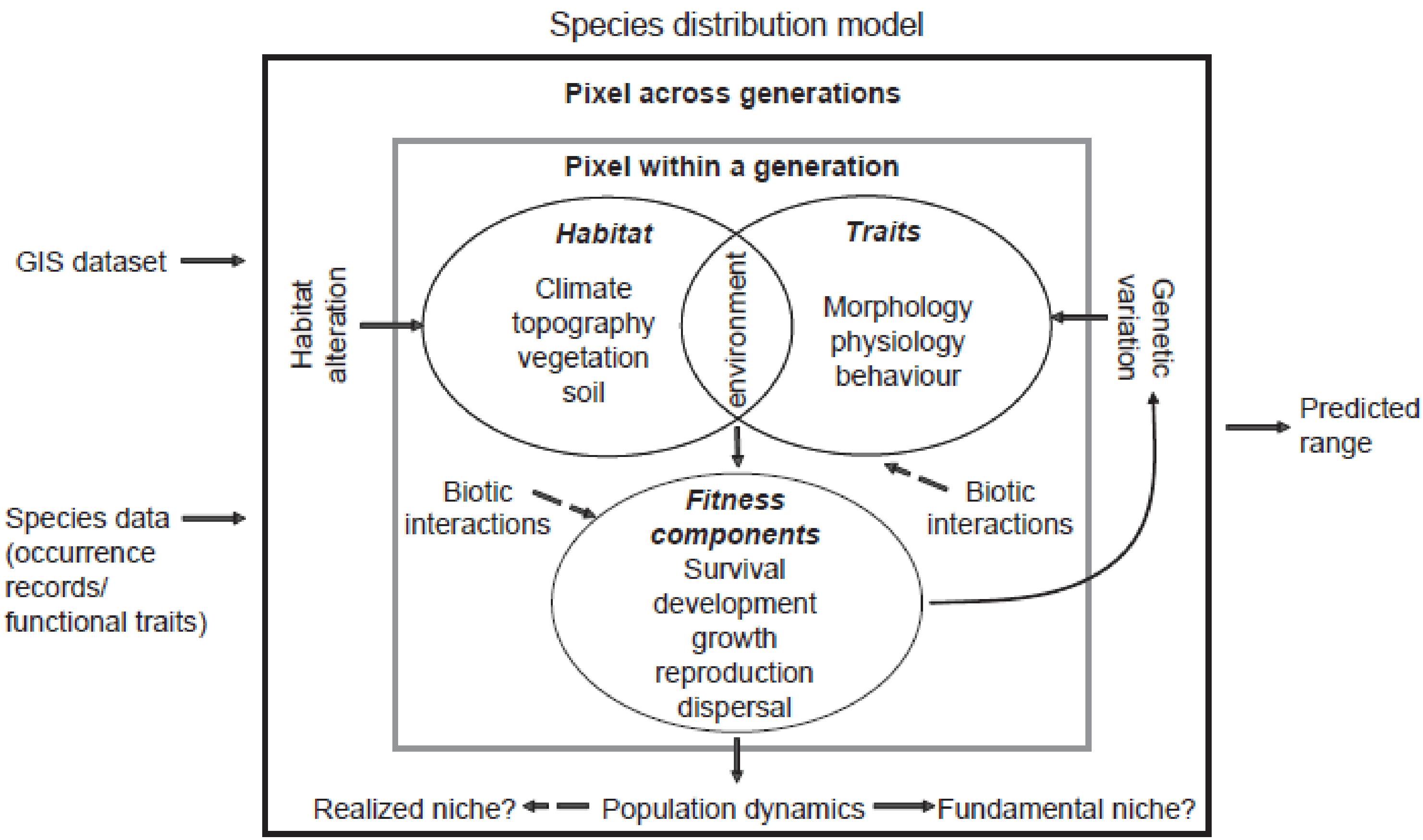
Pacifici et al., 2015

Comparison between approaches

Approach	Aim	Advantage	Disadvantage
Trait-based vulnerability assessment approach	To use species' biological characteristics as predictors of extinction risk due to Climate Change.	Permit a relatively rapid assessment for multiple species. Do not require extensive knowledge of modelling techniques.	Vulnerability thresholds associated with each trait are often unknown. Traits are weighted equally. Not possible to compare vulnerability between taxonomic groups if using different traits for each group. Uncertainty associated with the choice of traits, parameterisation of thresholds of associated vulnerability, and from gaps of knowledge of individual species' characteristics.

Pacifici et al., 2015

Niche modelling

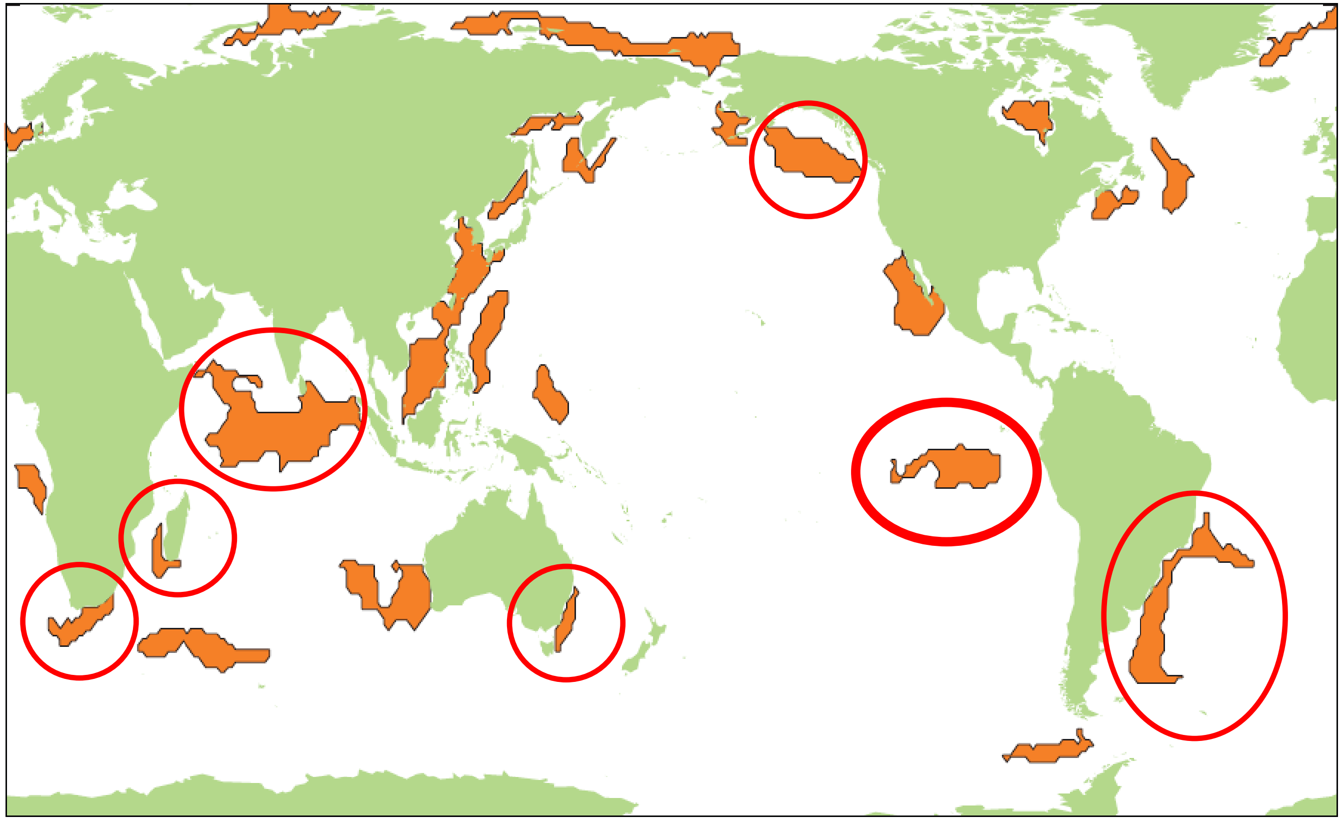


Kearney & Porter, 2009

11-12. Assessment of fisheries species sensitivity to Climate Change

Species Sensitivity Assessment

- Where?
  - Regions with greatest concentration of sensitive species
  - Most sensitive species within a particular region
  - Priorities for ….monitoring, management action, further assessment, etc.

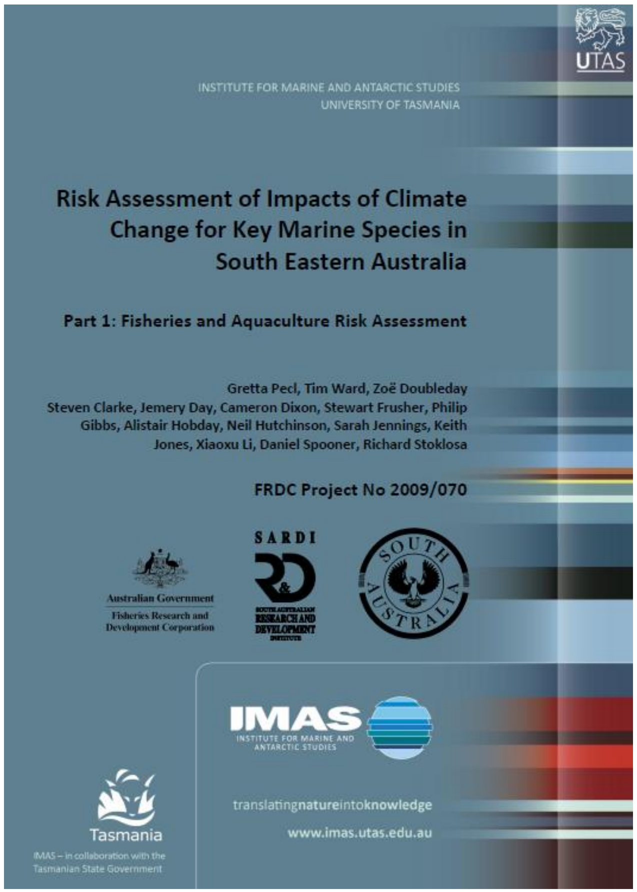


Species Sensitivity Assessment

- Approach
  - Correlative
    - projecting future distributions based on niche models, etc.
  - Mechanistic
    - laboratory and field observations, detailed and data intensive models
  - Trait-based
    - use biological characteristics as predictors of risk

Pecl et al., 2014

Trait-based approach for assessing relative species sensitivity within regions



- Conducted for South East Australia, but repeated in northern Australia and West Australia (total of approximately 120 species)
- Built on Ecological Risk Assessment for fisheries approach
- Adapted and applied by NOAA and Canada
- Adapted/adopted in Brazil, India and South Africa

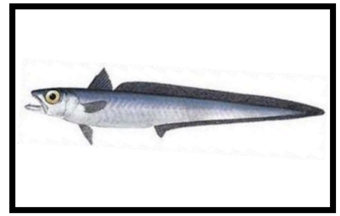
Pecl et al., 2014

Species selected for development of targeted adaptation strategies

Abalone (H)

Southern rock lobster (H)

Blue grenadier (H)



Snapper (M)

- Sensitivity - High or medium risk to Climate Change impacts
- High commercial value and/or recreational importance
- Rock lobster and abalone considered potential ecological indicators for rocky reefs
- Snapper is an important component of the coastal fish assemblages that occur in the region’s estuaries and large embayments
- Blue grenadier highest risk commonwealth species

- Likely to exhibit different responses
  - Declines in abundance
  - Shift in resource distribution at small (between communities) and large (between jurisdictions) spatial scales
  - Shifts in temporal patterns (timing of spawning/moulting)
  - Increases in abundance
- Different industry and sectoral features
- Different management systems

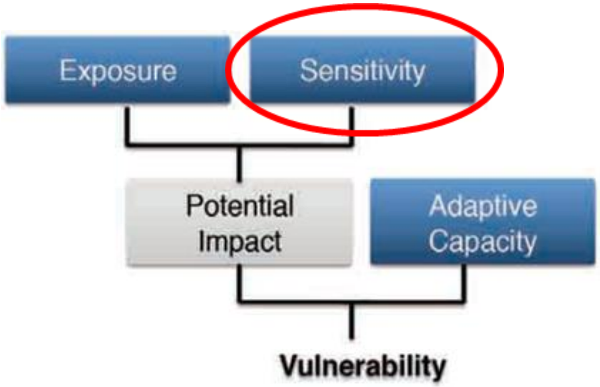
Trait-based approach for assessing species sensitivity

- Estimate sensitivity of species to climate change drivers based on:

  - ABUNDANCE - measures of potential for biological productivity
    - Egg production?
    - Age at maturity?

