Modeling the central North Pacific ecosystem response to predicted climate variations and fishery management scenarios

Evan A. Howell[1], John P. Dunne[2] and Jeffrey J. Polovina[1]

[1]NOAA Pacific Islands Fisheries Science Center, Honolulu, HI USA
[2]NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ USA

Why look at this?

Polovina et al. 2009 paper - central North Pacific (HI Longline Fishery)

Observed CPUE (biomass) changes over 10 years

%Target Species ↓

%Incidental Species ↑

Can we look forward?

Climate

Have GFDL data to 2100

Ecosystem

Build EwE model for CNP

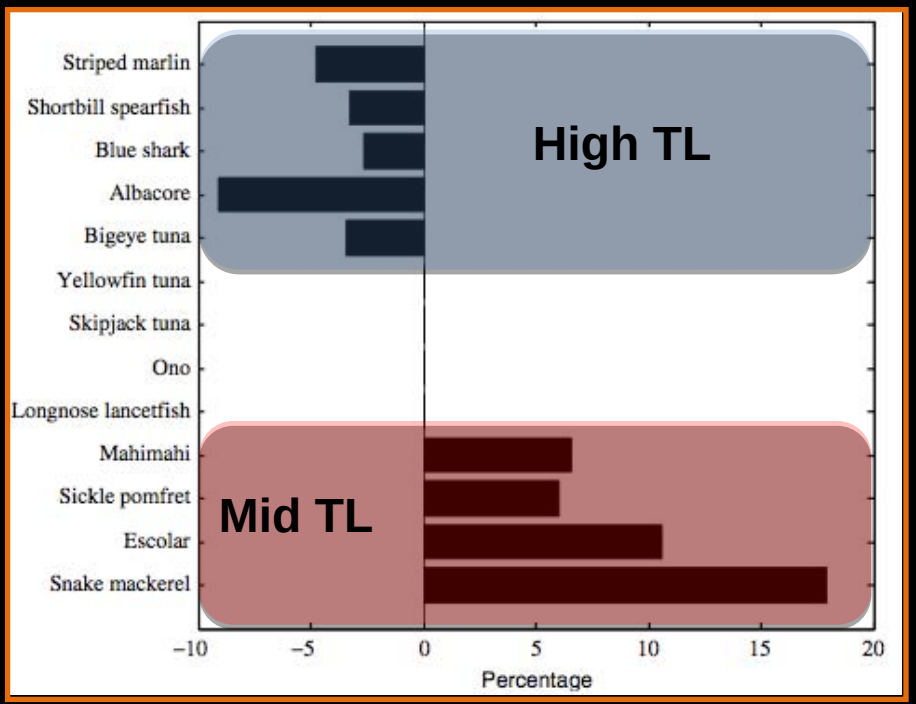
Fishing

F=1X | F=2X | F=0.5X

Do we expect trend to continue?

Increases in the relative abundance of mid-trophic level fishes concurrent with declines in apex predators in the subtropical North Pacific, 1996–2006

Jeffrey J. Polovina (contact author)[1]
Melanie Abecassis[2]
Evan A. Howell[1]
Phoebe Woodworth[2]
Email address for contact author: Jeffrey.Polovina@noaa.gov
[1] Pacific Islands Fisheries Science Center
NOAA Fisheries
2570 Dole St
Honolulu, Hawaii 96822-2396
[2] Joint Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Rd.
Honolulu, Hawaii 96822



Ecosystem Model construction (Ecopath)

Fishing (Top-down forcing): SPC + NOAA Longline

ETP EwE Model | *CNP Model* | *FishBase* | *Stock Assess.*

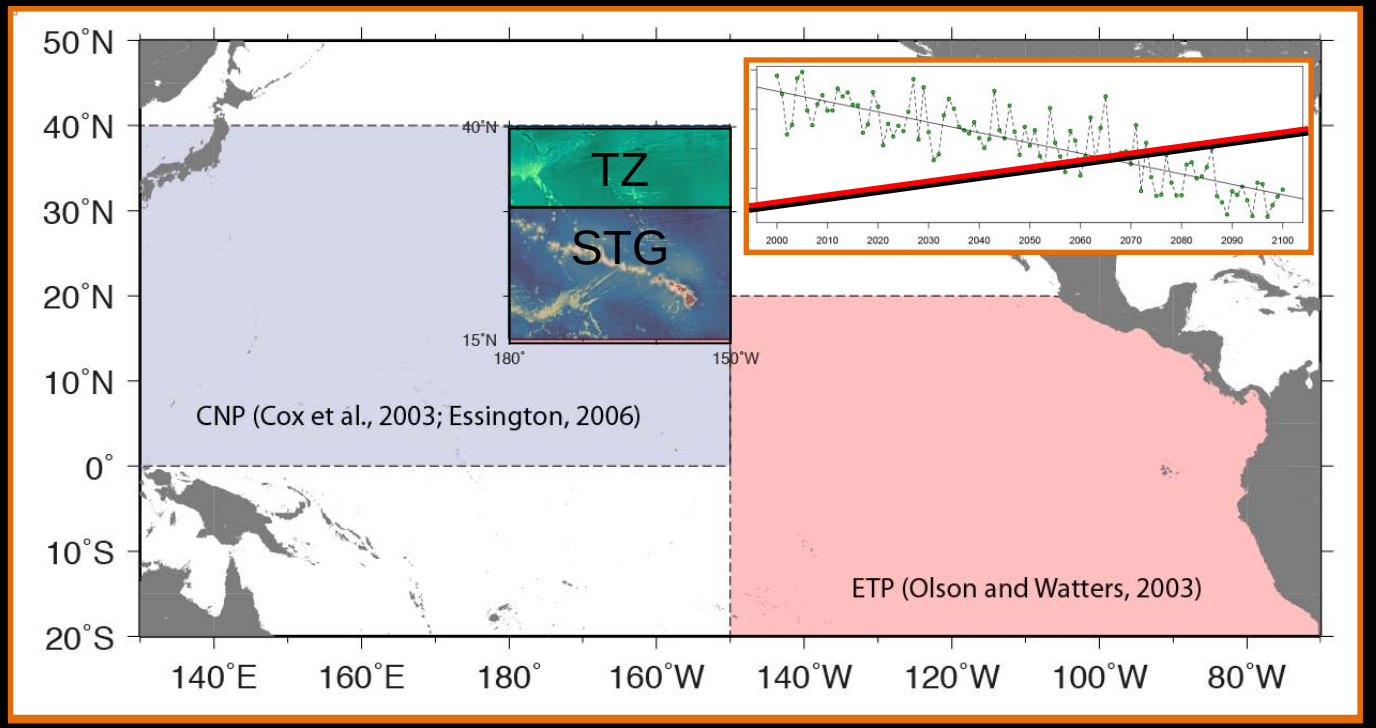
Phytoplankton (Bottom-up): GFDL ESM2.1 A2 NPZ projection

