Future climate changes: what effects on tuna resources and fisheries?

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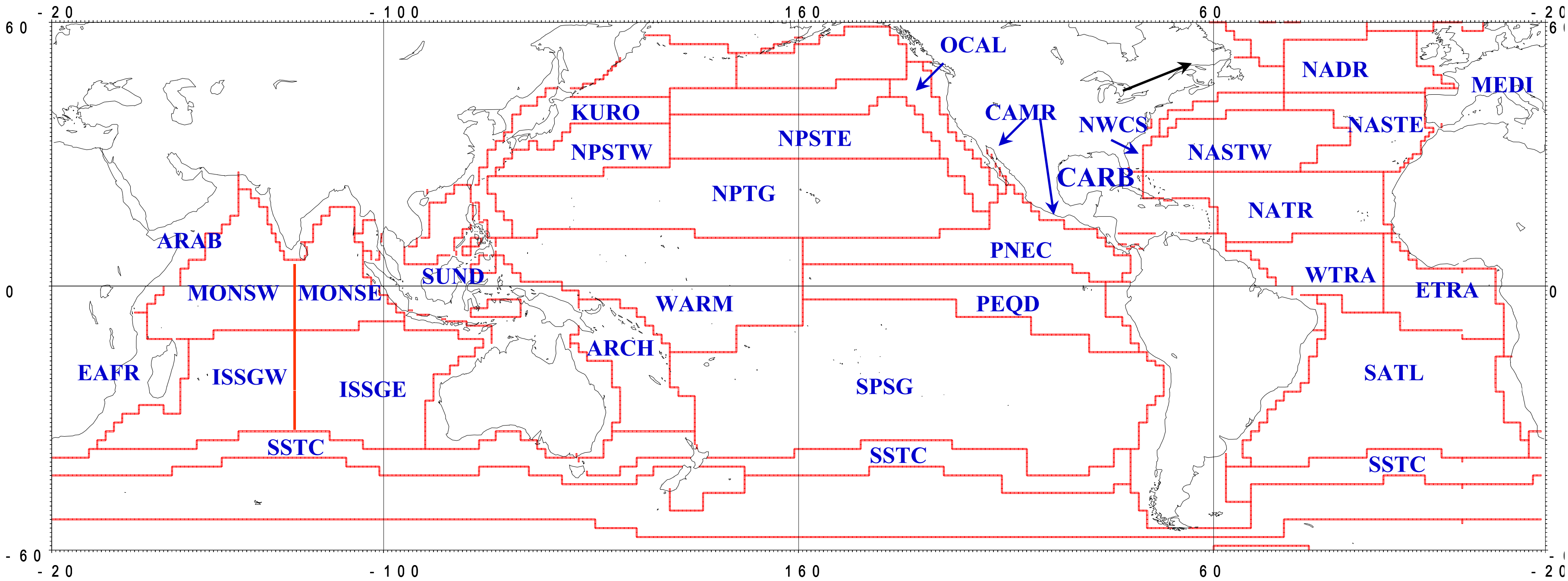
1. Introduction: tunas ecology is heavily linked to environmental spatial heterogenities
2. Global warming now a strong scientific fact
3. Future Changes in tuna stocks?
4. Can we model & forecast these changes?
5. Conclusion: toward a changing and unpredictible tuna world

1- Introduction

All highly migratory species, tunas and billfishes,
tropical and temperate ones,
are heavily linked to environmental spatial conditions and heterogenities

World oceans and their ecosystems are heavily stratified

Longhurst, A., 1998 - Ecological geography of the sea. Academic Press, 398 p.



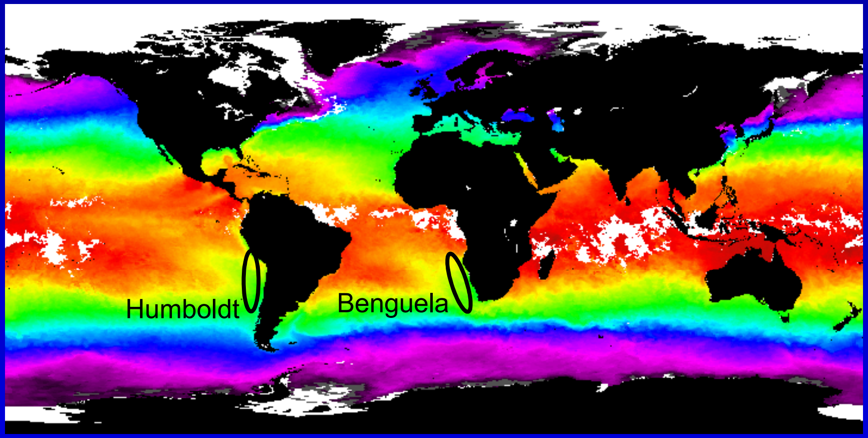
Marine ecosystems proposed by Alan Longhurst in 1998: their fixed frontiers without seasonal signal can be discussed , but these world ecosystems are highly valuable tools allowing to stratify the oceanic environment and to study the spatial heterogeneity of all tuna resources world wide

Each tuna species show typical preferendum and constraint for temperature and oxygen

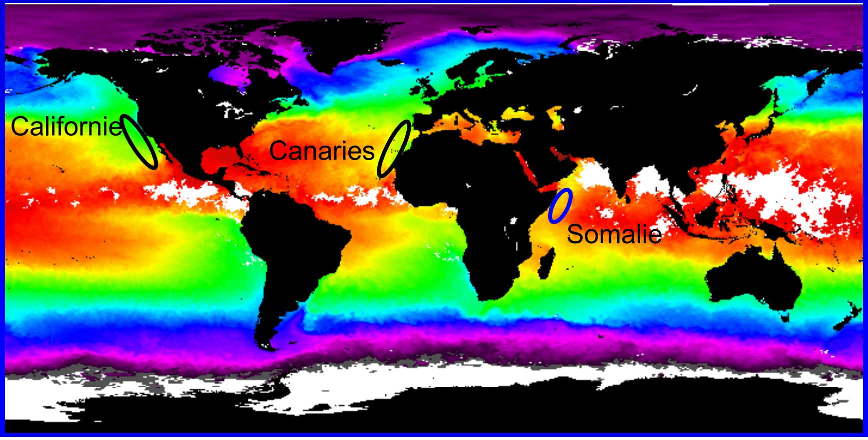
Species	*Taille (cm)*	*Thermal Preferendum*	*Minimal rate of solved O_2 (ml/l)*
Barrilete	**50 - 75**	**20 – 32°C**	**2.5 – 2.9**
Yellowfin	**50 - 75**	**23 – 32°C**	**1.5 – 2.4**
Bigeye	**50 - 75**	**11 – 23°C**	**0.5 – 0.7**