  - DISTRIBUTION – measures of capacity to shift
    - Capacity for larval dispersal?
    - Thermal tolerance?

  - PHENOLOGY – measures of potential impact on timing of life cycle events
    - Temperature as a cue for spawning or moulting?



In context of **ecological** vulnerability only

Pecl et al., 2014

Estimate sensitivity of species to climate drivers based on ABUNDANCE, DISTRIBUTION and PHENOLOGY

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Abundance	Fecundity – egg production	<100 eggs per year	100–20,000 eggs per year	>20,000 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Highly episodic recruitment event	Occasional and variable recruitment period	Consistent recruitment events every 1–2 years
	Average age at maturity	>10 years	2–10 years	≤2 years
	Generalist vs. specialist – food and habitat	Reliance on both habitat and prey	Reliance on either habitat or prey	Reliance on neither habitat or prey

Pecl et al., 2014

Estimate sensitivity of species to climate drivers based on ABUNDANCE, DISTRIBUTION and PHENOLOGY

e.g. Distribution attribute – southern rock lobster

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	<2 weeks or no larval stage	2–8 weeks	>2 months
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	<10 km	10–1000 km	>1000 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	<10º latitude	10–20º latitude	>20º latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	No unoccupied habitat; 0 – 2º latitude or longitude	Limited unoccupied habitat; 2–6º latitude or longitude	Substantial unoccupied habitat; >6º latitude or longitude

Pecl et al., 2014

Estimate sensitivity of species to climate drivers based on ABUNDANCE, DISTRIBUTION and PHENOLOGY

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Phenology	Environmental variable as a phenological cue for spawning or breeding – cues include salinity, temperature, currents, & freshwater flows.	Strong correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	No apparent correlation of spawning to environmental variable
	Environmental variable as a phenological cue for settlement or metamorphosis	Strong correlation to environmental variable	Weak correlation to environmental variable	No apparent correlation to environmental variable
	Temporal mismatches of life-cycle events – duration of spawning, breeding or moulting season.	Brief duration; <2 months	Wide duration; 2–4 months	Continuous duration; >4 months
	Migration (seasonal and spawning)	Migration is common for the whole population	Migration is common for some of the population	No migration

Pecl et al., 2014

Estimate sensitivity of species to climate drivers based on ABUNDANCE, DISTRIBUTION and PHENOLOGY

e.g. Distribution attribute – southern rock lobster

Sensitivity attribute		**Risk category (sensitivity and capacity to respond to change)**		
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(3+3+3+1)/4 = **2.5** (scores for each attribute added and totals ranked)

Pecl et al., 2014

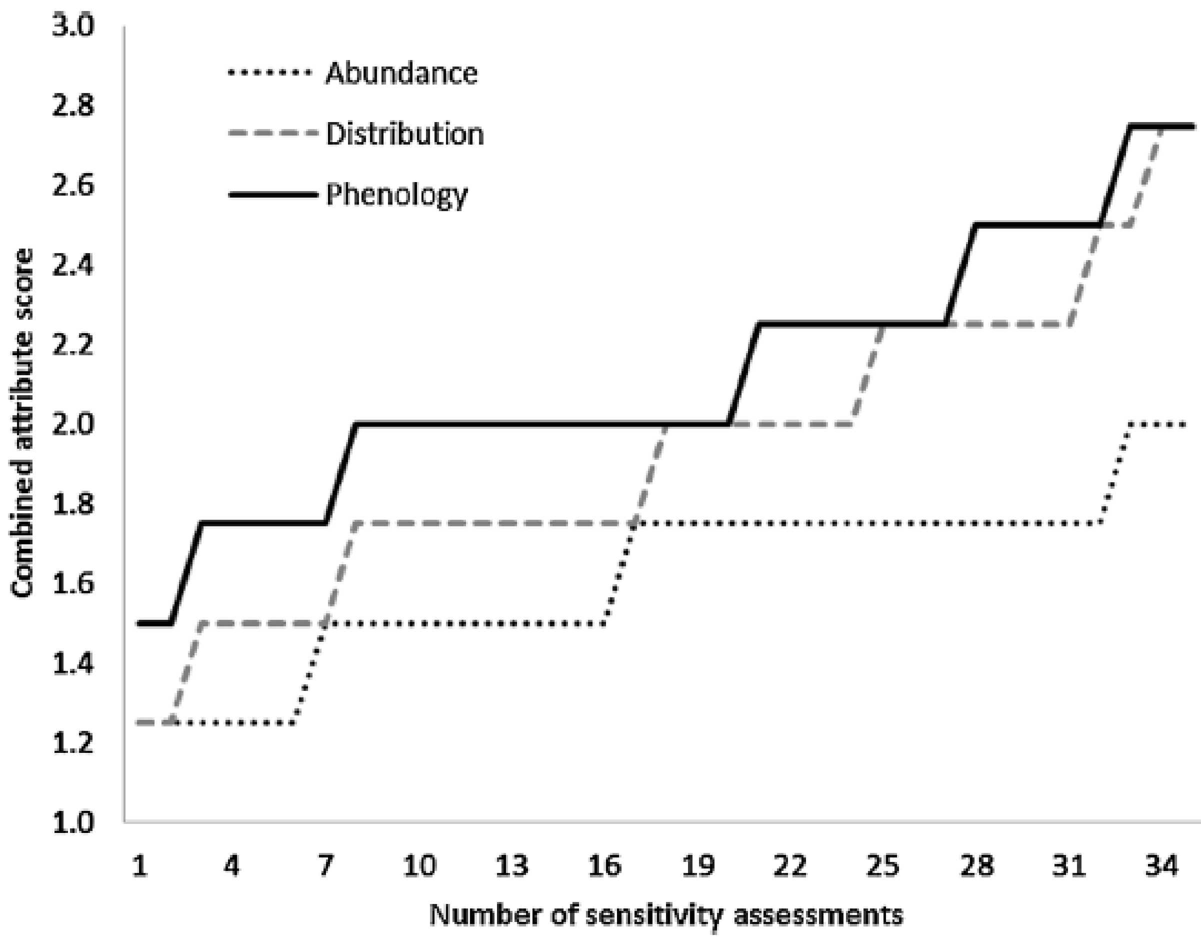
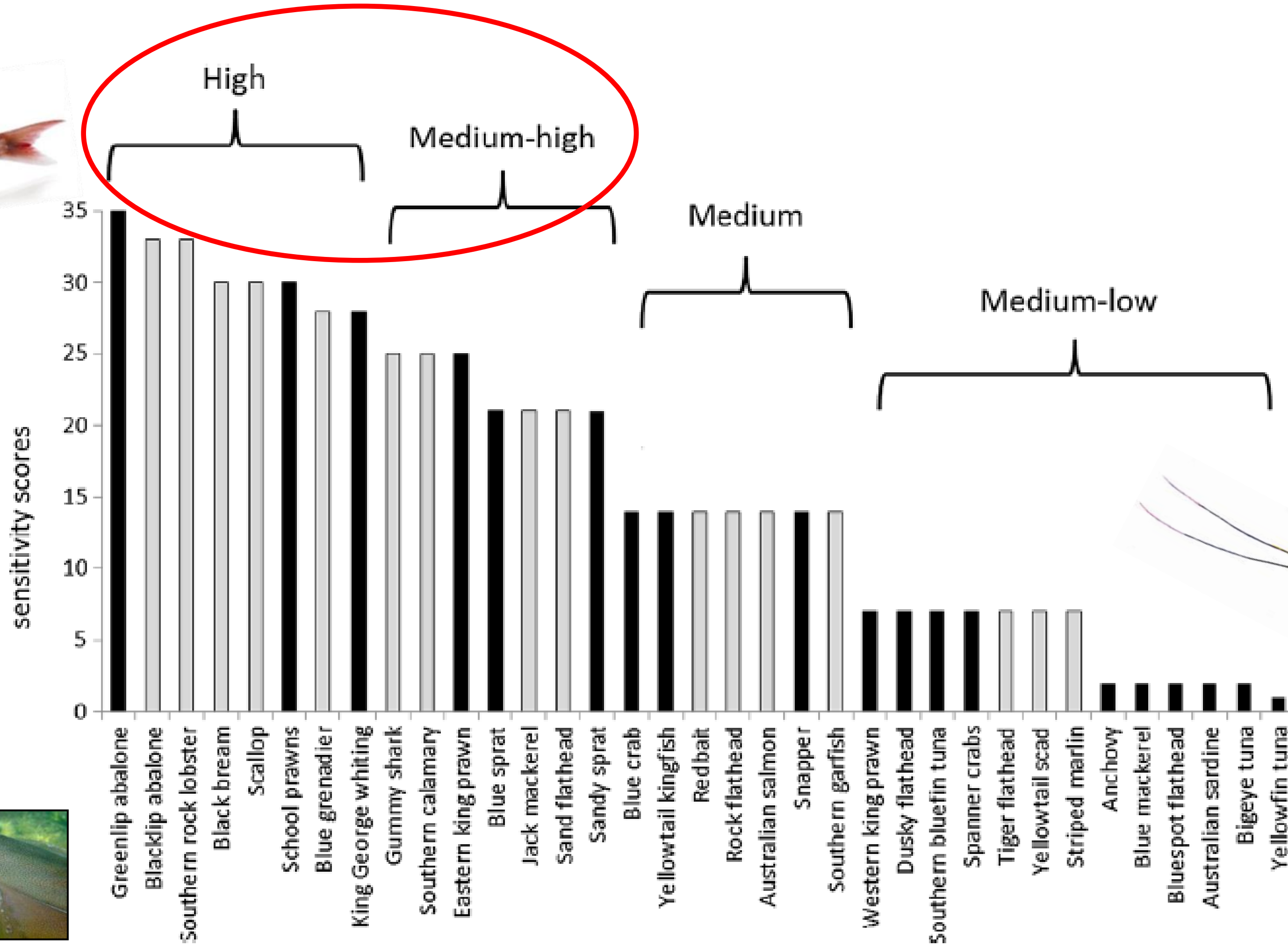