First: Build Ecopath for 1991, check with 1996-2006 data

Can we recreate trends observed ✔

Second: Ecosim runs 1991-2100

Observe similar trends?



NOAA GFDL Earth System Model 2.1 (*ESM2.1 A2 NPZ*)

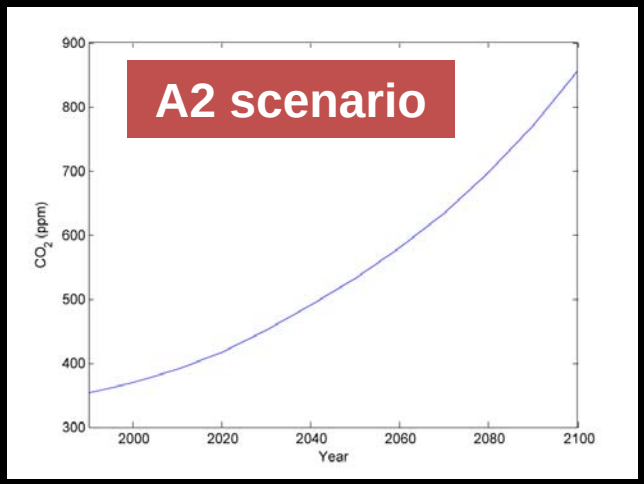
Phytoplankton (Bottom-up): GFDL ESM2.1 A2 NPZ projection

CM 2.1 (Atmos., Land, Ice)

Coupled Climate ⇕ Biogeochemical

Tracers of Phytoplankton with Allometric Zooplankton (TOPAZ)*

Major nutrients + 4 phytoplankton groups

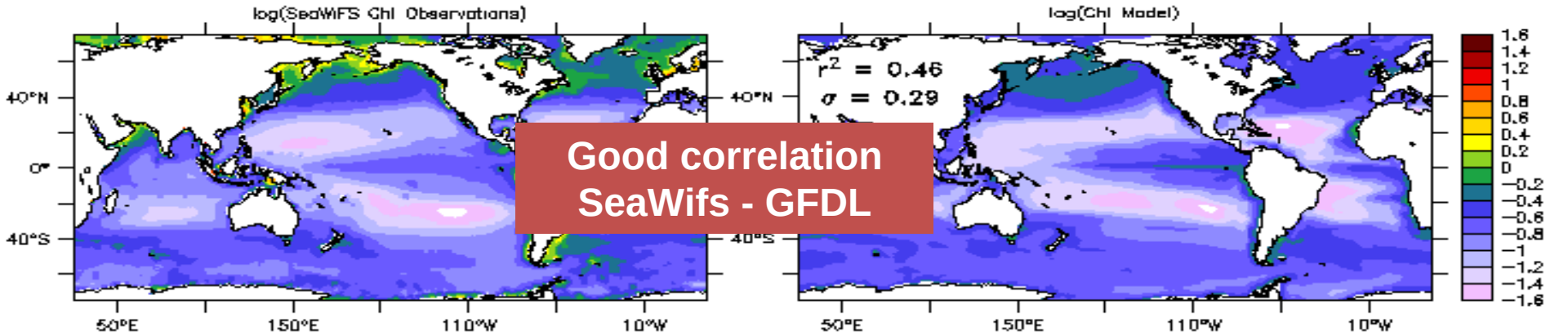


1˚ x 1˚ north of 30˚ N, with latitudinal resolution increasing to 0.33˚ at equator

Ocean has 50 levels, with 22 10m spacing levels in the upper 220m

We used Monthly values in HLFG box from 1991 - 2100

**Dunne et al. (2005, 2007)*

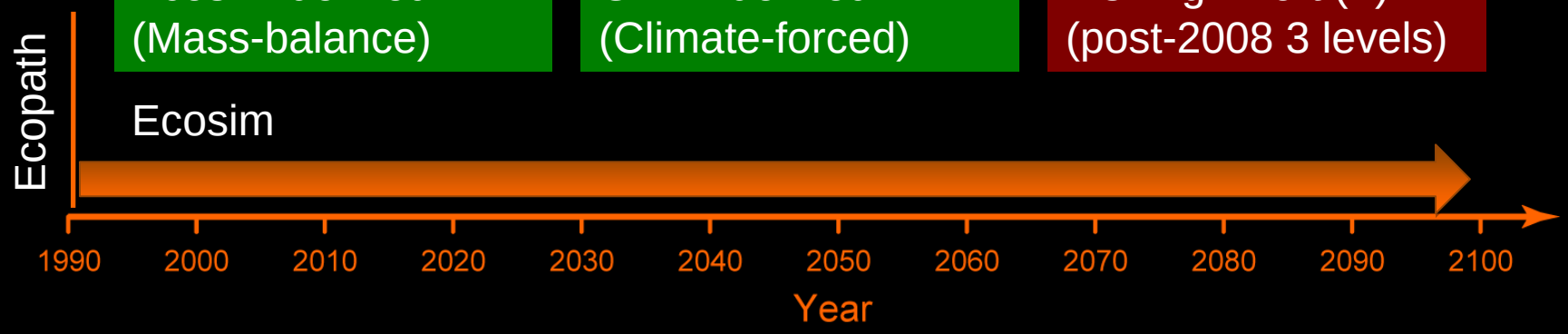


Ecosim runs 1991-2100

Ecosim-derived PP (Mass-balance)