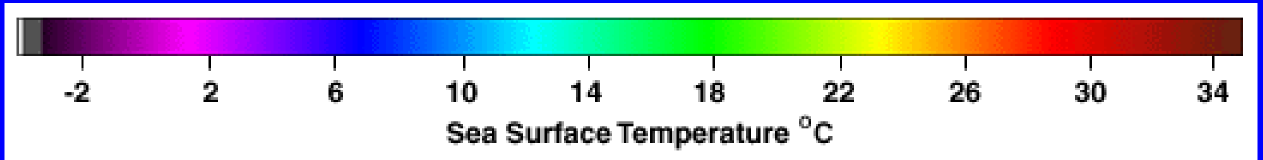
Seasonal Sea surface temperature in each ocean condition the distribution of each tuna species

January

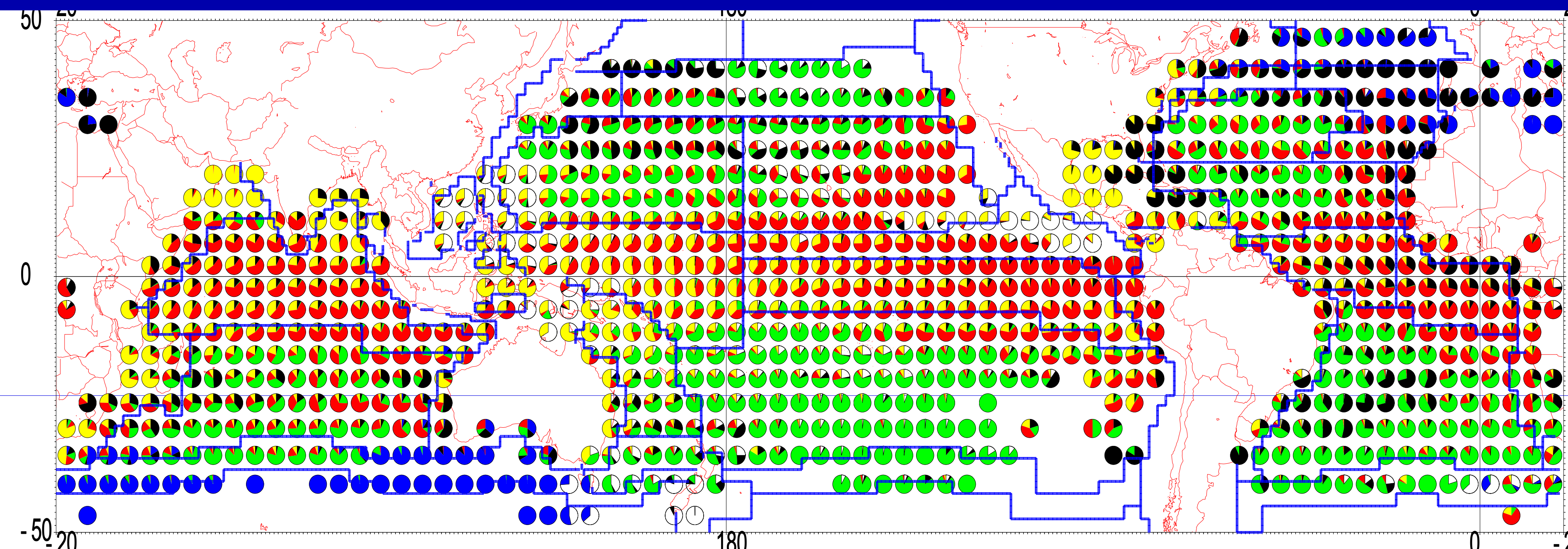


August

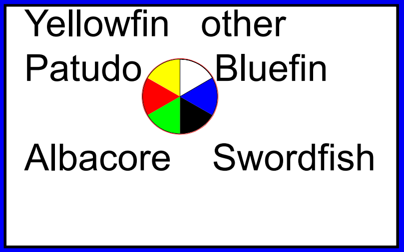




Typically the species composition of tuna catches are widely conditionned by the ecosystems



Average recent tuna catches by longliners and Longhurst areas (in %)



Low oxygen rates at thermocline levels are also conditionning the species composition of tuna catches: eliminating species and sizes with high need of oxygen.

Areas with low oxygen rates play an important role in conditionning local biomass and catchability: areas of shallow habitat

Oxygen at 100 m

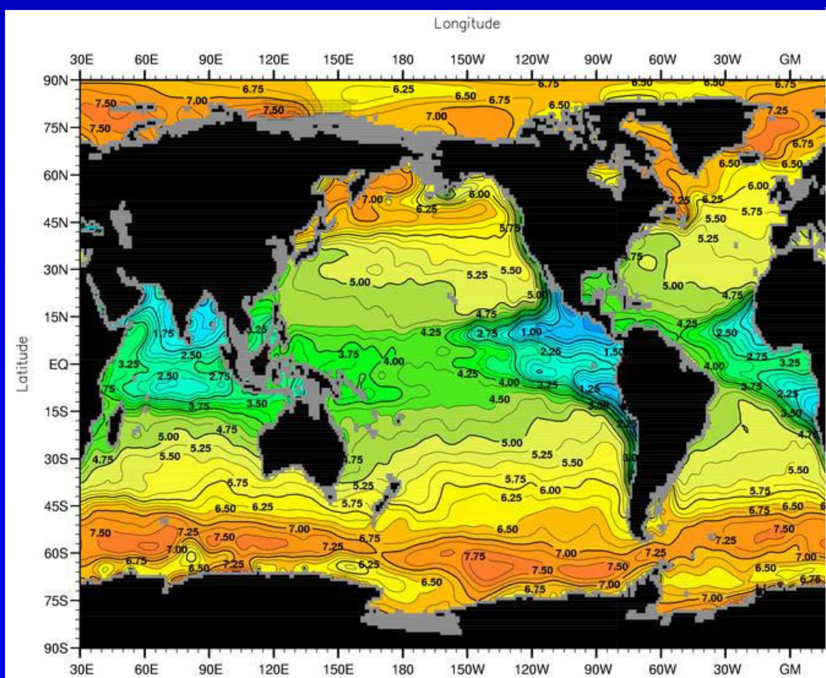


Fig. A2-7. Annual mean oxygen (ml/l) at 100 m. depth.
Minimum Value= 0.06 Maximum Value= 8.62 Contour Interval: 0.25