Fig. 1 Sensitivity scores plotted from highest to lowest for each of the three attributes. 3 = most sensitive/high risk, 1 = least sensitive/low risk. See Table 2 for the criteria used to define each attribute

Pecl et al., 2014

Relative sensitivity rankings – South East Australia



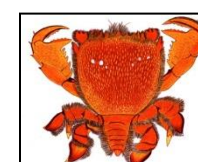


Fig. 2 Overall ranking of wild capture fishery species sensitivity based on an average of all attributes (distribution, abundance and phenology). Black columns = species which are predicted to undergo a range extension; grey columns = species which are predicted to undergo a range contraction

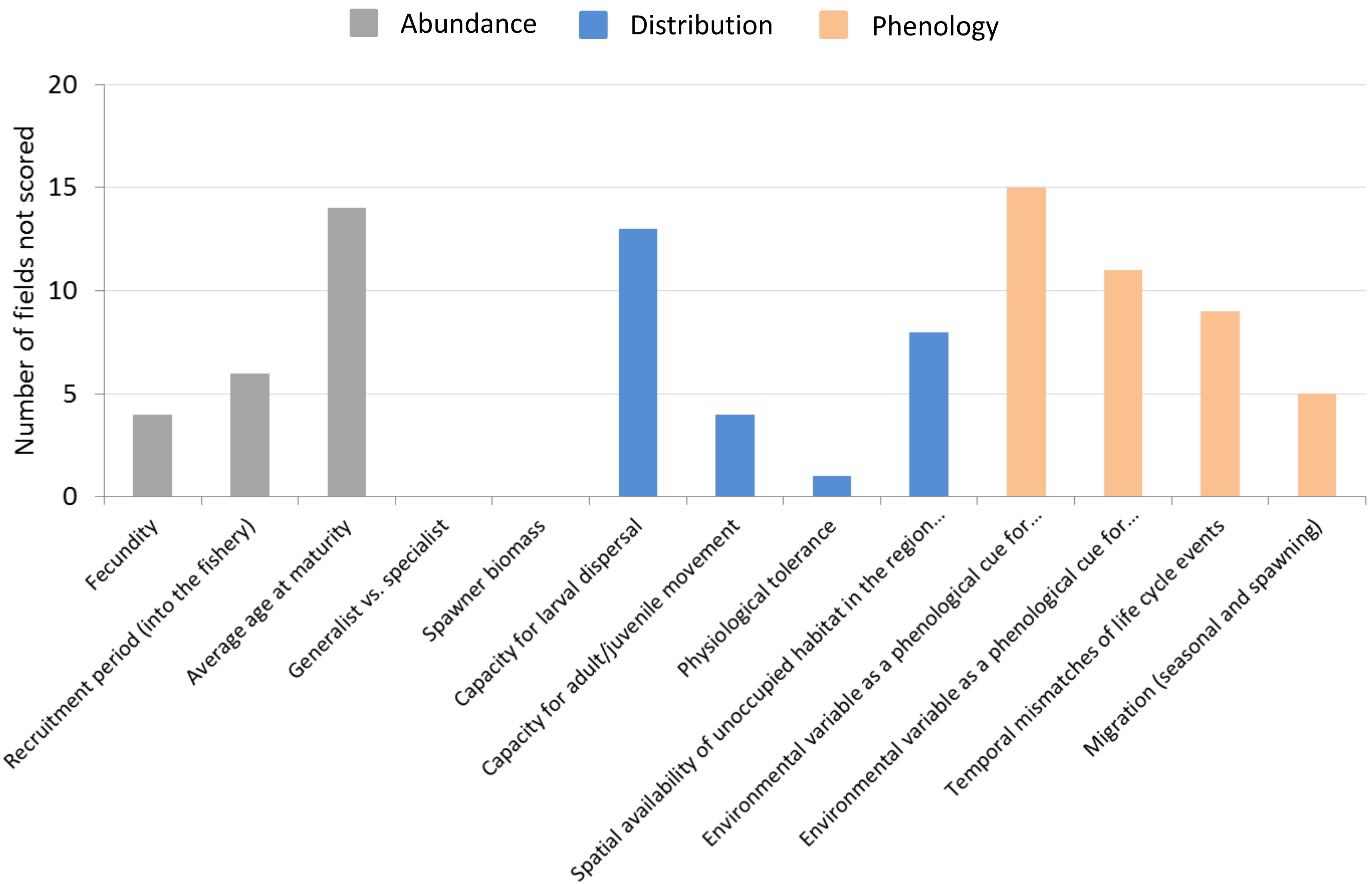
Pecl et al., 2014

Data quality score?

Data Quality Score	Description
3	**Adequate Data:** The score is based on data which have been observed, modeled or empirically measured for the species in question and comes from a reputable source.
2	**Limited Data:** The score is based on data which has a higher degree of uncertainty. The data used to score the attribute may be based on related or similar species, come from outside the study area, or the reliability of the source may be limited.
1	**Expert Judgment:** The attribute score reflects the expert judgment of the reviewer and is based on their general knowledge of the species, or other related species, and their relative role in the ecosystem.
0	**No Data:** No information to base an attribute score on. Very little is known about the species or related species and there is no basis for forming an expert opinion.

Pecl et al., 2014

Data obtained/missing



Pecl et al., 2014

Weaknesses?

- Precise sensitivity thresholds with each trait unknown
- Traits are weighted equally
- Choice of traits
- Needs expert review!
- Not made with all potential species in mind

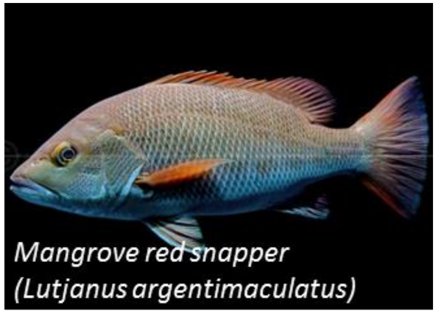
Strengths?

- Transparent
- Repeatable
- Can work with data poor and expert opinion
- Rapid assessment
- Prioritise

Pecl et al., 2014

Other potential improvements

- Incorporating uncertainty
  - Scored by multiple experts
  - Experts use ‘tallies’ per attribute
- Consider level of other stressors
- Check for general agreement but with rapid approach and modelling outcomes



Approach in Madagascar

- Spawner biomass field added
- Obtained largely from IUCN list

Attribute		**Category**		
		Low sensitivity (1), high capacity to respond (lower risk)	**Medium (2)**	**High sensitivity (3), low capacity to respond (higher risk)**
Abundance	Fecundity – egg production	>20,000 eggs per year	100–20,000 eggs per year	<100 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Consistent recruitment events every 1–2 years	Occasional and variable recruitment period	Highly episodic recruitment event
	Average age at maturity	≤2 years	2–10 years	>10 years
	Spawner biomass	robust	uncertain/vulnerable	threatened
	Generalist vs. specialist – food and habitat	Reliance on neither habitat or prey	Reliance on either habitat or prey	Reliance on both habitat and prey

Adaptations on Australian method

PLOS | ONE

RESEARCH ARTICLE

A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf

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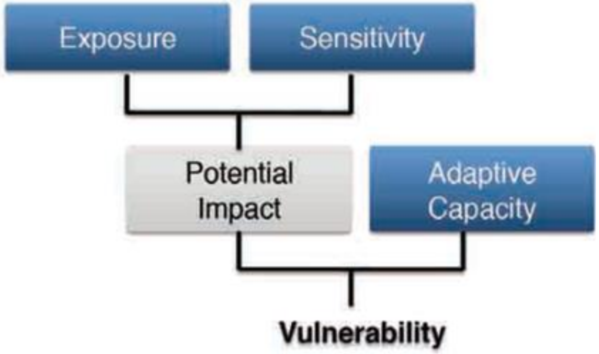


Looked at EXPOSURE and SENSITIVITY

Table 3. Logic rules for determining each species´ sensitivity and exposure component scores.

Component Score	Scoring Criteria
Very High	3 or more mean attribute or factor scores ≥ 3.5
High	2 or more mean attribute or factor scores ≥ 3.0
Moderate	2 or more mean attribute or factor scores ≥ 2.5
Low	Less than 2 or more mean attribute or factor scores ≥ 2.5

SENSITIVITY \ EXPOSURE	Low	Moderate	High	Very High
Very High	*Moderate*	*High*	*Very High*	*Very High*
High	*Low*	*Moderate*	*High*	*Very High*
Moderate	*Low*	*Moderate*	*Moderate*	*High*
Low	*Low*	*Low*	*Low*	*Moderate*

- Rather than averaging fields within ‘distribution’, ‘abundance’ and ‘phenology’ - use ‘logistic’ model
- Incorporate ‘exposure’ elements as well as ‘sensitivity’

Matrix for combining ‘exposure’ and ‘sensitivity’ and arriving at final species designation

Range shift specific assessment

- For species with room to shift south
  - based on Fishbase maps
- Range extension edge only (not contracting edge)

- Sunday et al., (2015)
  - Tested role of traits and climate velocity on rate of range extensions
  - Including traits doubled ability to explain variation
    - Adult mobility (benthic, <10km, 10-100, 100-1000, 1000+)
    - Trophic level (3-4 levels)
    - Latitudinal range size (look at literature, spilt into 4 categories)


Sculptured mitten lobster (Parribacus antarticus)

Leatherback turtle (Dermochelys coriacea)

