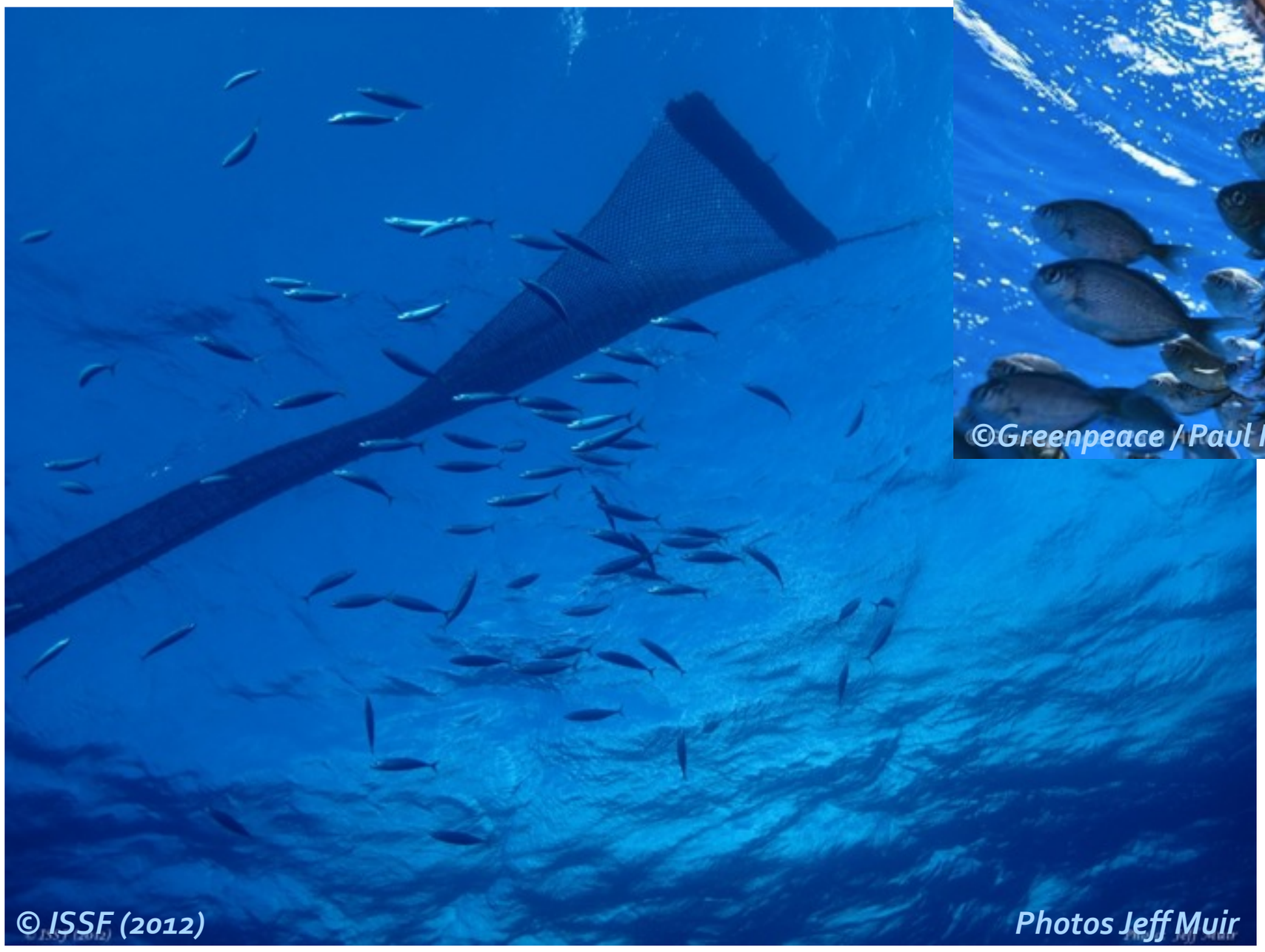
Simulation study on the distribution of skipjack tuna in relation to FADs during ENSO

Eunjung Kim and John R. Sibert

kimeunju@hawaii.edu
Department of Oceanography,
University of Hawaii at Manoa

Photo Jeff Muir

Fish under a FAD



© ISSF (2012)

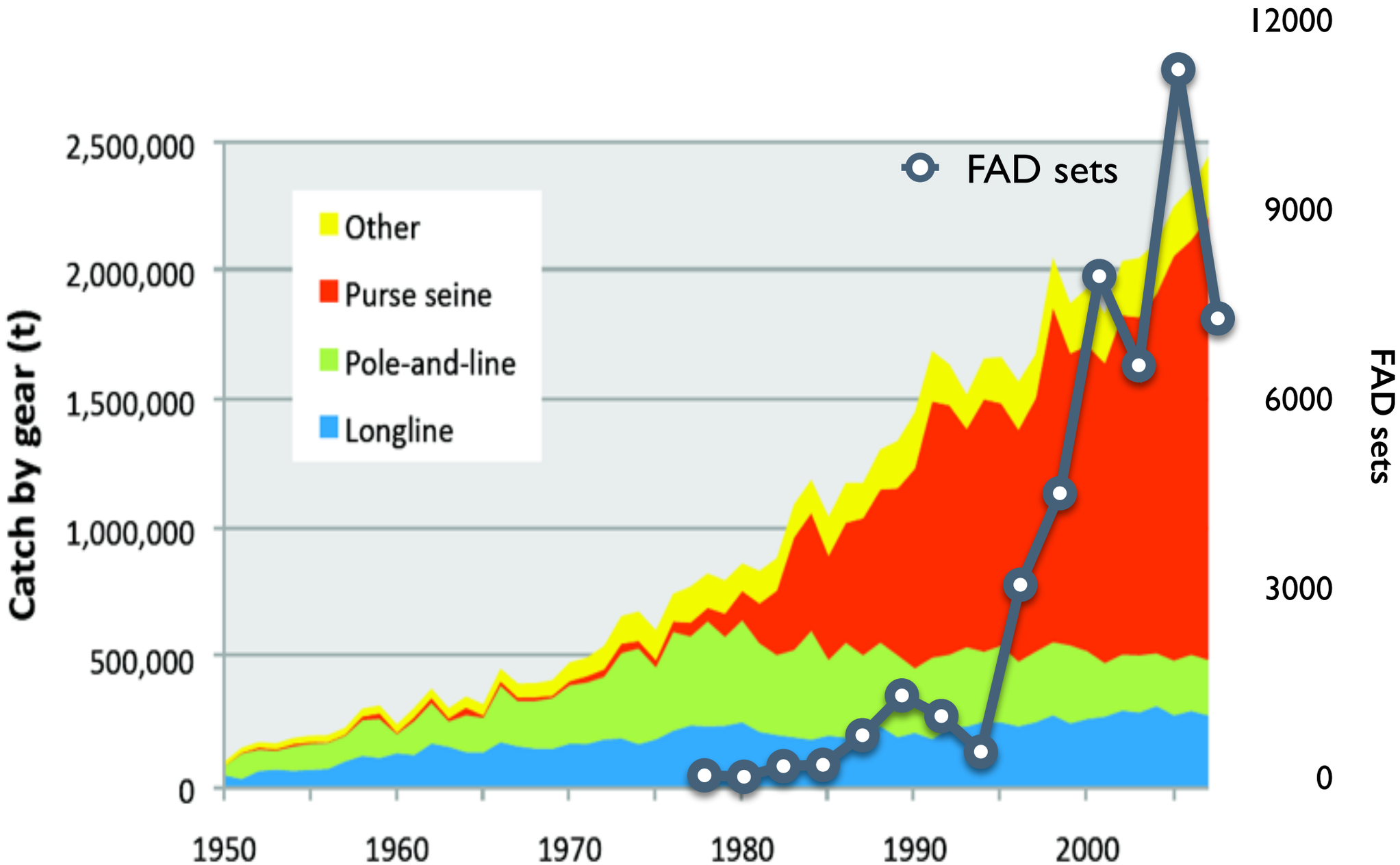
Photos Jeff Muir

©Greenpeace / Paul Hilton

video

Video by Jeff Muir (ISSF)