Oxygen at 300 m

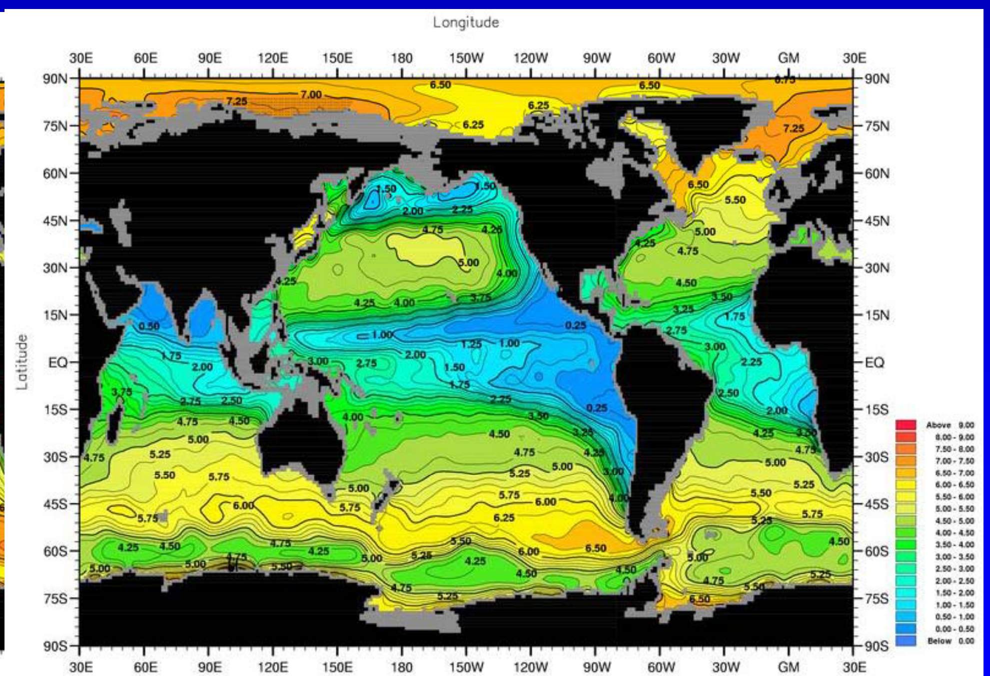
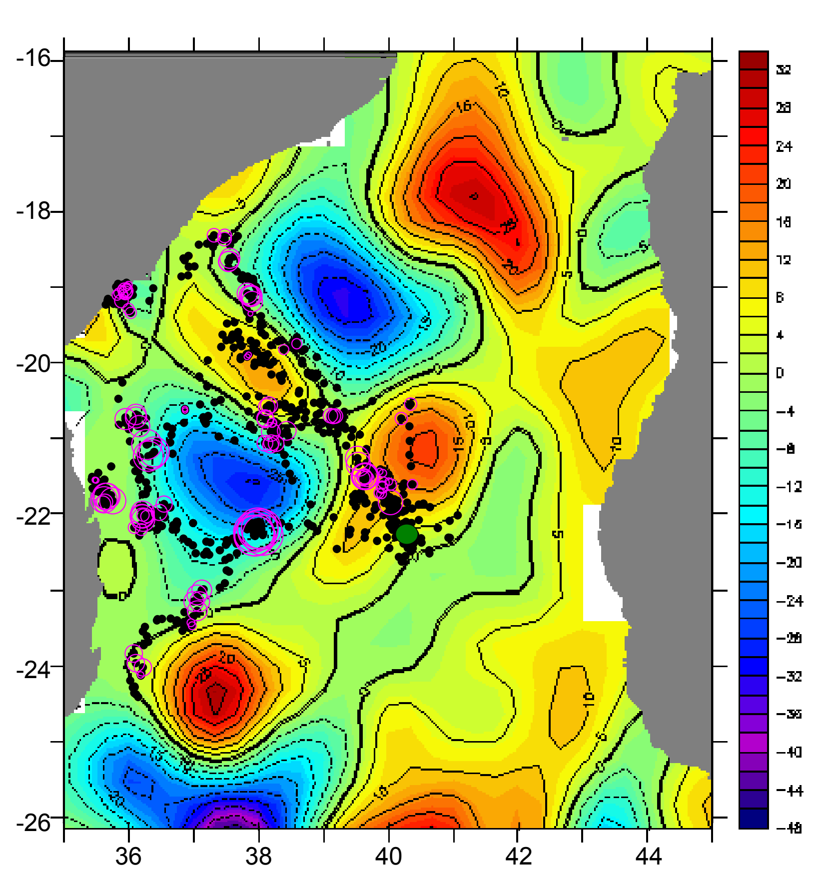


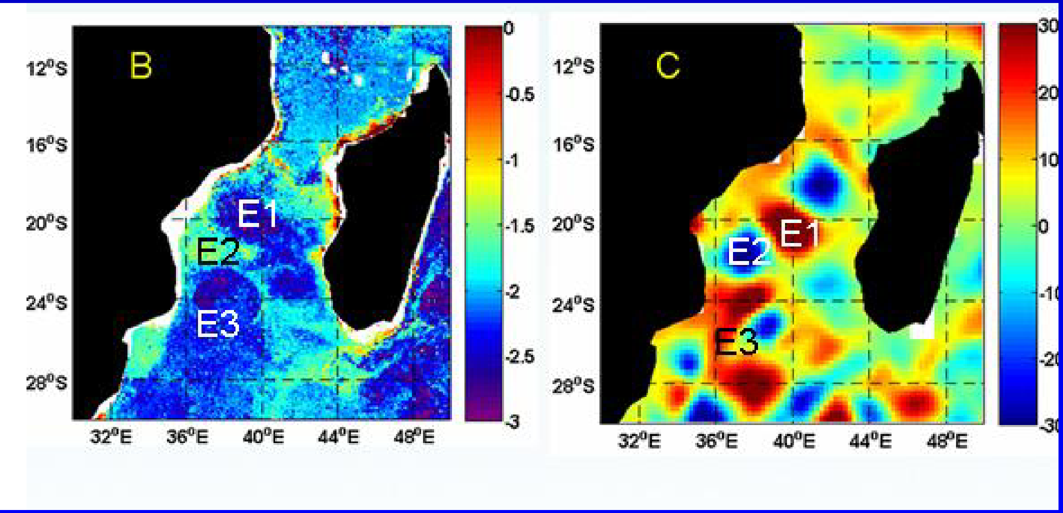
Fig. A2-12. Annual mean oxygen (ml/l) at 300 m. depth.
Minimum Value= 0.05 Maximum Value= 7.89 Contour Interval: 0.25

Mesoscale gyres play a major role in the local oceanic productivity: on plancton & tunas & other predators

> Cyclonic gyres are producing small scale local upwelling

> They often produce localized phytoplancton blooms that are often leading to tunas, mammals and bird concentrations