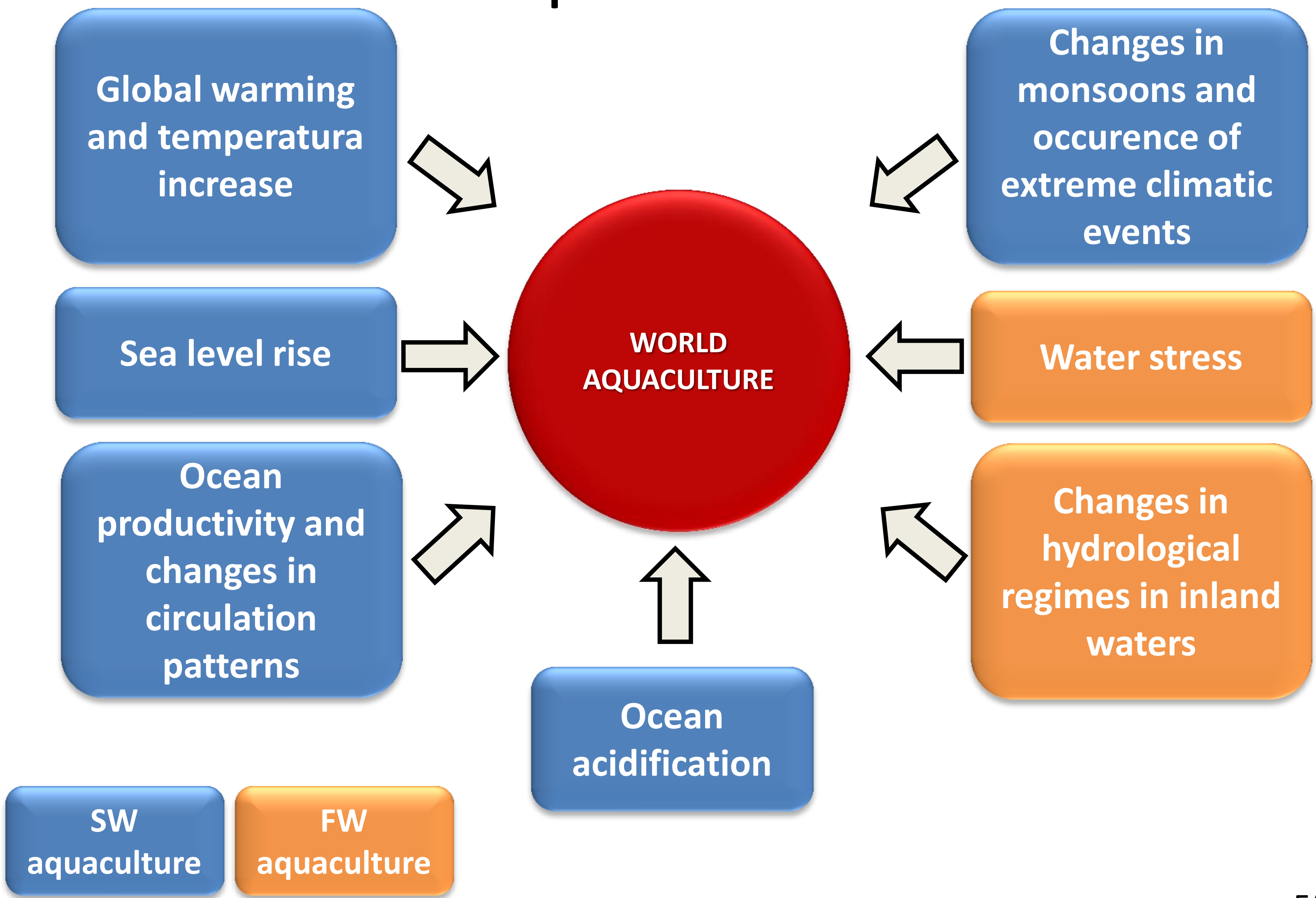

Ornate spiny lobster (Panulirus ornatus)


Indo-Pacific swamp crab (Scylla serrata)

13. Discussion on the assessment of fisheries species sensitivity to Climate Change

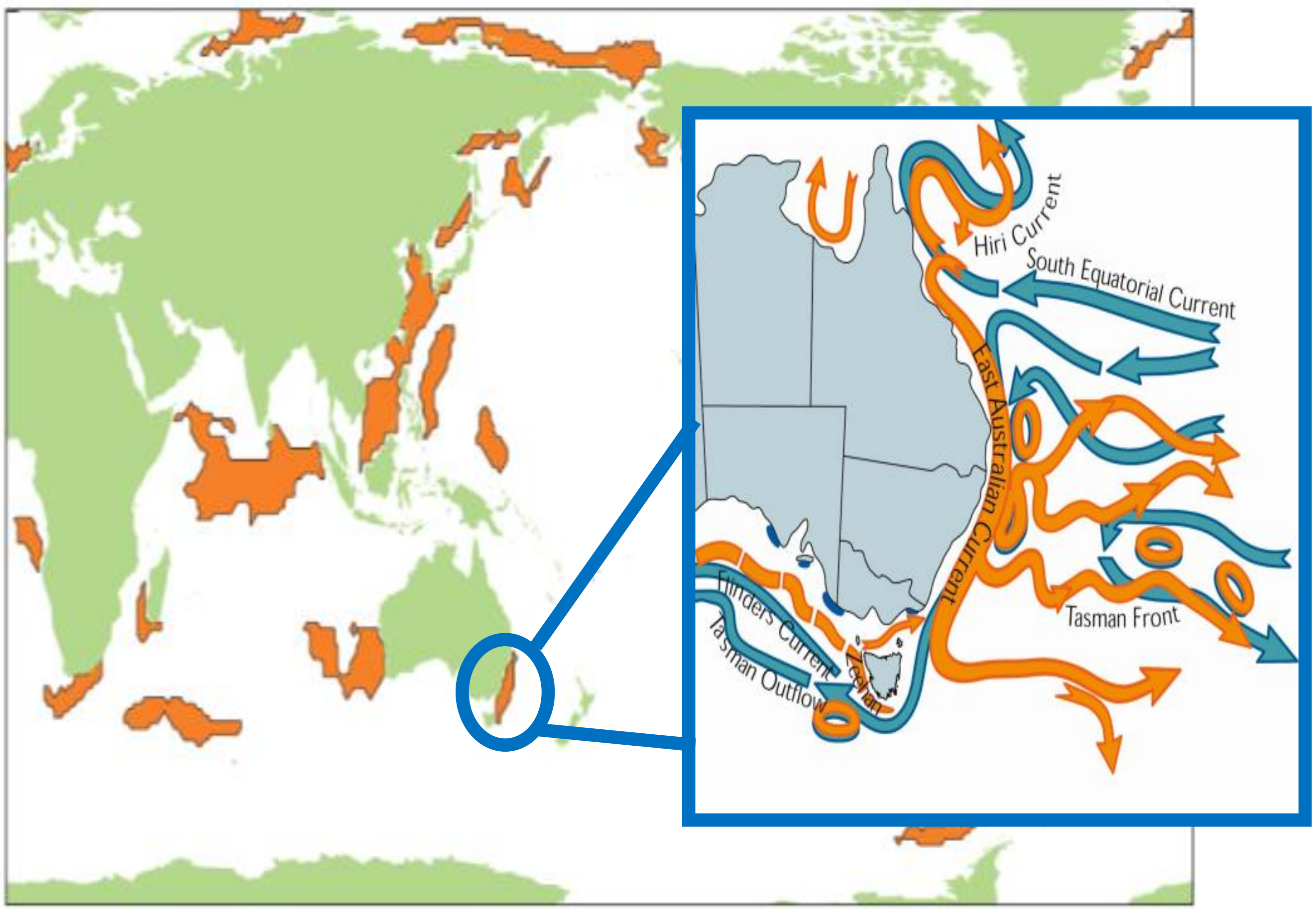
14-15. Assessment of aquaculture species sensitivity to Climate Change

Physical impacts of climate change on world aquaculture



FAO, 2006

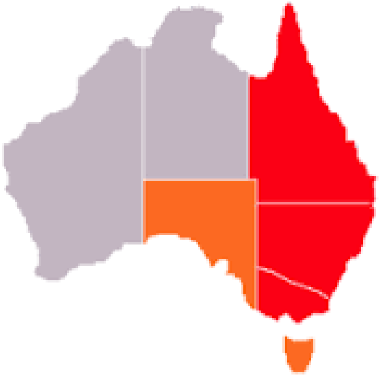
Ocean warming hotspots - the top 10% for rate of warming



Tasmania: 3.8x global average rate of warming

Hobday & Pecl, 2014

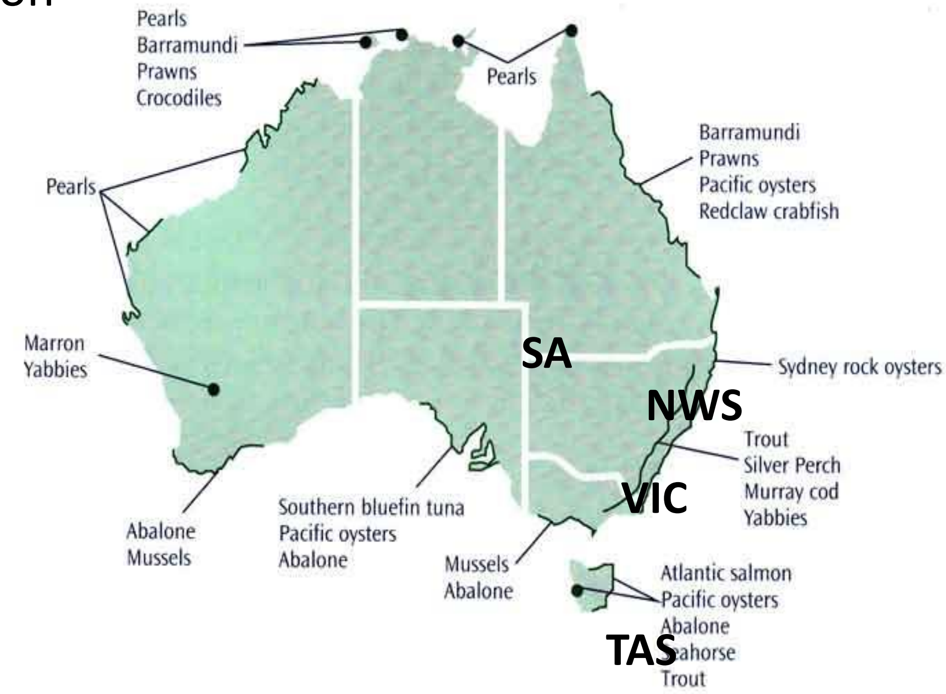
Part 1 – Background



- South east Australia as a hotspot region

- 4 states: NSW, TAS, SA and VIC
- 74% total value of aquaculture
- 30% sea food production

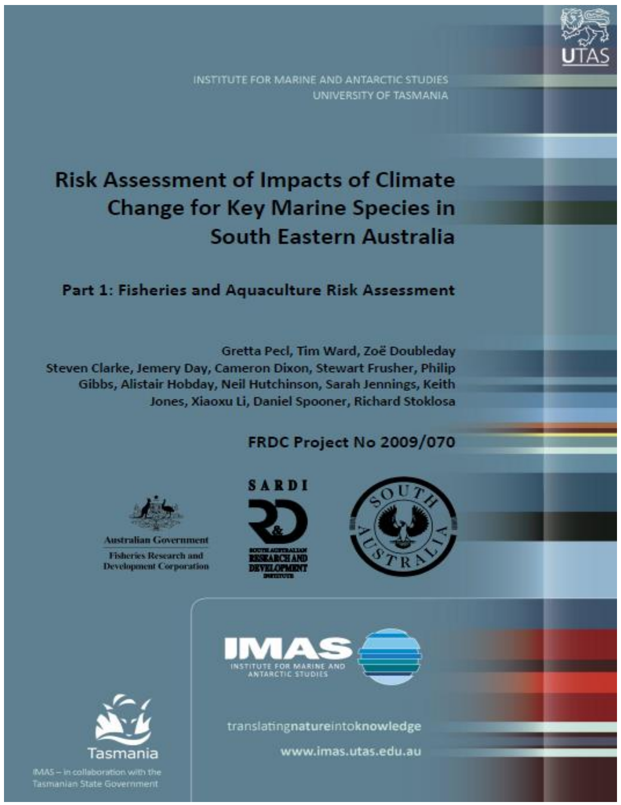
- Two main aquaculture groups:
- Finfish
- Shellfish