Tuna fisheries by fishing types and FADs sets in the Western and Central Pacific Ocean (WCPO)



Hampton 2008, SPC fisheries data

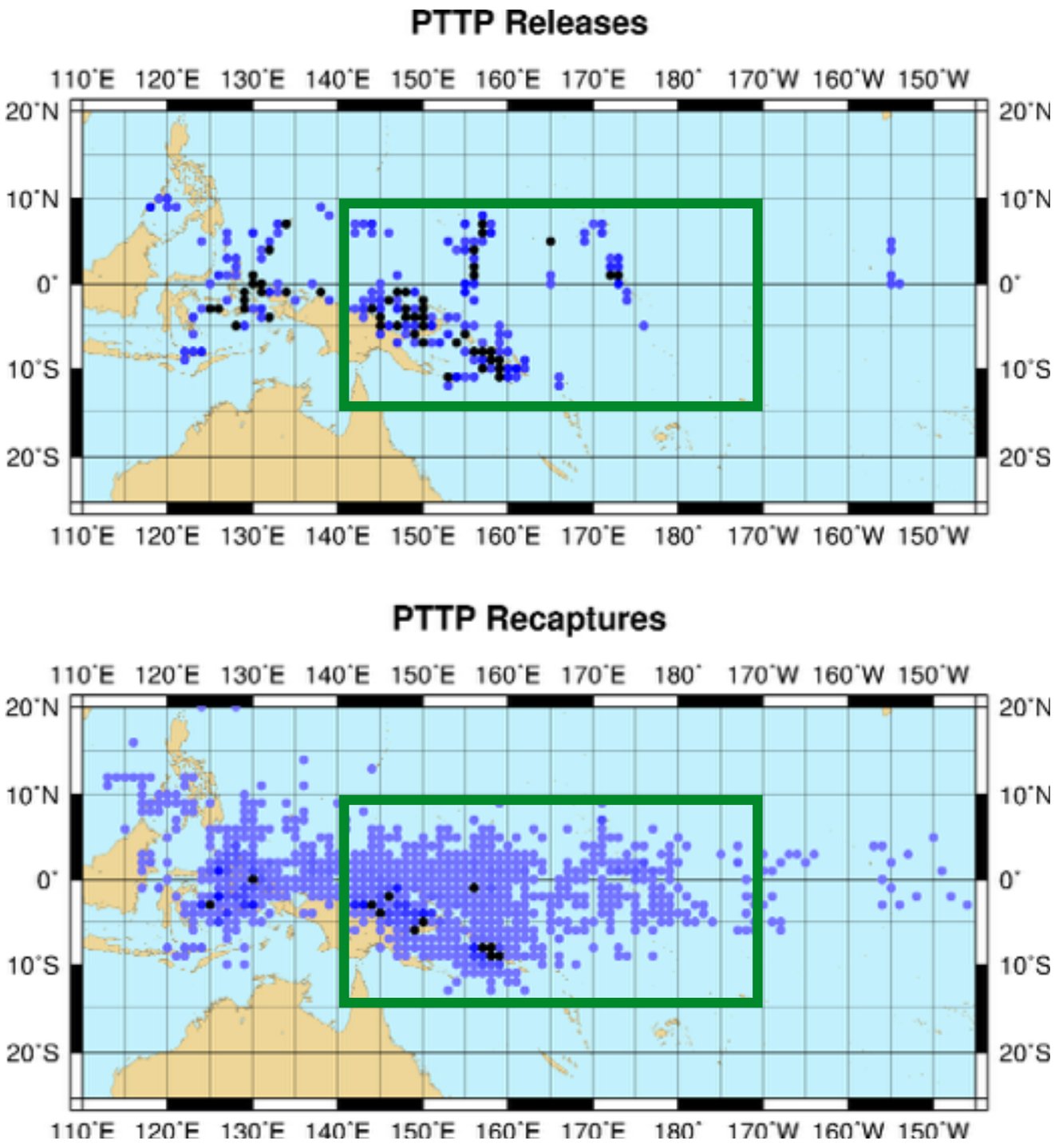
A model to quantify the effects of FADs on tuna movement

- **High catch on juvenile yellowfin and bigeye tuna (Freon and Dagorn 2000)**

- **Ecological traps by dFADs (Dagorn et al. 2012)**

Manage FAD usage

Pacific Tuna Tagging Programme



- Period: 2005-current
- Target species : **skipjack,** yellowfin, and bigeye tuna
- Release: 243,495
- Recaptures: 40,071 (16% recovery)

Fisheries Data

- **Fishing effort (F_{ijnf}) data (2005-2012)**

  - The Western and Central Pacific Fisheries Commission (WCPFC)

  Reported fishing effort by each Nationality in Fleet type (*f*)

  by month (*n*)

  by 1°geographic resolution (*i, j*)

- **FAD set data (2005-2012)**

  - The Western and Central Pacific Fisheries Commission (WCPFC)

  Reported position (p) of FAD sets (fishing date, position, type of sets)

  by month (n)

  by 1°geographic resolution (i, j)

  ➜ FAD density $\rho_{ijn} = \sum_{ijn} p$

Model description

- **Advection-Diffusion Reaction Model**

Mortality (Z)

$$\frac{\partial N}{\partial t} = \frac{\partial}{\partial x}(D\frac{\partial N}{\partial x}) + \frac{\partial}{\partial y}(D\frac{\partial N}{\partial y}) - \frac{\partial}{\partial x}(uN) - \frac{\partial}{\partial y}(vN) - ZN$$

