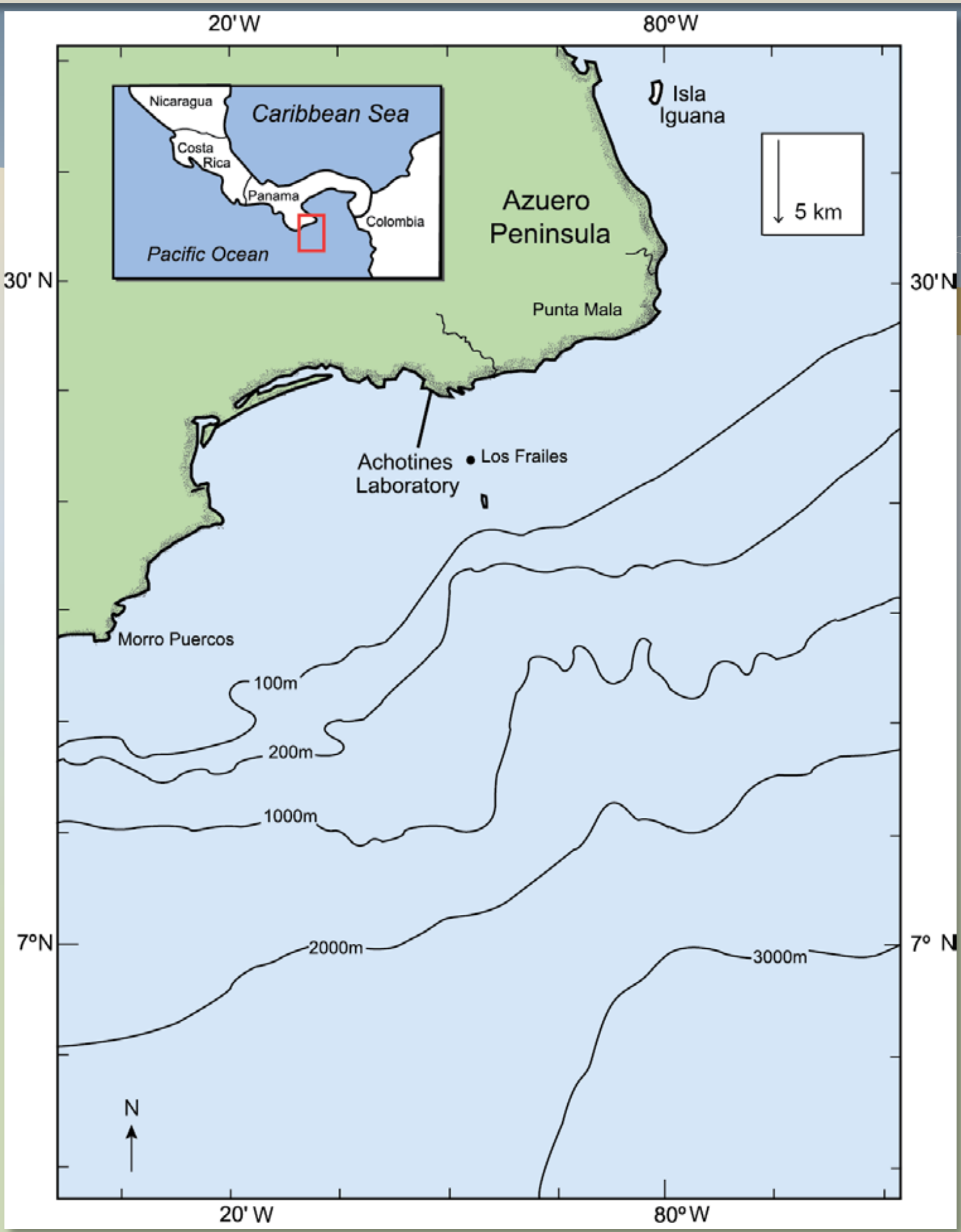
Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

Achotines Laboratory: Review of research

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

Location of Achotines Laboratory

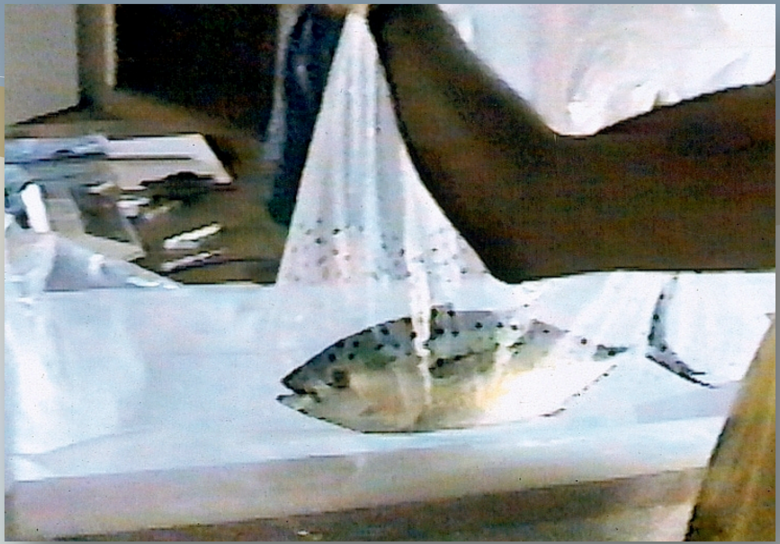


Research on coastal tropical scombrids (1986-1996)

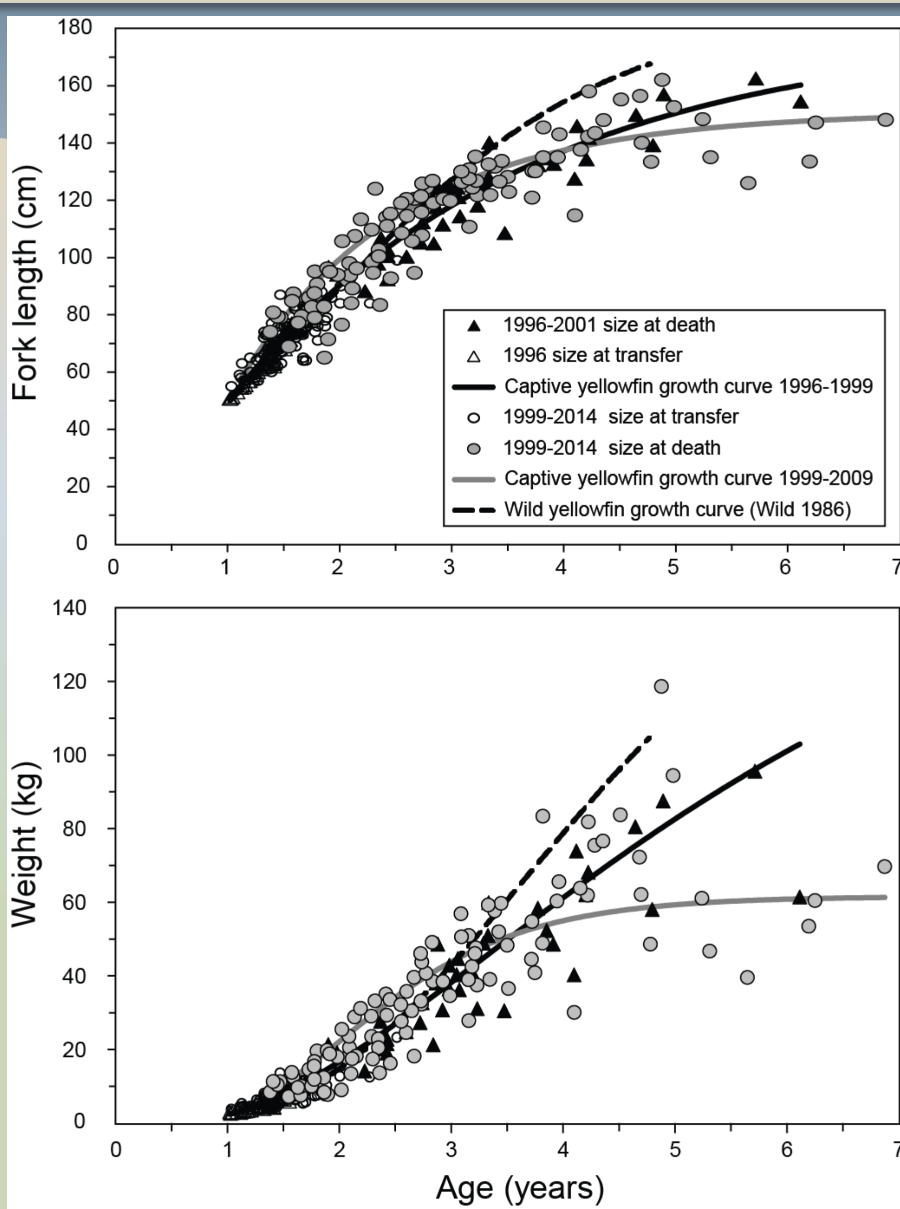
- Spatial and temporal distribution of larvae
- Estimates of *in situ* starvation rates of larvae: > 45%/day
- Larval diets in the Panama Bight