Trait-based approach for assessing relative species sensitivity within regions



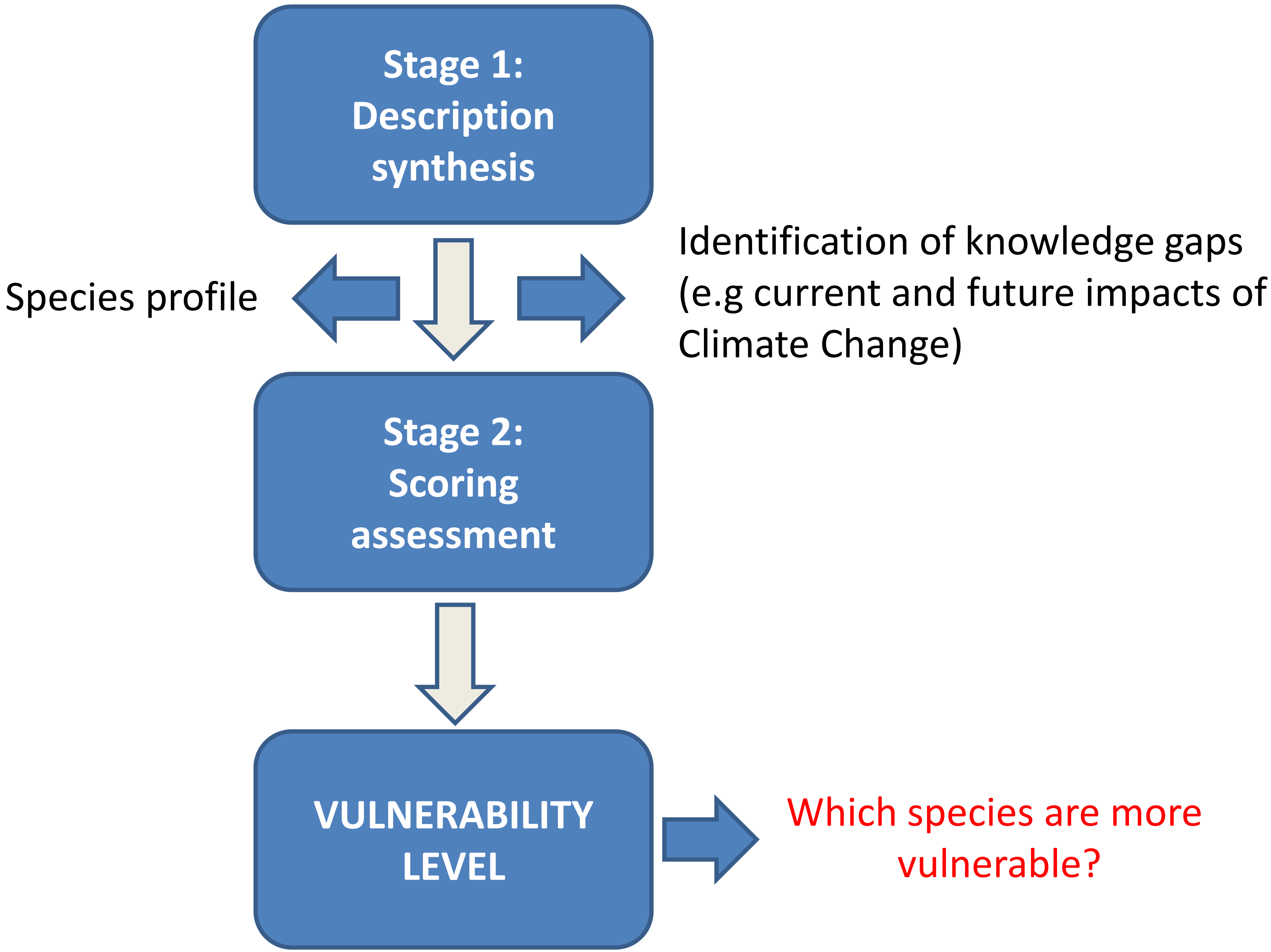
- Conducted for South East Australia, but repeated in northern Australia and West Australia (total of approx. 120 species)
- Built on Ecological Risk Assessment for fisheries approach
- Adapted and applied by NOAA and Canada
- Adapted/adopted in Brazil, India and South Africa

Available as Pecl et al., (2014)
(Aquaculture section – Doubleday et al., 2013)

Part 2 – The risk assessment approach

- Purpose
  - Regions with greatest concentration of sensitive species
  - Most sensitive species within a particular region
  - Priorities for ….monitoring, management action, further assessment etc
- Approach
  - Correlative
    - projecting future distributions based on niche models etc
  - Mechanistic
    - laboratory and field observations, detailed & data intensive models
  - Trait-based
    - use biological characteristics as predictors of risk
- Diversity:
  - Data requirements
  - Spatial and temporal scales of application
  - Modelling methods
  - Uncertainty/limitations

Components of the risk assessment approach



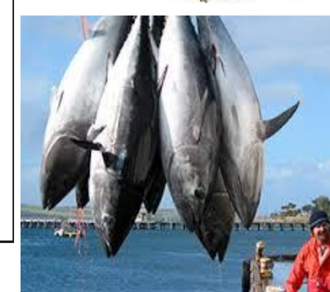
Part 3.1 - Species profiles

Table 1. Species selected for risk assessment analysis. A: adults; B: broodstock; L: larvae; S: spat; J: juveniles. Monetary values from the 2009/2010 financial year (ABARE 2011, Econsearch 2011); farming regions include commercial-level operations in the south-east region of Australia

Common name	Scientific name	Value (AUS$, in millions)	Farming methods	Farming regions
Abalone - Blacklip - Greenlip - Tiger	*Haliotis* spp. *H. rubra* *H. laevigata* A hybrid of the 2 species	15	Hatchery (B, L, S); land-based tanks and raceways or sea cages (A)	South Australia, Victoria, Tasmania
Atlantic salmon	*Salmo salar*	362	Hatchery (B, fry, parr); brackish and marine sea cages (smolts, A)	Tasmania
Blue mussel	*Mytilus galloprovincialis*	8	Hatchery (B, L, S) or collection from wild using longlines (S); longlines (A)	South Australia, Victoria, Tasmania
Pacific oyster	*Crassostrea gigas*	56	Hatchery (B, L, S); intertidal baskets (A)	South Australia, New South Wales, Tasmania
Southern bluefin tuna	*Thunnus maccoyii*	102	Hatchery (L) (production limited, currently in research and development stage); collection from wild, sea-ranching (J, A)	South Australia
Sydney rock oyster	*Saccostrea glomerata*	43	Hatchery (B, L, S) or collection from wild using stick culture (S); stick or tray culture (A)	New South Wales
Yellowtail kingfish	*Seriola lalandi*	27	Hatchery (B, L, J); marine sea cages (A)	South Australia







Part 3.2 - Scoring assessment

- The study is based on 9 biological attributes and farming methods encompassing all basic farming and life-history stages.
- It is key to have a strong knowledge on the main aquaculture trait of species.
- Source of information: scientists, experts from aquaculture industry, stakeholders, etc.

Part 3.2 - Scoring assessment

Table 2.2: Attributes and risk categories used assess level of sensitivity to climate change for aquaculture species in south-eastern Australia.

Attributes	Risk category (level of sensitivity)		
	Low risk (1)	Medium risk (2)	High risk (3)
1. Broodstock availability & conditioning – degree of environmental control	Broodstock are completely aquacultured, held at-sea or in indoor growout conditions; increased use of selective breeding	Broodstock collected from the wild but bred in a hatchery	Breed in the wild
2. Spawning & fertilisation – degree of difficulty and environmental control	Occurs in a fully controlled environment; spawning triggers well known; easy to hold large numbers of broodstock and/or differentiate their sex	Occurs in a fully controlled environment; spawning triggers are poorly known; difficult to hold large numbers of broodstock and/or differentiate their sex	Occurs naturally in the wild
3. Larval rearing – degree of complexity and environmental control	Occurs in fully controlled environment; few larval steps or stages; no live feeds required	Occurs in a fully controlled environment; longer or more complex series of steps during larval development; live feeds required	Occurs naturally in the wild
4. Juvenile rearing (to stage stocked into growout system) – degree of complexity and environmental control	Occurs in a fully controlled environment; manufactured feeds required	Occurs in a partially controlled environment; some natural feeds required	Occurs naturally in the wild
5. Growout: connectivity to natural environment – degree of environmental control	Almost fully closed, highly controlled environmental system (e.g. intensive recirculation system)	Partially closed and environmentally controlled system (e.g. ponds, tanks, raceways)	Open system in the natural environment (e.g. sea cages, longlines)
6. Growout: availability of alternative farm sites & systems – capacity to relocate farm site or use of alternative farming system	Readily identifiable alternative farm areas, some which may already have been allocated for another form of aquaculture	Some potential to move to alternative sites, but requires new area to be allocated through the relevant resource allocation process, or to use alternative farming systems	No identifiable potential for alternative sites or changed farming systems

Part 4 - Attributes and risk assessment categories

7. Growout: feed – wild verses manufactured sources; frequency of manual feeding	Manufactured feeds used	Live feeds from wild, used but with some capacity to vary species or use manufactured feeds	Natural productivity
8. Growout: farm operations – level of exposure to the natural environment and environmental extremes	Full farm cycle and infrastructure onshore, readily accessible and not subject to environmental extremes	Part of farming cycle in areas subject to occasional flooding, king tides or storm damage, but generally easy to access with good environmental conditions	Full farm cycle at sea requiring frequent site visitation in a challenging operating environment (e.g. sea and swell conditions)
9. Growout: diseases and pests – management and susceptibility	Published papers on diseases/pests suggesting some natural resistance and no existing major disease/pest issue(s)	Published papers on diseases/pests suggesting some natural disease resistance, but with some existing disease/pest issue(s) that are being managed	Extensive documented disease and pest issues for farmed taxa/related taxa and current major disease/pest issue(s) that are not well managed and likely to be exacerbated by climate change

Brood stock availability

Spawning fertilization

Larval rearing

Juvenile rearing

Grow out – degree of environmental control

Growout – farm sites

Growout - feed

Growout – farm operations

Growout – diseases and pests

Table 3. Example scoring for land-based abalone risk assessment with explanation for each score provided. The risk score is the sensitivity score (see Table 2) multiplied by the impact score (mild negative impact, positive impact, or no impact anticipated [0]; moderate negative impact or level of impact unknown [1] and strong negative impact [2]); the total risk score is the sum of risk scores. Attributes are detailed in Table 2. Similar scoring tables were developed for each species under assessment (see Appendix 1)

Attribute	Sensitivity score		Impact score		Risk score
	Score	Explanation	Score	Explanation	
1	2	Broodstock collected from the wild, but increasingly being held in the aquaculture system	1	Slightly extended temperature-controlling period during summer	2
2	1	Spawning occurs in fully controlled environment	1	Level of impact unknown	1
3	1	Larval rearing occurs in fully controlled environment	2	Strong negative impacts of seawater acidification on larval development	2
4	2	Juvenile rearing occurs in a partially controlled environment	2	Strong negative impacts of increased intensity and duration of high temperature	4
5	2	Growout occurs in partially controlled environment	2	Strong negative impacts of increased intensity and duration of high temperature	4
6	2	Some potential to move to alternative sites or use alternative farming systems	1	Level of impact unknown	2
7	1	Manufactured feeds used feeding practices	1	Mild impacts on feed storage, transportation and	1
8	1	Full farm cycle and infrastructure are onshore and readily accessible	0	Limited impacts on farming facilities and their accessibilities	0
9	3	temperature-related disease impacts are already occurring in summer on many farms	2	Increased intensity and duration of disease impacts	6
				Total risk score	22