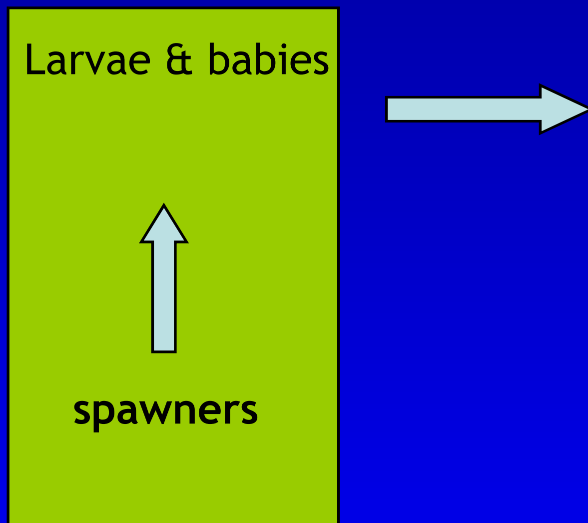


Water colour **Altimetry**

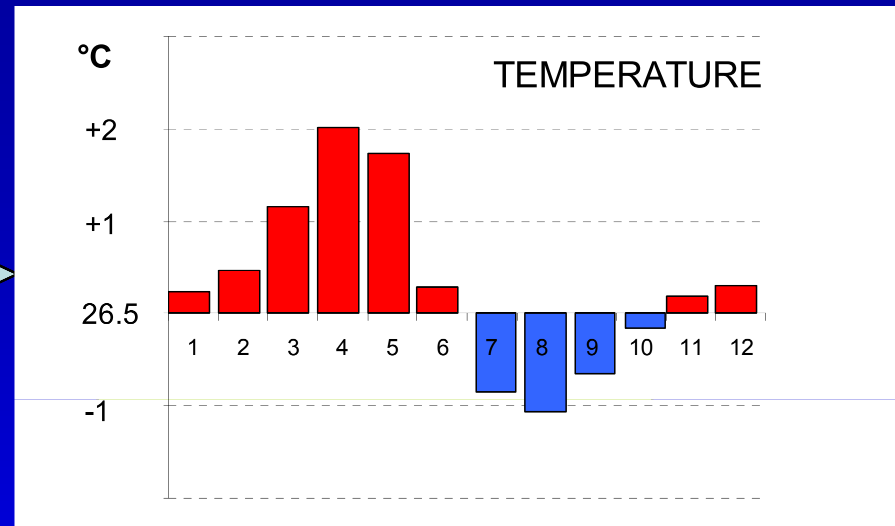
E1 & E3 cyclonic gyres
E2 anticyclonic gyre

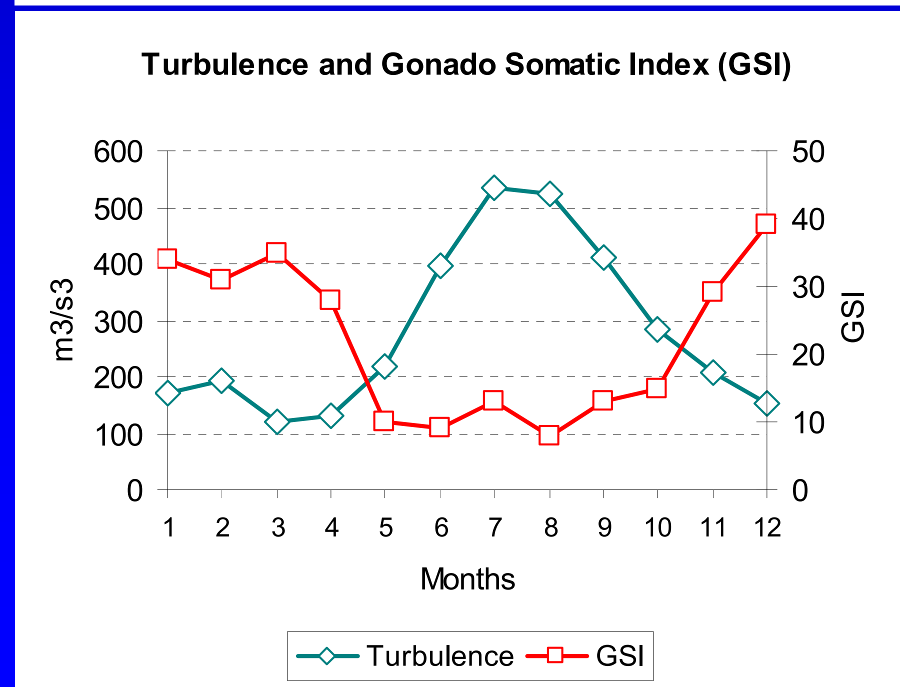
Yellowfin tuna spawning areas show are typical patterns world wide and highly related with SST

