Developing an understanding of recent and future changes in the North Pacific Subtropical Gyre marine ecosystem

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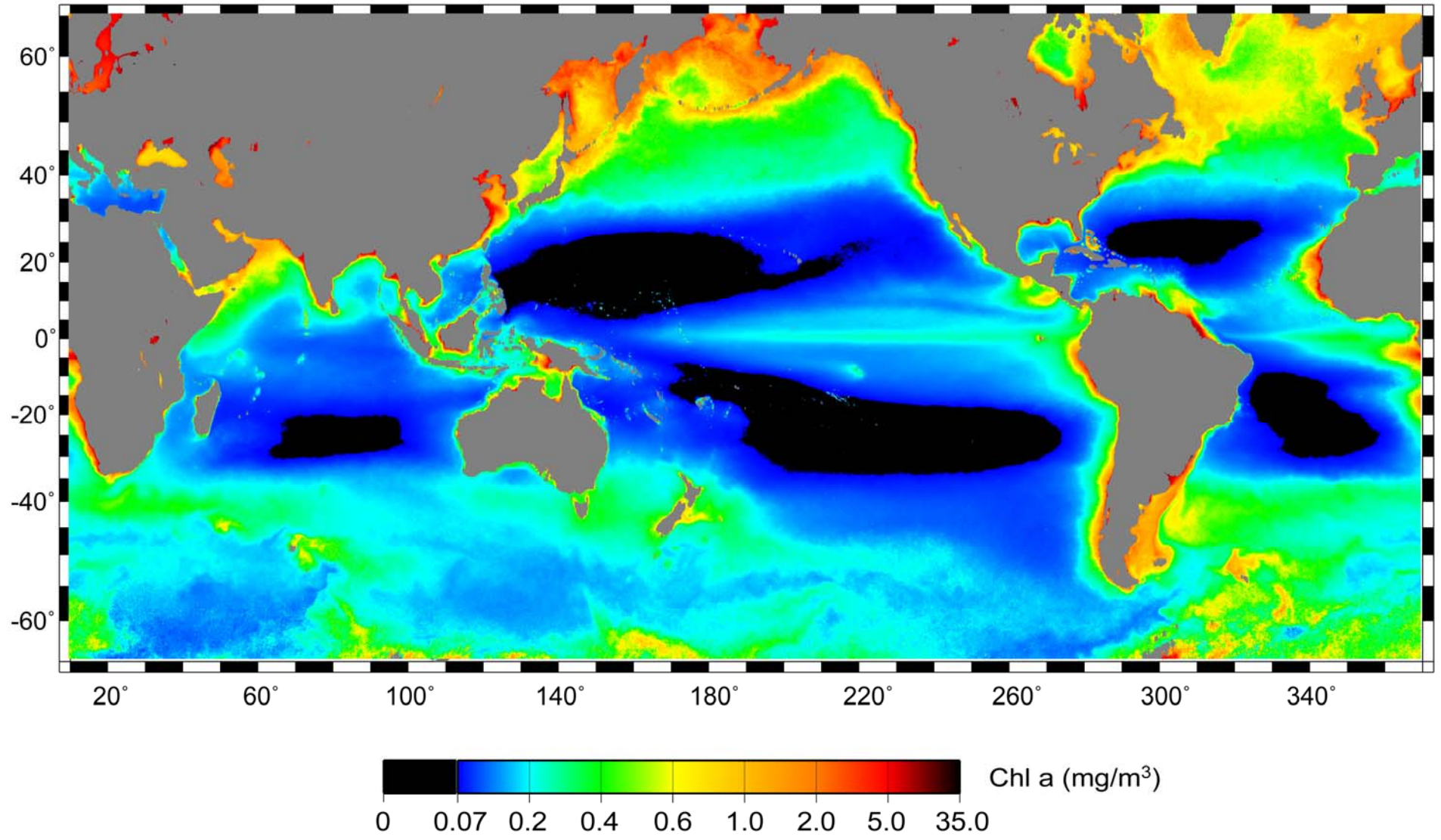
SeawiFS surface chlorophyll climatology with oligotrophic gyres in black



