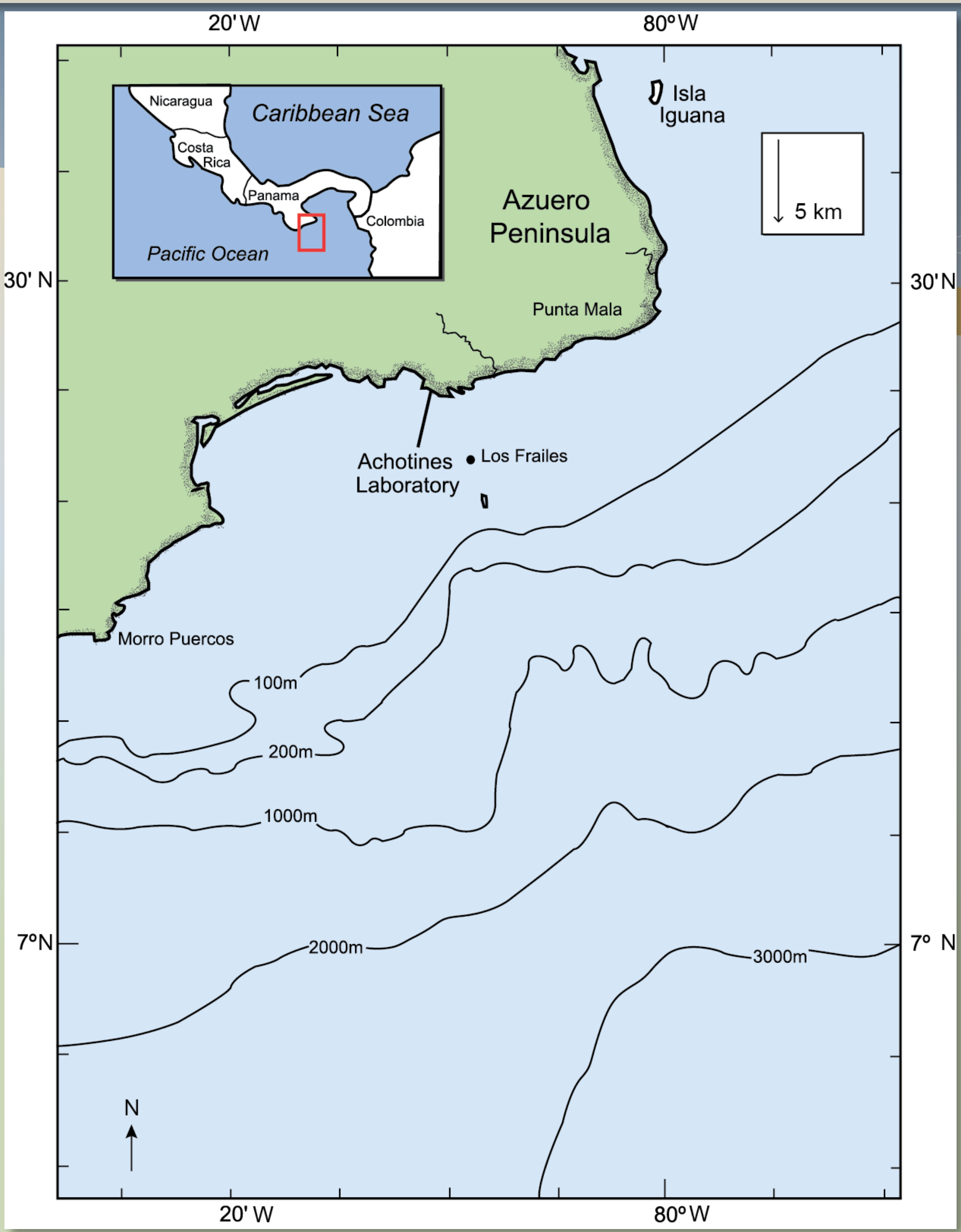
Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

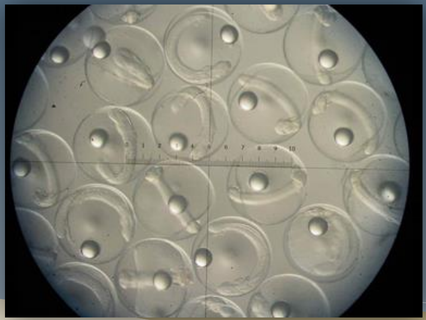
Achotines Laboratory: Review of research

Daniel Margulies, Vernon P. Scholey, Jeanne B. Wexler, and Maria S. Stein

Location of Achotines Laboratory



Research on yellowfin tuna (1996 to present)

Broodstock adults | Fertilized eggs | Yolk-sac larvae | First-feeding larvae

Achotines Laboratory : Yellowfin Research

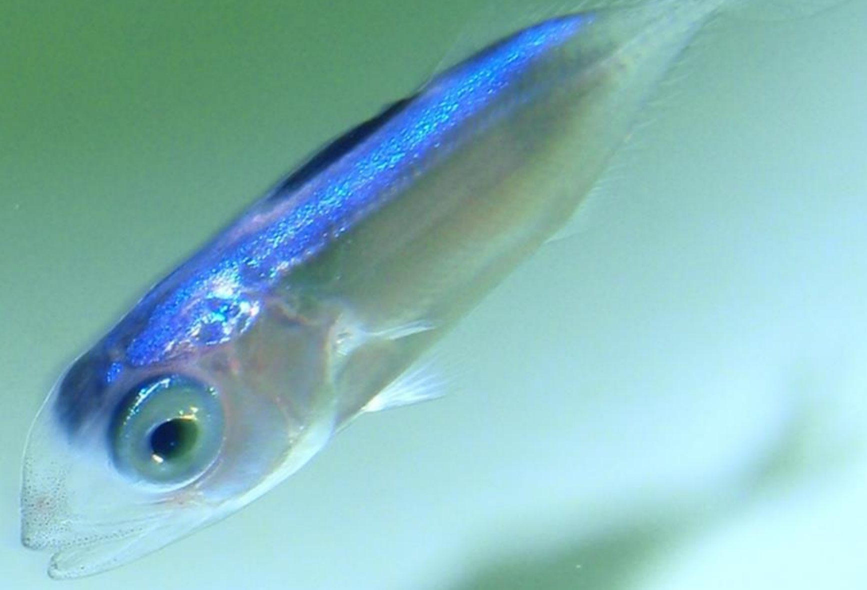
Studies of yellowfin tuna: 19 years of research have yielded important findings related to spawning, growth and genetics of adult yellowfin and key factors affecting survival in pre-recruit stages

12-day-old larva | Late larva – 2.5 wks old | Early Juvenile – 30 d old



Advances in TUNA AQUACULTURE
FROM HATCHERY TO MARKET

Editors Daniel D. Benetti, Gavin J. Partridge, and Alejandro Buentello



Chapter 5. Research on the Reproductive Biology and Early Life History of Yellowfin Tuna *Thunnus albacares* in Panama