GFDL-derived PP (Climate-forced)

Fishing Effort (*F*) (post-2008 3 levels)

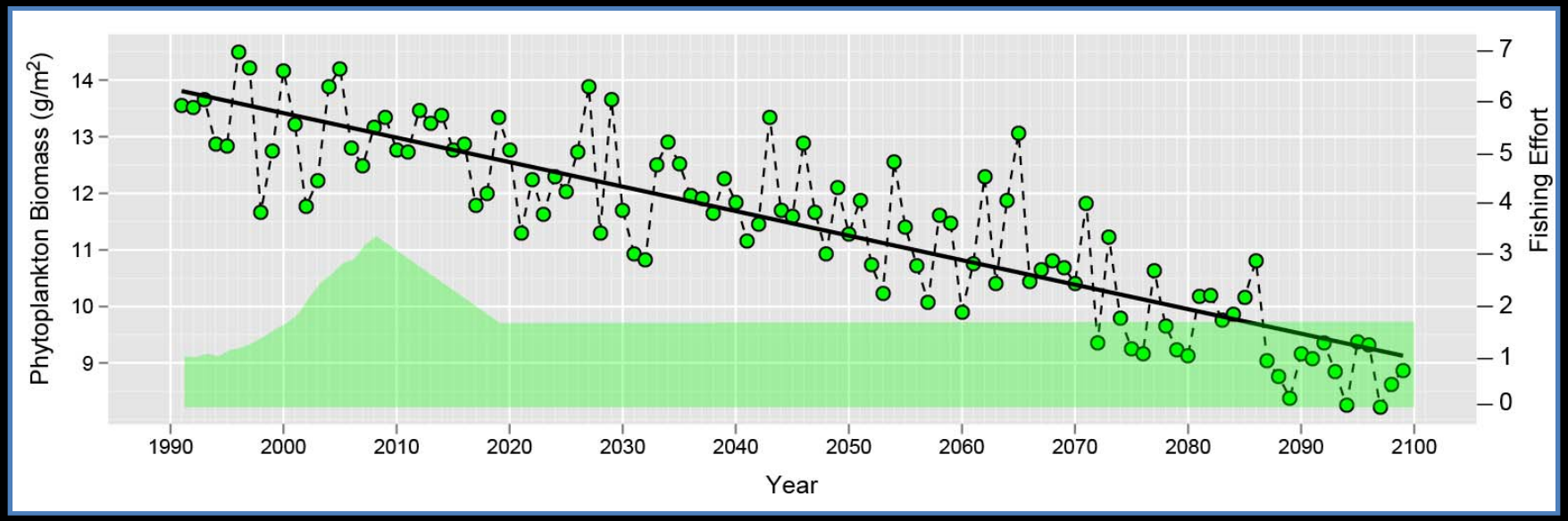


F = 1X 2008 levels

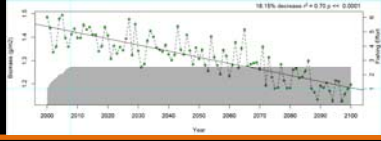
F = 2X 2008 levels

F = 0.5X 2008 levels

Small phytoplankton is 10X large phytoplankton biomass (groups 1:3)