Diffusion (D) Advection (u,v)

$$N_{xyt} = \sum_{c=1}^{c_t} \widetilde{N}_{xytc}$$

$$Z_{xyt} = M + \sum_{f} F_{xytf}$$

$$F_{xytf} = Q_f E_{xytf}$$

N = tag density

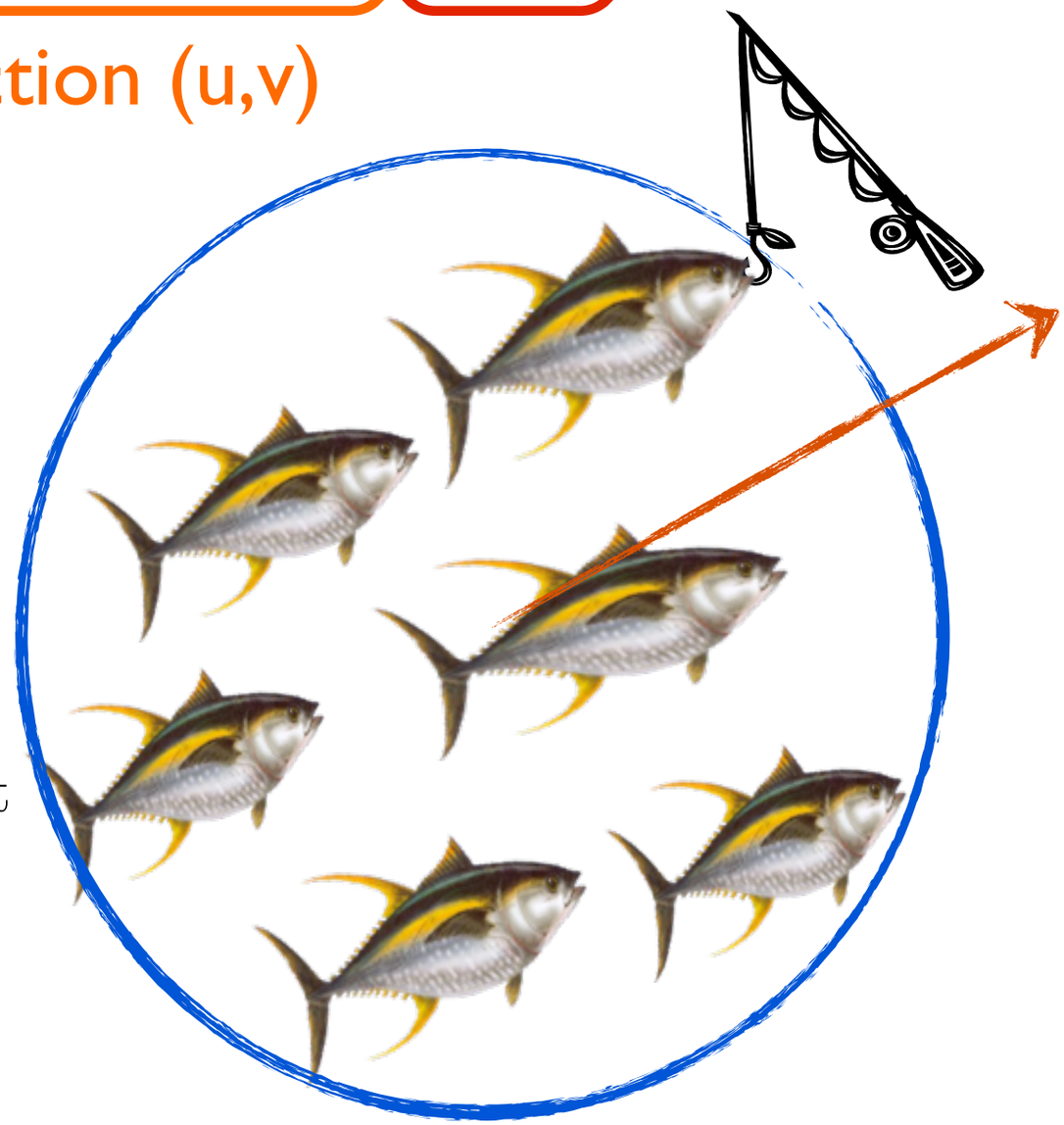
C = cohort

M = natural mortality

F = fishing mortality

Q = catchability coefficient

E = fishing effort



- **FAD-Advection-Diffusion Reaction Model**

Advection component