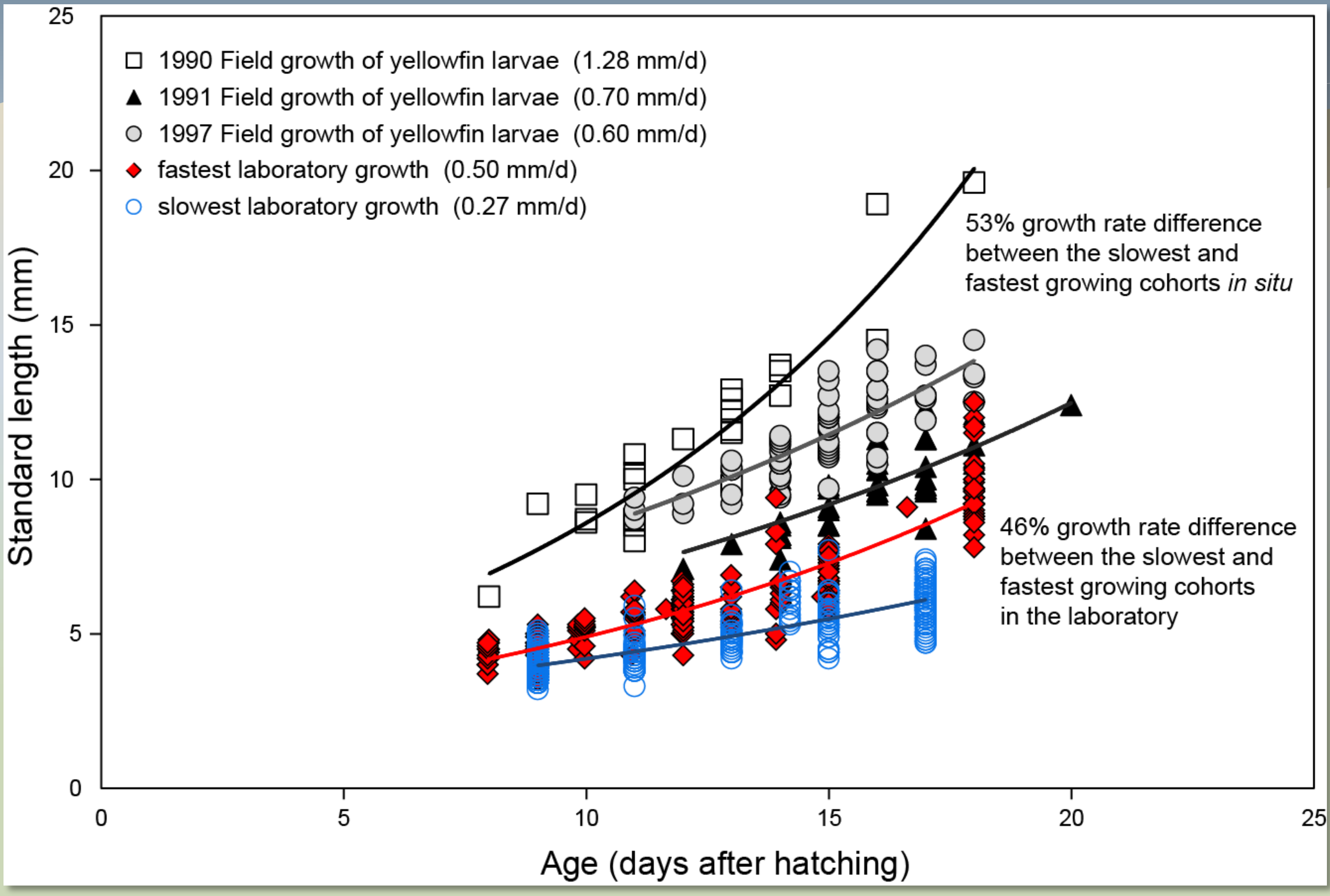
D. Margulies, V.P. Scholey, J.B. Wexler, M.S. Stein

CIAT IATTC

Promising links between yellowfin early life research and stock assessment

- **Laboratory and *in situ* growth of larval and juvenile yellowfin**
- **Effects of wind-induced turbulence on yellowfin larval survival**
- **Comparative studies of the early life histories of yellowfin and Pacific bluefin**
- **The effects of ocean acidification on yellowfin eggs and larvae**

Laboratory and *in situ* growth of yellowfin larvae



Association between *in situ* growth rates of larvae in the Panama Bight and recruitment estimates for yellowfin in the EPO

Month/Year	Average growth rate (mm/d) and (SE) of night-light caught yellowfin larvae	Recruitment estimates 6 months following each period of growth[1]	Standardized plankton volumes (mL) (mean ± SE and range)[2]
June 1990	1.28(0.134)	3.11 x 10^7 individuals	157.3 ± 13.53 106.5 - 310.4
Sept 1991	0.60(0.033)	1.44 x 10^7 individuals	62.8 ± 5.86 43.7 - 102.4
Aug 1997	0.71(0.038)	3.06 x 10^7 individuals	NA

[1](IATTC; Maunder and Harley, 2004; Maunder, Pers. comm.)
[2]means are significantly different (*P*<0.001, 1990>1991)

Indirect evidence of density effects on *in situ* growth rates of yellowfin tuna larvae and associated recruitment estimates

Month /Year	CPUE[1] of night light- caught yellowfin	Density of scombrid larvae (mean ± SE and range) [2]	Density of non-scombrid larvae (mean ± SE and range) [2]	Standardized plankton volumes (mL) (mean ± SE and range)[3]	Average growth rate (mm/d) and (SE) 8-20 DAH	Recruitment estimates 6 months following each period of growth[4]
June 1990	**6.05**	**0.76** ± 0.29 0 - 2.7	**1399.5** ± 273.73 686.8 - 4786.1	157.3 ± 13.53 106.5 - 310.4	**1.28**(0.134)	**3.11** x 10^7 individuals
Sept 1991	**14.08**	**2.41** ± 1.35 0 – 12.7	**1937.4** ± 323.68 934.5 - 2685.6	62.8 ± 5.86 43.7 - 102.4	**0.60**(0.033)	**1.44** x 10^7 individuals
Aug 1997	**32.67**	NA	NA	NA	**0.71**(0.038)	**3.06** x 10^7 individuals

[1]CPUE calculated as the number of larvae caught per hours fished
[2]Numbers of larvae under $10m^2$ of sea surface
[3]Means are significantly different (*P*<0.001, 1990>1991)
[4](Maunder and Harley, 2004; Maunder, Pers. comm.)

(Wexler *et al.*, Fish. Bull. 105: 1-18 (2007))