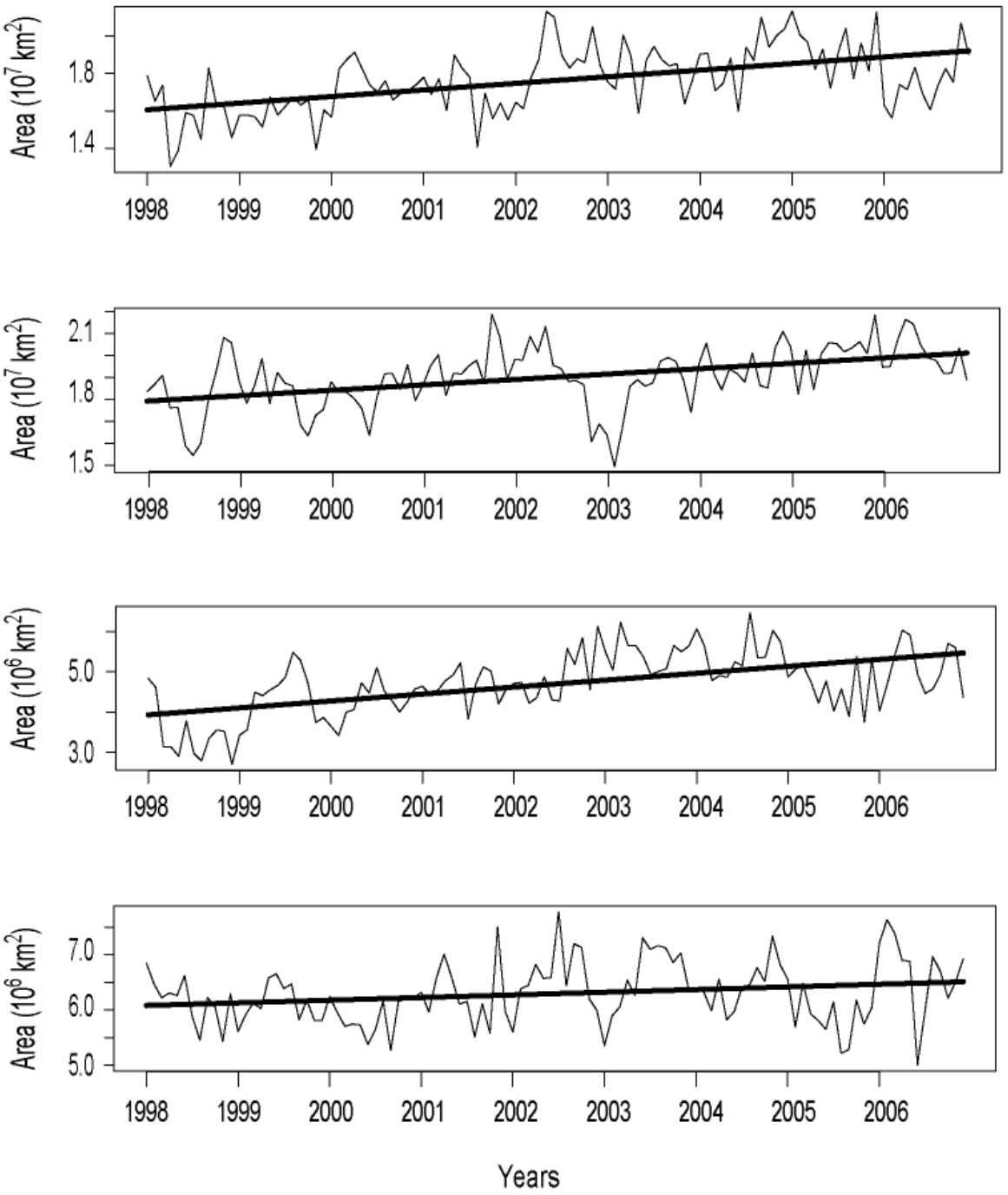
Linear term

N Pacific

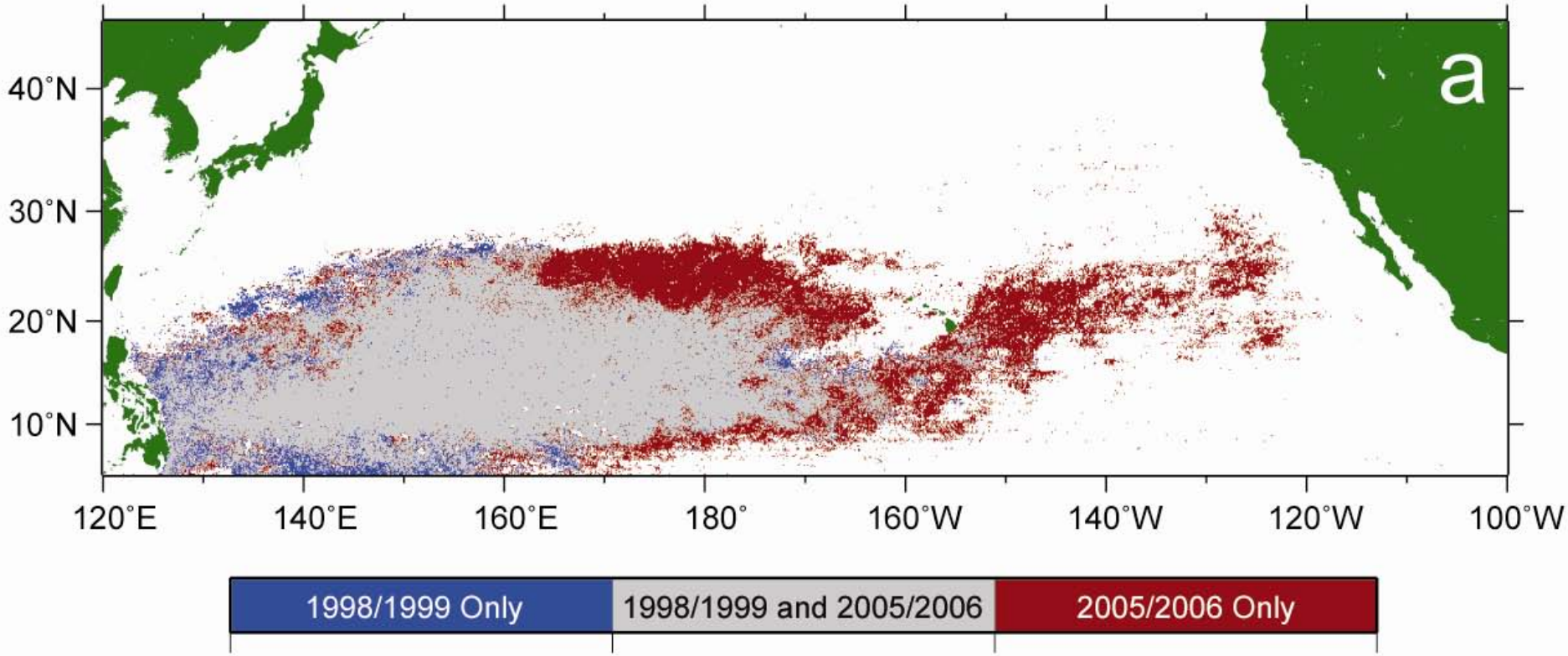