$$u = u_r + \frac{\partial \rho}{\partial x} \frac{\psi}{G_{max}}$$

$$v = v_r + \frac{\partial \rho}{\partial y} \frac{\psi}{G_{max}}$$

$u_r =$ natural advection in E-W

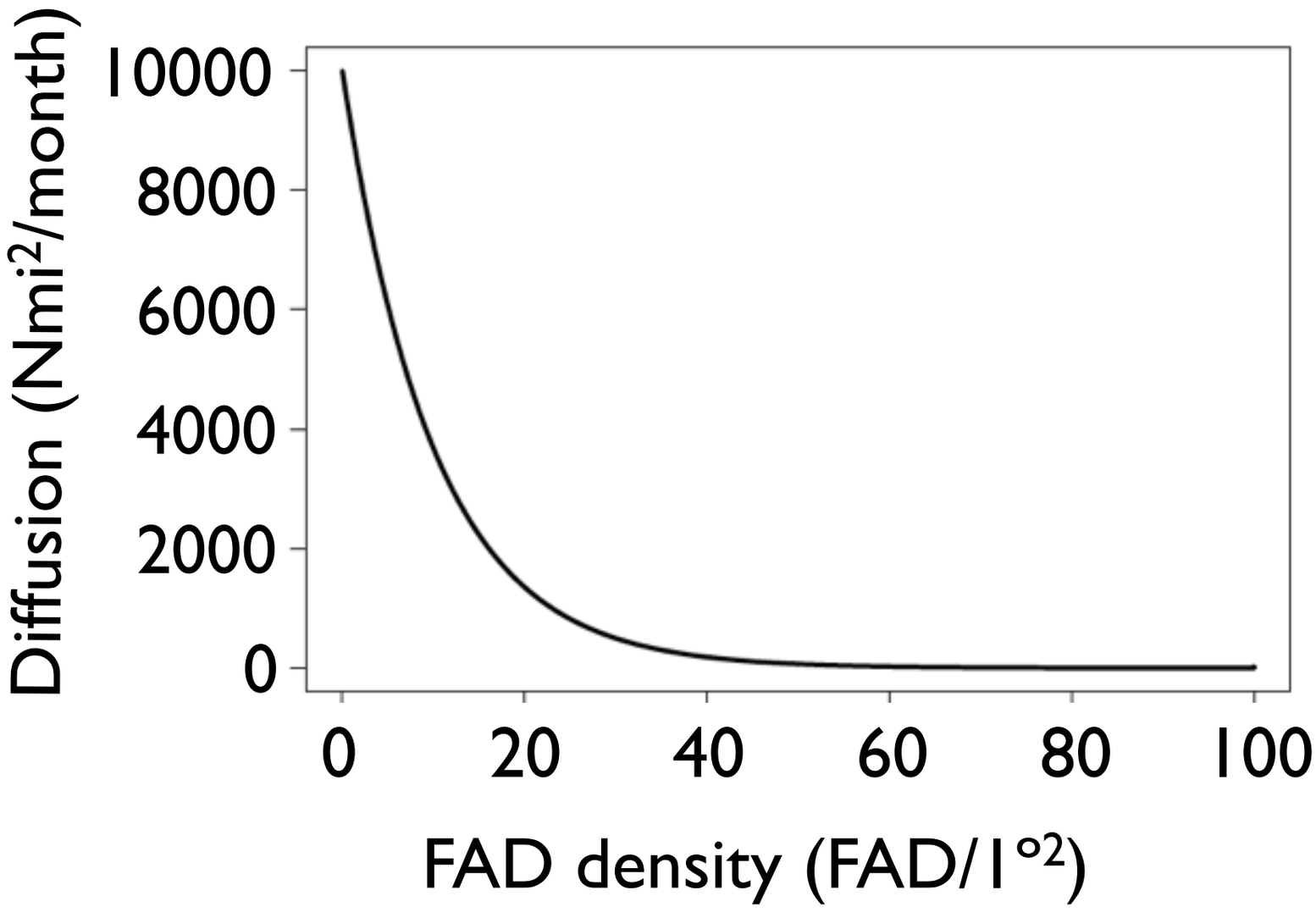
$v_r =$ natural advection in N-S

$G_{max} =$ maximum gradient of FAD

$\psi =$ taxis coefficient

- **FAD-Advection-Diffusion Reaction Model**

Diffusion Component

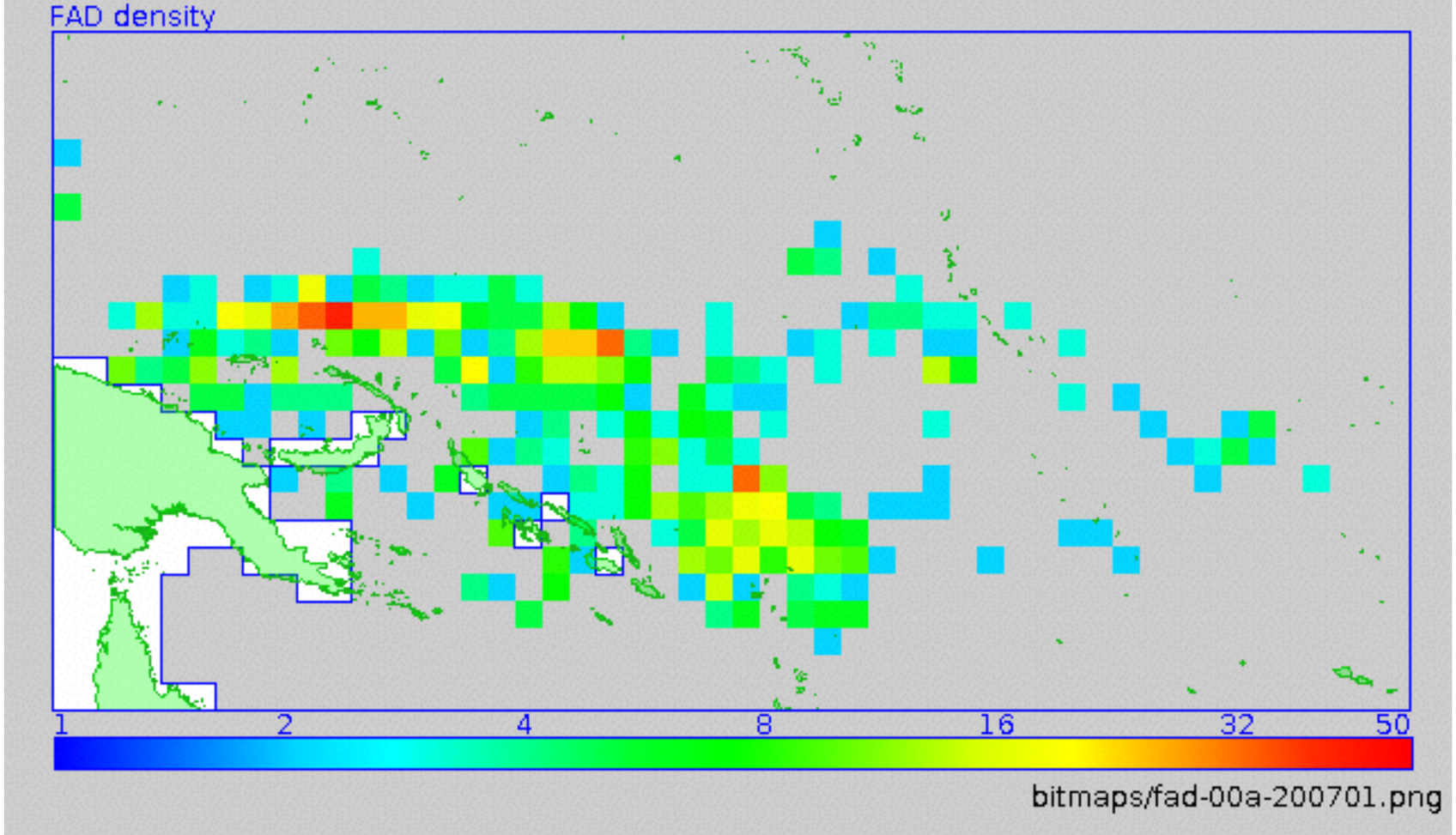