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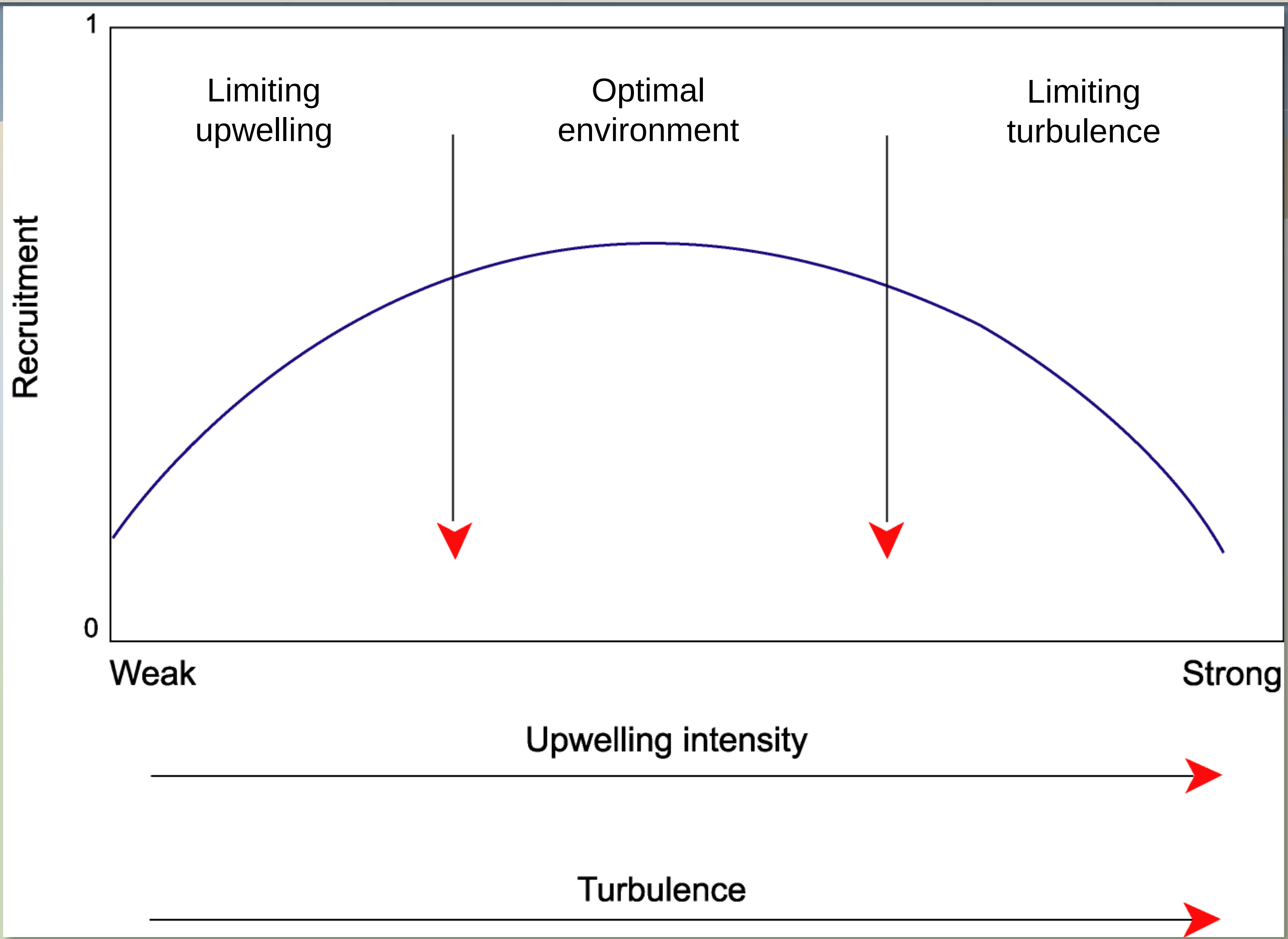
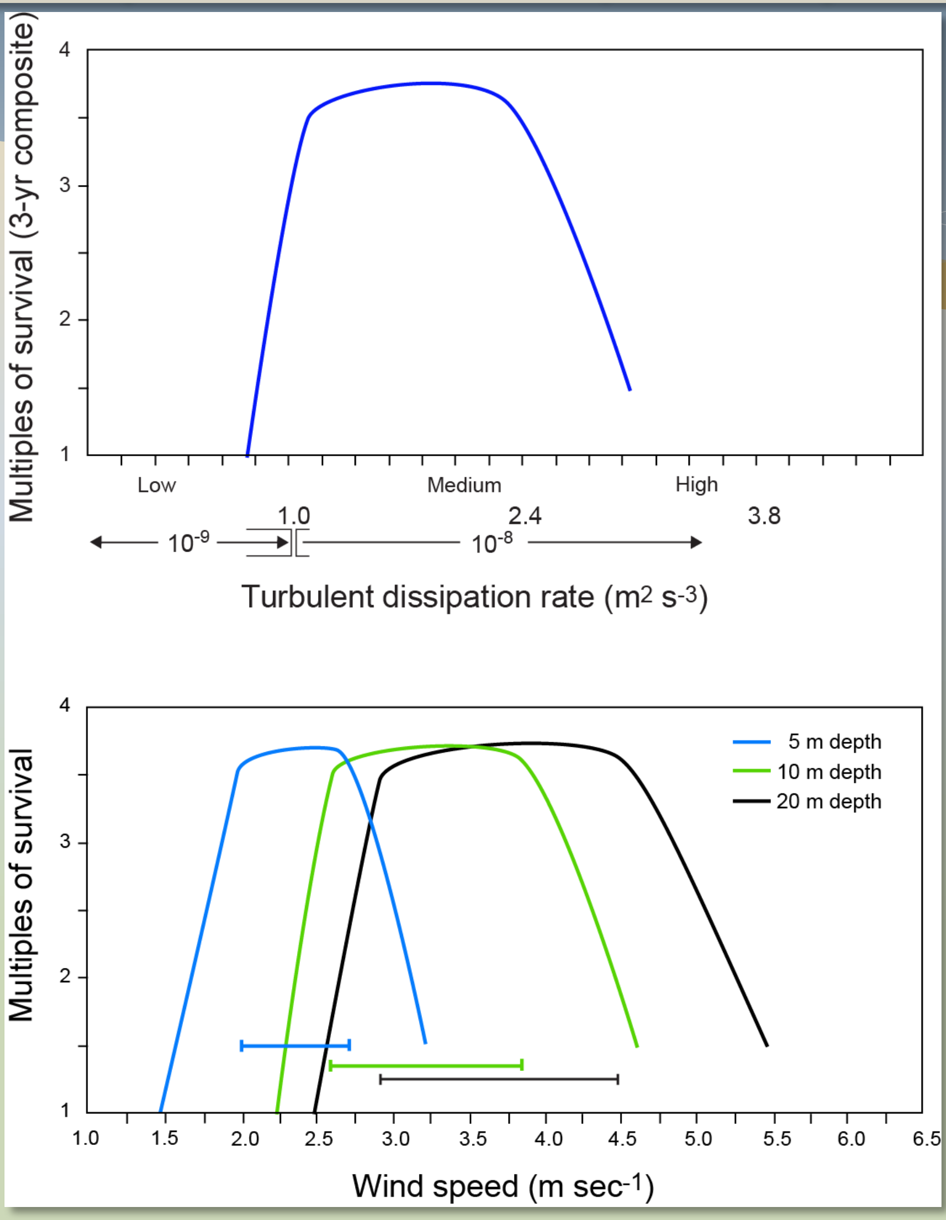
Figure 10 Relationship between turbulence and recruitment success hypothesized by Cury and Roy. (Redrawn from Cury and Roy, 1989.)



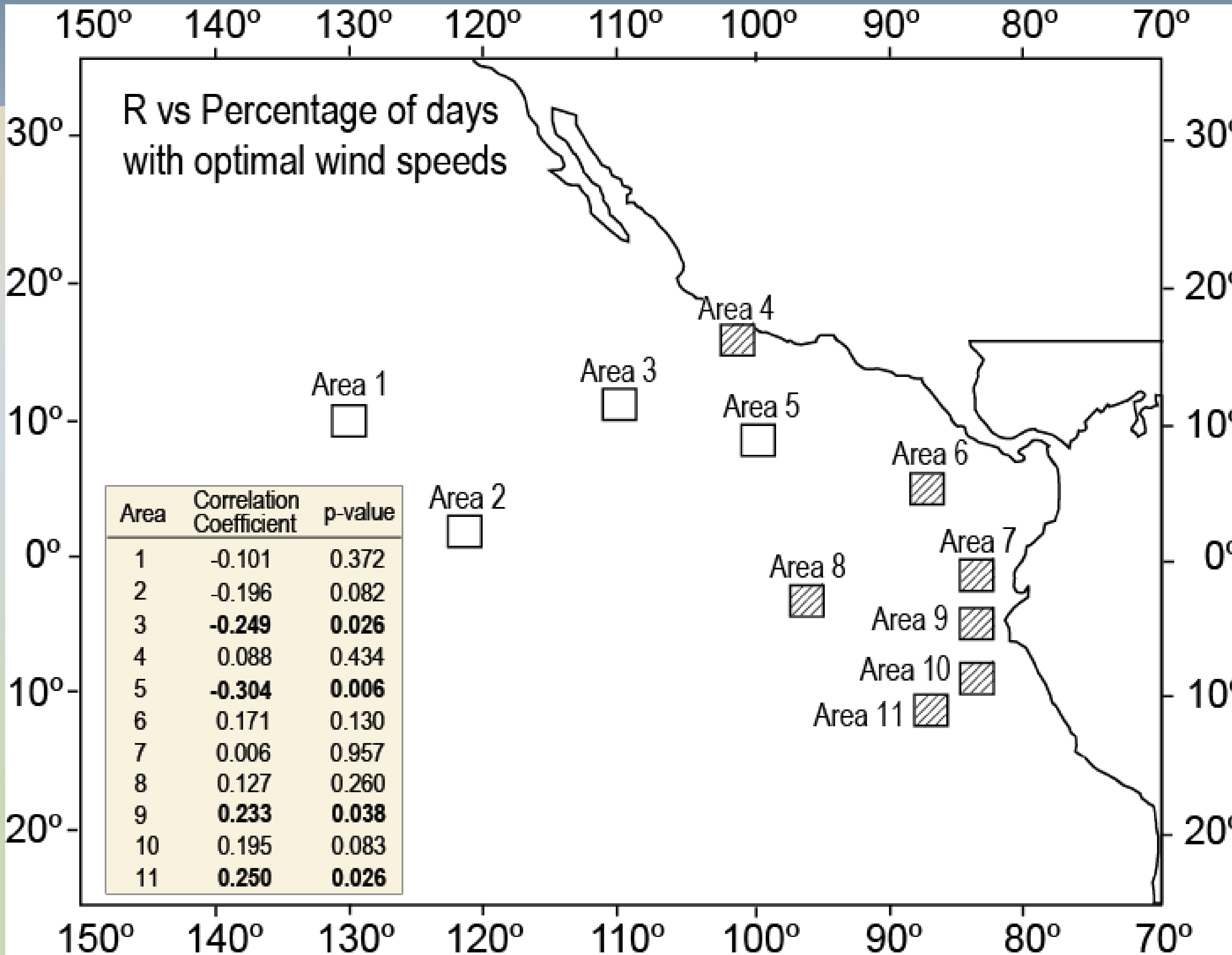
Experimental studies of the effects of microturbulence on yellowfin larvae

- Seven experimental trials conducted from 1997 – 2000
- YFT larvae exposed to a gradient of microturbulence
- Microturbulence levels calibrated with an Acoustic Doppler Velocimeter (ADV)
- Larval survival, optimal microturbulence, and equivalent windspeed estimated