Relative sensitivity ranking - aquaculture

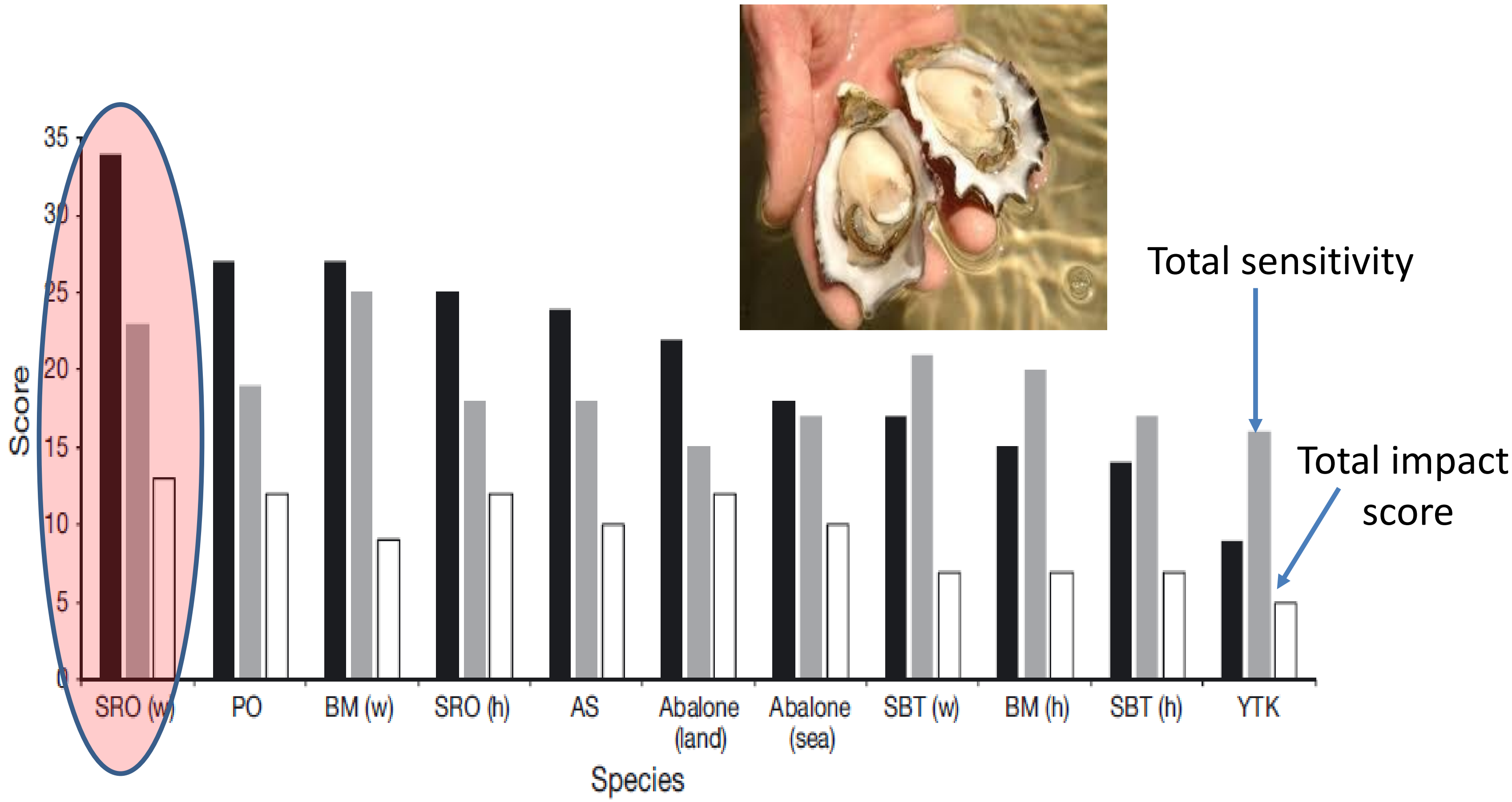


Fig. 2. Total risk scores for each species and farming system (black columns), ordered from high risk to low risk. Total sensitivity (grey columns) and total impact scores (white columns) are also displayed. Data chart of all scores is presented in Appendix 1. SRO: Sydney rock oyster; PO: Pacific oyster; BM: blue mussel; AS: Atlantic salmon; SBT: southern bluefin tuna; YTK: yellowtail kingfish; w: juveniles or spat sourced from the wild; h: spat produced in hatcheries

Gaps in knowledge – always present!

Table 5. Summary of data gaps (*) as collated from individual species profiles (Stage 1 of the risk assessment). Ab: abalone; PO: Pacific oyster; AS = Atlantic salmon; SBT: southern bluefin tuna; YTK: yellowtail kingfish; BM: blue mussel; SRO: Sydney rock oyster

Data gap	Ab	PO	AS	SBT	YTK	BM	SRO
Ability of selective breeding and/or genetic variation to counteract impacts of climate change	*	*		*	*	*	*
Fine-scale climate change modelling and monitoring relevant to aquaculture farms	*	*	*	*	*		*
Impacts of climate change on inter-specific interactions which may affect performance and survival (e.g. pest, fouling and pathogenic species)	*	*	*	*	*	*	
Impacts of climate change on the species' physiology and immunology	*	*	*	*	*		
Impacts of ocean acidification	*		*	*	*		
Precise cause of summer mortality	*	*					
Effect of elevated temperature on vaccine efficacy			*				
General biology and impacts of climate change on wild populations						*	

Main aquaculture species in Peru

MARINE SPECIES

Langostino

Litopeneus vannamei

Concha de Abanico

Argopecten purpuratus

FRESHWATER SPECIES

Trucha

Oncorhynchus mykiss

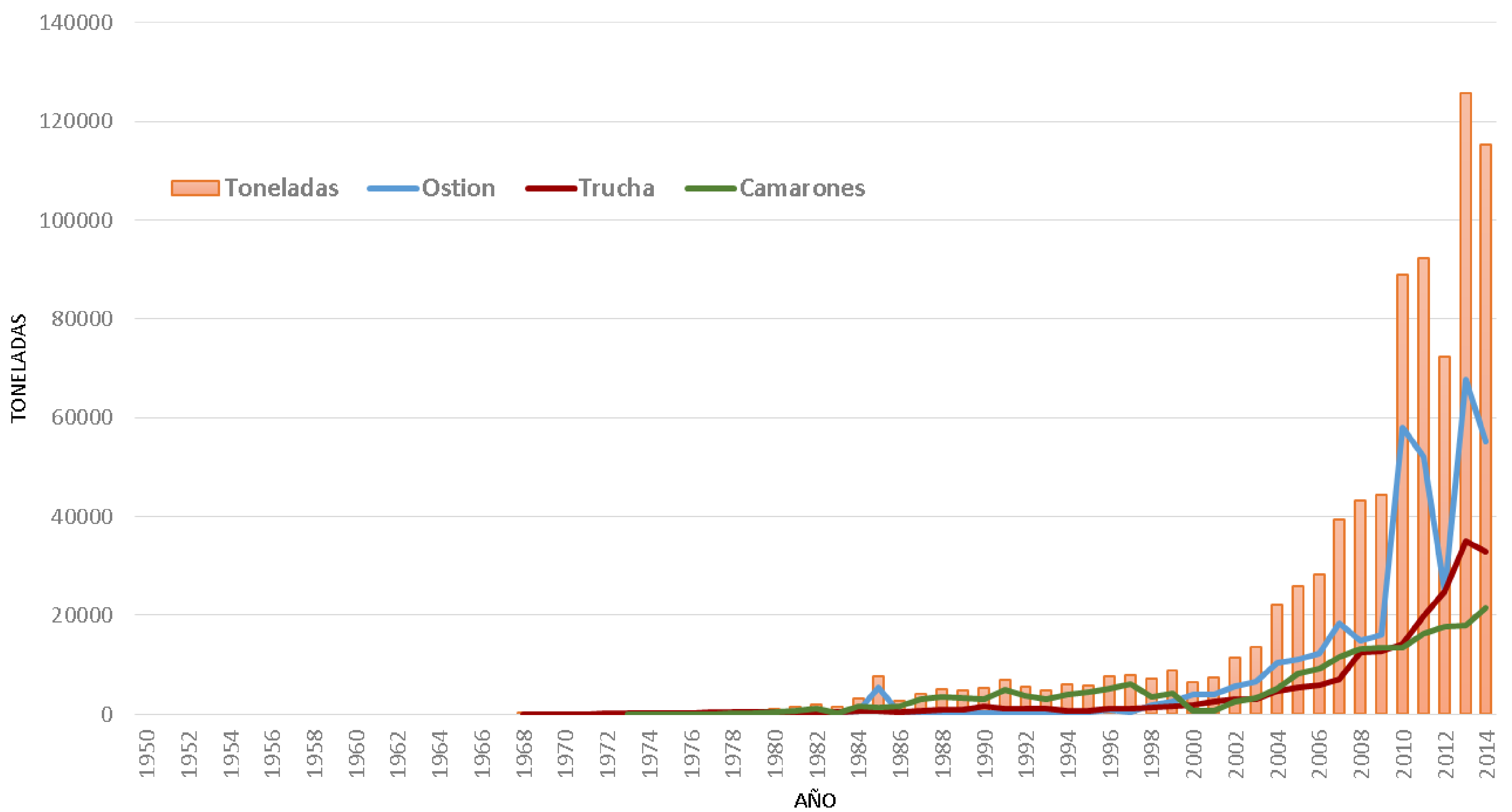
Tilapia

Oreochromis niloticus

Paiche

Arapaima gigas

Aquaculture production in Peru (1950-2014)