Nighlight Surveys: Growth Dynamics

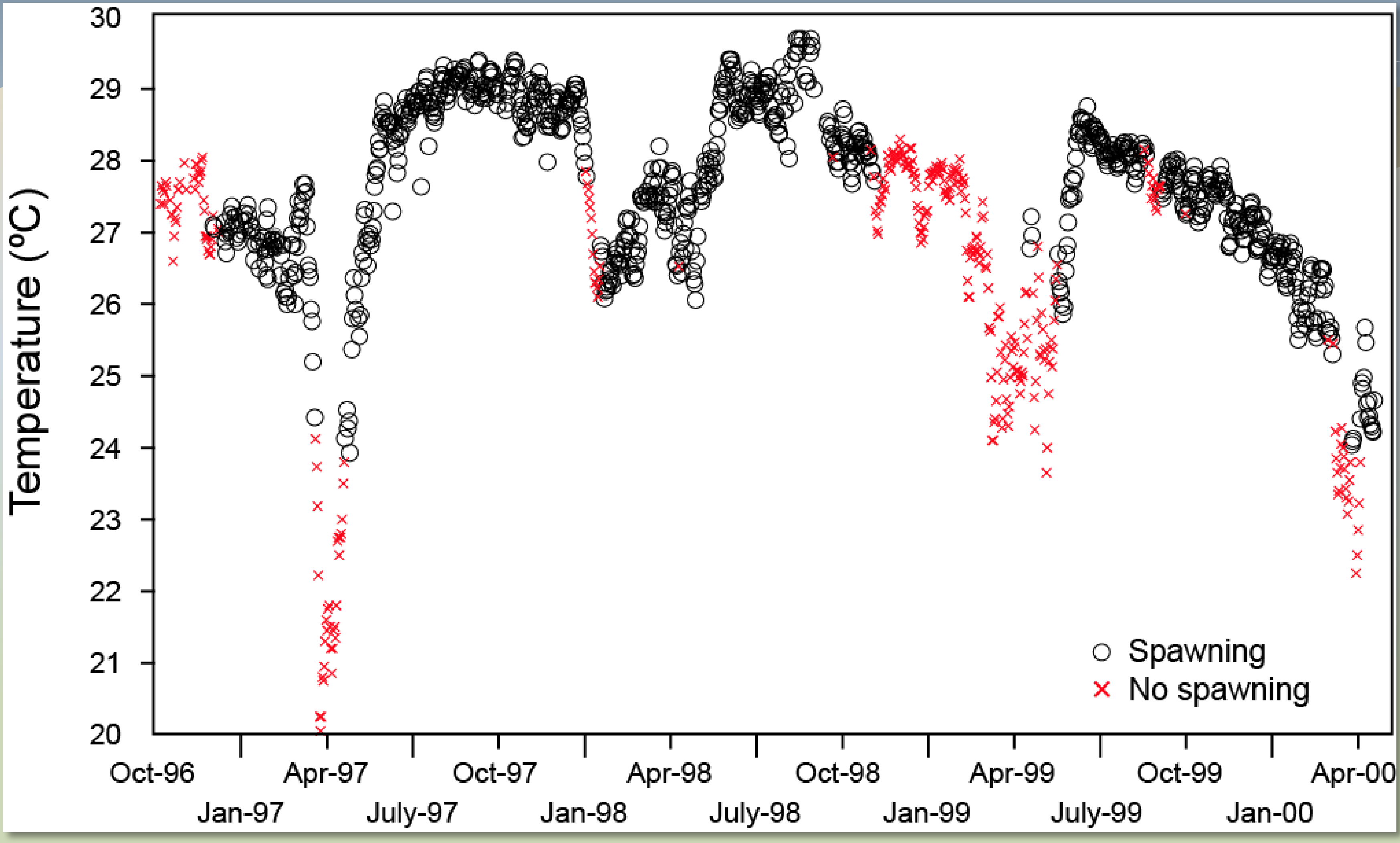
Research on yellowfin tuna (1996 to present)



Growth and estimated ages of captive and wild yellowfin



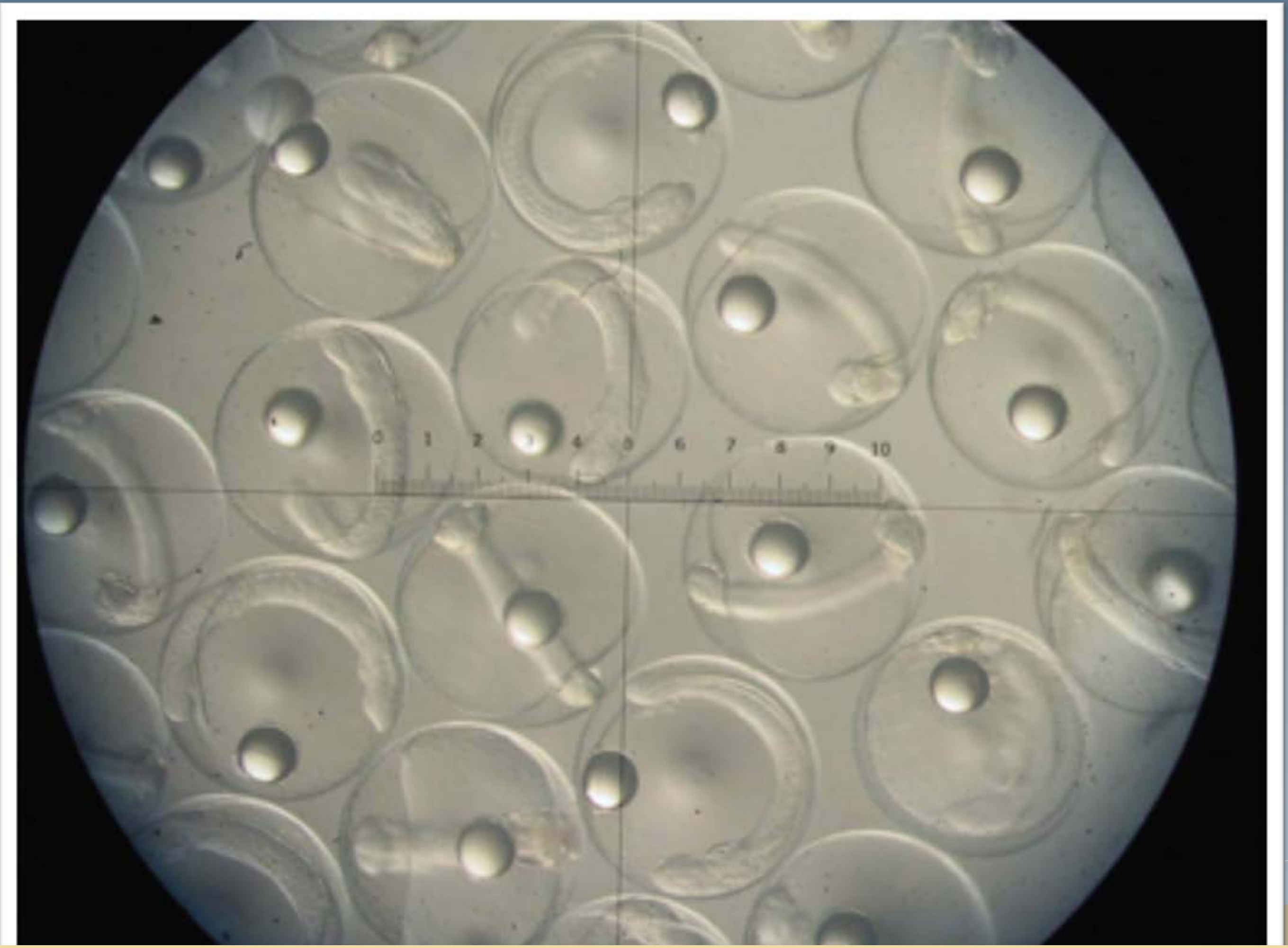
Relationship between water temperature and the occurrence of yellowfin spawning in captivity from 1996 - 2000



Yellowfin tuna

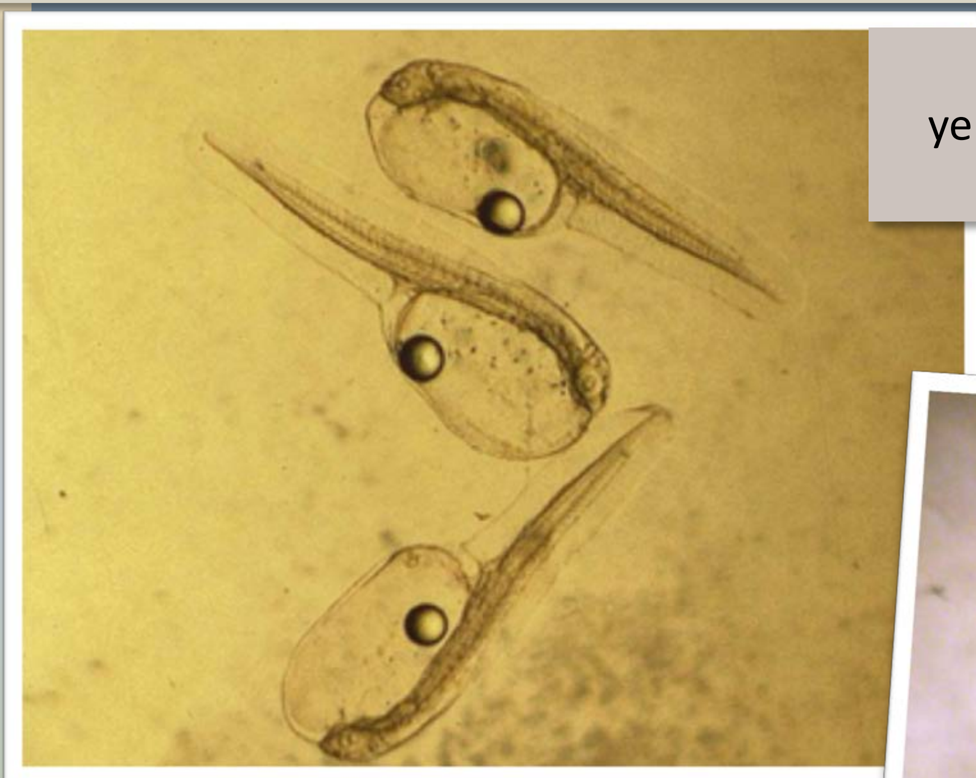
Rare footage of tunas spawning

Yellowfin tuna eggs



Fertilized yellowfin tuna eggs produced by broodstock held at the Achotines Laboratory

Yellowfin larvae



Newly hatched yolk-sac larvae of yellowfin, 2.6 millimeters in length, 0.5 days post hatching