Microturbulence vs. larval survival (top panel) and estimates of optimal windspeeds for survival (bottom panel)



Correlations between windspeed and quarterly recruitment estimates for selected 2x2˚ areas



Area	Correlation Coefficient	p-value
1	-0.101	0.372
2	-0.196	0.082
3	**-0.249**	**0.026**
4	0.088	0.434
5	**-0.304**	**0.006**
6	0.171	0.130
7	0.006	0.957
8	0.127	0.260
9	**0.233**	**0.038**
10	0.195	0.083
11	**0.250**	**0.026**

Bold values are statistically significant at an alpha level of 0.05

Correlation analysis results :
QTRS 1 & 2 and R compared to All QTRS and R

	Spearman Test	
	correlation coefficients	
alpha=0.05	**QTRS 1&2 ONLY**	**All QTRS**
Area: 1	**-0.507**	-0.101
Area: 2	0.083	-0.196
Area: 3	**-0.461**	**-0.249**
Area: 4	0.131	0.088
Area: 5	**-0.319**	**-0.304**
Area: 6	**0.560**	0.171
Area: 7	**0.406**	0.006
Area: 8	**0.507**	0.127
Area: 9	**0.473**	**0.233**
Area: 10	**0.366**	0.195
Area: 11	0.238	**0.250**

	Spearman Test	
	p-value table	
alpha=0.05	**QTRS 1&2 ONLY**	**All QTRS**
Area: 1	**0.001**	0.372
Area: 2	0.609	0.082
Area: 3	**0.003**	**0.026**
Area: 4	0.419	0.434
Area: 5	**0.045**	**0.006**
Area: 6	**0.000**	0.130
Area: 7	**0.010**	0.957
Area: 8	**0.001**	0.260
Area: 9	**0.002**	**0.038**
Area: 10	**0.021**	0.083
Area: 11	0.138	**0.026**

Promising links between yellowfin early life research and stock assessment

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- **Comparative studies of the early life histories of yellowfin and Pacific bluefin**
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Comparative Studies of the Reproductive Biology and Early Life History of Yellowfin (*Thunnus albacares*) and Pacific Bluefin Tuna (*Thunnus orientalis*) Applications to Tuna Resource Management and Aquaculture Development

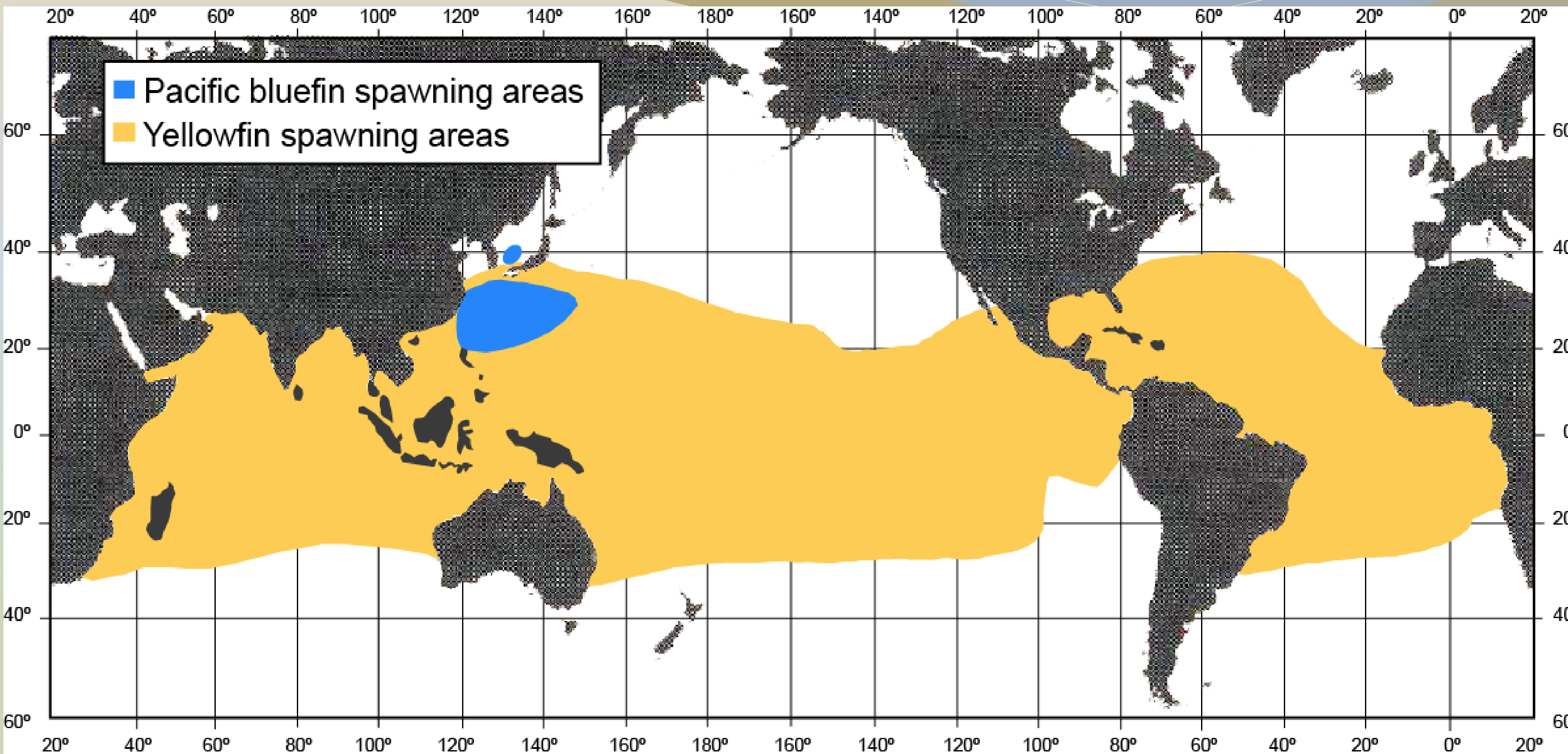
SCIENCE AND TECHNOLOGY RESEARCH PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT (SATREPS)

CIAT
IATTC

ARAP
AUTORIDAD DE LOS RECURSOS ACUÁTICOS DE PANAMÁ

1. Growth and survival studies at multiple background prey levels
2. Starvation durations
3. Feeding dynamics and prey selectivity
4. Juvenile rearing and sea-cage culture of yellowfin tuna to recruitment size

Spawning distributions of Pacific bluefin and yellowfin tuna



Pacific bluefin tuna
(Thunnus orientalis)

- Slightly larger at egg, yolk sac, and first-feeding larval stages
- Longer duration until starvation at the first-feeding stage at similar water temperatures
- Slower growth and lower survival under food limiting, uniformly small prey conditions during the first week of feeding
- Minimum light levels required for successful feeding at the first-feeding stage are extremely low, possibly as low as 0.04 µmol m^{-2} s^{-1}
- Gastric evacuation time at the first-feeding stage < 1 hour

Yellowfin tuna
(Thunnus albacares)

- Slightly smaller at egg, yolk sac, and first-feeding larval stages
- Shorter duration until starvation at the first-feeding stage at similar water temperatures
- Faster growth and higher survival under food limiting, uniformly small prey conditions during the first week of feeding
- Minimum light levels required for successful feeding at the first-feeding stage appear higher, >0.17 µmol m^{-2} s^{-1}
- Gastric evacuation time at the first-feeding stage < 1 hour

Juvenile Sea Cages - 1 km offshore from Achotines (Financial Support by JICA, Technical Support Dainichi Corp/Kindai Univ./ARAP)

Yellowfin stocking size: 9 – 13 cm

- YFT Juveniles : Transfer to Sea Cage at 52 days old and 9-13 cm
- The Sea-Cage Transfer Was a World-First for YFT Juveniles

Juveniles Reared in Sea Cage for 1 Month, Then Harvested and Returned To Land-based Tank

Oldest individual grew to 28 cm in length (158 days old)