Age 0



Age 3+

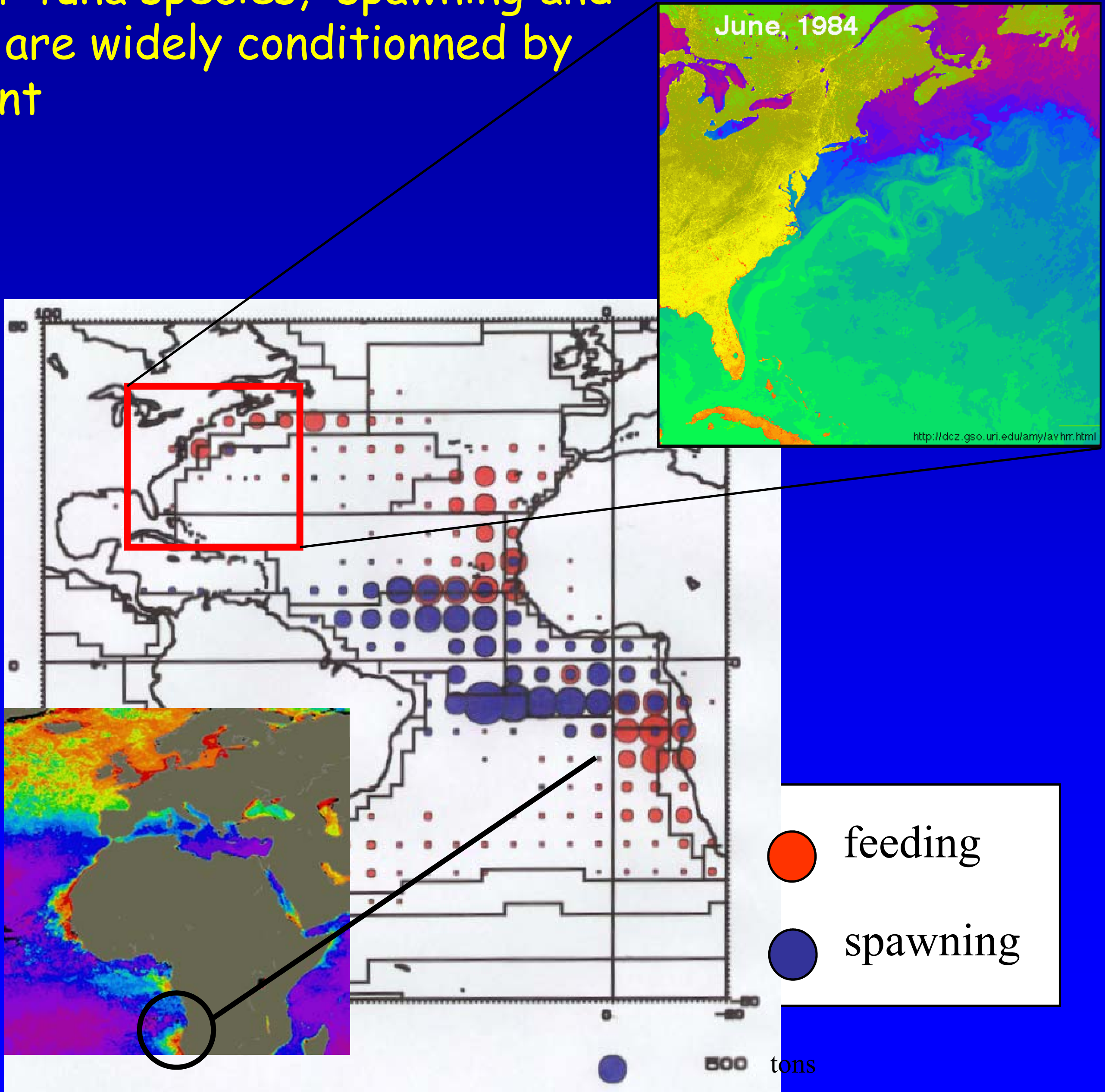




Spawning in equatorial areas with SST > 26.5°C & low turbulence

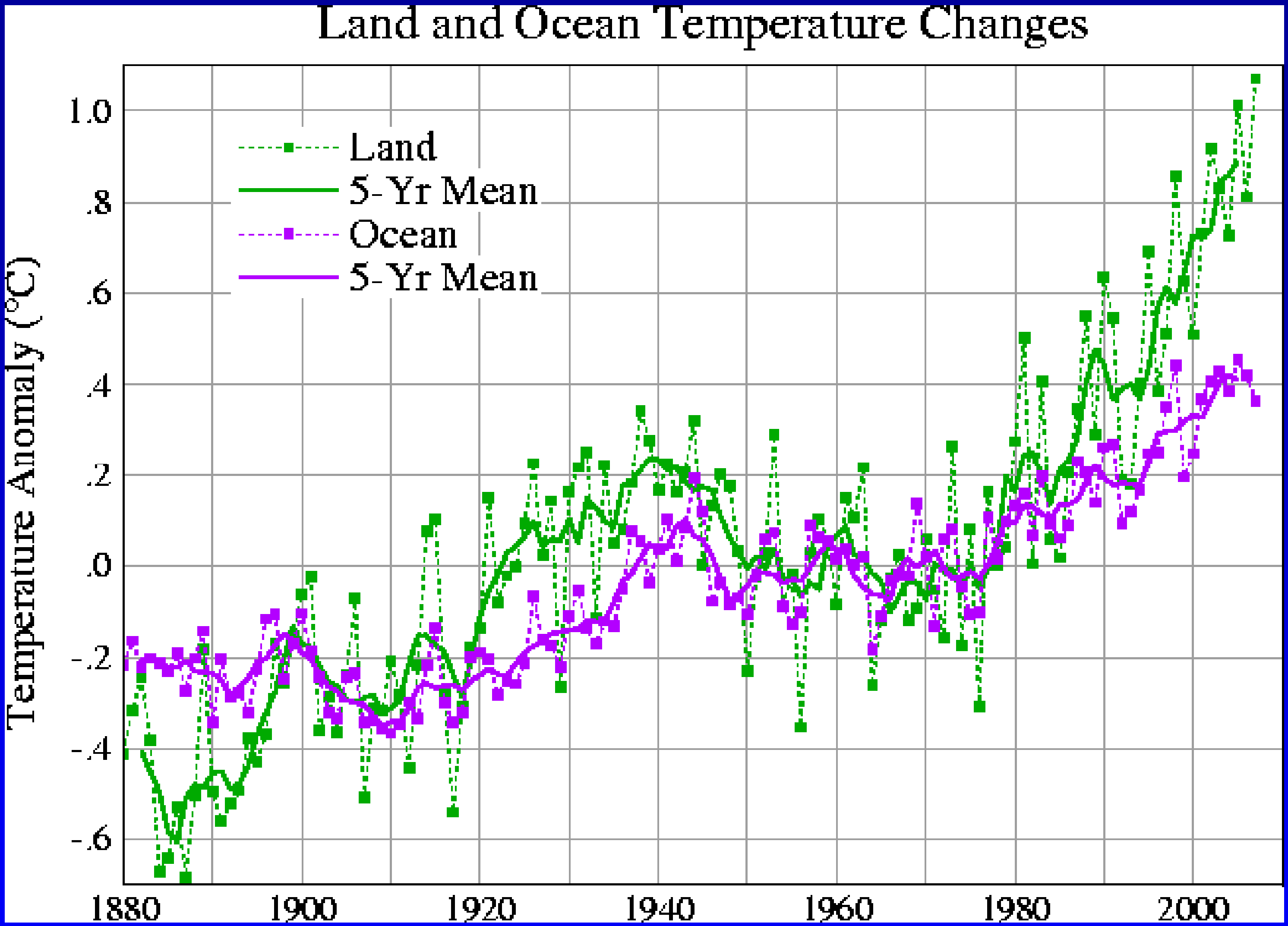
Atlantic bigeye:

as for all other tuna species, spawning and feeding zones are widely conditionned by the environment