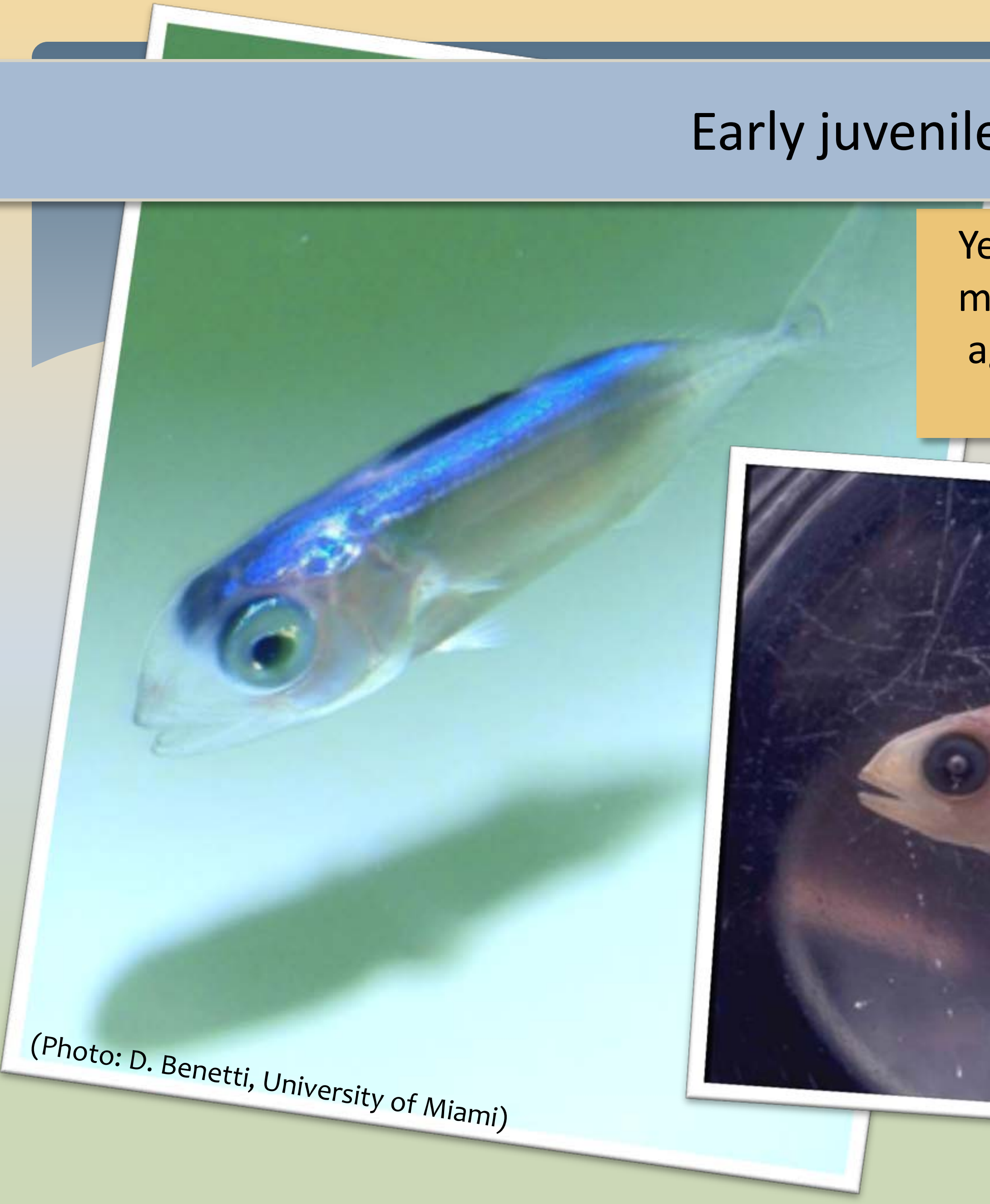
First-feeding yellowfin larvae, 3.2 millimeters in length, 2.5 days post hatching

Yellowfin larvae

14 days post hatching yellowfin larva (7.5 mm standard length) feeding on fish larvae

Yellowfin tuna late-larva prior to juvenile transformation, ca. 11.0 mm in length, 16 days of age, collected by nightlighting in the Panama Bight

Early juveniles



(Photo: D. Benetti, University of Miami)

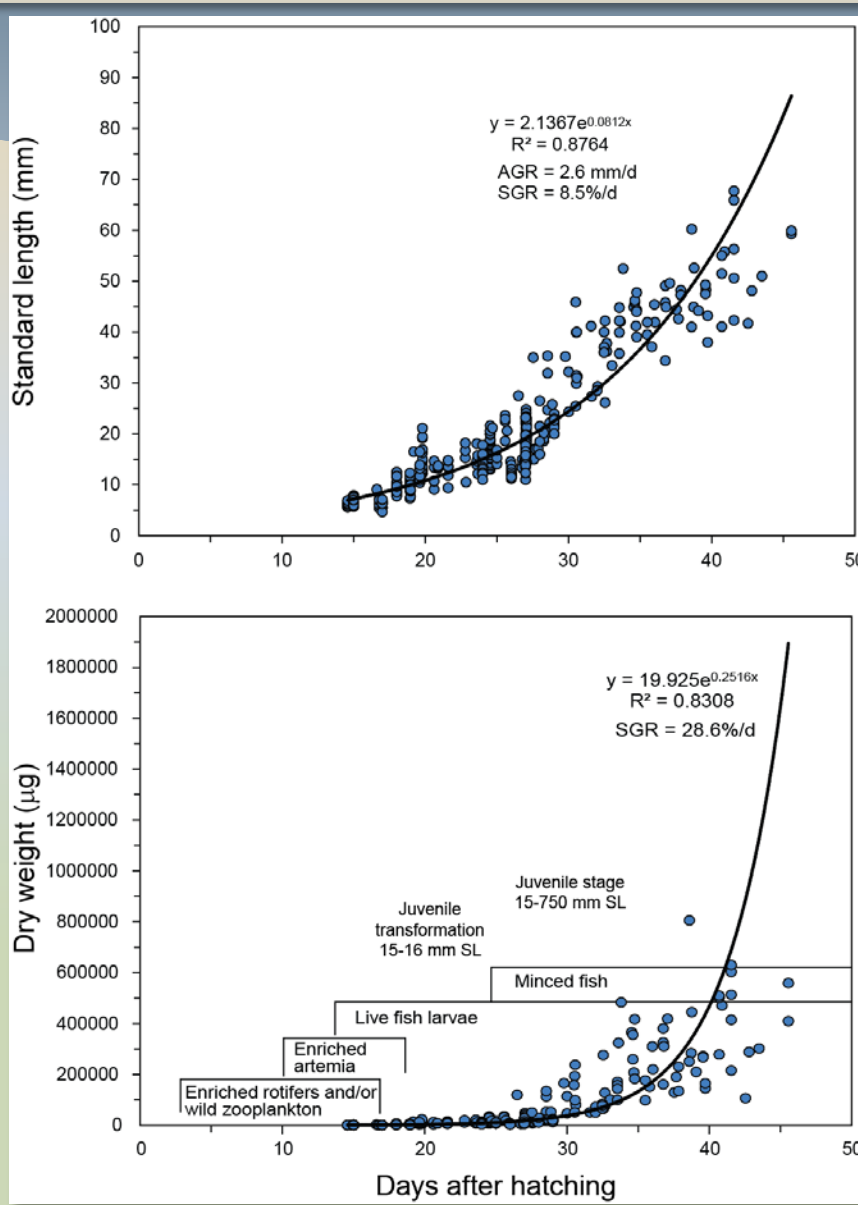
Yellowfin tuna early juvenile, 25 millimeters in length, 30 days of age, hatched in captivity at the Achotines Laboratory