Promising links between yellowfin early life research and stock assessment

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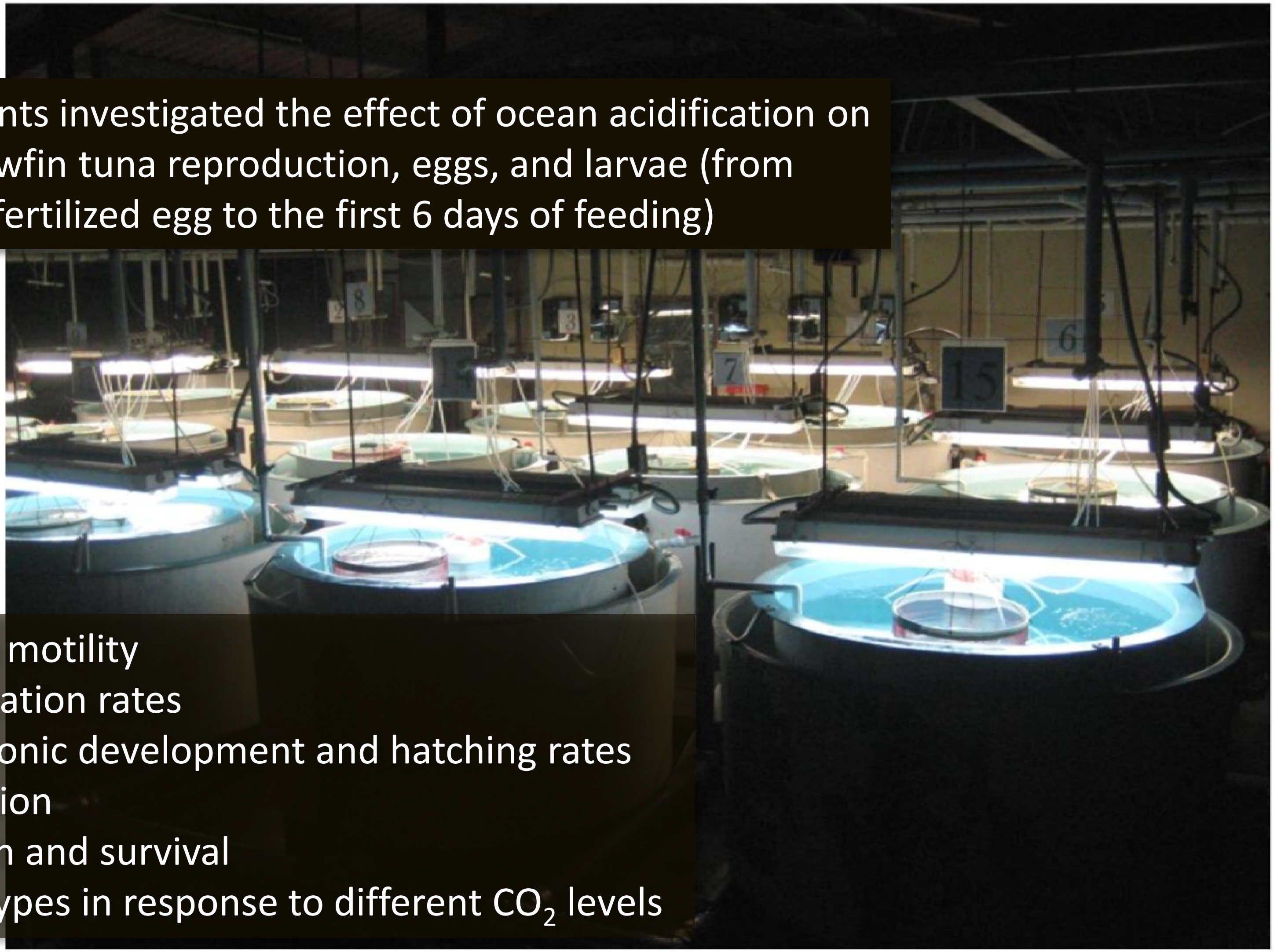
Ocean acidification impacts upon tropical tuna populations

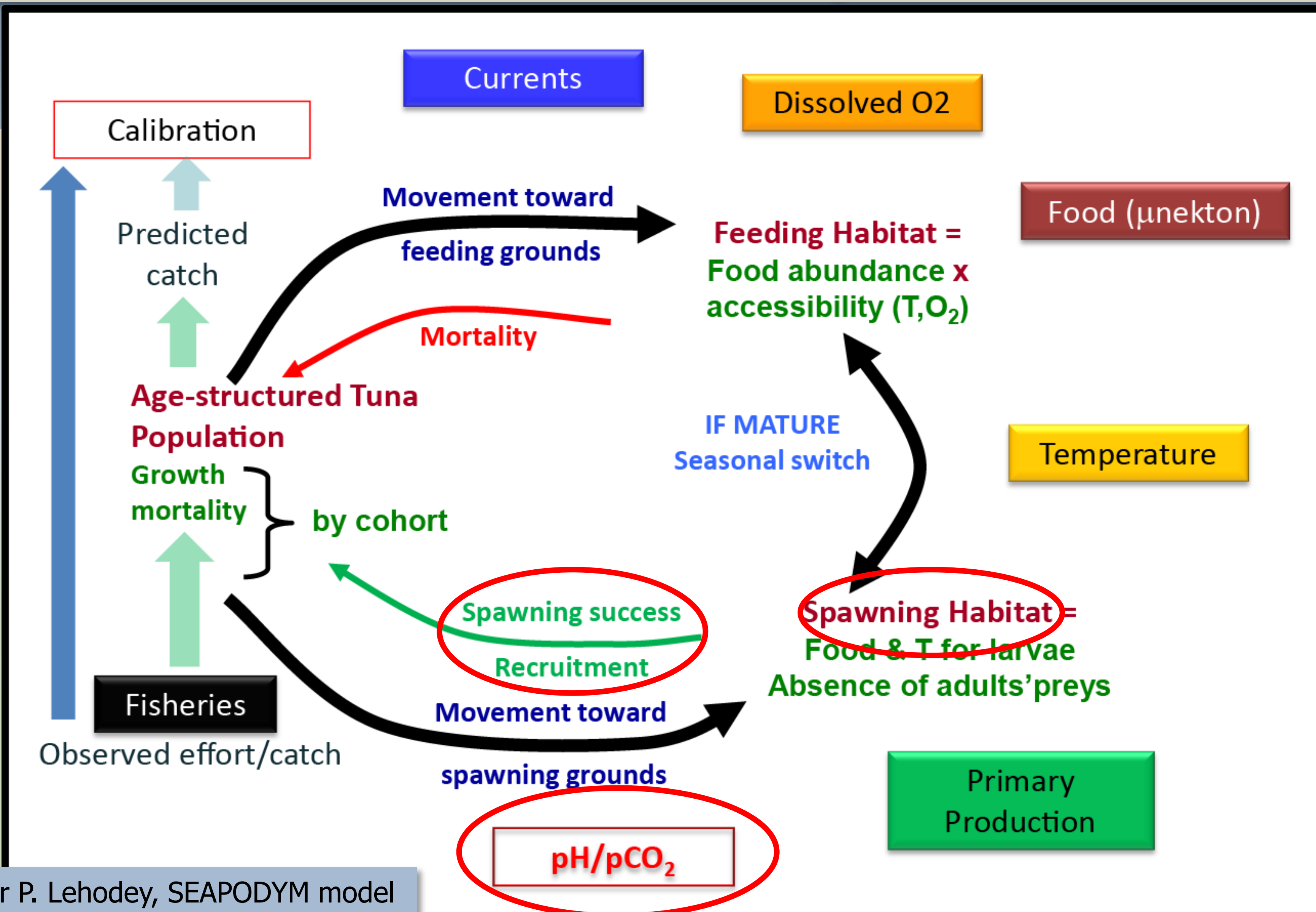
Don Bromhead, Vernon Scholey, Simon Nicol, Daniel Margulies, Jeanne Wexler, Maria Stein, Simon Hoyle, Cleridy Lennert-Cody, Jane Williamson, Jonathan Havenhand, Tatiana Ilyina, and Patrick Lehodey



Experiments investigated the effect of ocean acidification on yellowfin tuna reproduction, eggs, and larvae (from fertilized egg to the first 6 days of feeding)