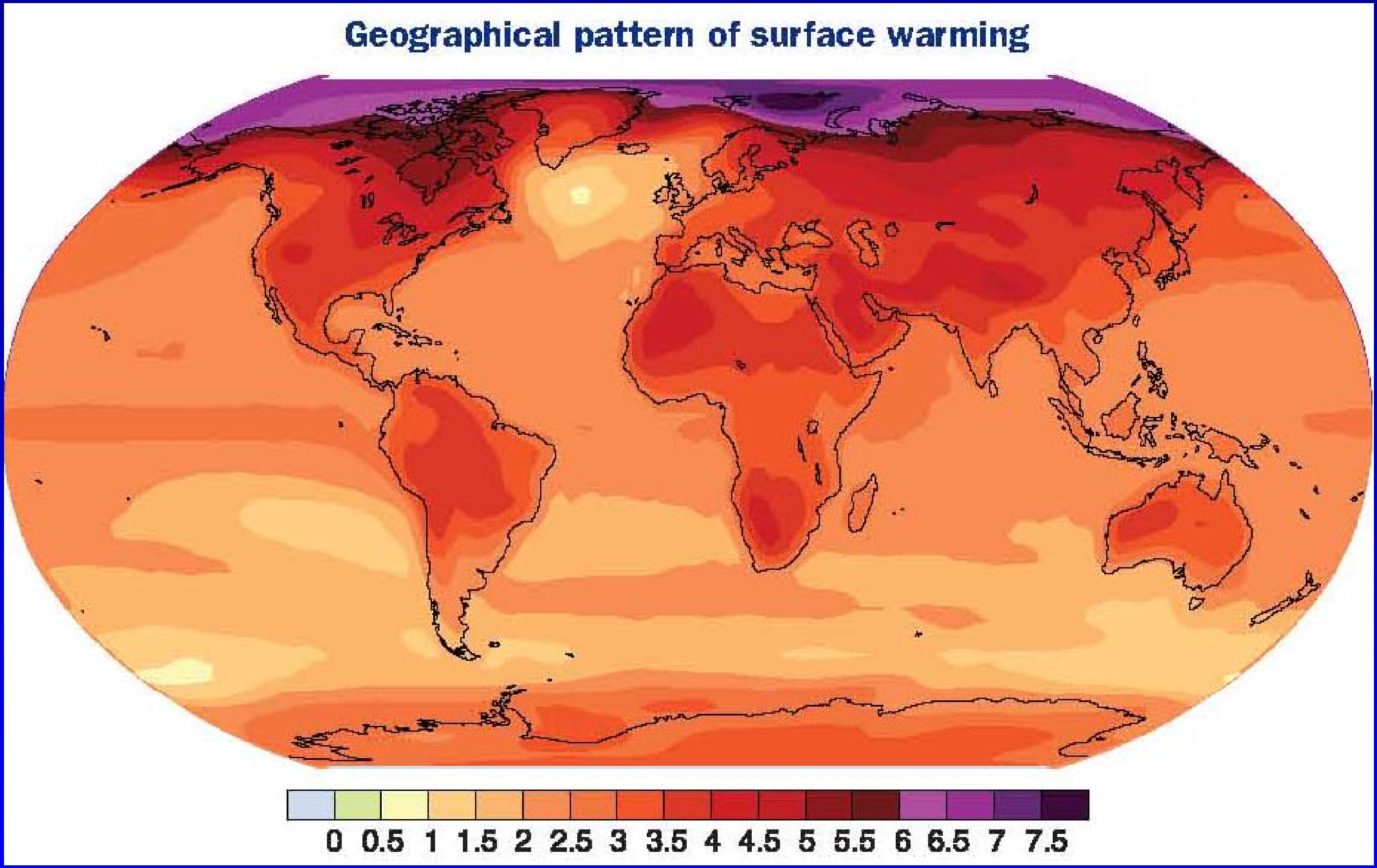


2- Global warming: now a strong scientific evidence

- Global warming of the world atmosphere and oceans is now a strong scientific fact that is now well studied by scientists: IPCC reports.
- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.
- This warming is mainly due to human causes
- Prospects for this warming are now increasingly clear in all the models, but it is still quite uncertain to project the expected real changes in temperature in each area & ocean.



Major changes and warming have been observed in both atmosphere and oceans during the last 125 years.

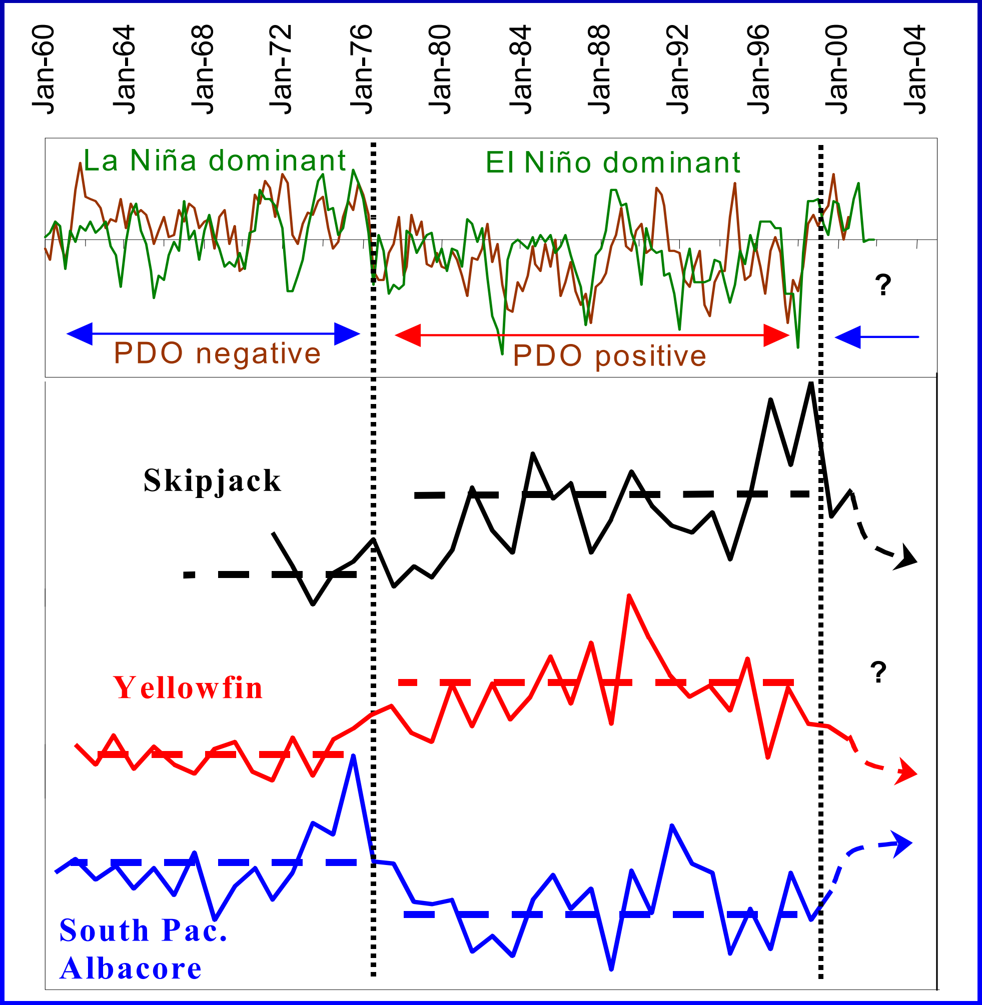


Projected surface temperature changes for the late 21st century (2090-2099) by Intergovernmental Panel on Climate Change (IPCC).

Effects of global warming will be different in each ocean areas

3- Global warming and expected changes in tuna stocks?

ENSO & regime changes: producing major effects on tuna recruitment levels? A global increase?



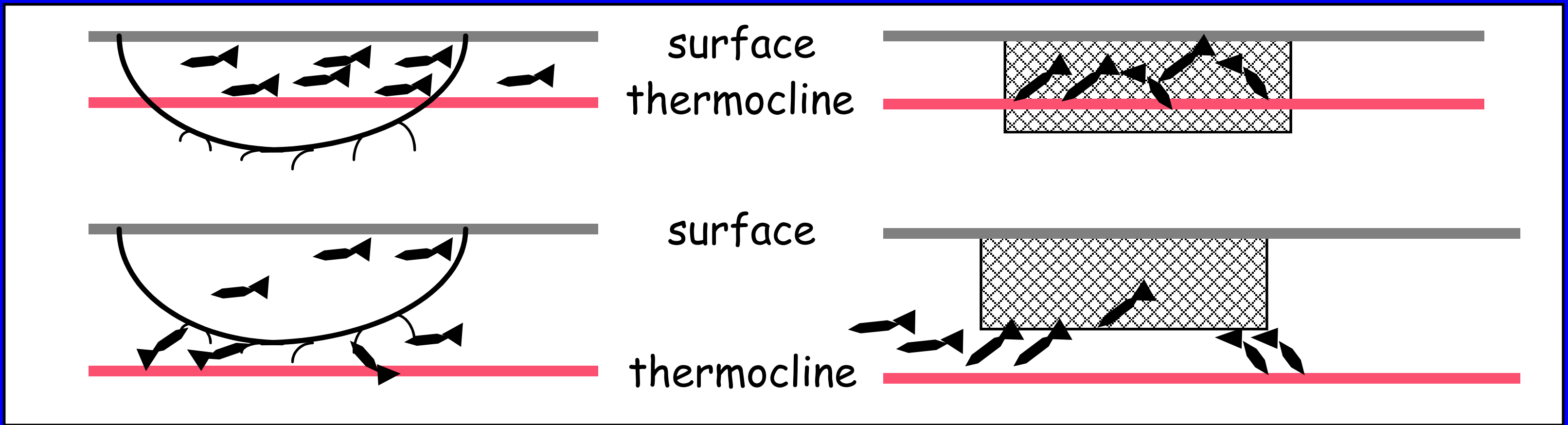
Global warming should change thermocline depth and then stock catchability to fishing gears