S Pacific

N Atlantic

S Atlantic

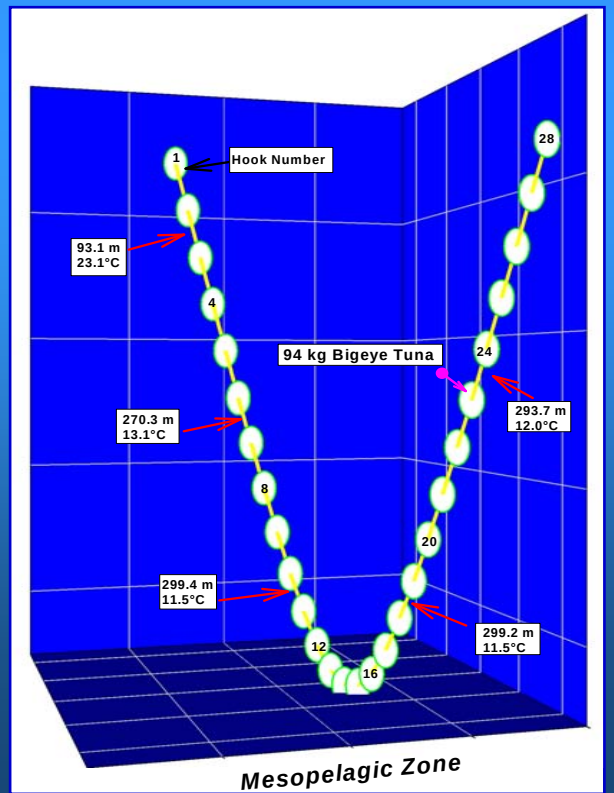


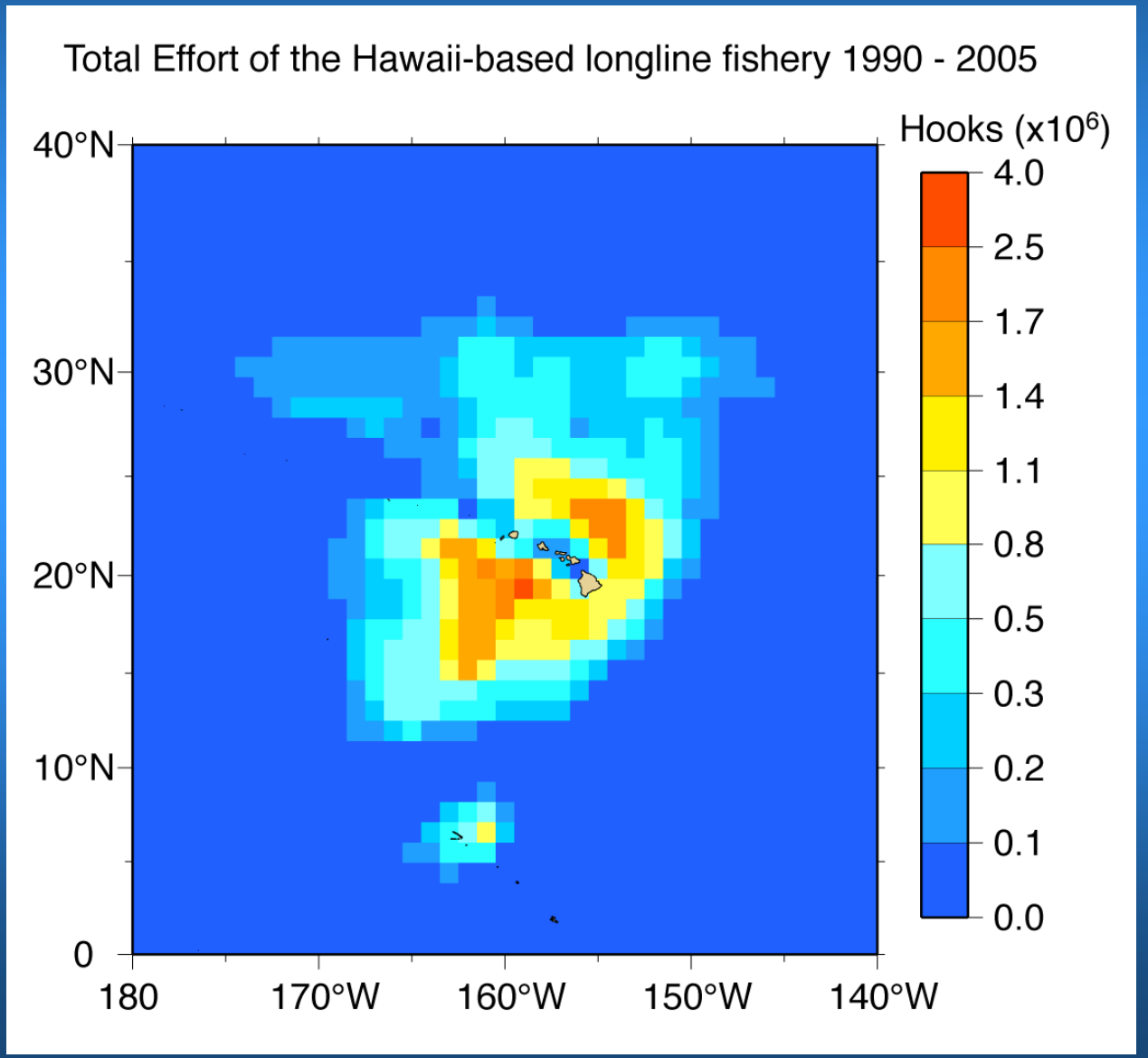
Expansion of low surface chlorophyll waters into the Hawaii longline fishing grounds