$$D = D_{max}e^{-\gamma\rho}$$

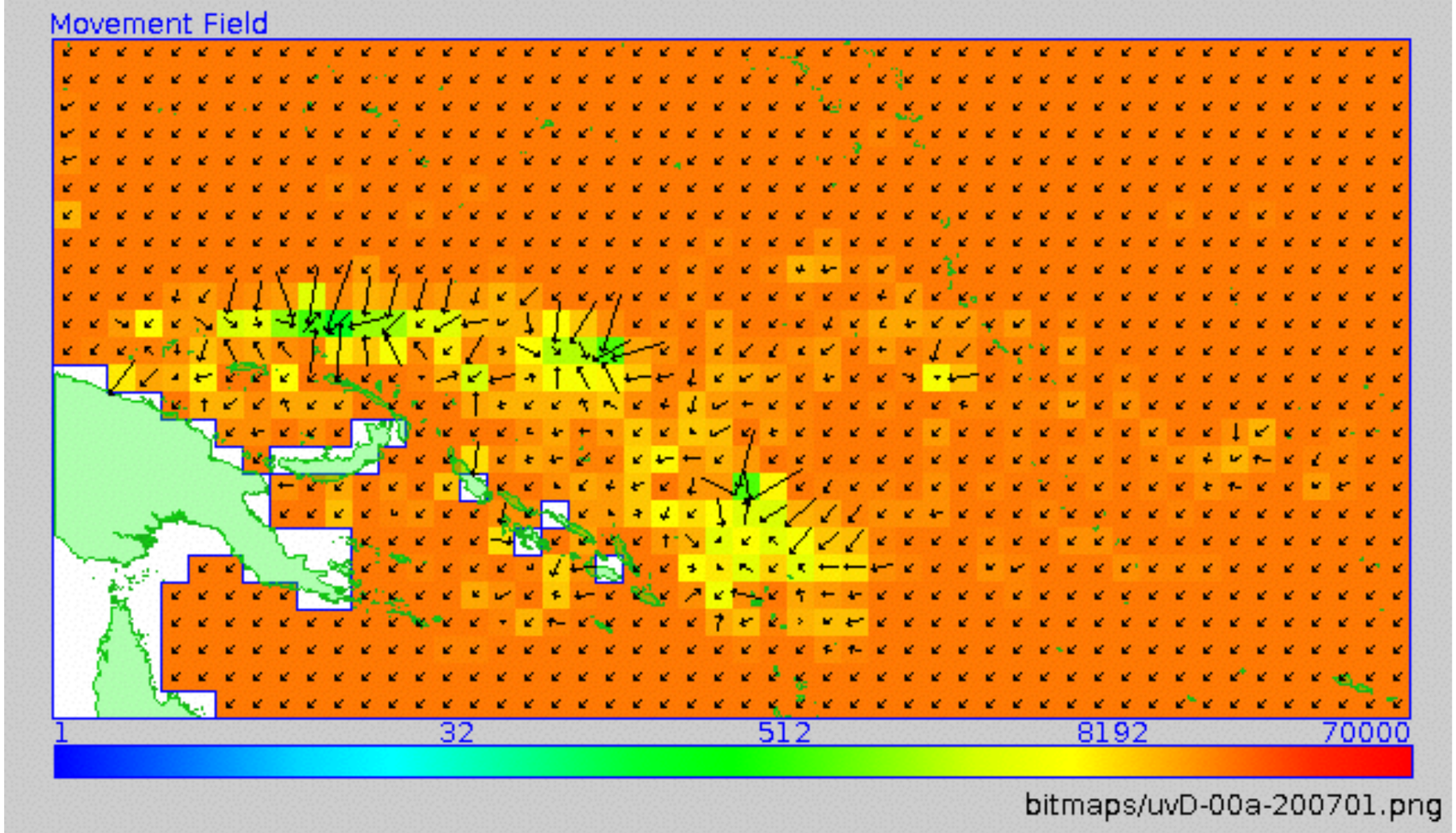
ρ = FAD density

γ = reduction rate of D

FAD density



u,v and D



Simulation process

My Ph.D. work

PTTP Skipjack conventional tag data

FAD-ADR model

Movement parameters

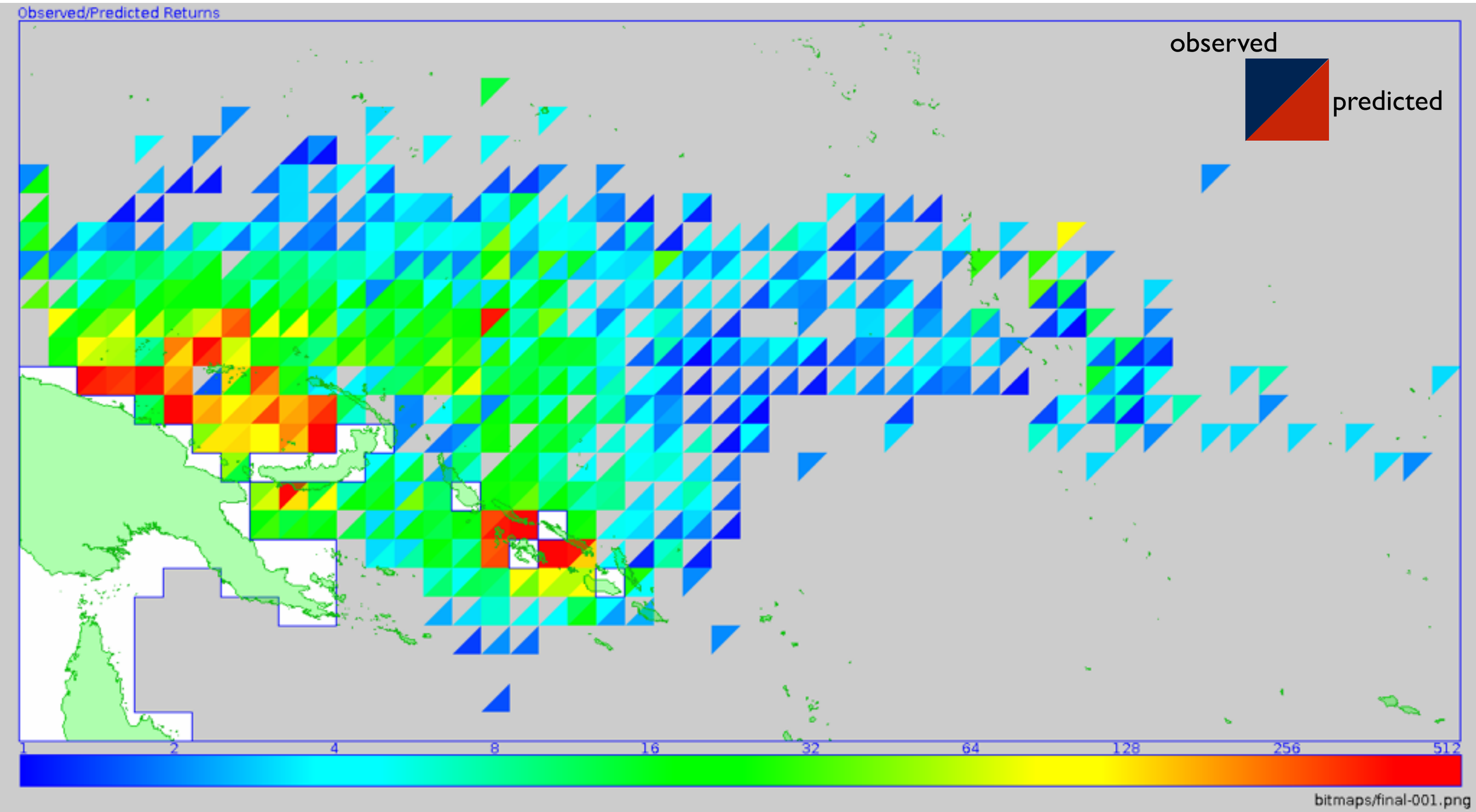
ψ= FAD taxi coefficient (11.9)
γ= reduction rate of D (0.11)
D=maximum diffusion (15500.2)