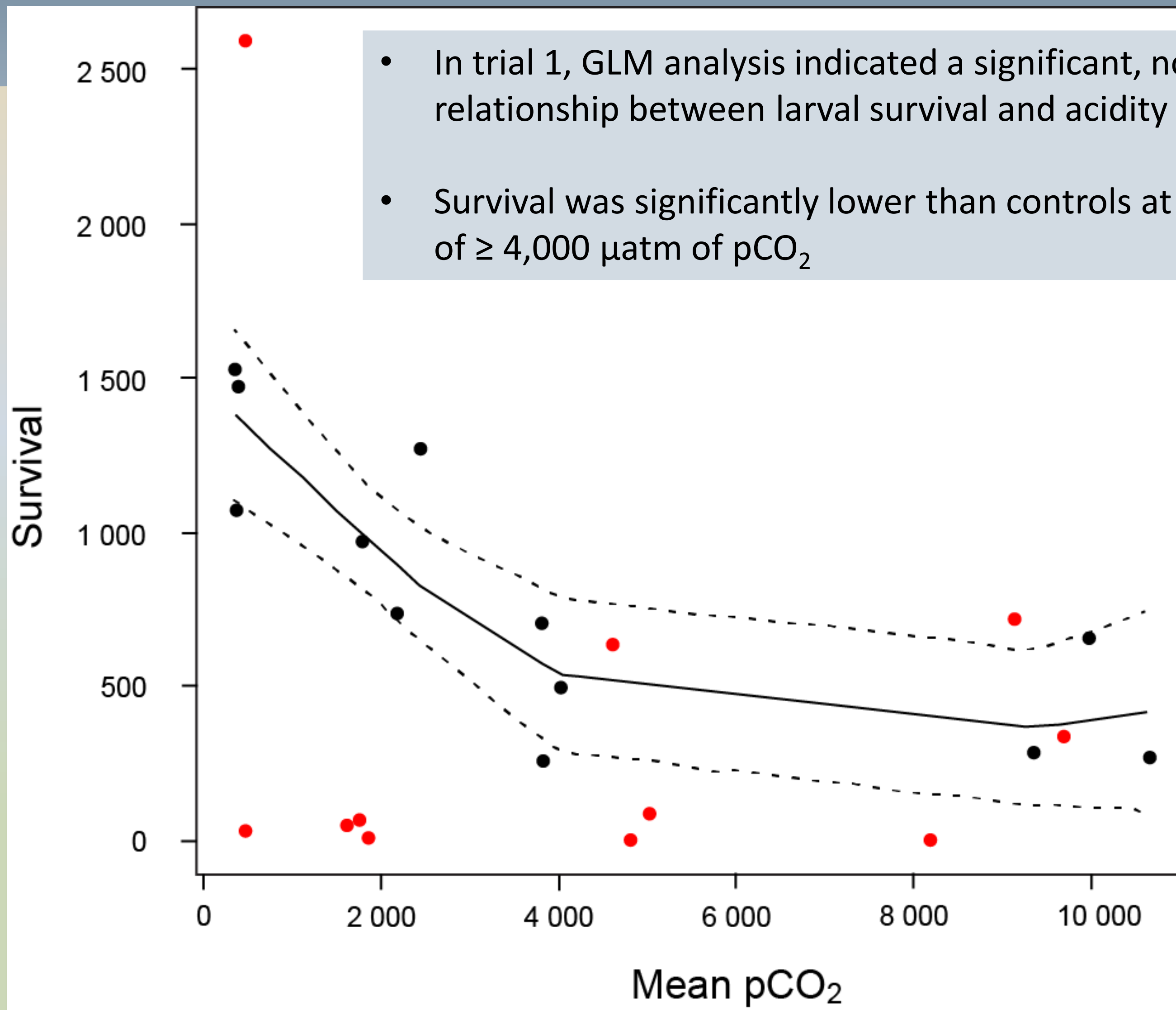
- Sperm motility
- Fertilization rates
- Embryonic development and hatching rates
- Condition
- Growth and survival
- Genotypes in response to different CO_2 levels

SEAPODYM: A model developed for investigating spatial tuna population dynamics, under the influence of both fishing and environmental effects