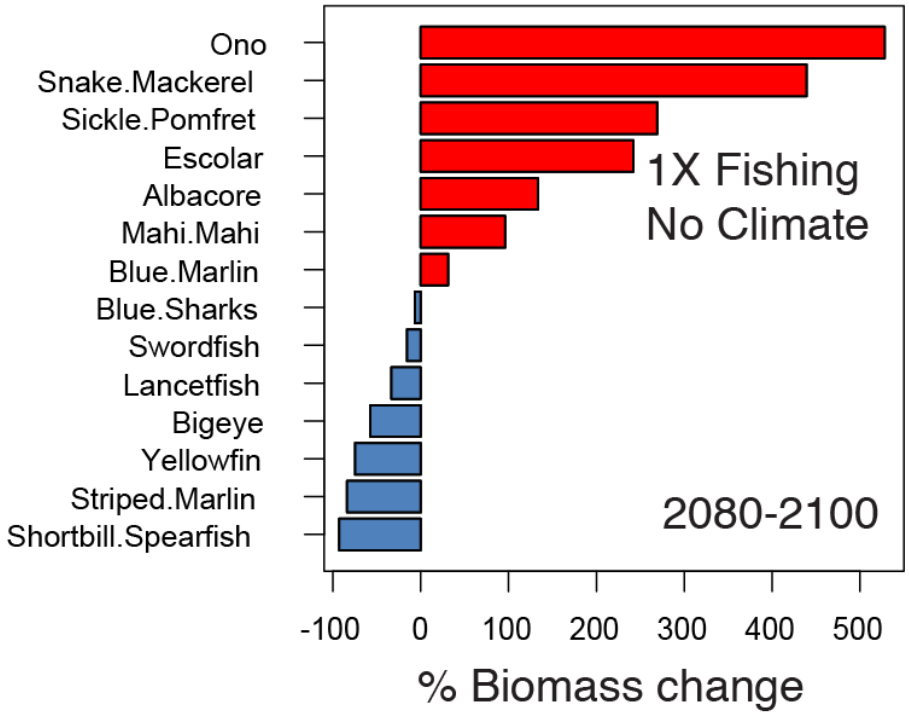
Results: F = 1X2008

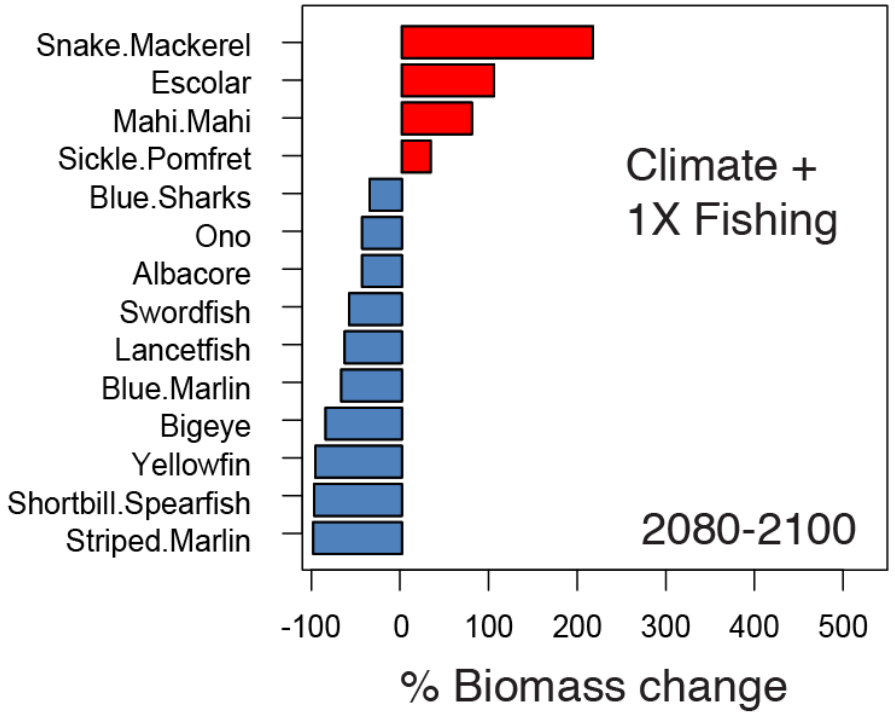


2080 - 2100

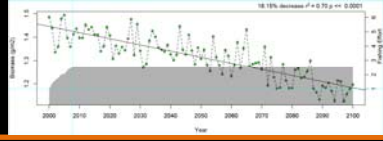
%Target Species ↓

%Incidental Species ↑





Results: F = 1X2008

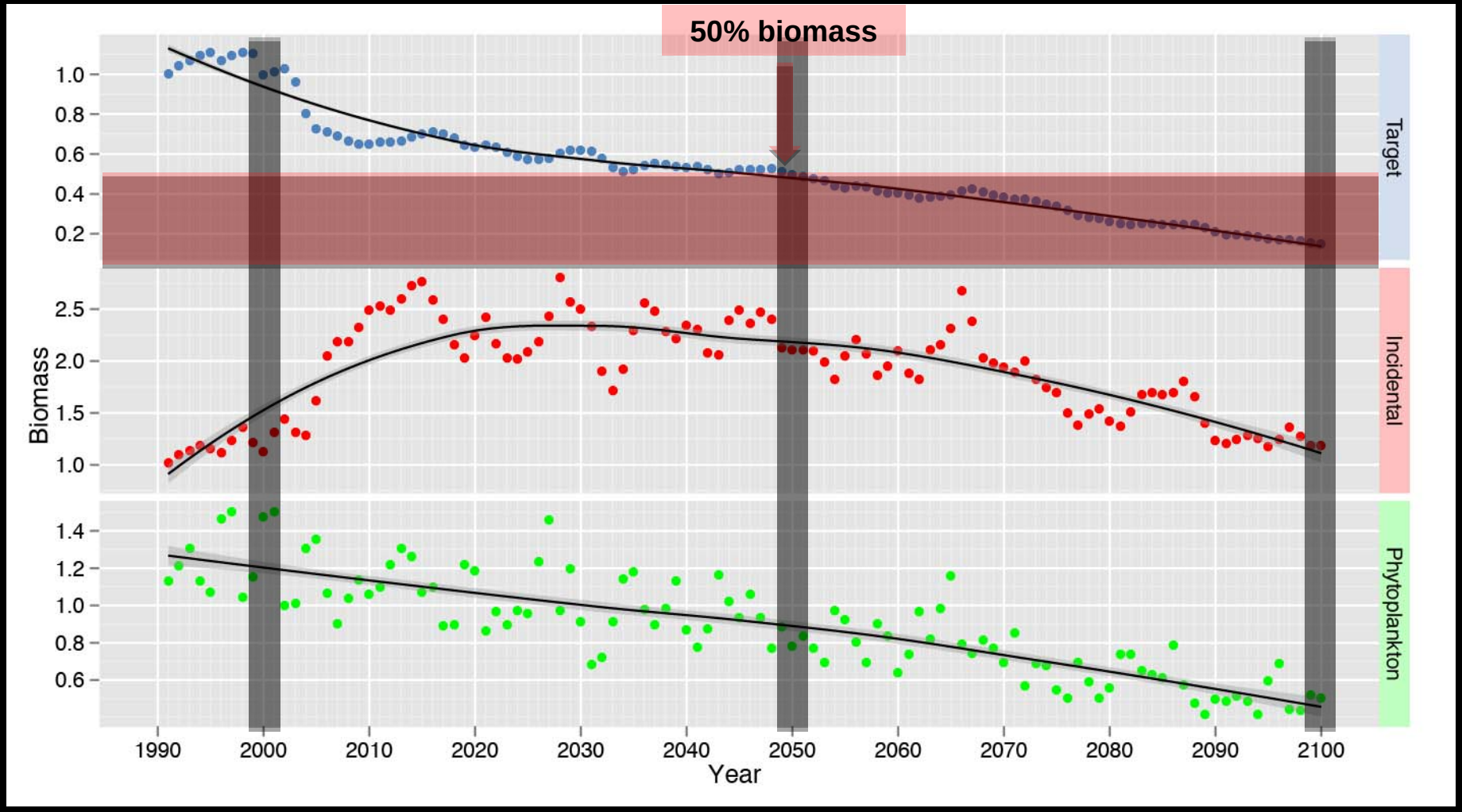


%Target Species ↓