Basic catch equation: Catch = q x f x B

Tuna catches are a function of:
- ✓ local biomass B
- ✓ fishing effort, f
- ✓ Catchability q

Thermocline depth widely condition total tuna catches:
=> especially for purse seiners,
=> but also for other gears

Longline | Purse Seine

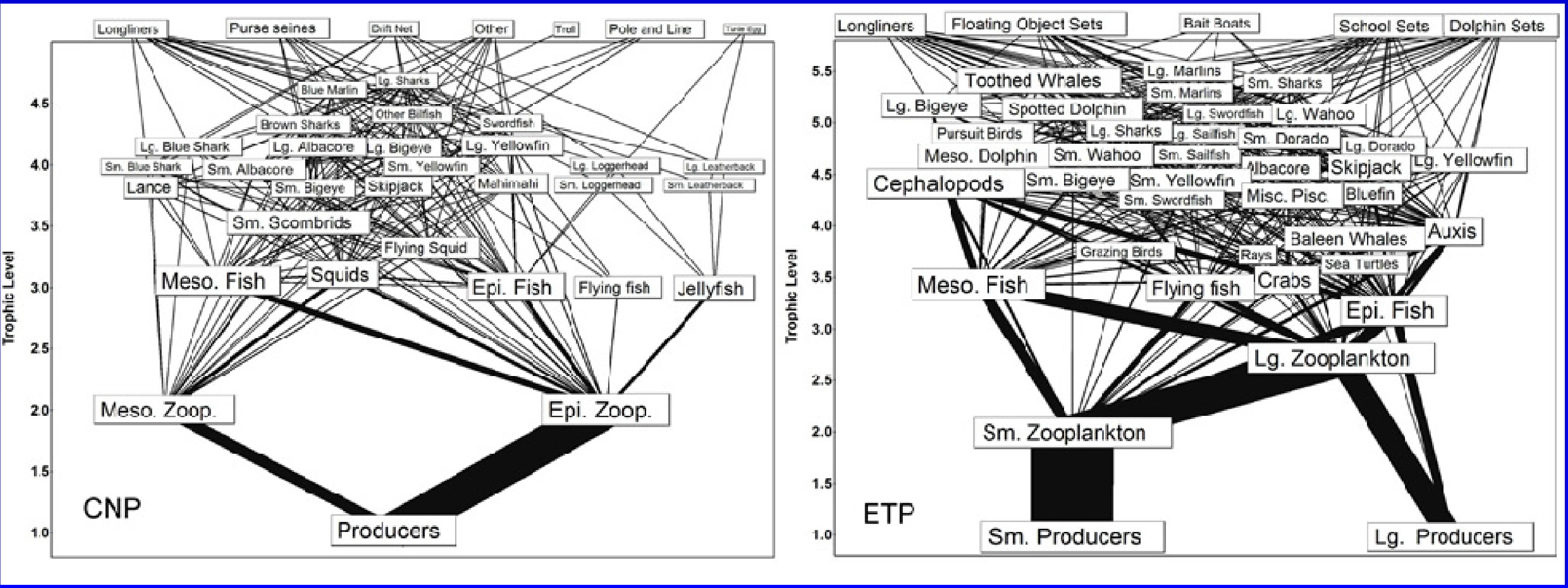


Changes in tuna stocks: effects on pelagic ecosystems and on tuna resources?

- Global warming should not produce total collapse of tuna stocks,
- But it should widely change their geographical distribution, spawning and feeding zones and movement pattern.
- Localized artisanal fisheries will face major potential changes in the tuna species and quantities available and caught in each area, for instance in islands fisheries
- Offshore large scale & mobile tuna fisheries (large longliners and purse seiners) will move their fishing zones
- Collapse of tuna stocks should not be envisaged, but the levels of MSY will be widely modified due to changes in spawning strata and to changes in the carrying capacity of the world pelagic ecosystems
- Potential reduction in mid water oxygen rates may reduce the potential oceanic habitat available for various tuna species.

4- Can we model future changes in the pelagic ecosystems and tuna resources?

- Present prospect to obtain realistic ecosystem models is still very weak in the offshore pelagic ecosystems.
- The attempts to use ECOPATH in these ecosystems are not really convincing: tunas are too flexible in their feeding behavior, too mobile, too many unknown components
- New ecosystemic models are now increasingly developped, but they are still difficult to structure and to parametrize