Hawaii-based longline fishery

Ex-vessel value 2007 US$ 70 million

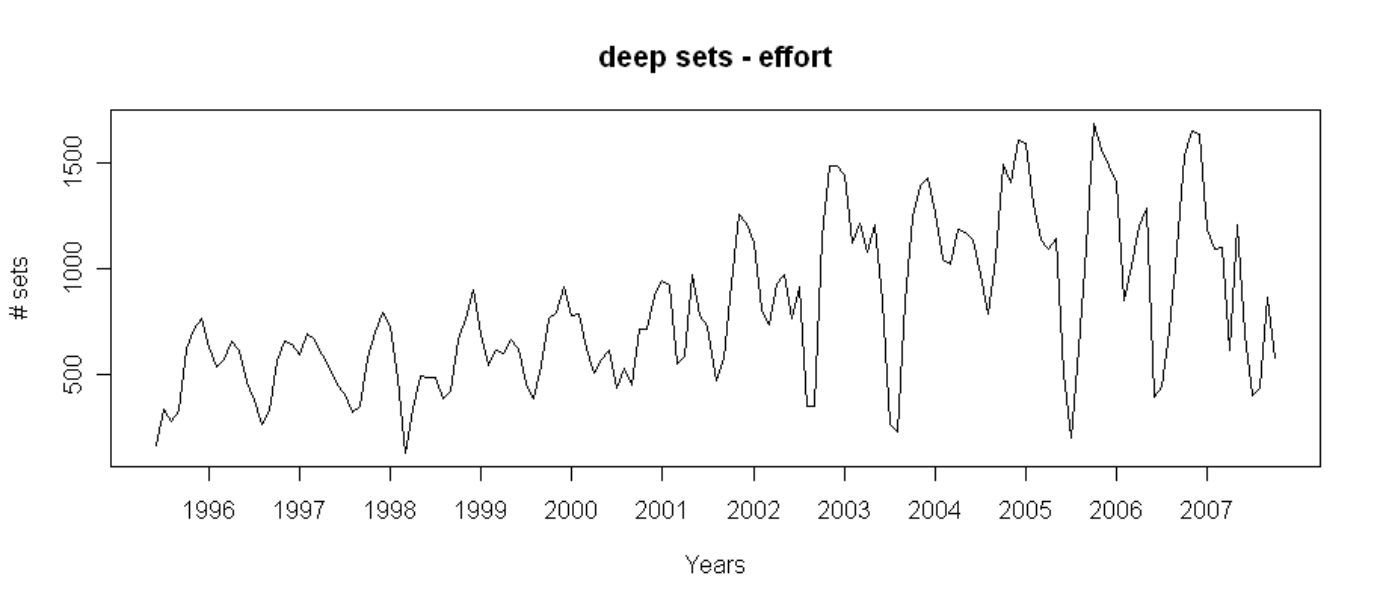


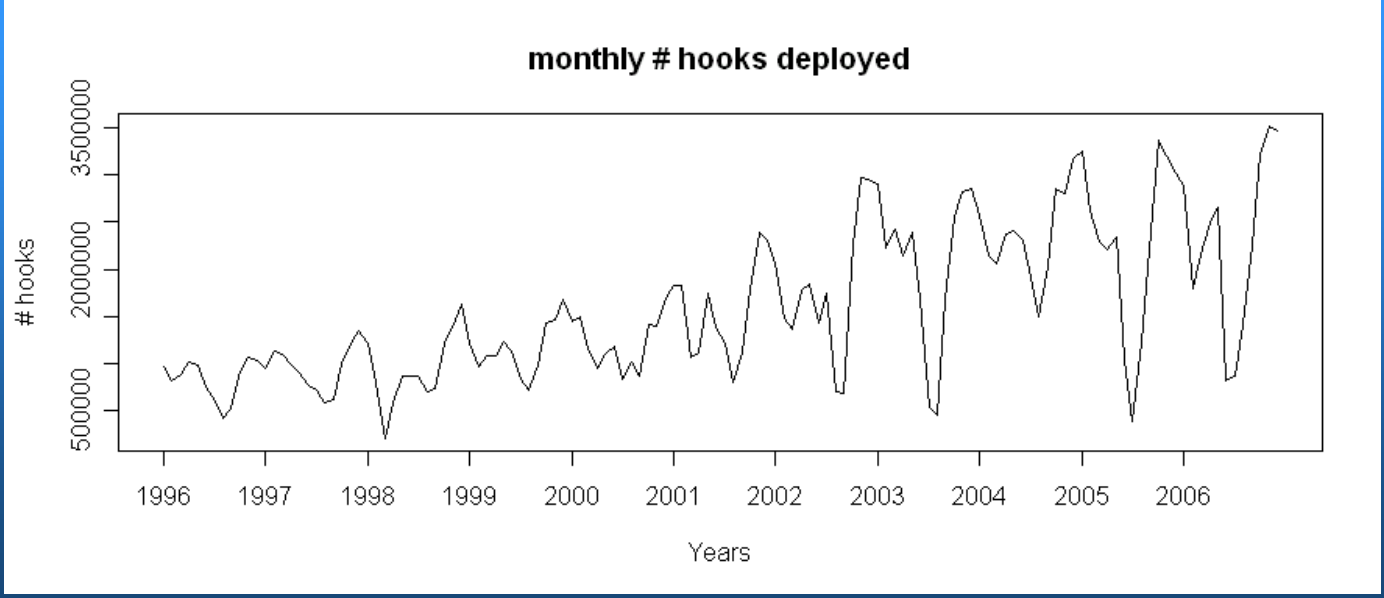


Top 10 most commonly caught species in the Hawaii deep-set longline fishery, 1996-2006:

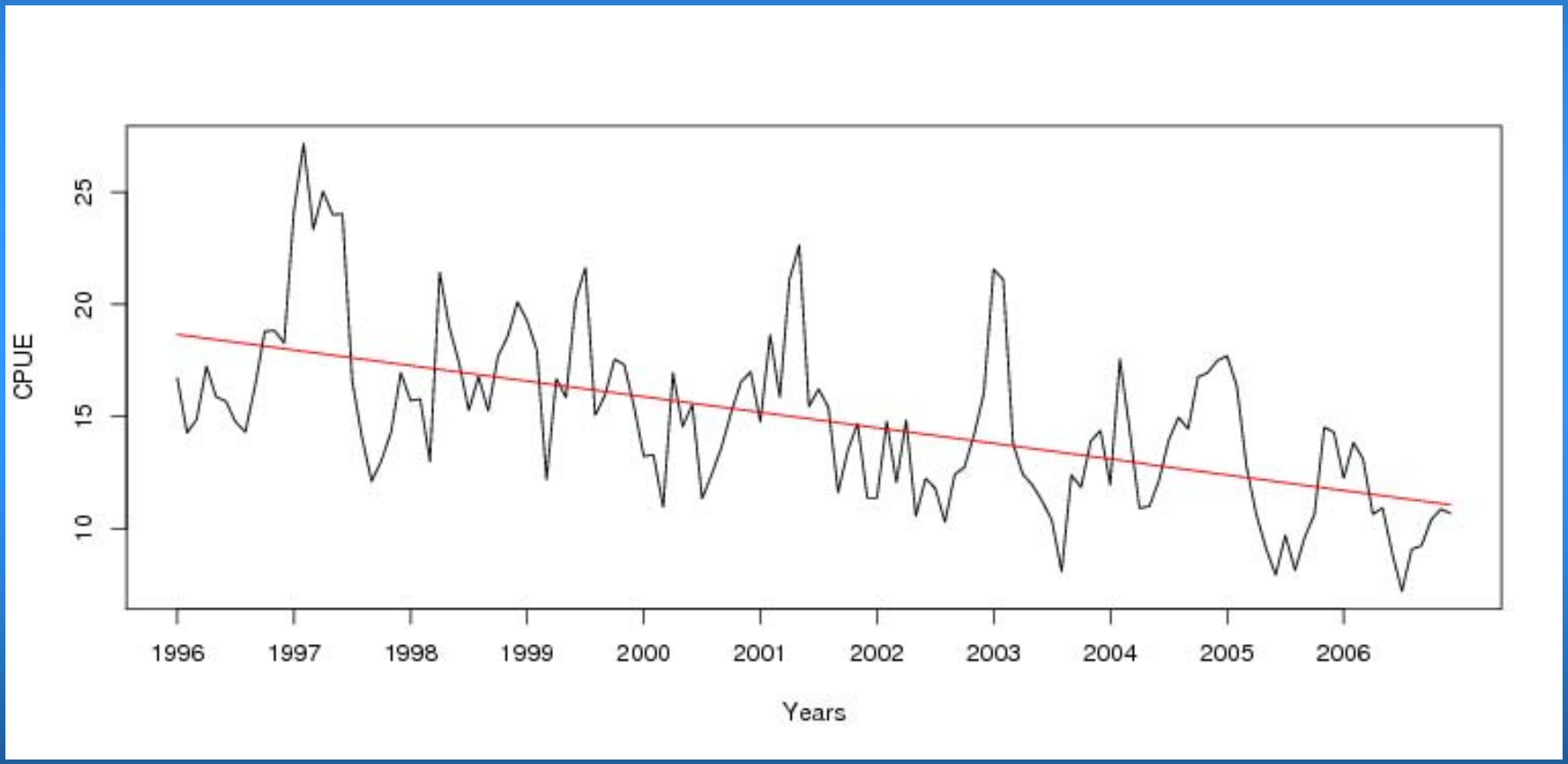
Bigeye, Blue Shark, Albacore Tuna, Yellowfin Tuna, Skipjack Tuna, Striped Marlin, Shortbill Spearfish, Mahi mahi, Ono, Monchong(*Taractichthys steindachneri*)