Yellowfin tuna early juvenile, 35 millimeters in length, ca. 35 days of age

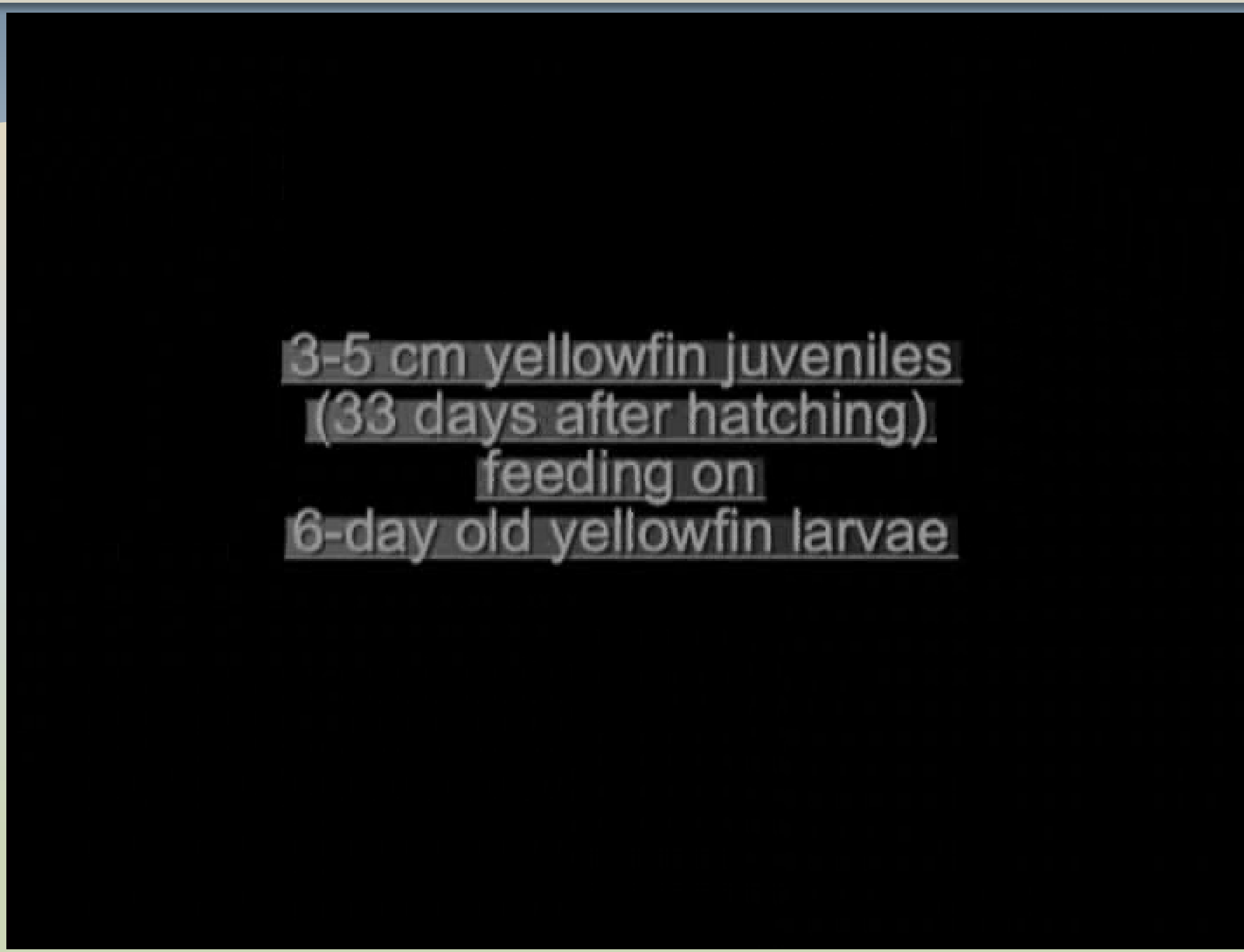
Egg and first feeding larvae

Footage taken by the BBC at the Achotines Laboratory

Laboratory growth of late-larval and early juvenile yellowfin



Early juvenile yellowfin video

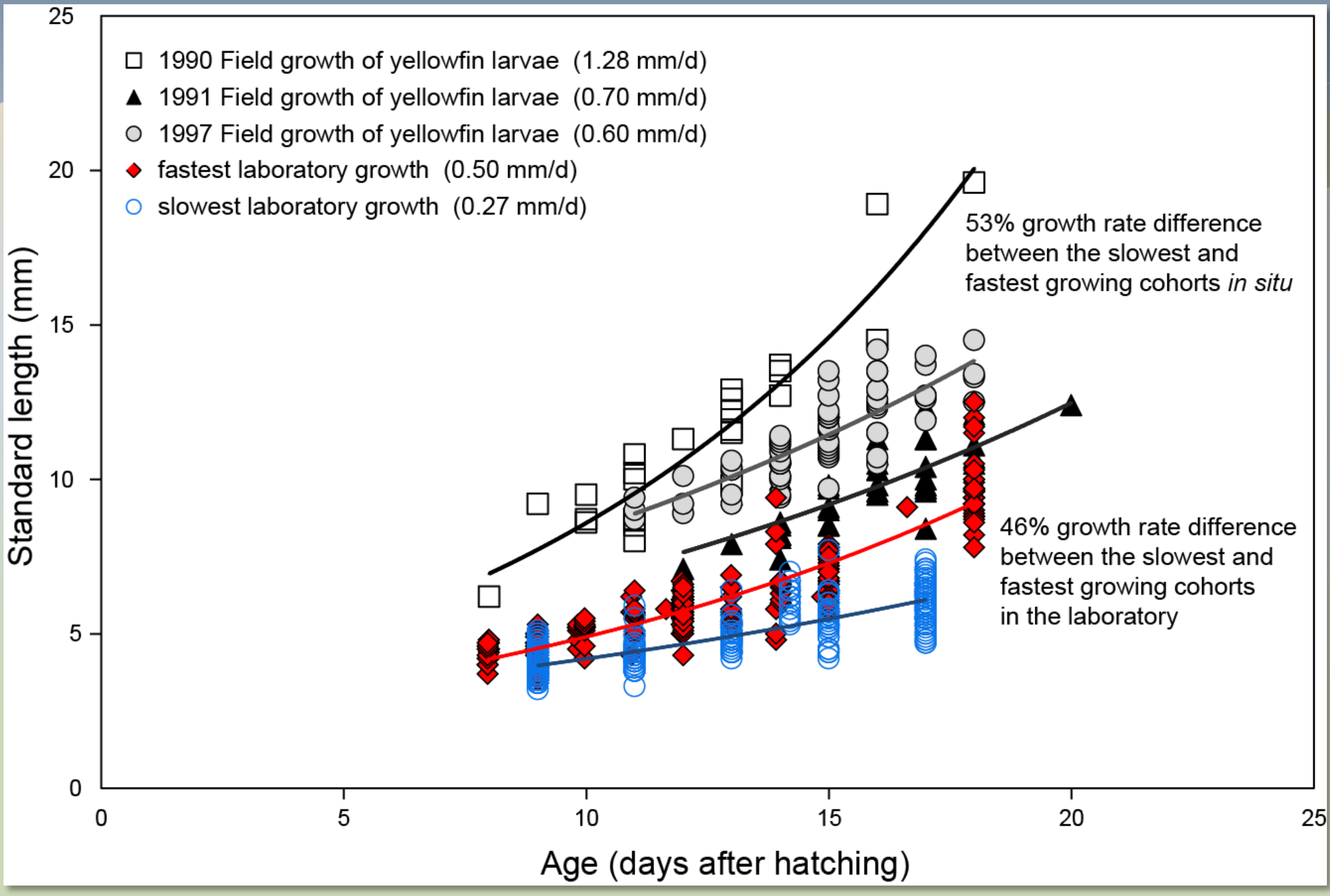


3-5 cm yellowfin juveniles (33 days after hatching) feeding on 6-day old yellowfin larvae

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)	3.11×10^7 individuals	157.3 ± 13.53 106.5 - 310.4
Sept 1991	0.60(0.033)	1.44×10^7 individuals	62.8 ± 5.86 43.7 - 102.4
Aug 1997	0.71(0.038)	3.06×10^7 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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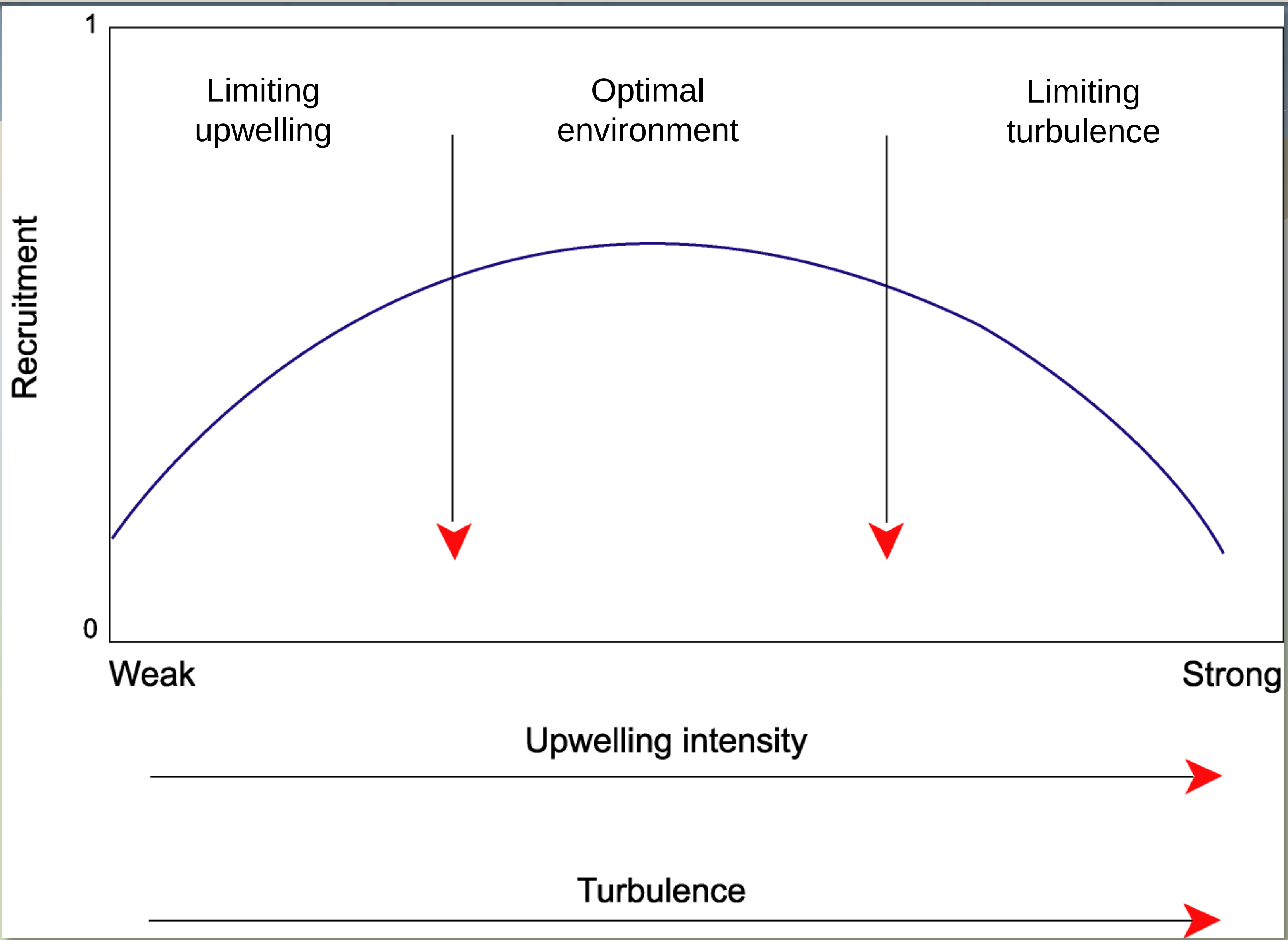
Figure 10 Relationship between turbulence and recruitment success hypothesized by Cury and Roy. (Redrawn from Cury and Roy, 1989.)



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

Turbulent energy dissipation rate

*(This model is adapted for small-scale microturbulence environments and estimates "**ε**" as the variance of a single component of shear*)

$$\boldsymbol{\varepsilon} = \mathbf{7.5v}\left(\frac{du}{dz}\right)^2$$

Where: **ε = turbulent energy dissipation rate**

v = molecular kinematic viscosity (10^{-6} m^{2}s^{-1})

u = a velocity component transverse to the direction of motion *z* of the ADV probe

(Kimura *et al.* 2004)

Boundary layer model of turbulent dissipation:

$$\boldsymbol{\varepsilon = 5.82 \times 10^{-9}} W^{3} / Z$$

Where

ε = turbulent dissipation rate ($m^2\ s^{-3}$)

W = windspeed ($m\ sec^{-1}$)

Z = depth (m)

(MacKenzie and Leggett, 1993)