%Incidental Species ↑

%Target Species ↓

%Incidental Species ↑



Fishing scenario comparison

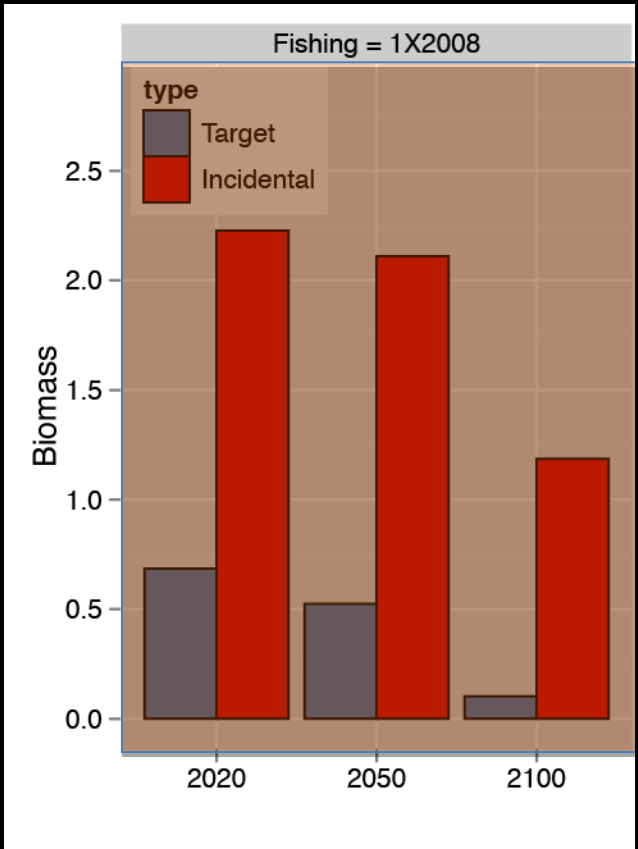
Grouped biomass snapshots at 2020, 2050, 2100

Target Species
(e.g. Tunas, Billfish)

Incidental Species (mid-TL)
(e.g. Snake Mackerel, Escolar, Mahi)