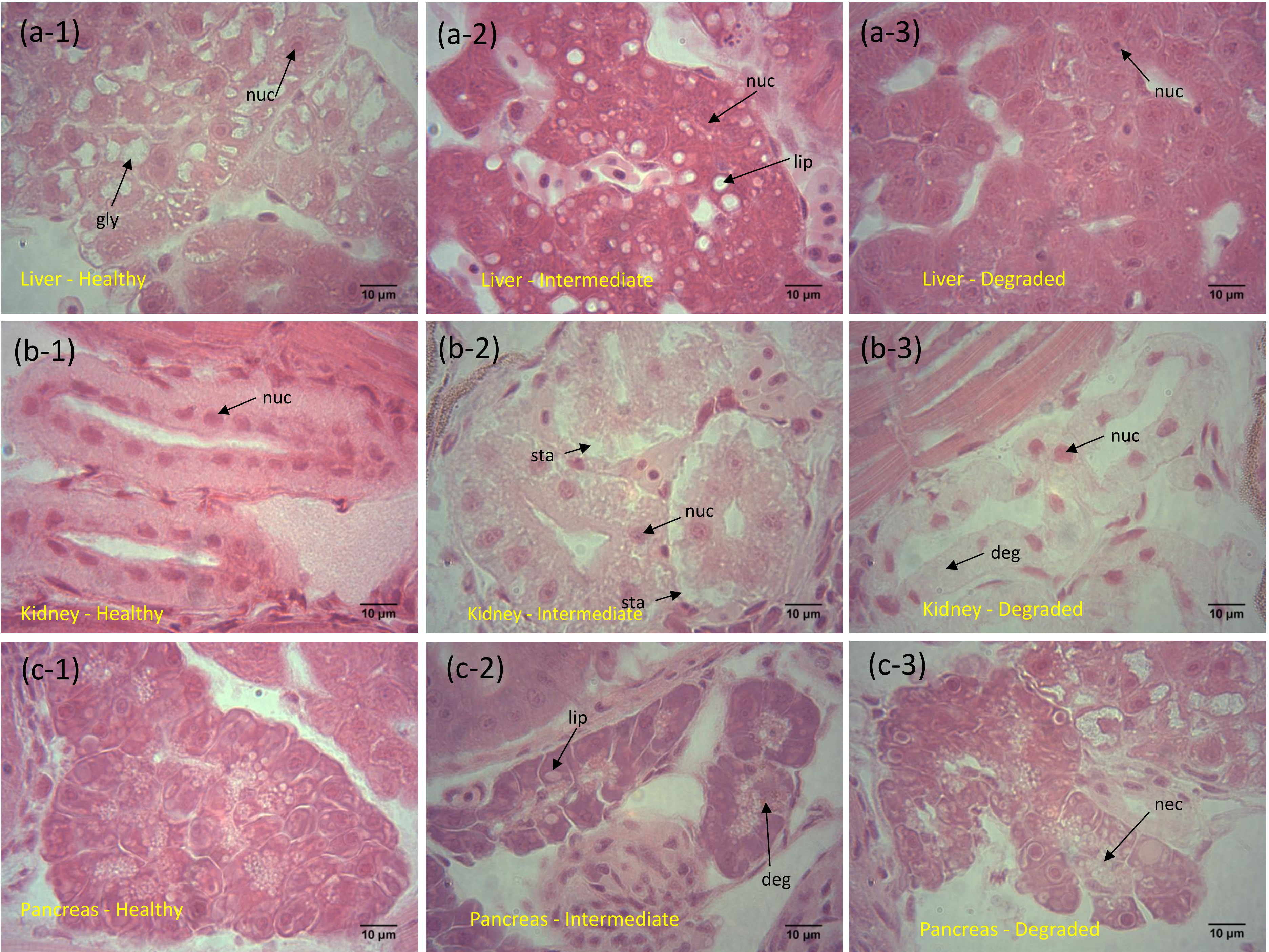


After P. Lehodey, SEAPODYM model

The effect of ocean acidification on survival of yellowfin larvae

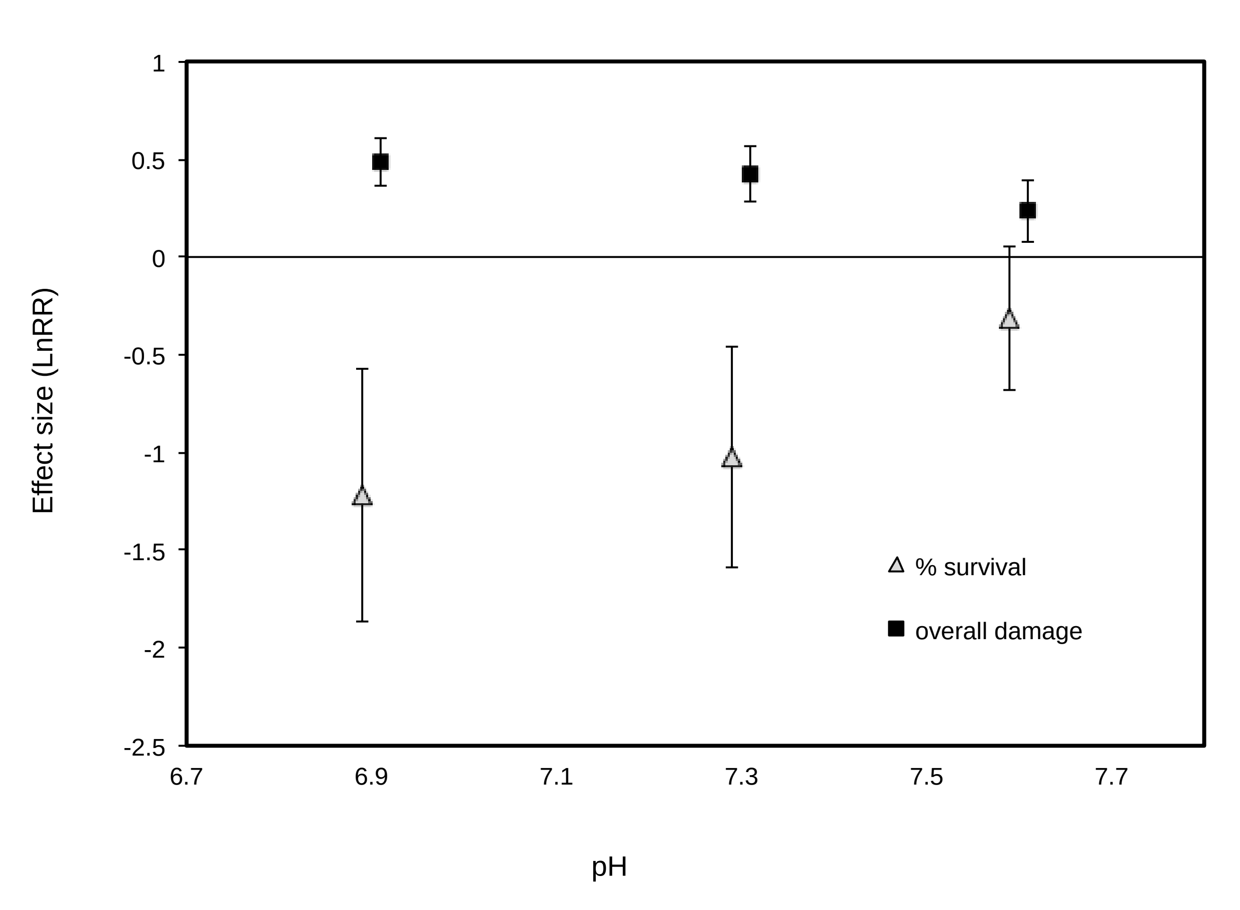


- In trial 1, GLM analysis indicated a significant, non-linear relationship between larval survival and acidity
- Survival was significantly lower than controls at acidity levels of ≥ 4,000 µatm of pCO_2

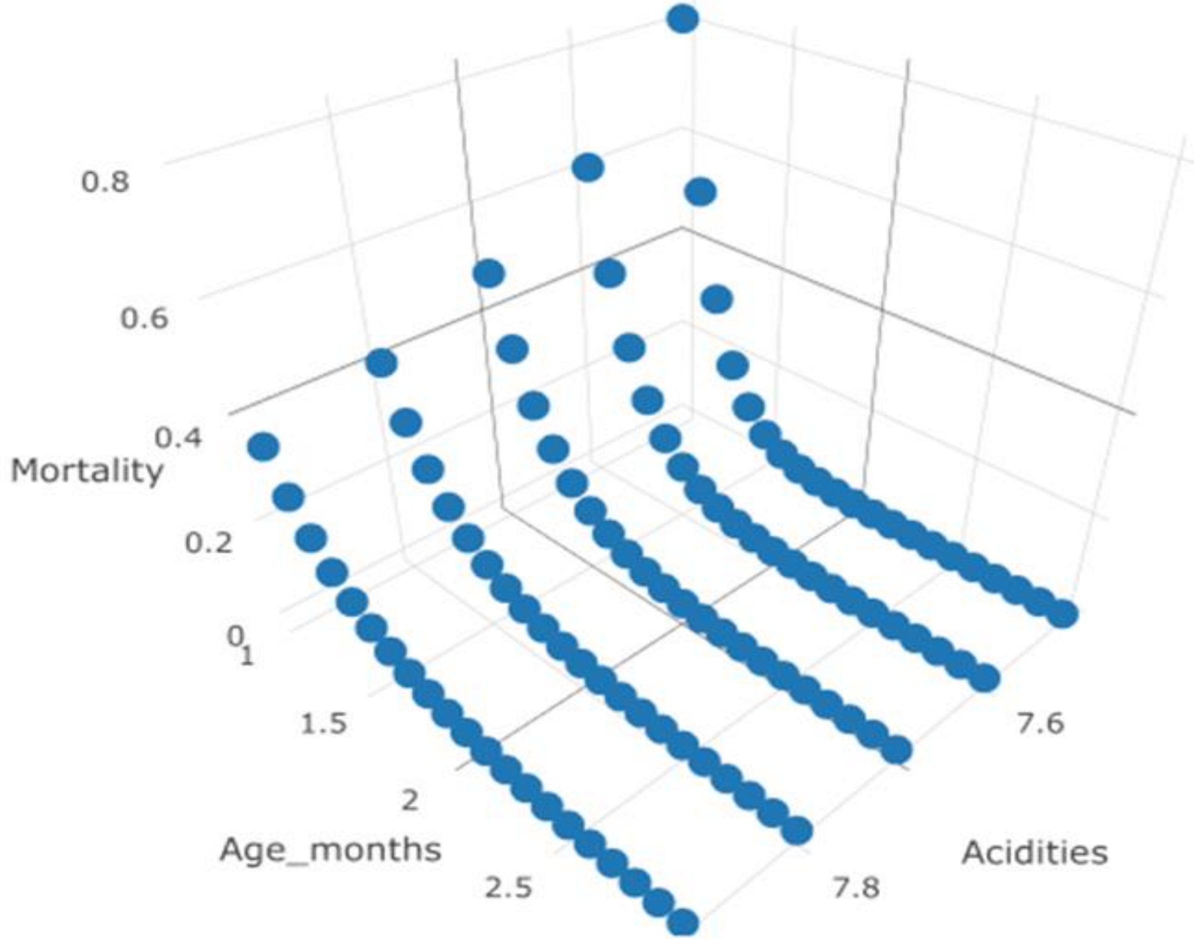


(a-1)
nuc
gly
Liver - Healthy
10 μm
(a-2)
nuc
lip
Liver - Intermediate
10 μm
(a-3)
nuc
Liver - Degraded
10 μm
(b-1)
nuc
Kidney - Healthy
10 μm
(b-2)
sta
nuc
sta
Kidney - Intermediate
10 μm
(b-3)
nuc
deg
Kidney - Degraded
10 μm
(c-1)
Pancreas - Healthy
10 μm
(c-2)
lip
deg
Pancreas - Intermediate
10 μm
(c-3)
nec
Pancreas - Degraded
10 μm

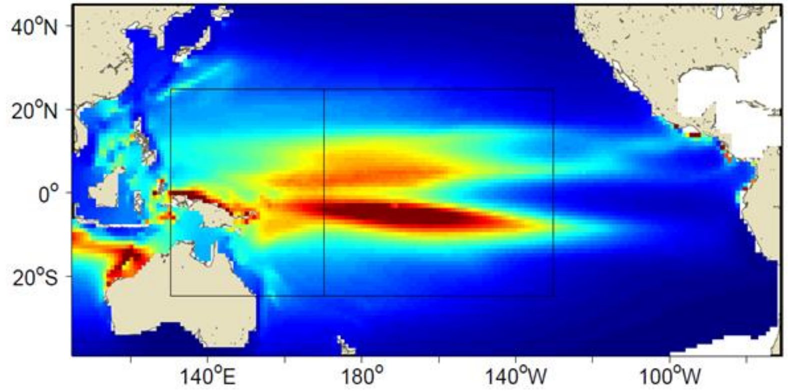
Effect Size Analysis : Organ Damage and Survival vs. pH