And

$$w^2 = \mathbf{3.6\ (\varepsilon r)^{2/3}}$$

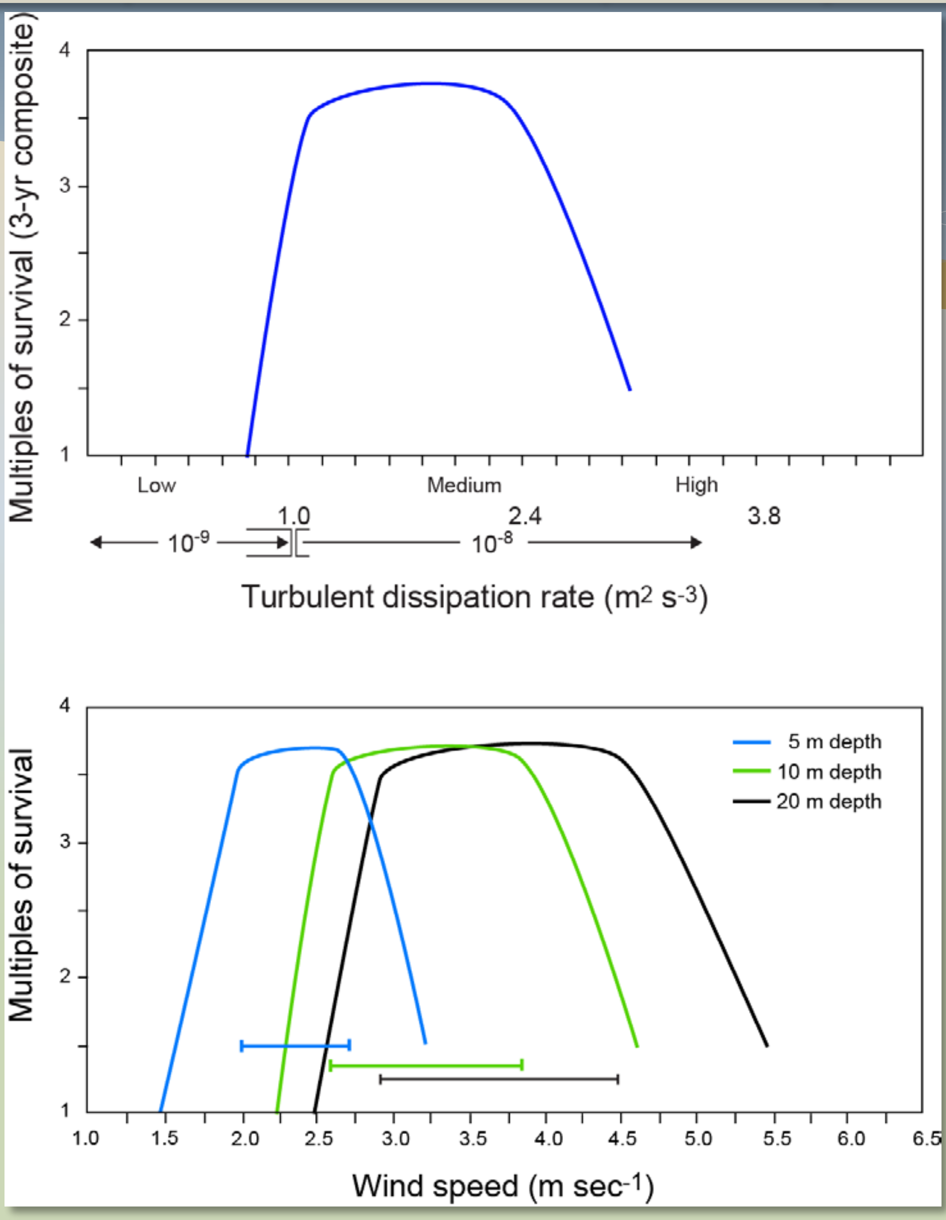
Where

w = turbulent velocity ($cm\ sec^{-1}$)

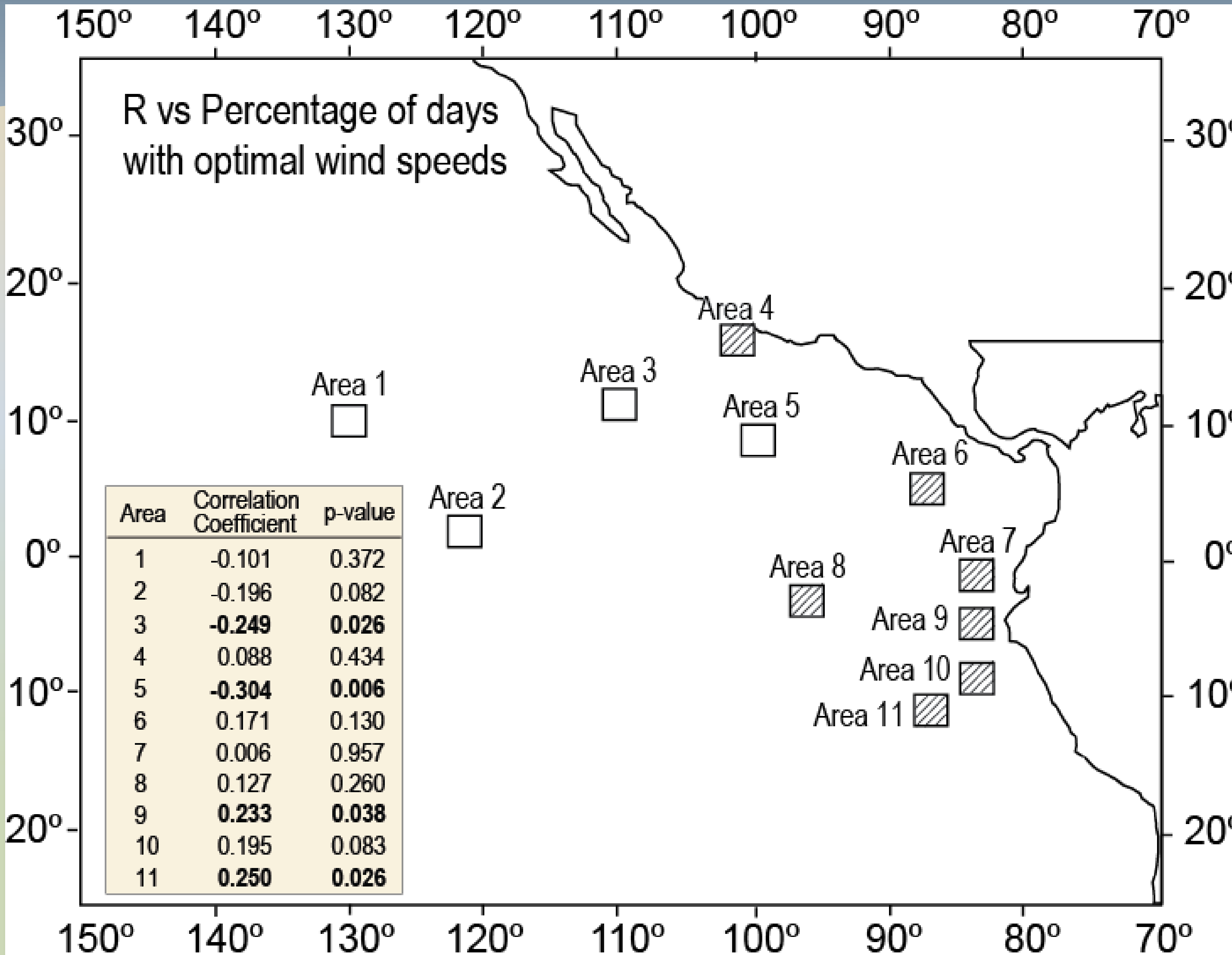
r = separation distance between predator and prey (m)

(MacKenzie *et al.*, 1994)

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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Science and technology research partnership for sustainable development (SATREPS)

5-YEAR PROJECT FUNDED BY JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) AND JAPAN SCIENCE AND TECHNOLOGY AGENCY (JST)

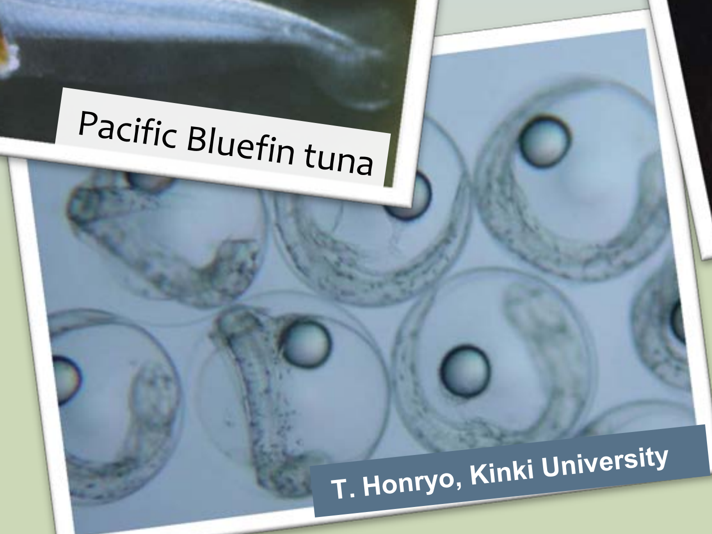
Fisheries Laboratory of Kinki University

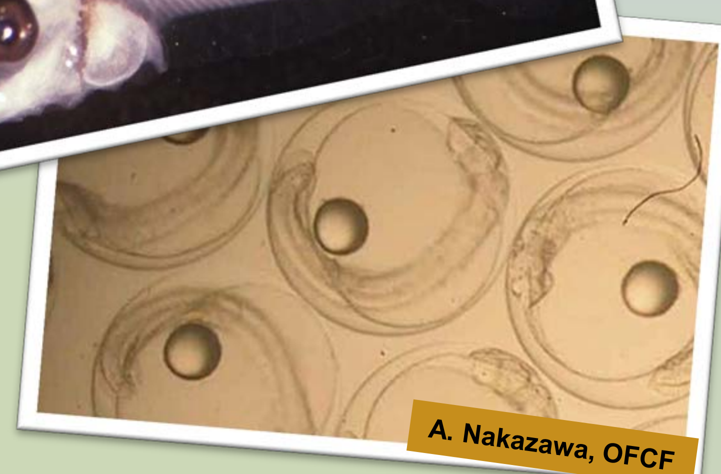
CIAT IATTC

Achotines Laboratory

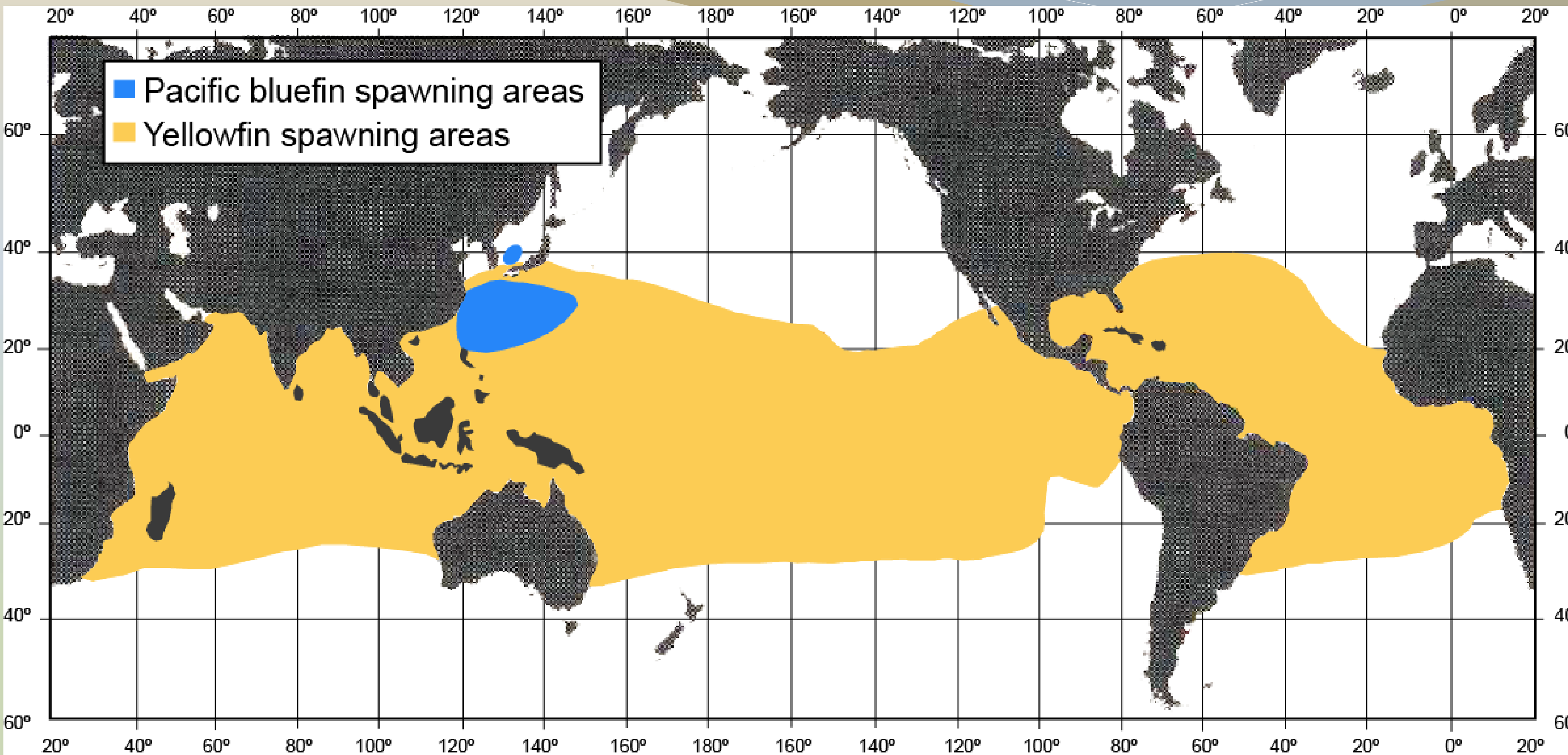
ARAP
AUTORIDAD DE LOS RECURSOS ACUÁTICOS DE PANAMÁ