Application

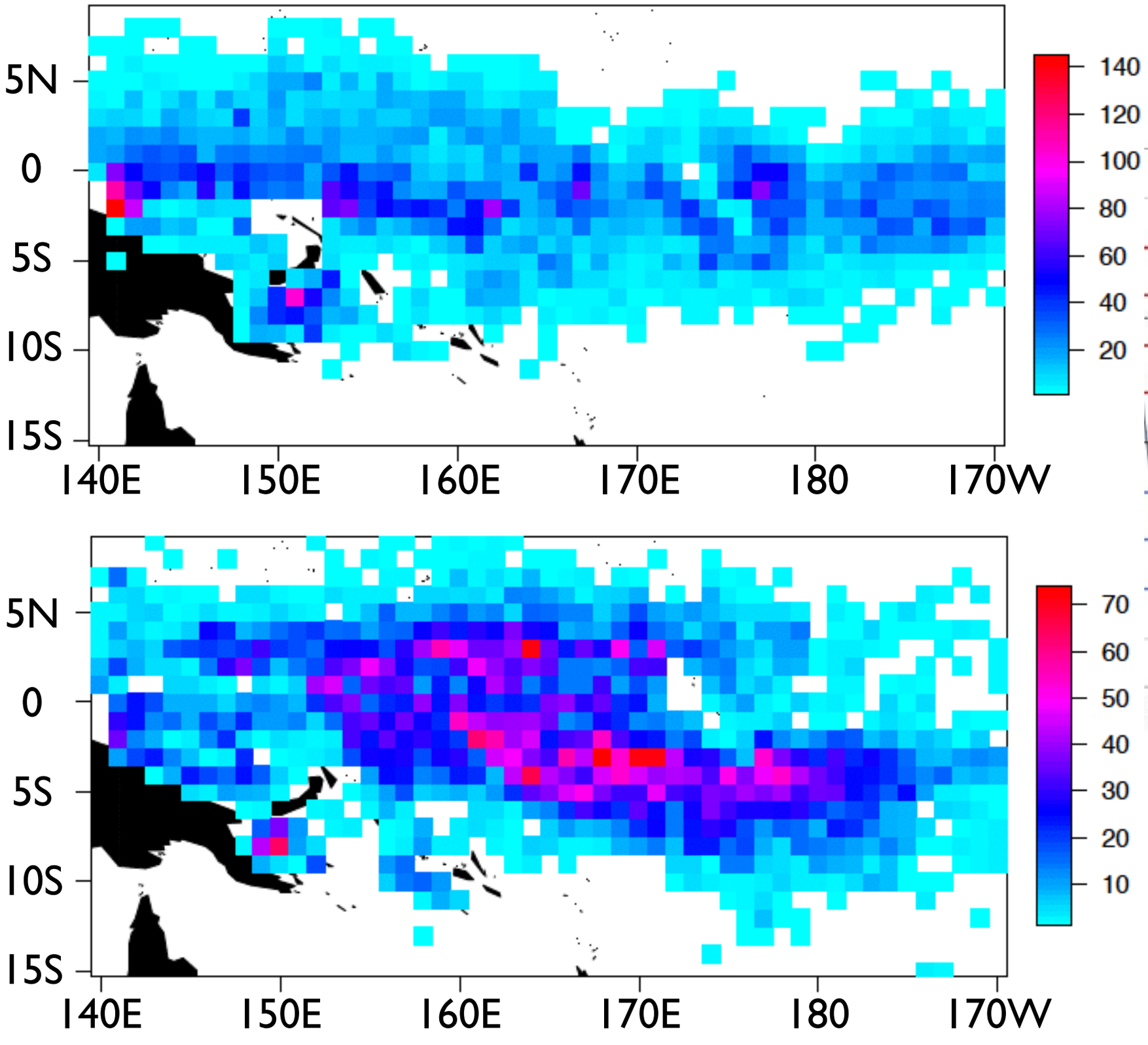
Simulation on 1997/98 El Niño
FAD distribution

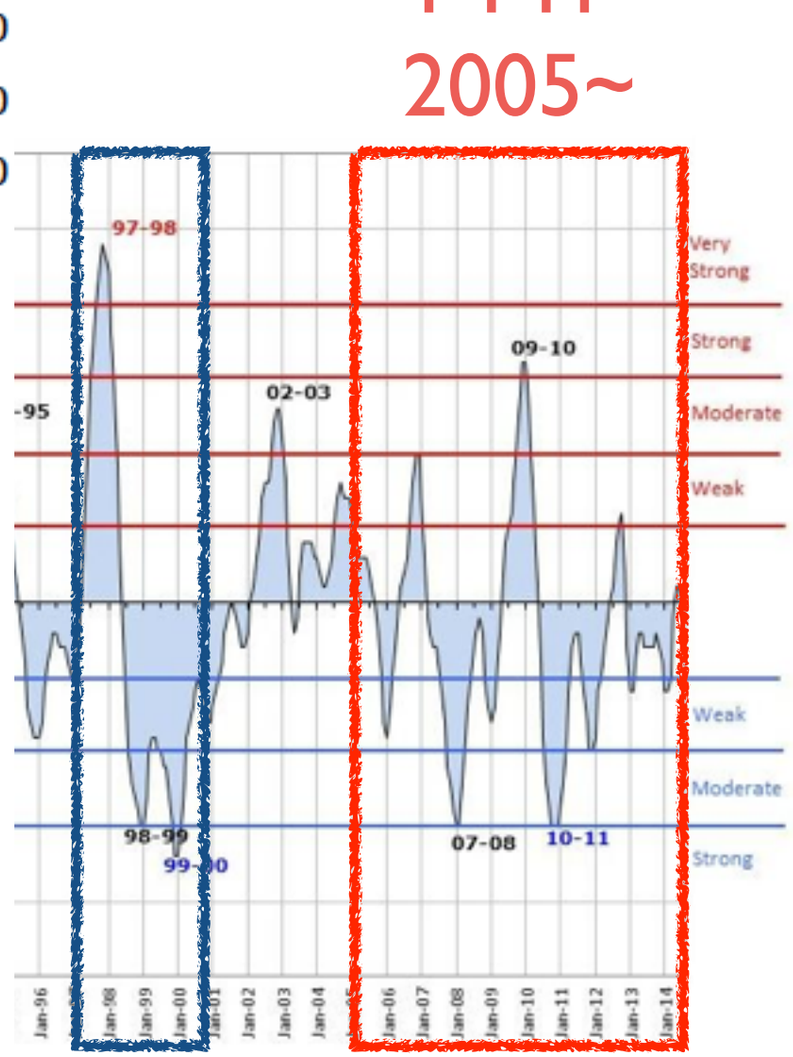
Simulation on 1998/99 La Niña
FAD distribution

Model fit with PTTP skipjack data



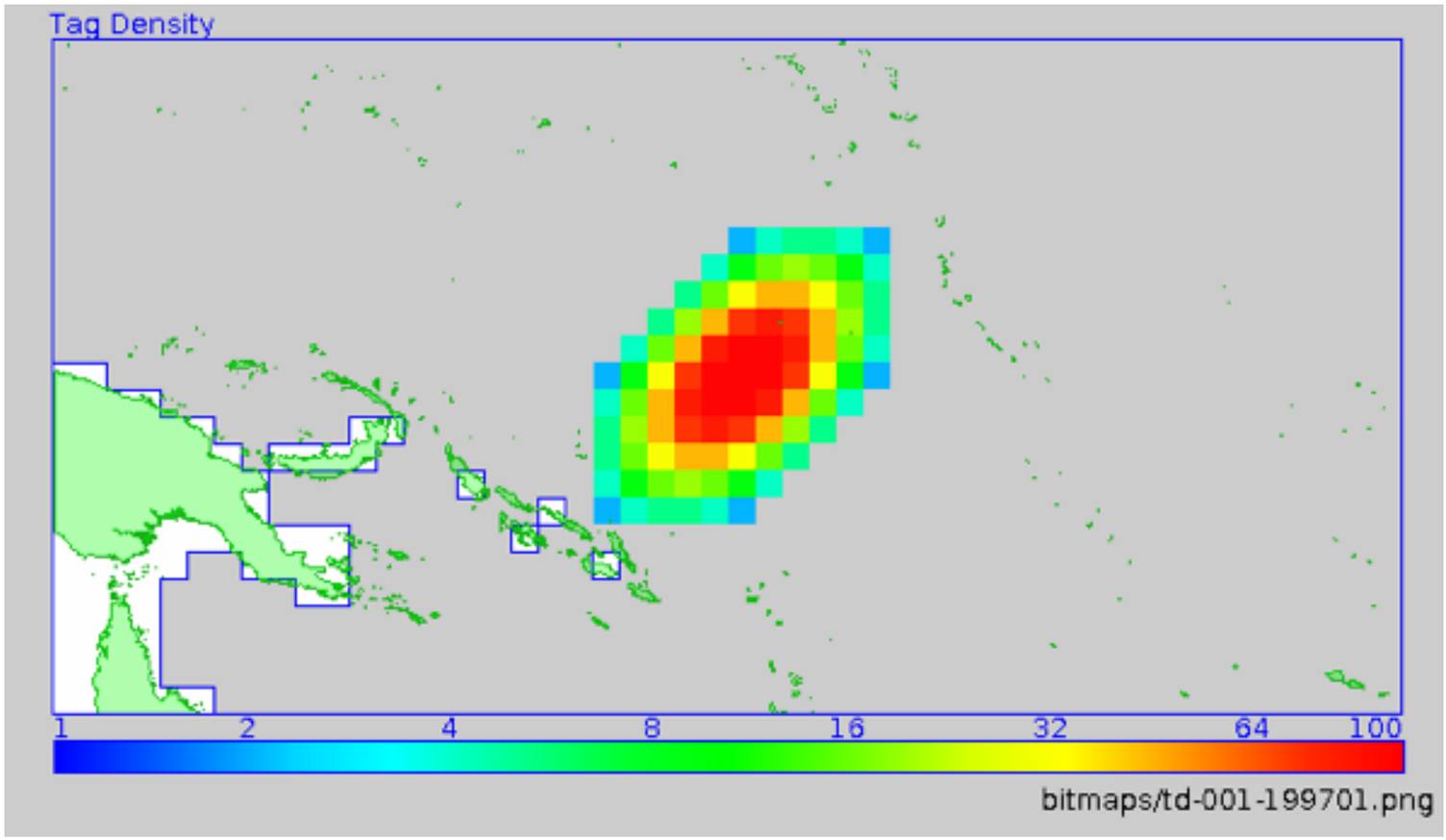
Oceanic Nino Index (ONI)