Fishing 1X,2X: Larger split target/incidental species

Fishing 0.5X: Comp. decrease in species over time



Example biomass trends– Bigeye, Swordfish

F = 1X2008

F = 2X2008

F = 0.5X2008

Example management goal:
Effort to allow B >= B_{50}

For bigeye, swordfish, F=0.5X2008 OK?
All target species above $B_{50?}$

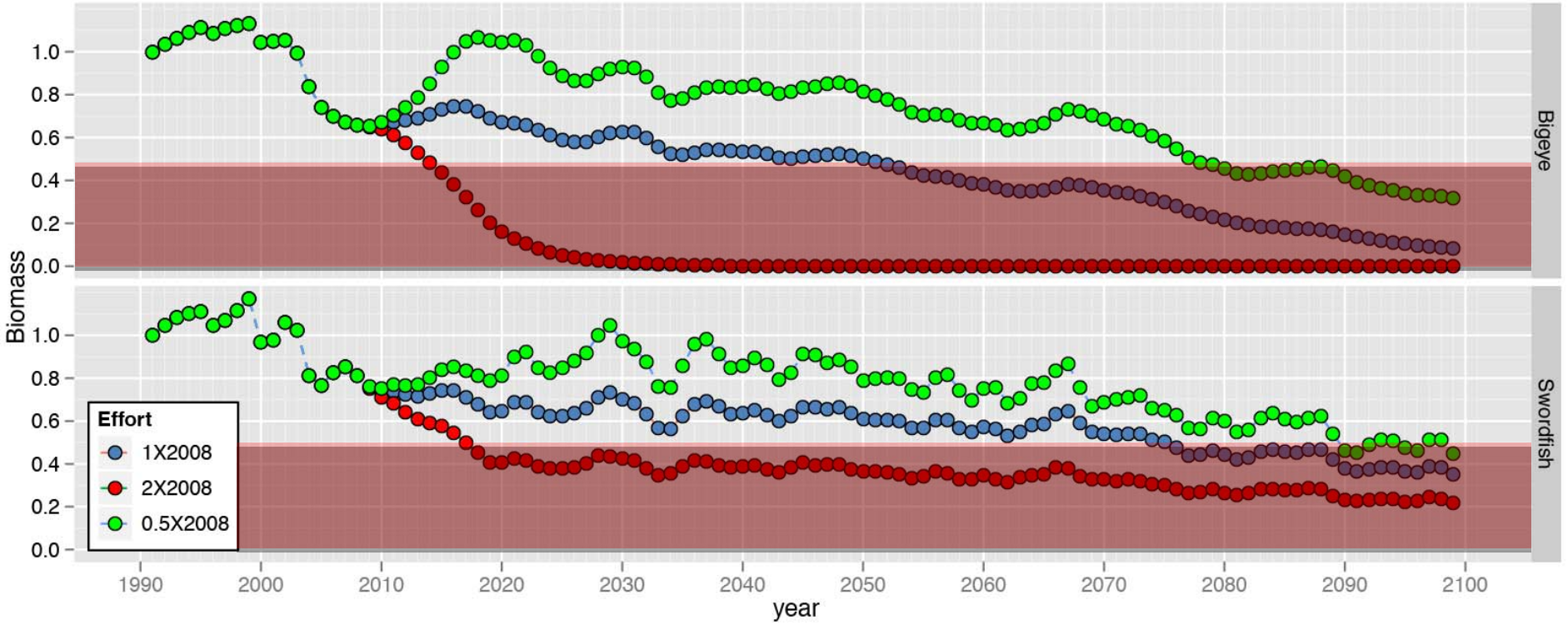
MSE module in Ecosim

No effort cap

B_{tar} >= B_{50}

Incidentals = OK

100 runs, took median



Management Strategy Evaluation Trial

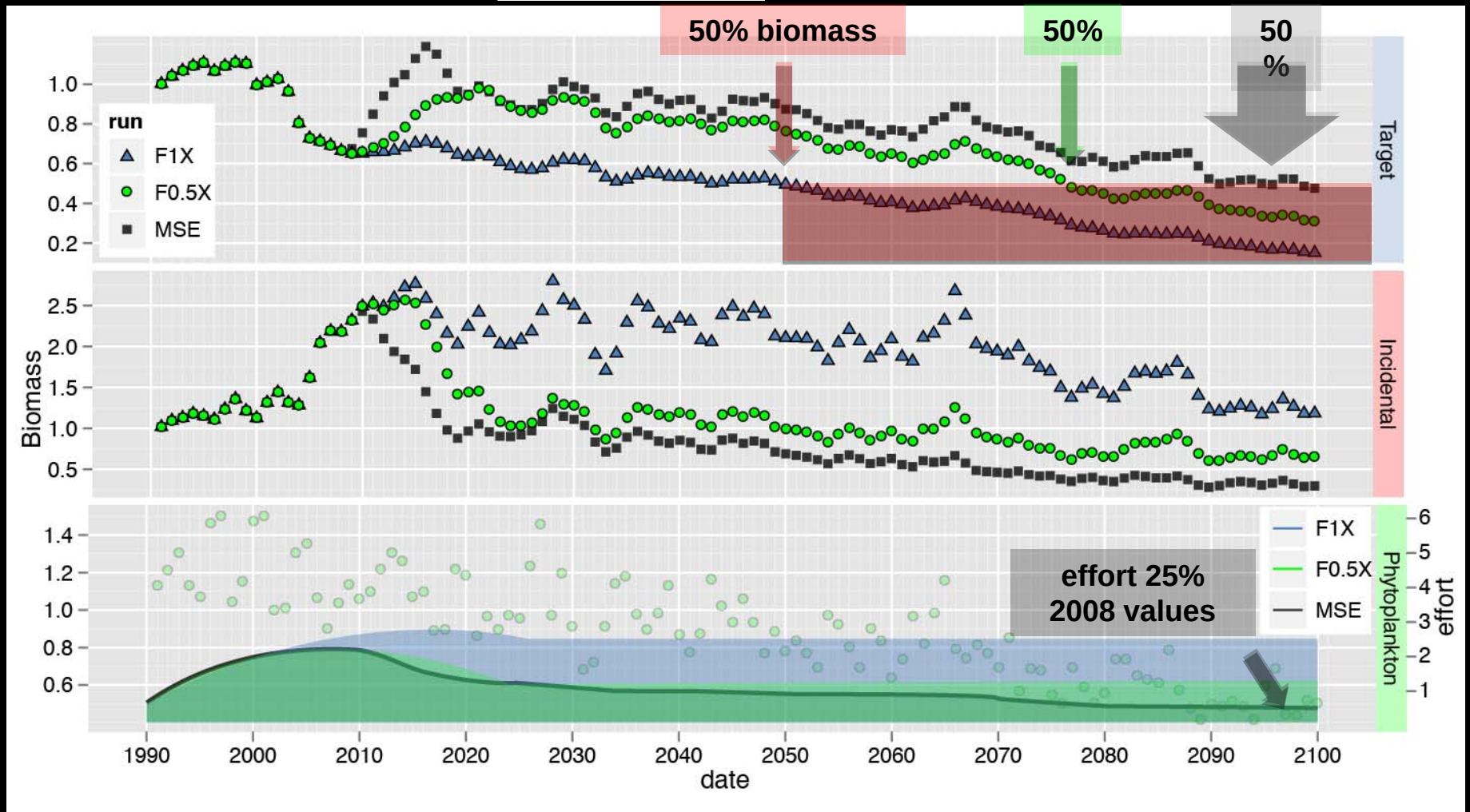
Want: effort scenario max effort
Target B > B_{50}
MSE