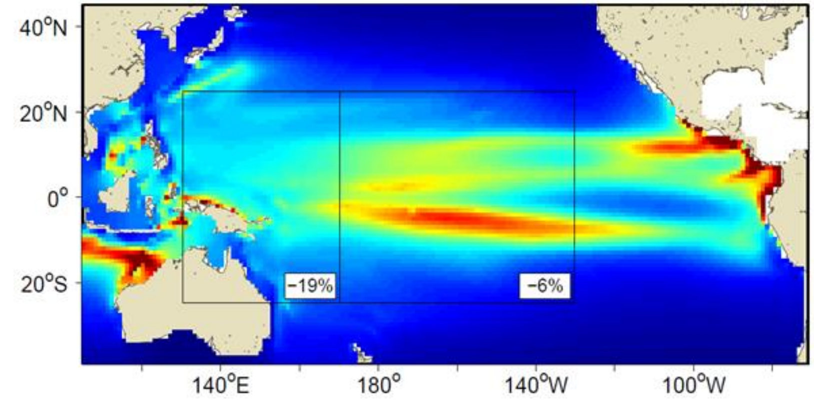
OA Workshop Estimate: Larval YFT Daily Mortality vs. Ocean pH vs. Larval Age



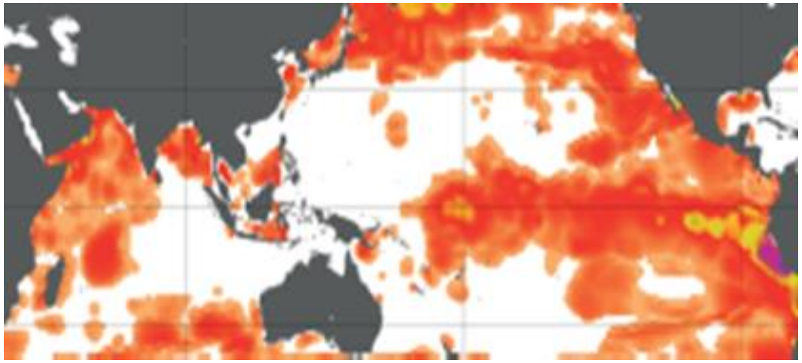
Yellowfin Distribution : 2005
(Lehodey et al. 2016)



Yellowfin Distribution: 2050
(Lehodey et al. 2016)

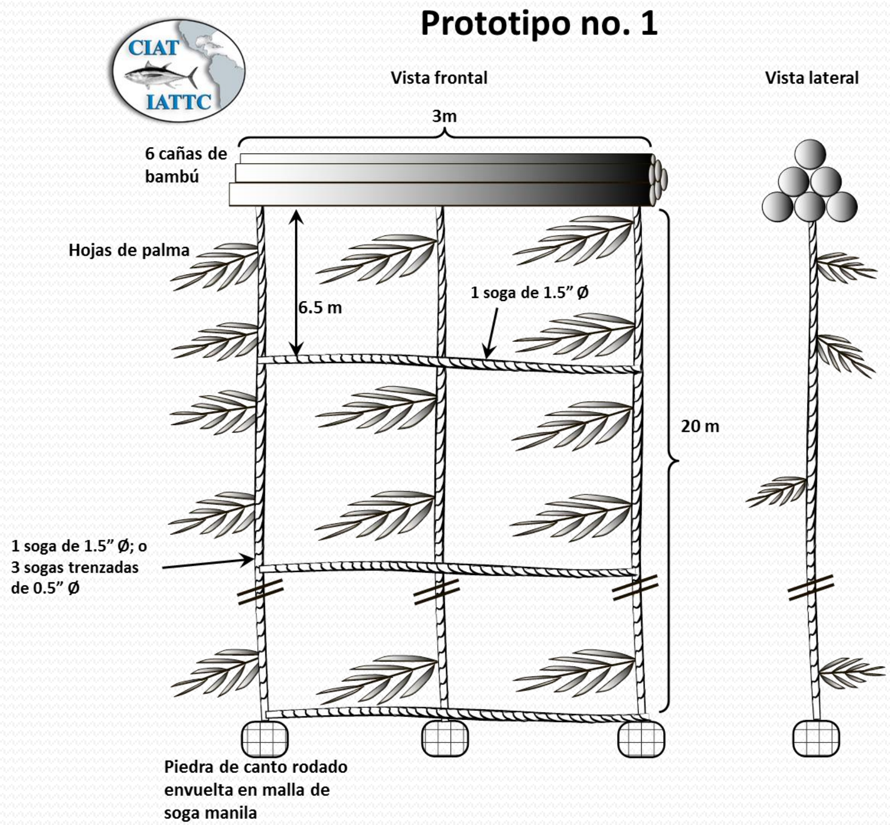


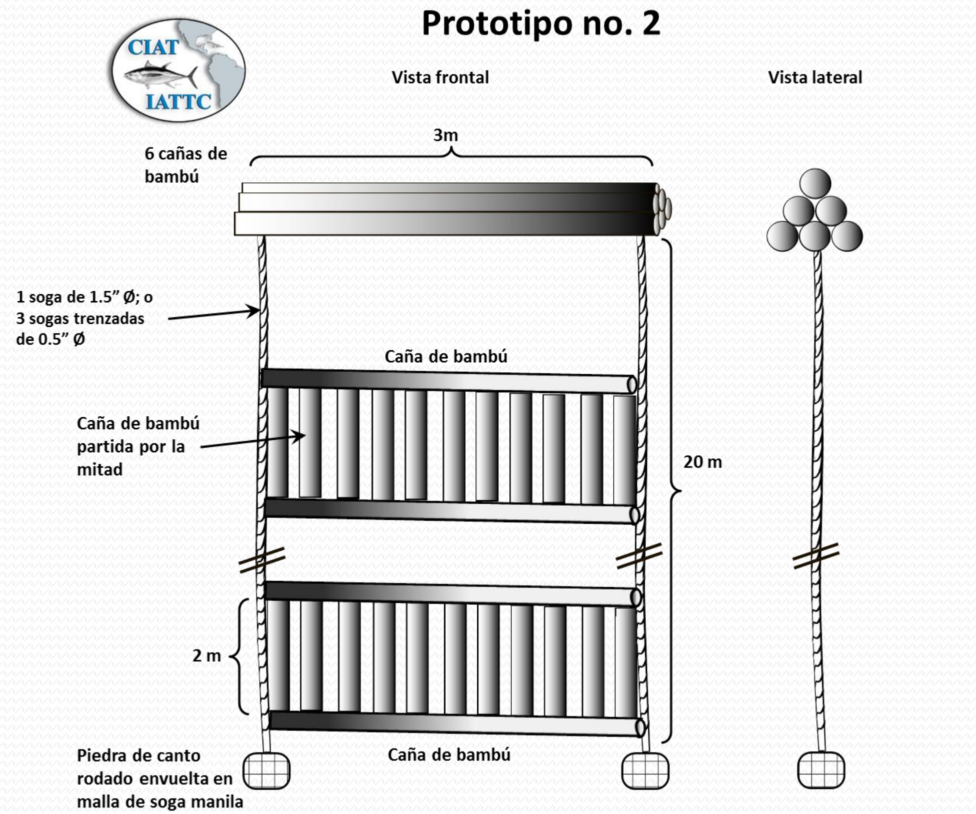
Ocean Acidification Hotspots : 2050 – 2100
(McNeil and Sasse 2016)



- SEAPODYM Predictions of Yellowfin Distributions in Pacific from 2005-2050 (Top)
- Prediction of Ocean Acidification Hotspots in the Pacific from 2050-2100 (Bottom)

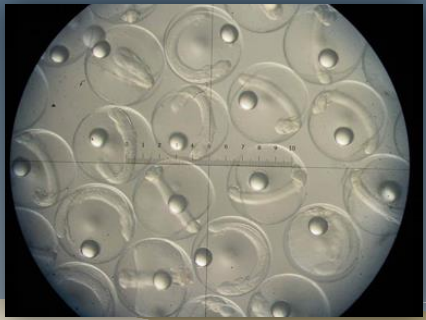
Feasibility study on the use of non-entangling and biodegradable materials for FADs [Bycatch research program, IATTC]
Martin Hall and Marlon Roman, EU funded





Acoustic studies of 40-60 cm yellowfin tuna
International Seafood Sustainability Foundation (ISSF)

Drs. Gala Moreno and Guillermo Boyra

Achotines Laboratory : Yellowfin Research Program

Studies of yellowfin tuna: 19 years of research have yielded important findings related to spawning, growth and genetics of adult yellowfin and key factors affecting survival in prerecruit stages

Potential tools for use in stock assessment

- Larval or juvenile growth indices
- Analysis of windspeed vs. recruitment
- Early life history of yellowfin vs. Pacific bluefin
- Impact of ocean acidification on yellowfin spawning and nursery habitat
- Juvenile studies now possible with fish that are 1-6 months old