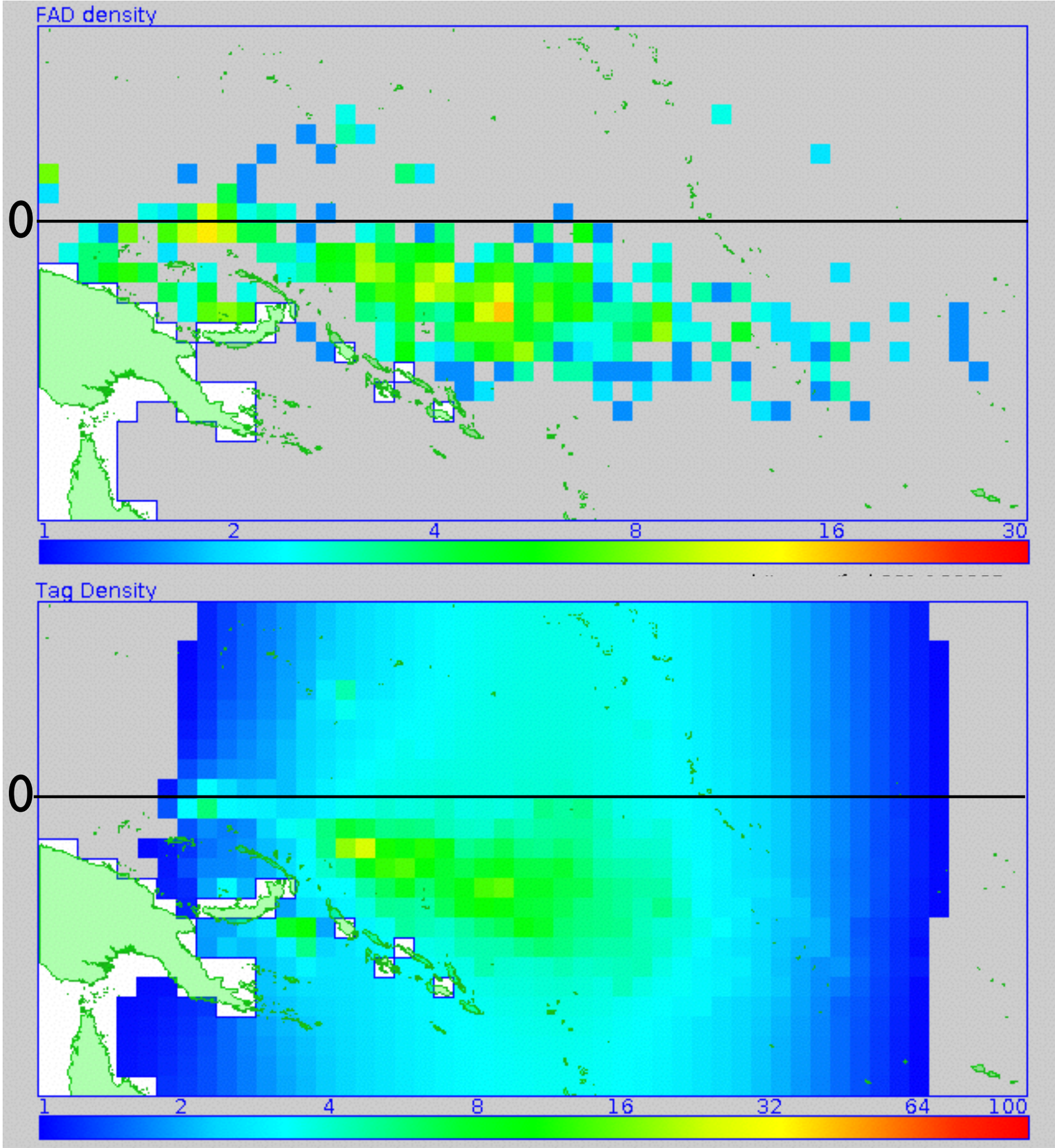
2009
FAD
closure

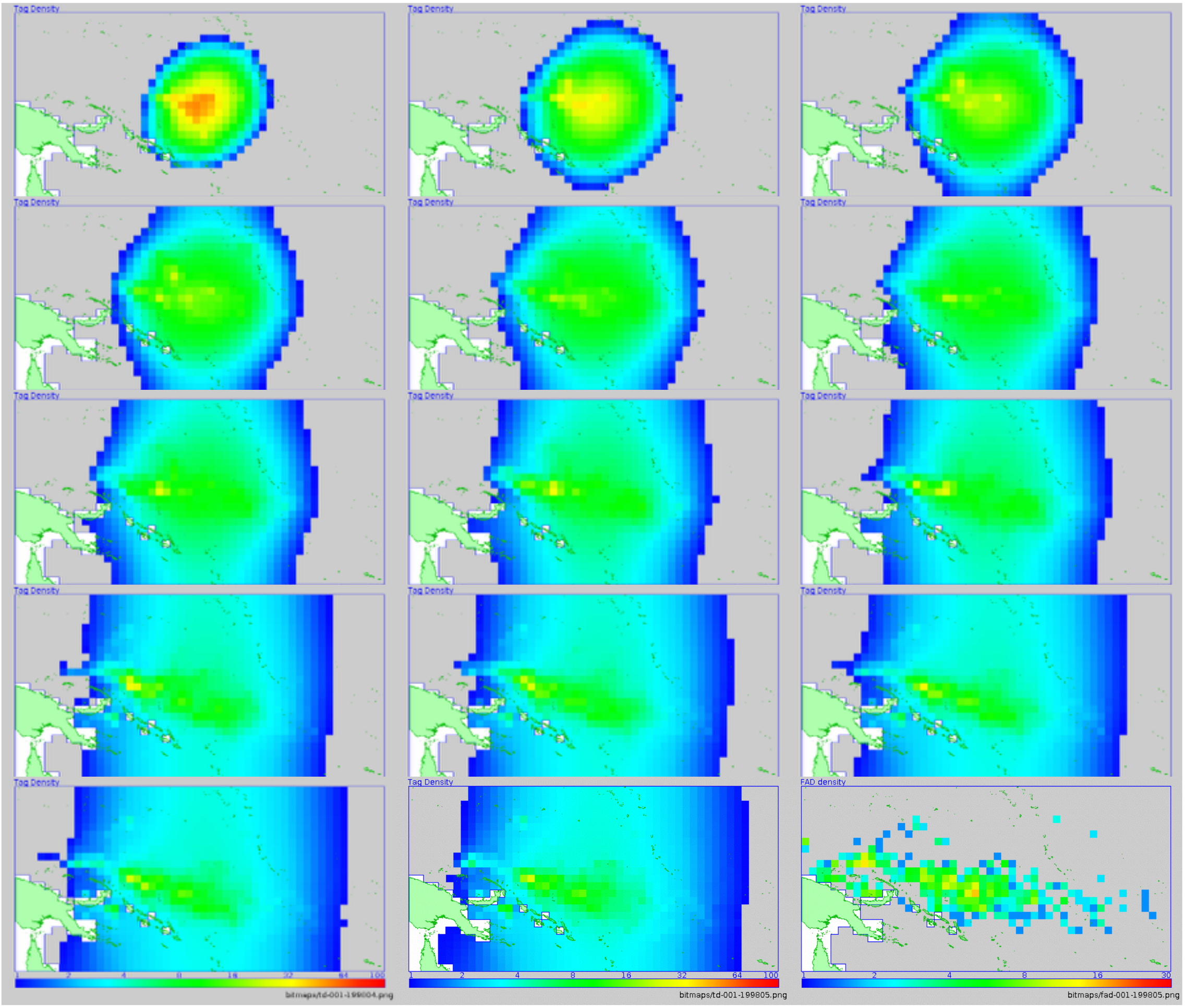
Initial condition for simulation



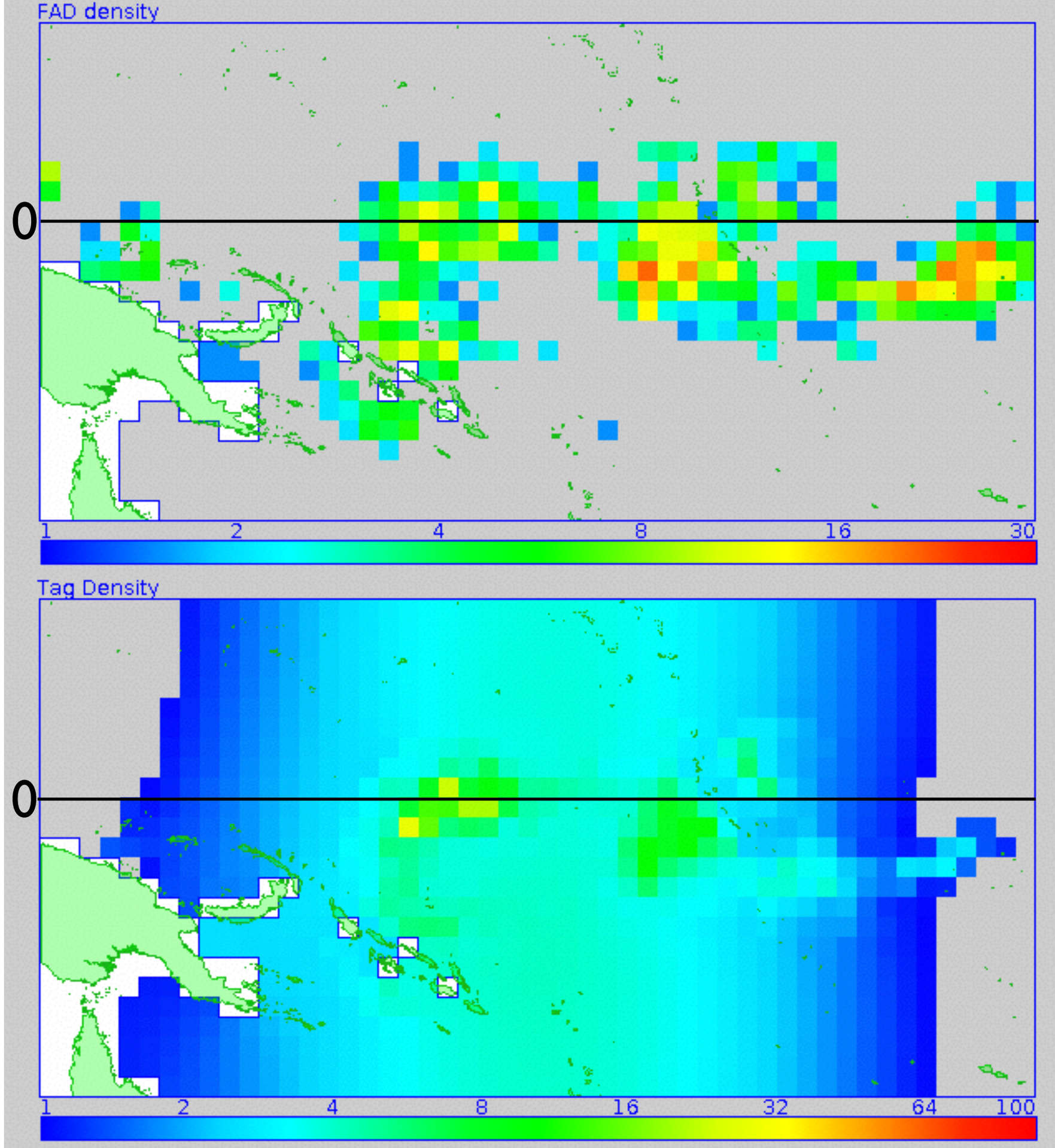
- **running month :18 month**
- **Fishing and natural mortality = 0**
- **Movement of fish : D, γ, and ψ**

1997/98 El Niño




Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
Tag Density
FAD density
1 2 4 8 16 32 64 100
1 2 4 8 16 32 64 100
1 2 4 8 16 30
bitmaps/td-001-199804.png
bitmaps/td-001-199805.png
bitmaps/fad-001-199805.png

1998/99 La Niña



Results and summary

- **The use of FADs in the tuna fishing is increasing by development to buoy technology.**

- **The affect of FAD on tuna population is unknown.**

- **FAD-ADR model can quantify the effect of FAD on tuna using tagging data.**

- **Densities of dFAD in 1997/98 El Niño and 1998/1999 La Niña reflect the surface ocean current.**

- **Simulated fish densities during El Niño and La Niña are controlled by the distribution of FAD densities.**

Future works

- **Regional study on the most attractive regions for yellowfin and bigeye tuna.**
- **Understanding the distribution of dFAD**
- **2011 tsunami debris with temperate tuna species?**

acknowledgment

- SPC
- WCPFC
- PFRP
- JIMAR
- PICES/NSF for travel fund