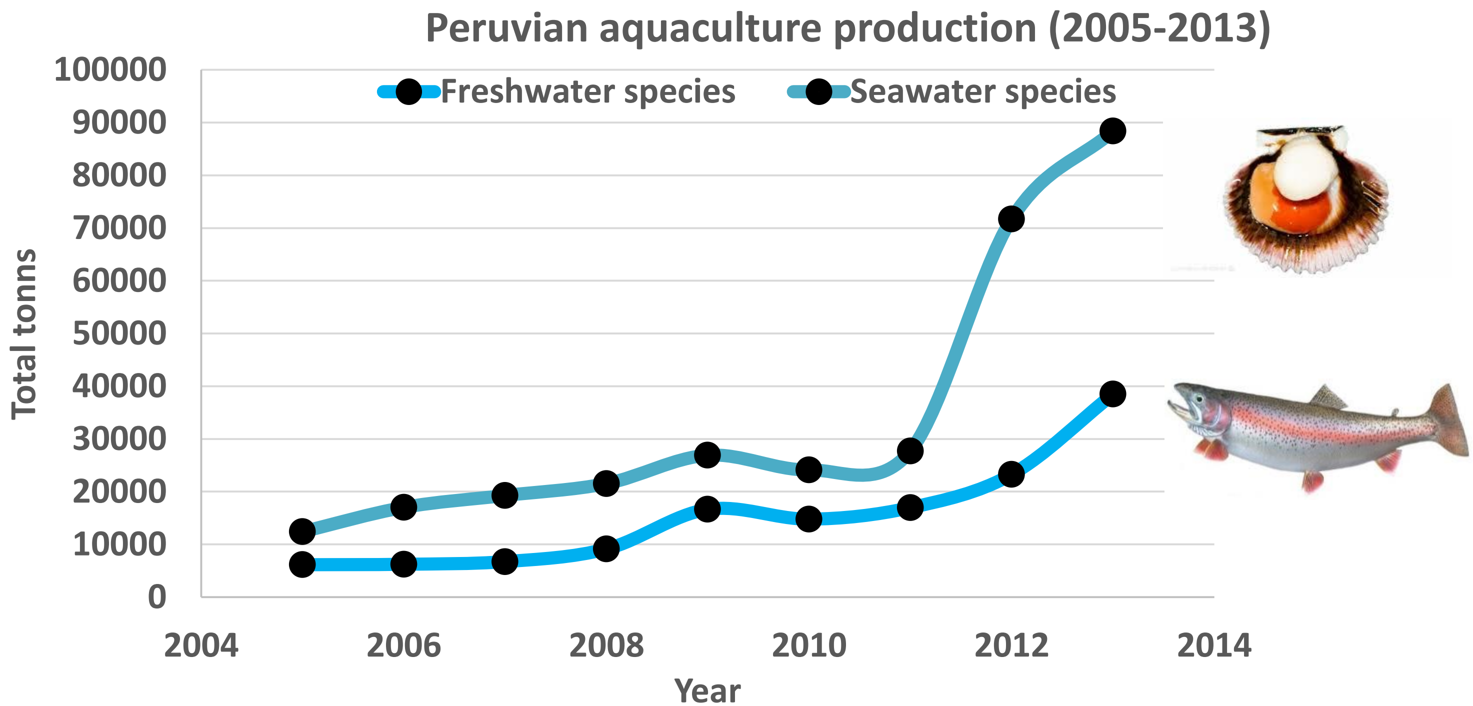
Source: PRODUCE

- There are three aquaculture production levels in Peru for farming site permits:

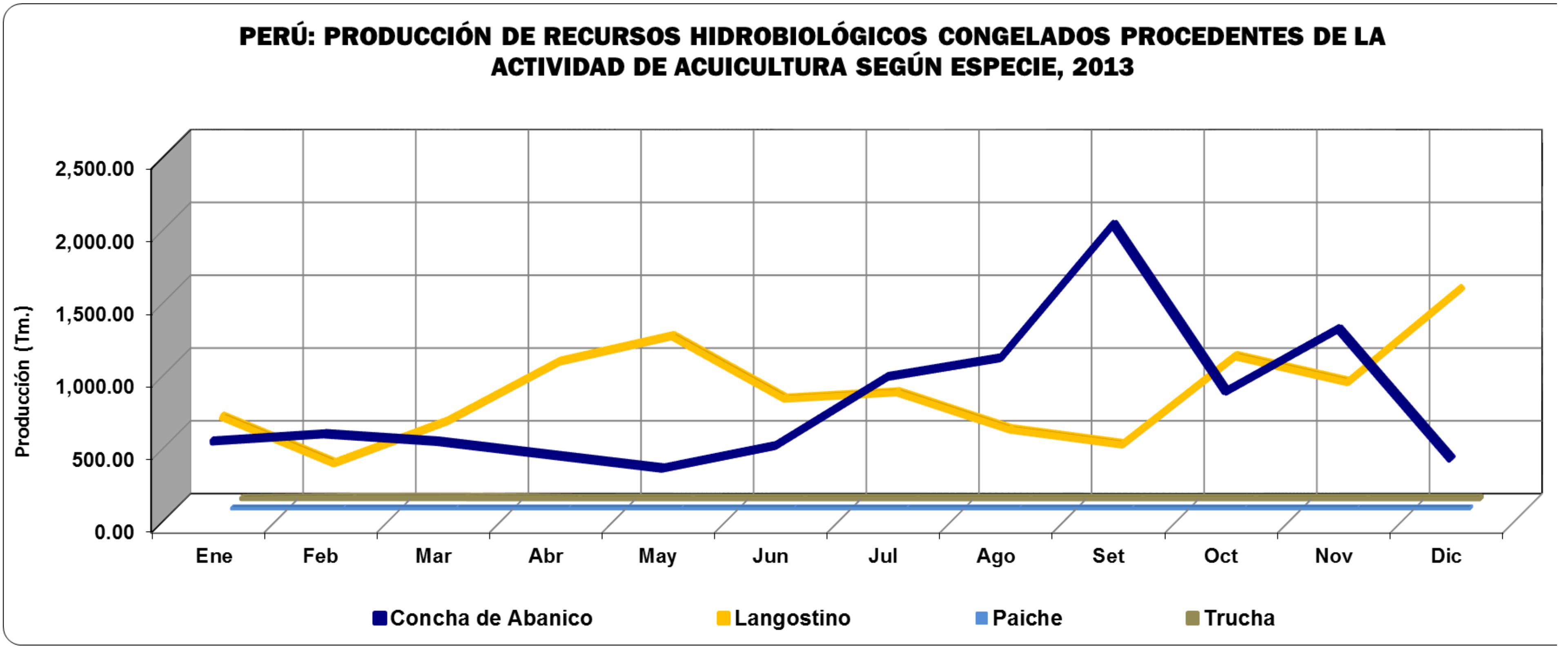
- **Subsistence aquaculture:** < 2 tons per year, with 10 years of permit.

- **Small scale aquaculture:** 2-50 tons per year, with 15 years of permit. Alevin production farms are included in this category.

- **Large scale aquaculture:** > 50 tons per year, with 30 years of permit.

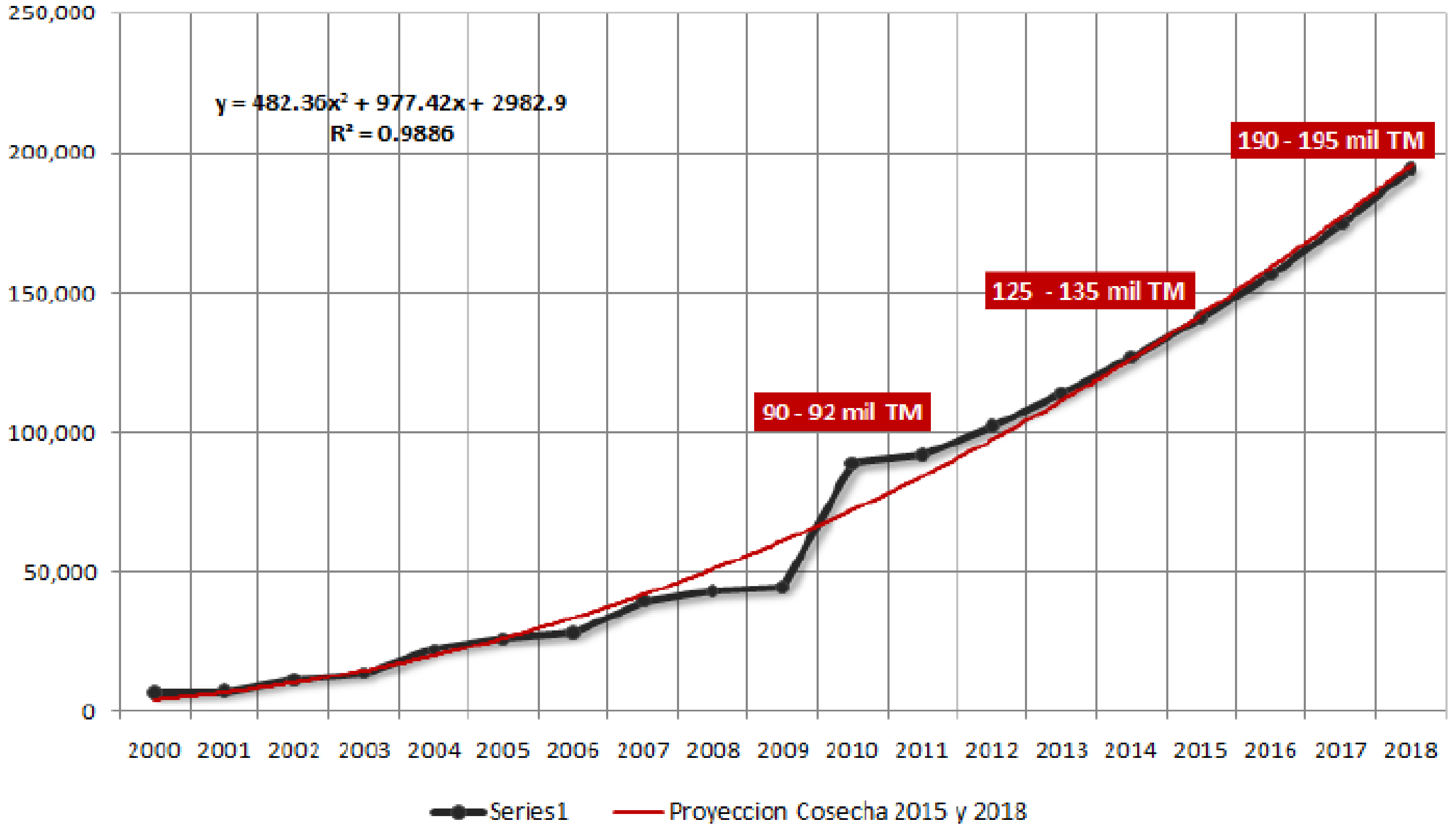


Seasonal trends in aquaculture production in Peru, 2013



Fuente: Produce

Projections of Peruvian aquaculture (2000-2018)



Fuente: Informe: Panorama de la Acuicultura Mundial, en América Latina y el Caribe y en el Perú
DGCHD-Dirección de Acuicultura – Ministerio de la Producción