Comparative studies of the early life history of Pacific bluefin tuna (*Thunnus orientalis*) and yellowfin tuna (*Thunnus albacares*) for the sustainable use of these resources





Spawning distributions of Pacific bluefin and yellowfin tuna




Honshu
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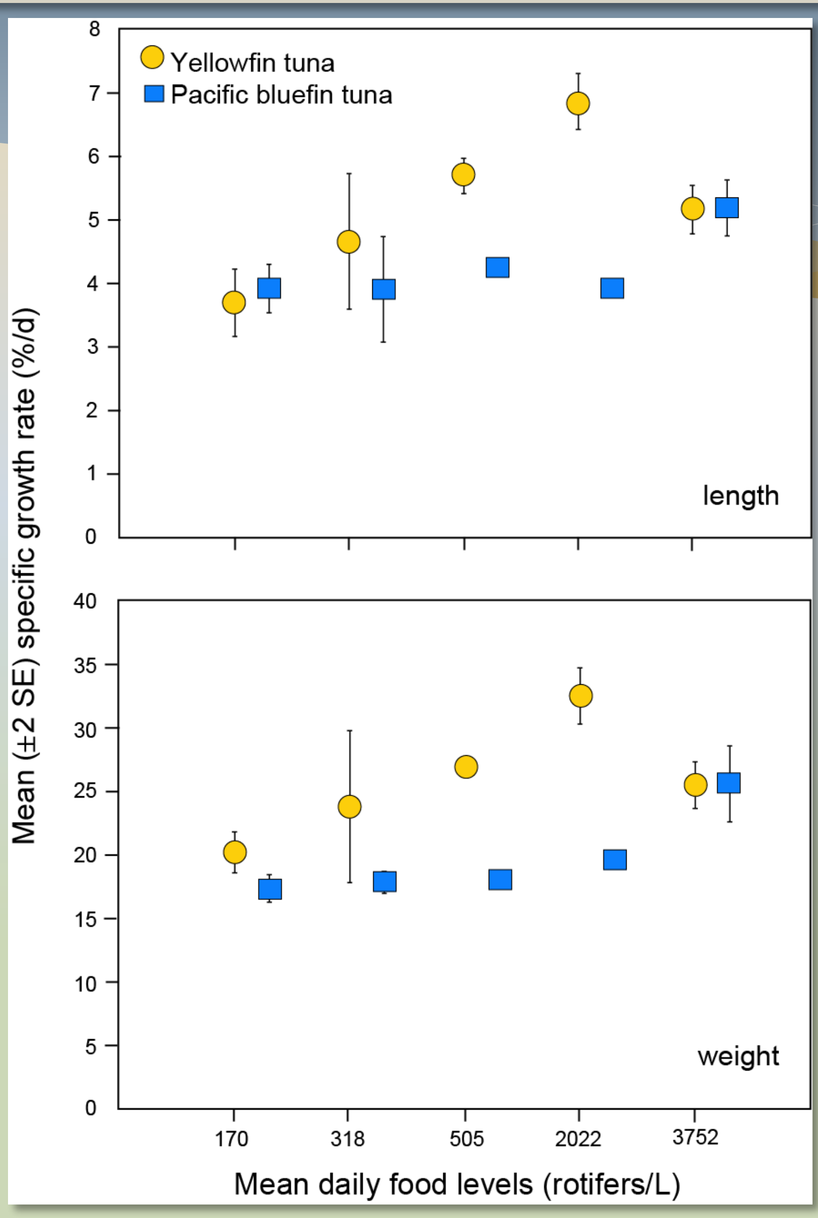
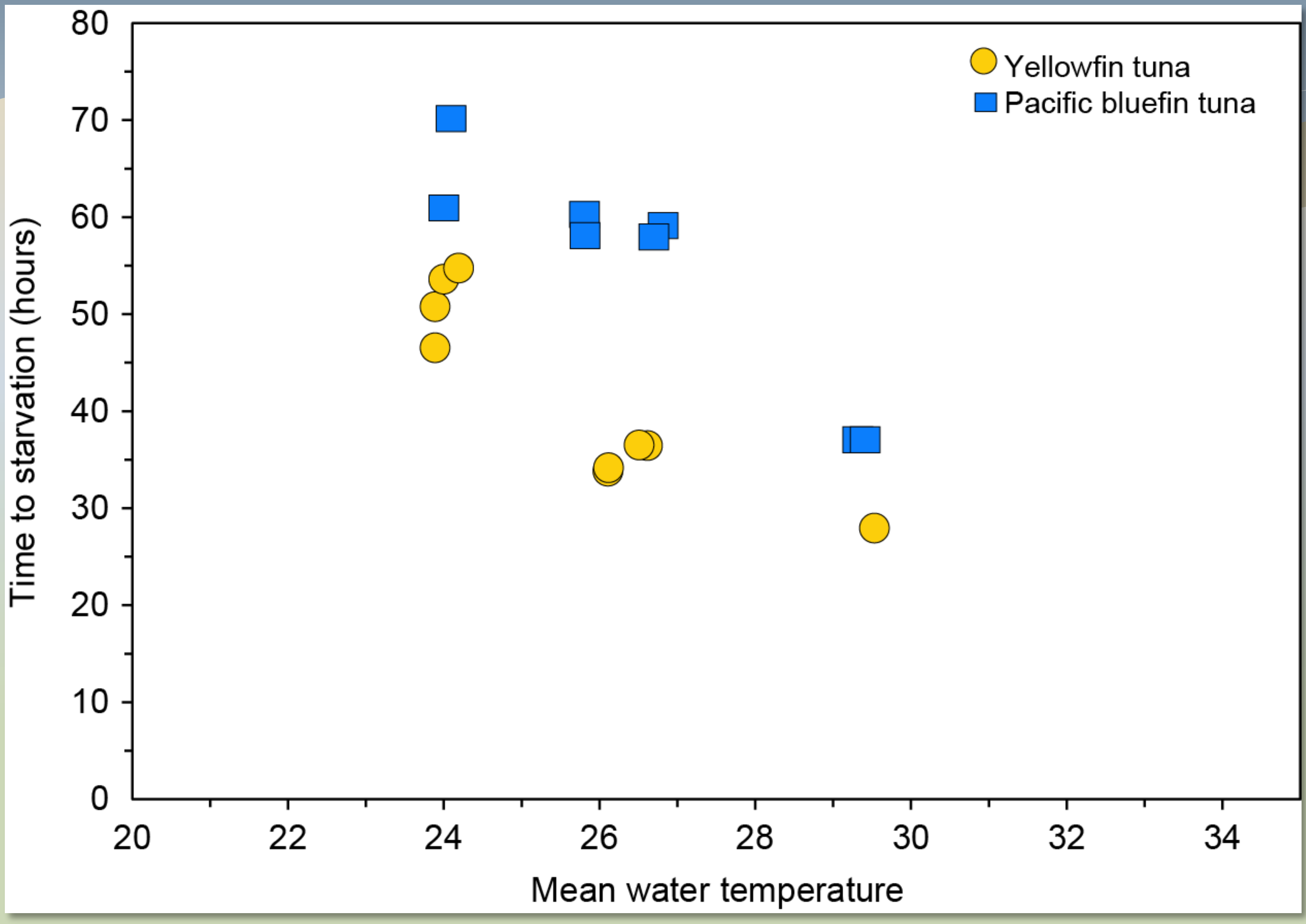
Wakayama
Prefecture
Amami Experiment Station
Oshima Experiment
Station

Growth of bluefin and yellowfin tuna larvae at different food levels



Time to starvation of bluefin and yellowfin tuna larvae at different water temperatures