F = 1X2008

F = .5X2008

F = MSE

Target close to 50% level
Need to drop 2008 effort 75%
Incidental biomass 50%



MSE biomass trends – Bigeye, Swordfish

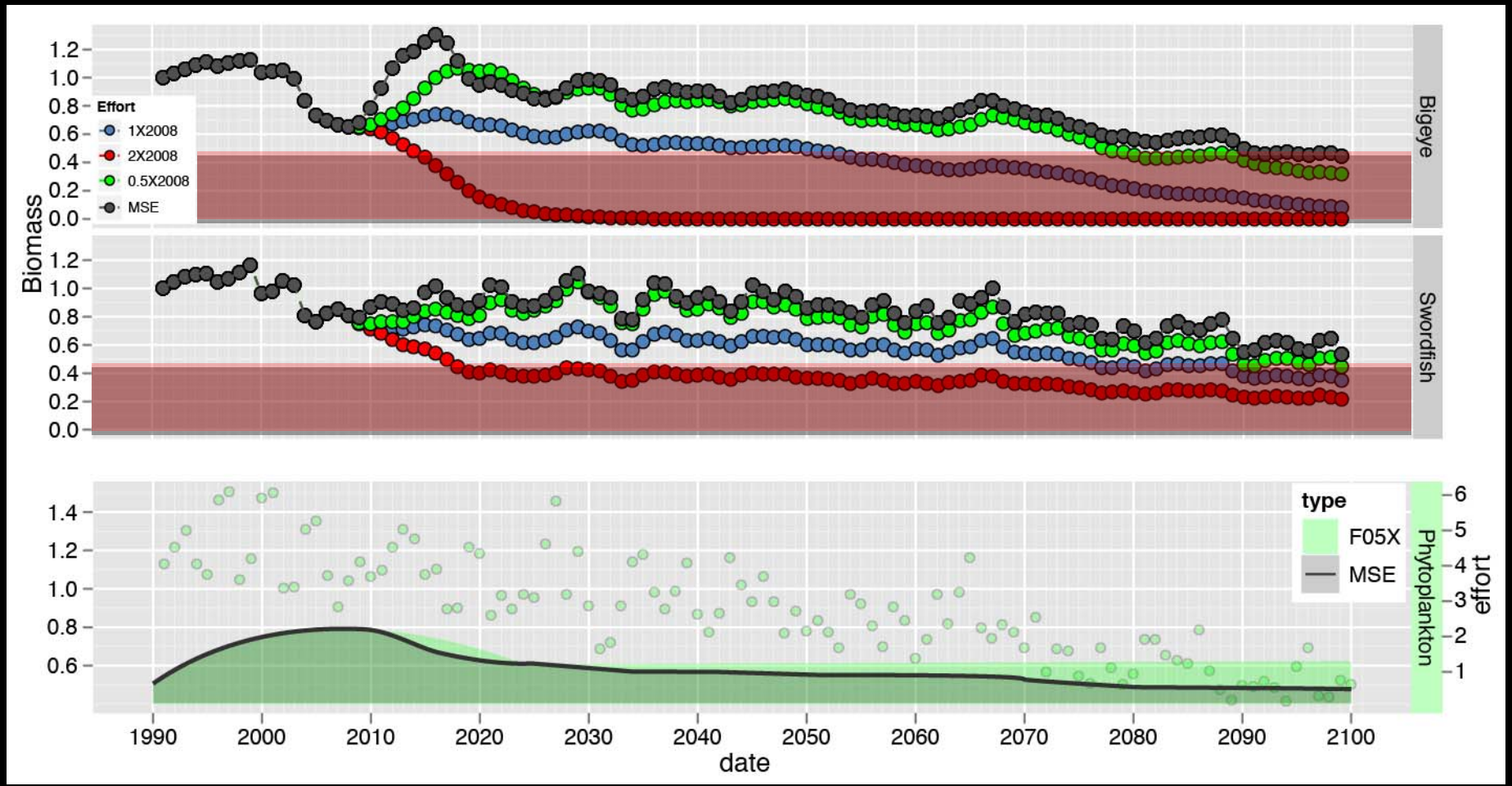
F = 1X2008

F = 2X2008

F = 0.5X2008

Example management goal: Effort to allow B >= B_{50}

MSE effort scenario doesn't change B much from F0.5X2008 scenario



Fishing scenario comparison

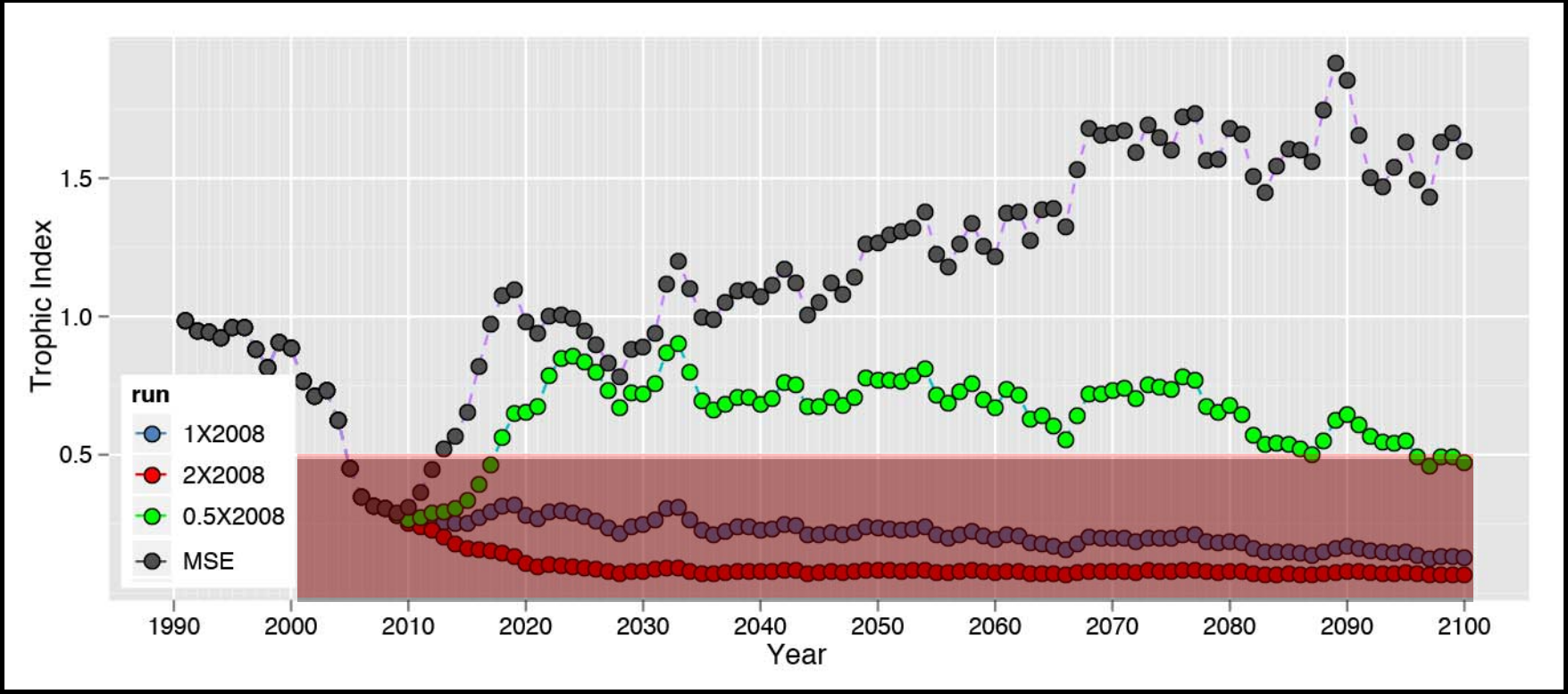
$$\text{T/I Ratio} = \frac{\text{Target Species}}{\text{Incidental Species}}$$