Marine aquaculture in Peru

Langostinos
Tumbes

Concha de Abanico
Sechura

Concha de Abanico
Samanco y Casma

Concha de Abanico
Pisco

61.35 %

Argopecten purpuratus

38.65 %

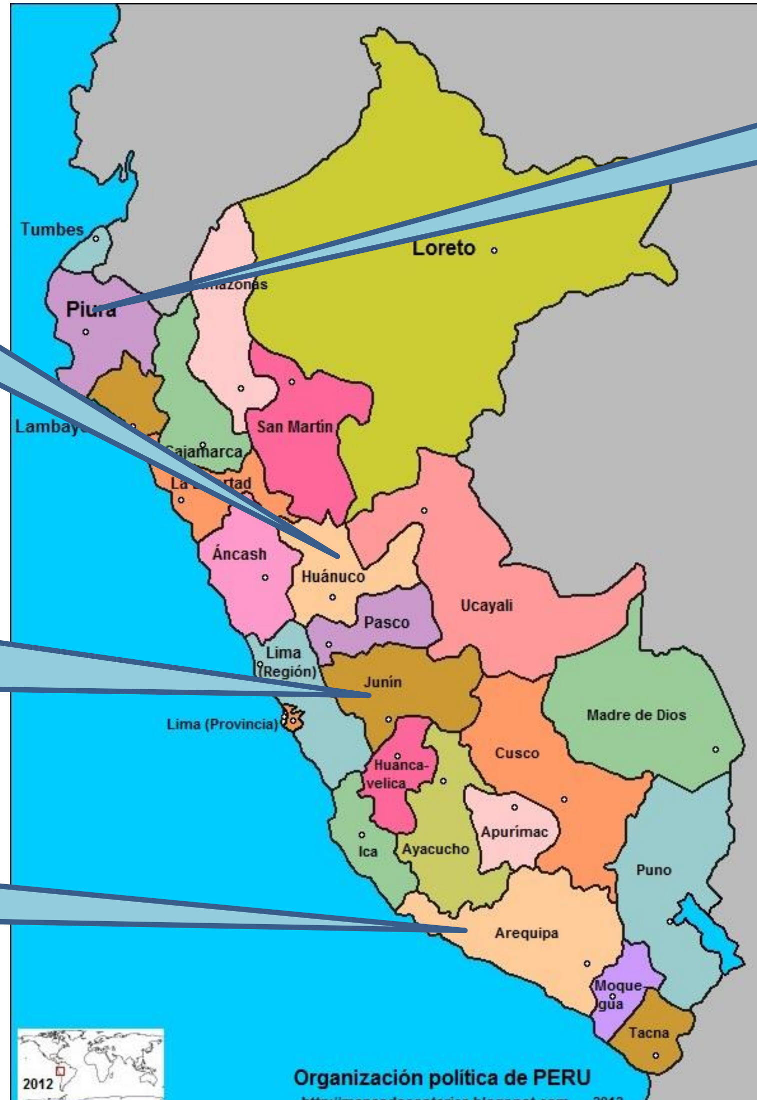
Litopenaeus vannamei

Freshwater aquaculture in Peru

Tilapia
San Martin

Trucha
Junín, Huancavelica, Lima and Pasco

Trucha
Puno



Tilapia
Sullana

18.62%

Oreochromis niloticus

74.85%

Oncorhynchus mykiss

Minor freshwater species

Gamitana, Paco, Sábalo, Paiche and Ornamental fishes
Loreto, Ucayali, M. de Dios and San Martin

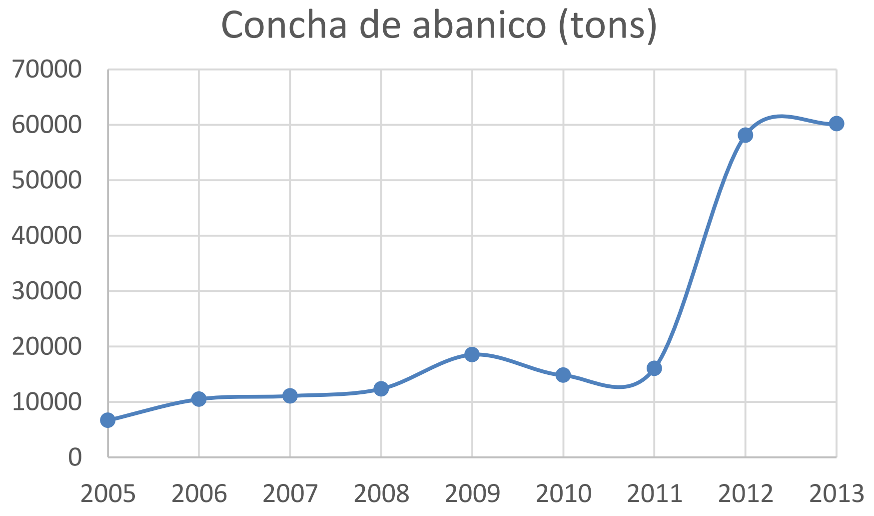
Arapaima gigas

Concha de abanico

- Two culture systems: on-bottom and off-bottom (suspended, pearl nets).
- Seeds from natural banks and hatchery.
- Production depends on key factors such as food, temperature and dissolved oxygen (DO).
- ENSO events can impact scallop productivity by modifying these key factors.

Impacts from climate change are unclear, but it could be expected (*):

- Physiological challenges from rising of SST, lowering of DO and salinity changes.
- Morphological challenges from ocean acidification (e.g. shell structure/shape).
- Infrastructure damage from extreme events, changes in winds, waves and currents.



- Risk of spreading diseases and plagues from extreme events, increasing risk of mortality.

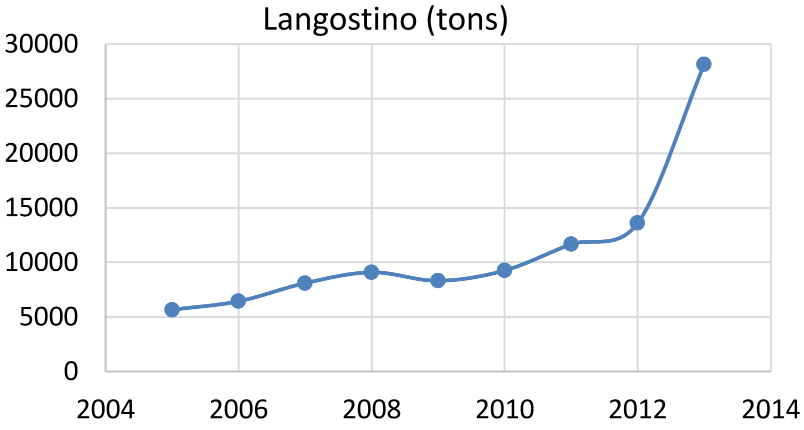
González et al., 2011

Langostino

- 'Seeds' imported from Equator
- Two hatcheries in Peru (post-larval stage)
- Extensive, semi-intensive and intensive production

Impacts from climate change are unclear, but we could expect:

- Physiological challenges from rising SST, decreasing DO, and salinity changes.
- Infrastructure damage from extreme events, changes in winds, waves and currents.
- Risk of spreading diseases and plagues from extreme events, increasing risk of mortality.



Trucha

- Semi-intensive and intensive production systems.
- FW land-based facilities and floating cages.
- Format: mostly pan size, but also 'Truchon'.
- Trout farming occurs mainly in Andean lakes (e.g. Titicaca).
- Inlet waters from rivers and mountain snow.
- Egg ('ovas') importation from EEUU (80%), Denmark and other countries.
- Over the last years trout production has rapidly increased.
- Trout production in Puno has been preliminary examined as case study of climate change effects.

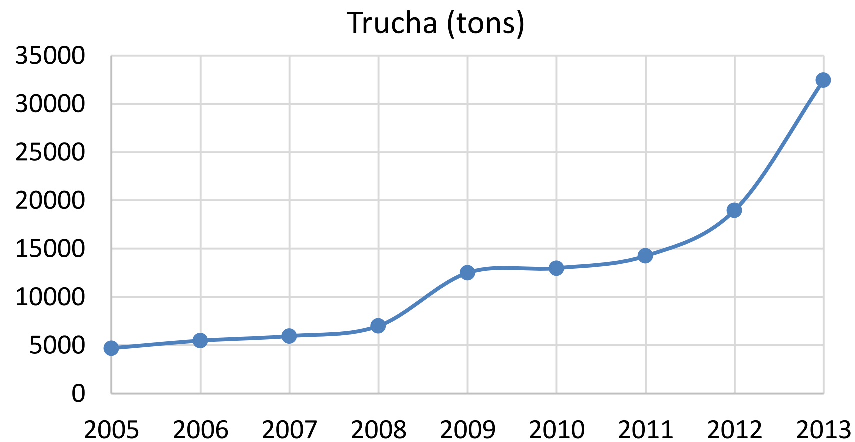


Tabla 8. Caracterización y análisis del riesgo para la acuicultura en Puno

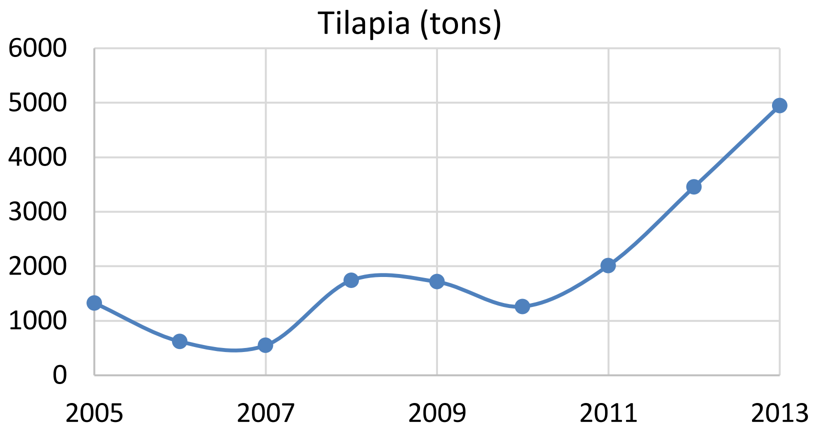
AMENAZAS		VULNERABILIDAD: EXPOSICIÓN	VULNERABILIDAD: SENSIBILIDAD	VULNERABILIDAD: CAPACIDAD ADAPTATIVA	ANÁLISIS DEL RIESGO ACTUAL (cadena de impactos potenciales)			VALORACIÓN DEL RIESGO
CLIMÁTICA	Eventos extremos (heladas, vientos)	Volumen de cosecha: 83% de la producción acuícola nacional de trucha Alto número de personas que se dedican a la acuicultura: 732 acuicultores, de los cuales 59 tienen la acuicultura como su única actividad económica	Derechos de menor escala: 92% de los derechos acuícolas otorgados de la región Autoconsumo: 13.35% de la cosecha para autoconsumo Diversificación productiva (no es única actividad) Baja diversificación de especies Sensibilidad de la trucha	Existencia de un marco institucional para acuicultura Interés político en la promoción de la actividad Asociatividad: 117 asociaciones Acceso a extensión y capacitación Acceso a financiamiento: 23% ROPA del Lago Titicaca	Impactos a los medios de vida del acuicultor		Empobrecimiento de acuicultores y déficit nutricional	Medio
	Alteraciones en la temperatura (polarización) y precipitación							
NO CLIMÁTICA	Presión de múltiples actividades en el Lago Titicaca				Impactos en la calidad del agua	Menor cantidad / calidad de producción		
	Contaminación del Lago Titicaca							

Fuente: Elaboración propia

DIAGNÓSTICO DEL SECTOR PESQUERO Y ACUÍCOLA frente al cambio climático y lineamientos de adaptación - Produce

Tilapia

- Introduced in Peru in 1970's.
- Production in extensive, semi-intensive and intensive systems (tanks and floating cages).
- Total farms: 668 (476 are from subsistence).
- Monoculture, but also polyculture (paco, gamitana and paiche).
- Water inlets of FW land-based farms include rivers and dams.
- Technology has improve local production.



Impacts from climate change are unclear, but we could expect:

- Water supply for inland farms by changes in water quantity/quality.
- Key water quality parameters (DO, pH, alkalinity) can be altered, impacting tilapia physiology and productive outputs.

16. Discussion on the assessment of aquaculture species sensitivity to Climate Change

17. Questions session on the approaches

18. Workshop on the assessment of fisheries species sensitivity to Climate Change

19. Workshop on the assessment of aquaculture species sensitivity to Climate Change