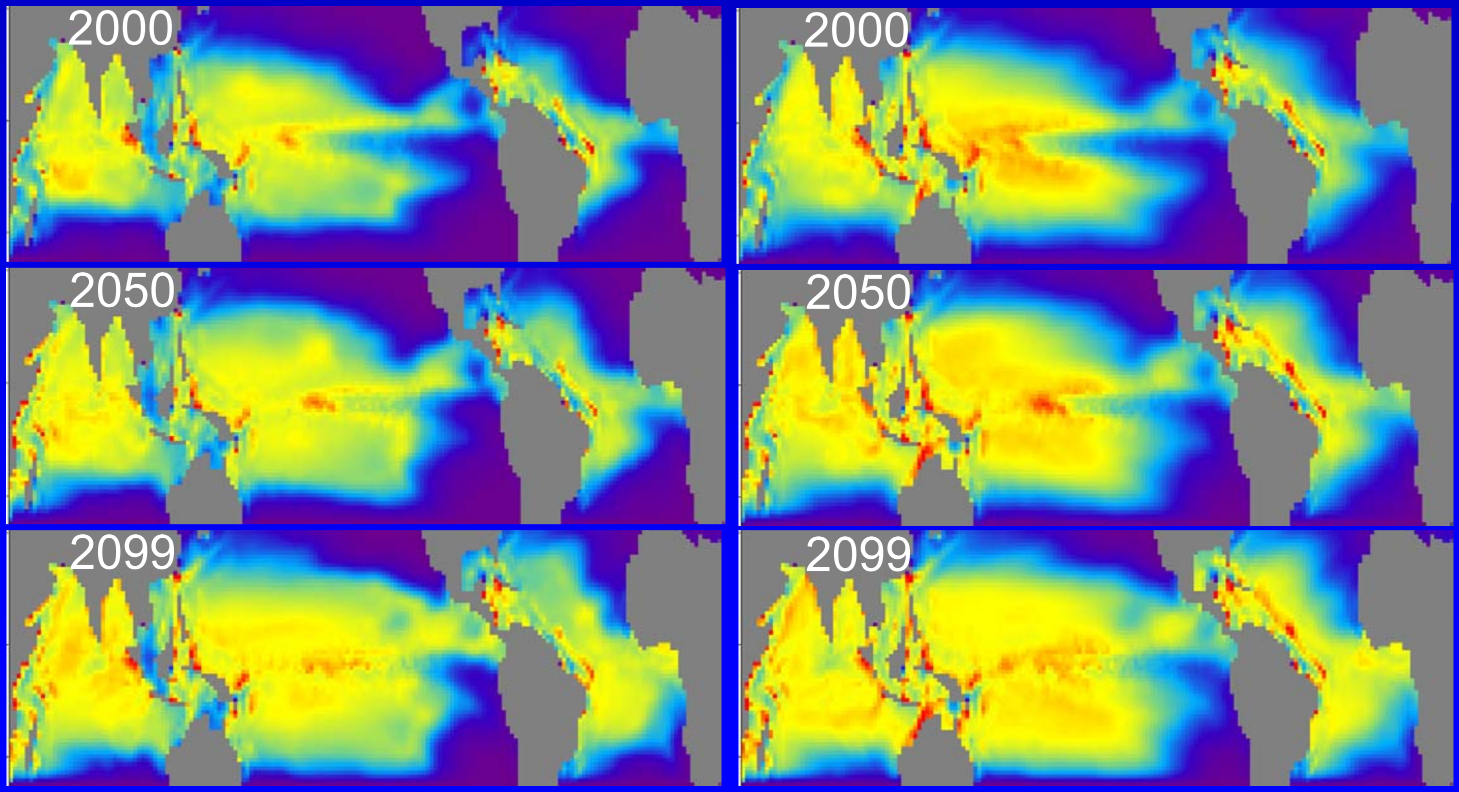


Recent attempts by Lehodey and al 2008 to model by SEAPODYM 2 the expected changes in bigeye and skipjack spawning sites (black) and larvae distribution

Effects of global Warming: running IPCC scenarios:

Change in larvae distribution

Bigeye **Skipjack**

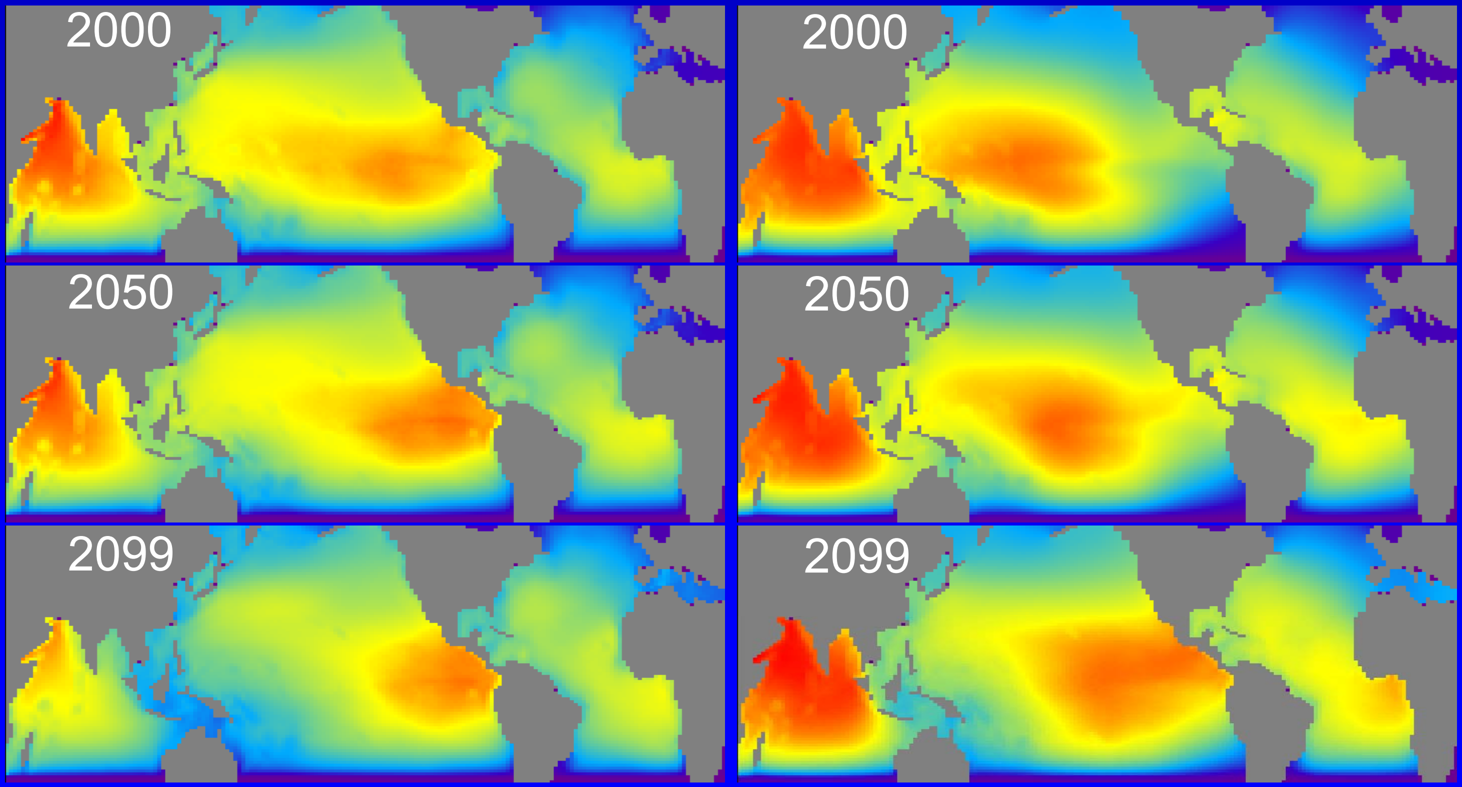


Recent attempts by Lehodey and al 2008 to model by SEAPODYM 2 the expected changes in bigeye and skipjack distribution

Running IPCC scenarios:

Simulated changes in adult distribution

Bigeye **Skipjack**



- Present ecosystem models, such as SEAPODYM developped by P. Lehodey, are interesting tools, but they are still far to be realistic in their projections.
- Other more complex ecosystemic models, presently under development, such as APECOSM by O. Maury, are more complex and more ambitious, but their potential predictive capacity is still unknown, especially in a context of expected major changes in the environment.

Conclusion

- The global warming of the oceans should soon modify both the geographical distribution and the biomass levels of all tuna stocks world wide, as well as their availability to the various gears and regional fisherie
- These changes will possibly be major ones, at least ir some areas and for some species
- Ecosystem models are increasingly developped by scientists to project these future changes, but these models are still far to be realistic in their understanding of present resources and in the projection of their expected changes


RRR!
Life can only be understood backwards, but it must be lived forwards
SØREN KIERKEGAARD (1813-1855) DANISH PHILOSOPHER