Promising links between yellowfin early life research and stock assessment

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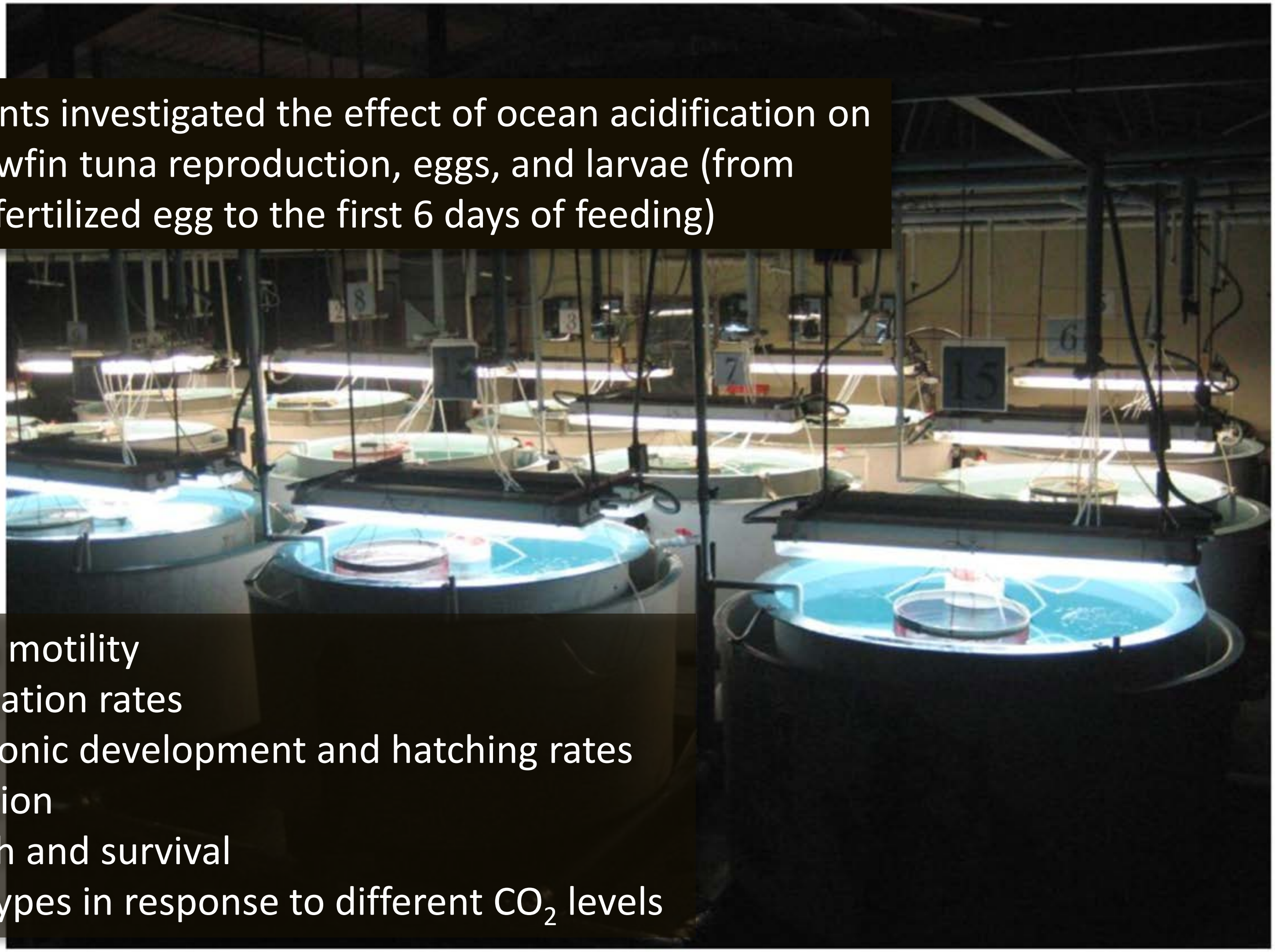
Ocean acidification impacts upon tropical tuna populations

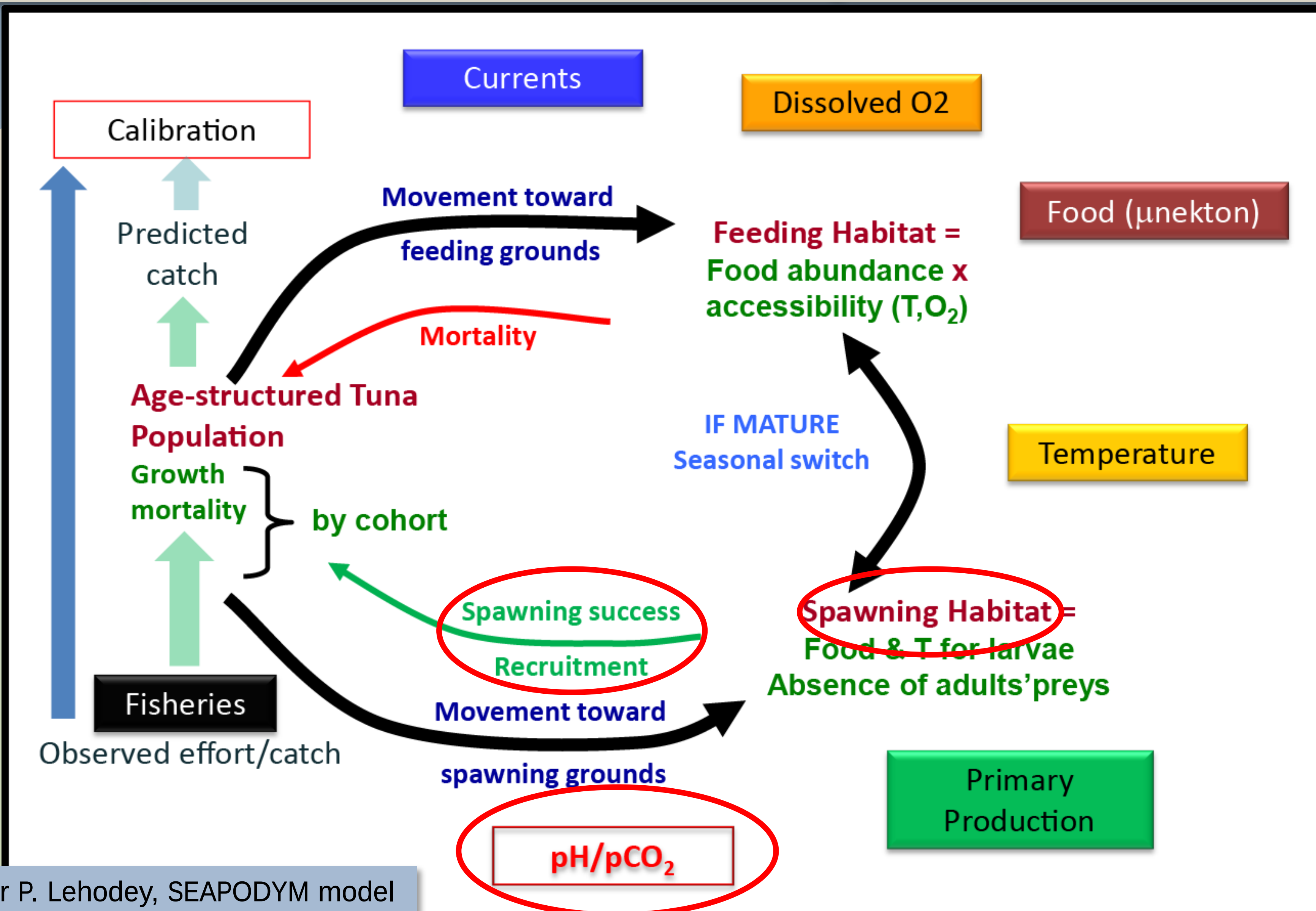
Don Bromhead, Vernon Scholey, Simon Nicol, Daniel Margulies, Jeanne Wexler, Maria Stein, Simon Hoyle, Cleridy Lennert-Cody, Jane Williamson, Jonathan Havenhand, Tatiana Ilyina, and Patrick Lehodey

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



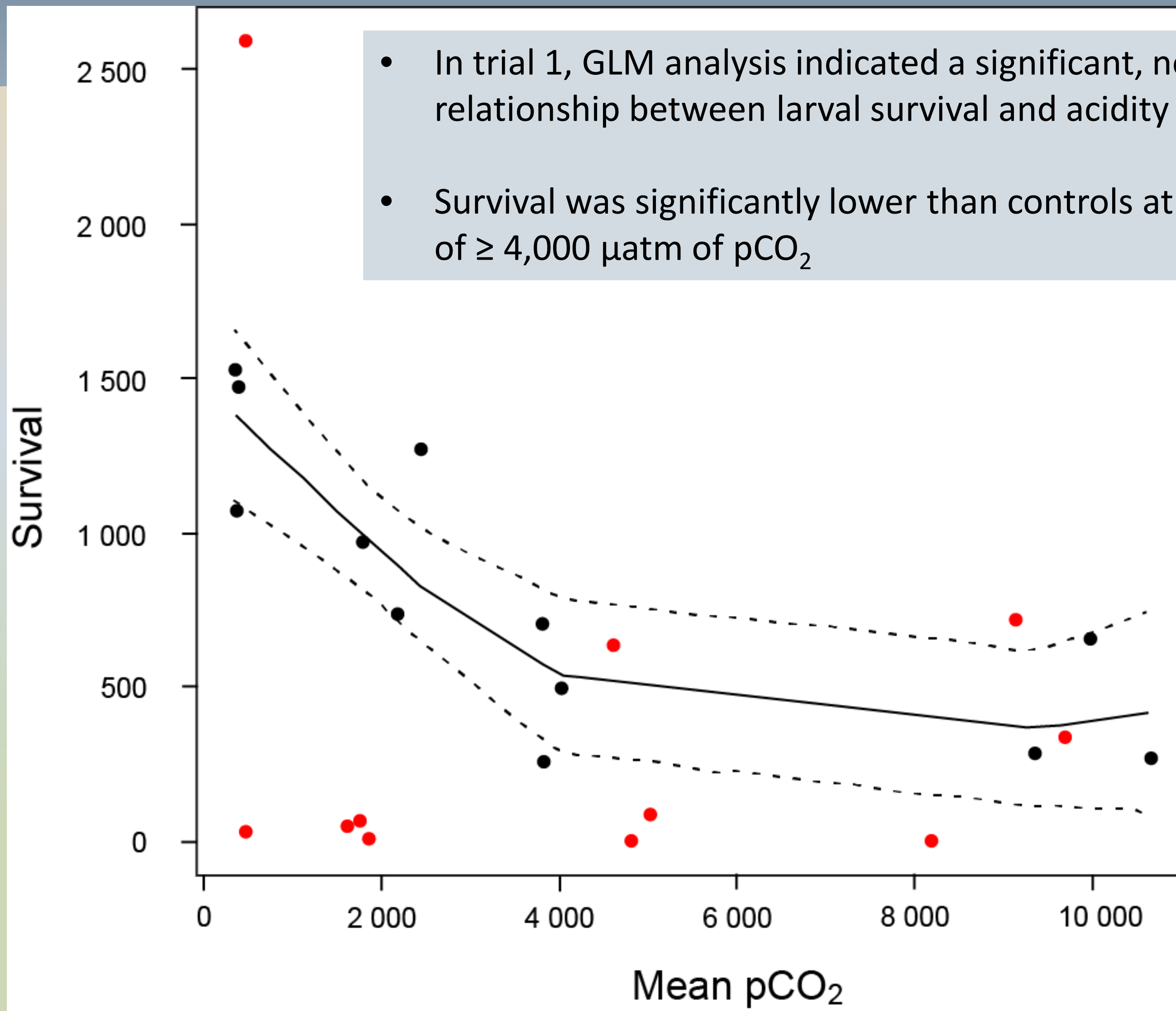
- Sperm motility
- Fertilization rates
- Embryonic development and hatching rates
- Condition
- Growth and survival
- Genotypes in response to different CO_2 levels