Time series of deep-set fishing effort

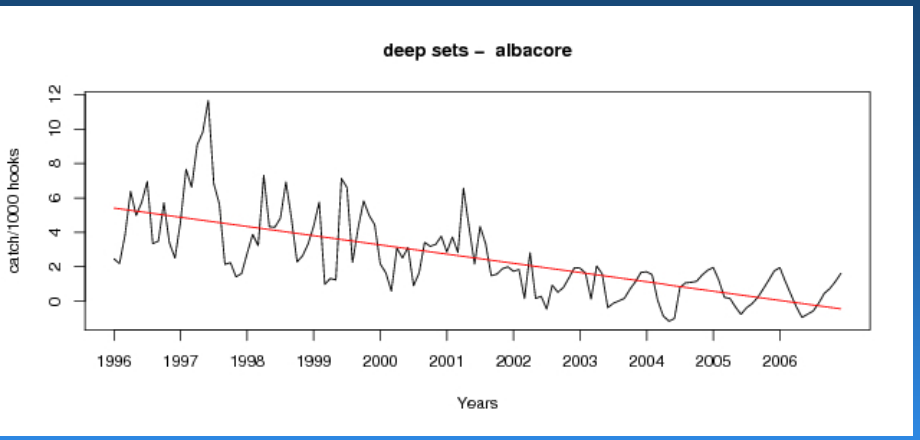


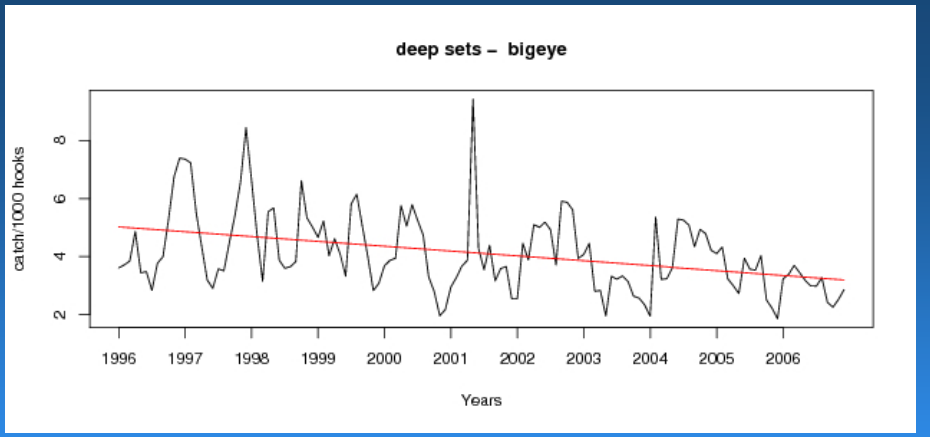


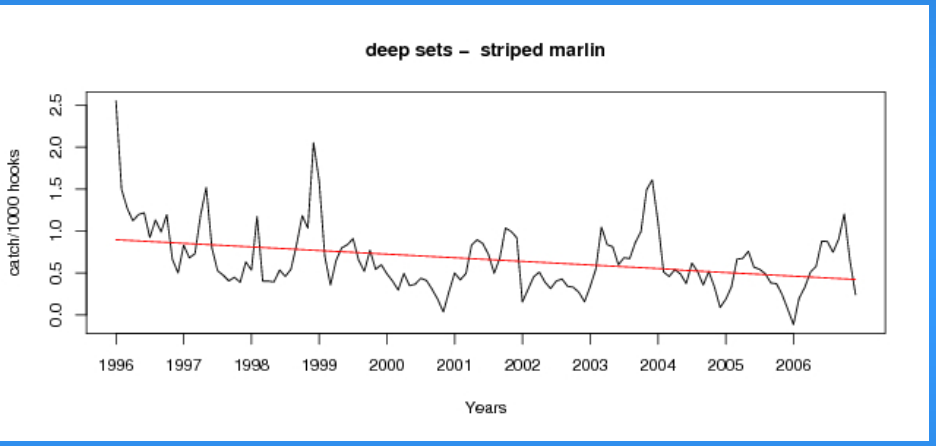
Computed catch-per unit-effort (CPUE as number of fish per 