Overall view: almost all species decline in any scenario

Fishing 1X,2X: More effort affects T/I ratio greatly

Fishing 0.5X: Species decrease yet smaller decline in targets

Fishing MSE: Species decrease yet more decline in incidentals



Fishing scenario comparison

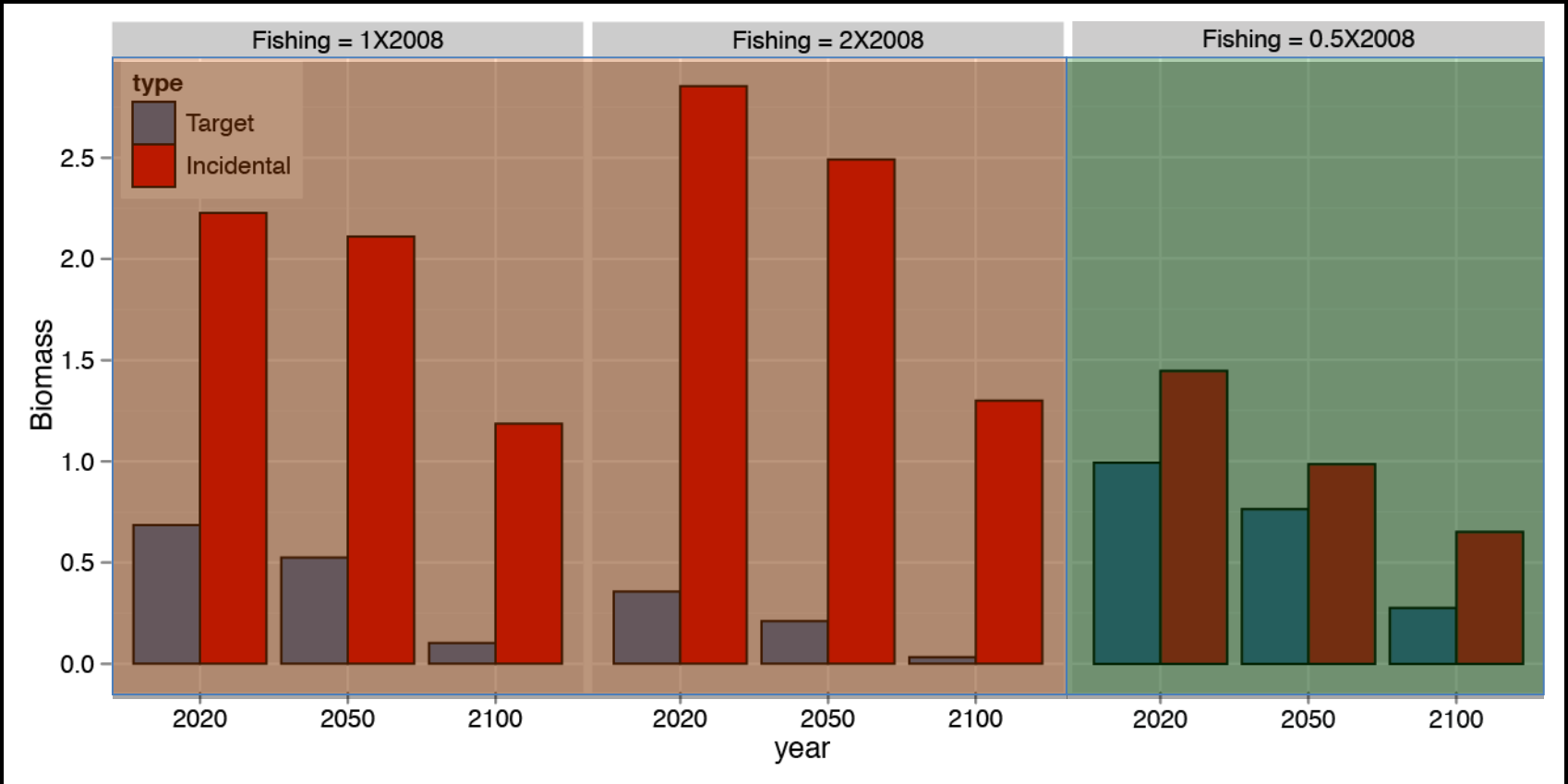
Grouped biomass snapshots at 2020, 2050, 2100

Fishing 1X,2X: Larger split target/incidental species

Fishing 0.5X: Comp. decrease in species over time

Fishing MSE: decrease in species over time, T/I > 1

Incidental species hit from top-down and bottom-up



Summary and Future Work

GFDL climate scenario: ~37% drop in combined phytoplankton in HLFG. Bottom-up forcing = projected species decrease

Climate effects compounded by top-down fishing pressure. This results in lower projected target species B and T/I ratio

Results suggest to preserve bigeye/swordfish: decrease effort in HLFG to 50% E_{2008} levels by 2020

To maintain TI (tar/inc) and minimize biomass reduction for all target species, continue to decrease effort (25% E_{2008} by 2100)

Example MSE results in less decrease in target species, yet large decreases in incidentals (high fishing effect)

Future: More MSE work, maximize bigeye/sword? protect incidentals such as ono, mahi? Total Ecosystem effects of MSE