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



After P. Lehodey, SEAPODYM model

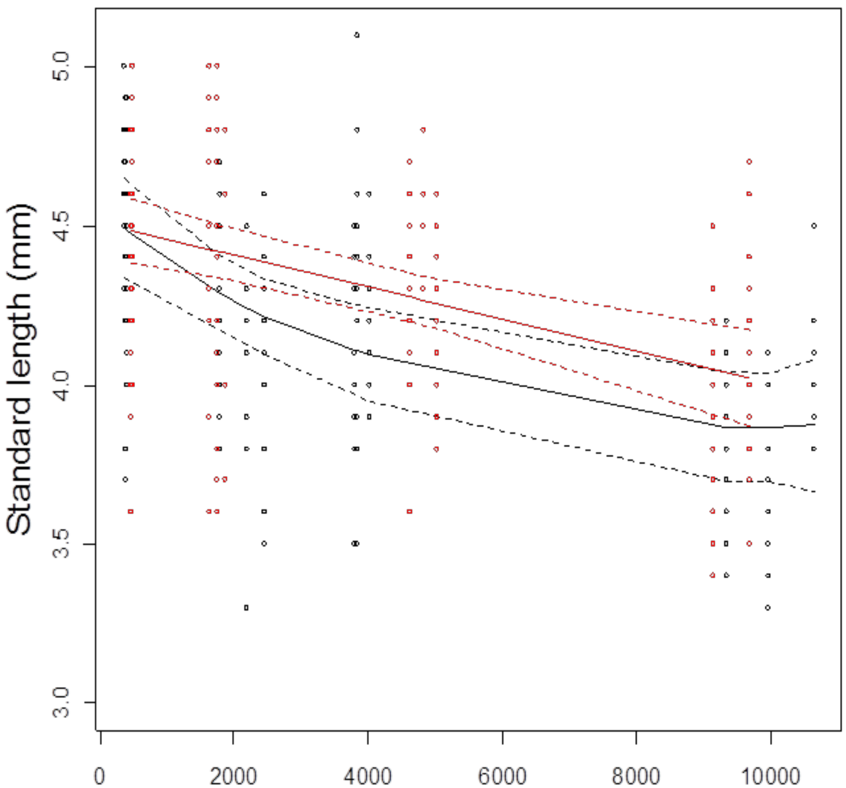
The effect of ocean acidification on survival of yellowfin larvae

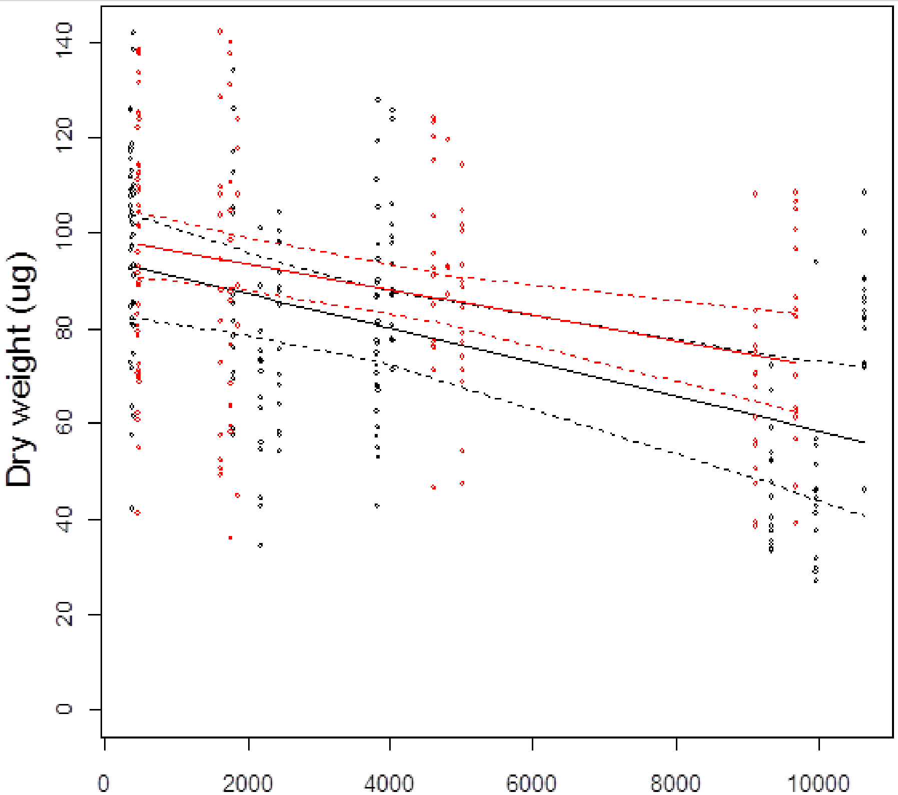


- In trial 1, GLM analysis indicated a significant, non-linear relationship between larval survival and acidity
- Survival was significantly lower than controls at acidity levels of ≥ 4,000 µatm of pCO_2

The effect of ocean acidification on growth of yellowfin larvae

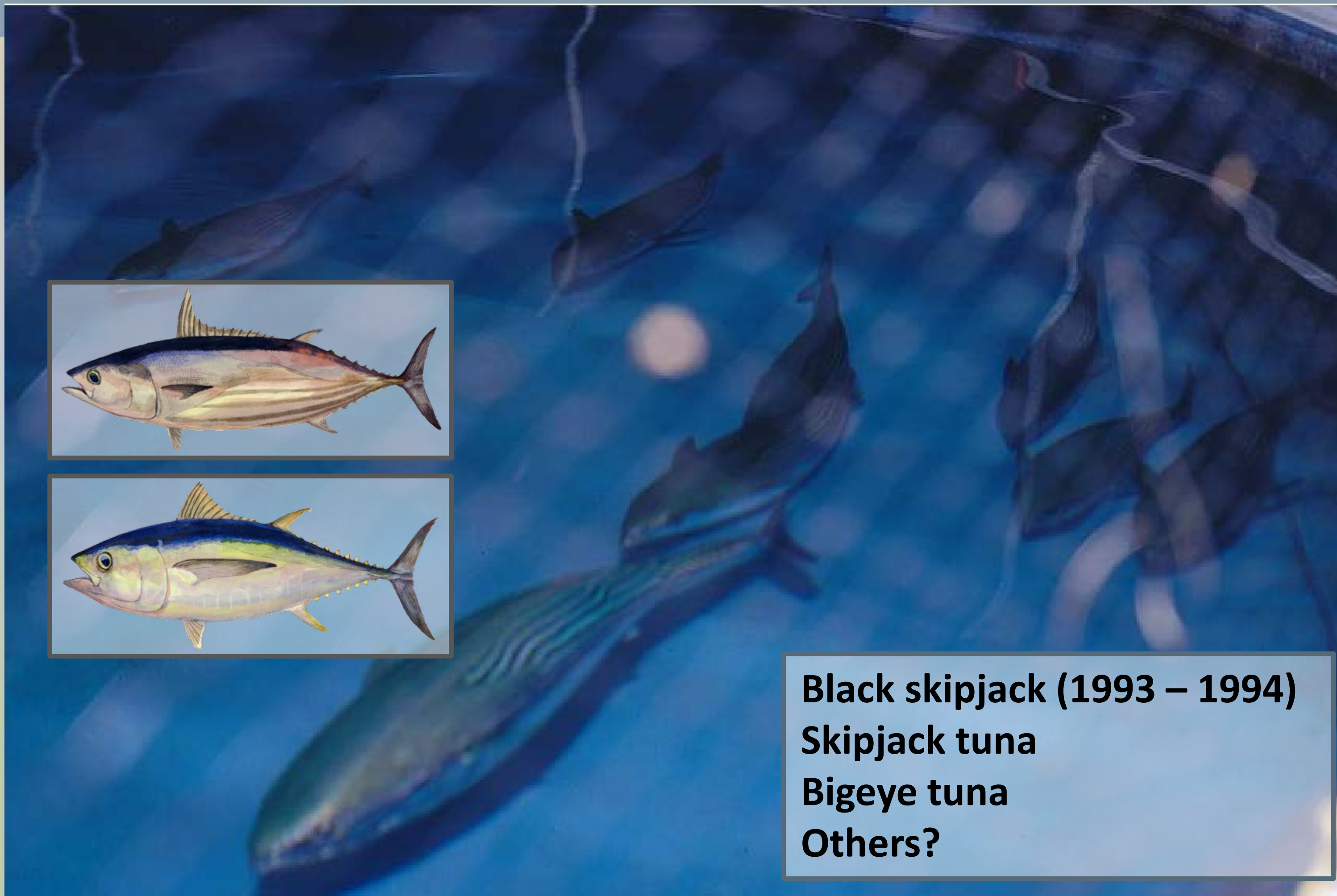
- GAMMs indicated significantly negative relationships between size of larvae and pCO_2
- In trial 1, standard length of larvae was significantly smaller than controls at acidity levels ≥ 2,100 µatm of pCO2; dry weights of larvae were significantly less than controls at acidity levels ≥ 8,800 µatm of pCO_2



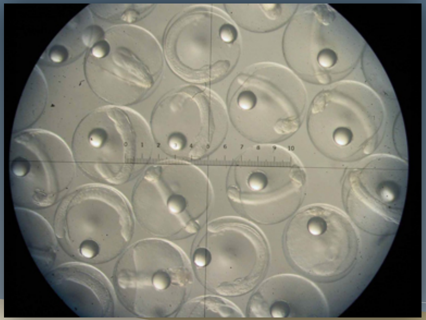
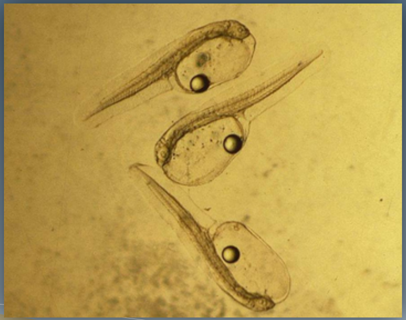


Mean pCO_2

Other potential species for study at Achotines Laboratory



Black skipjack (1993 – 1994)
Skipjack tuna
Bigeye tuna
Others?


Studies of coastal scombrids: first description of growth dynamics, starvation rates, and temporal and spatial distribution of larval scombrids

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