1000 hooks. Fit a GAM CPUE = A + B*Time + S(month) + error

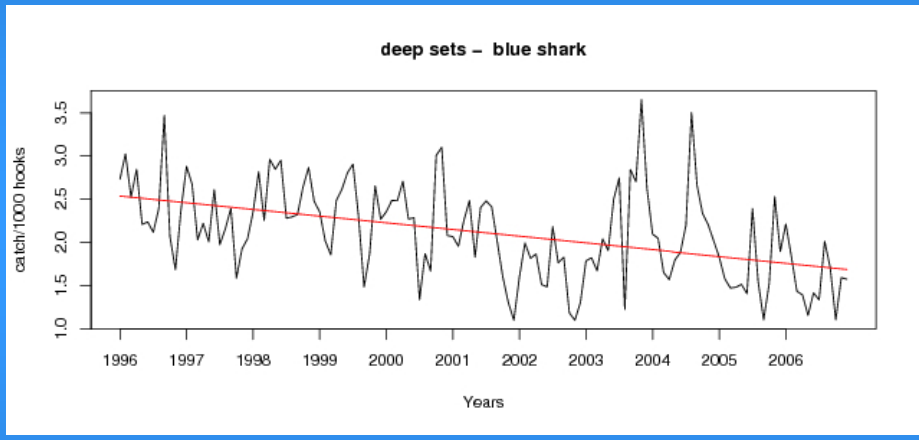


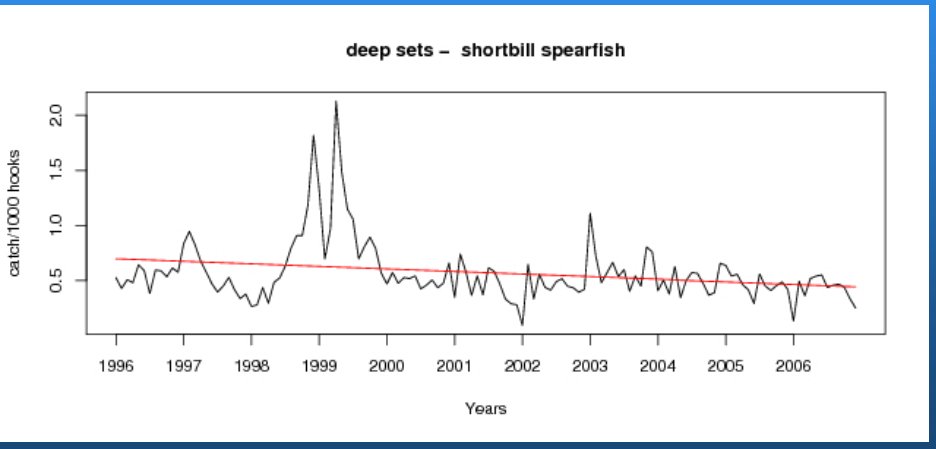
CPUE time series for top 10 species together with estimated linear trend from GAM

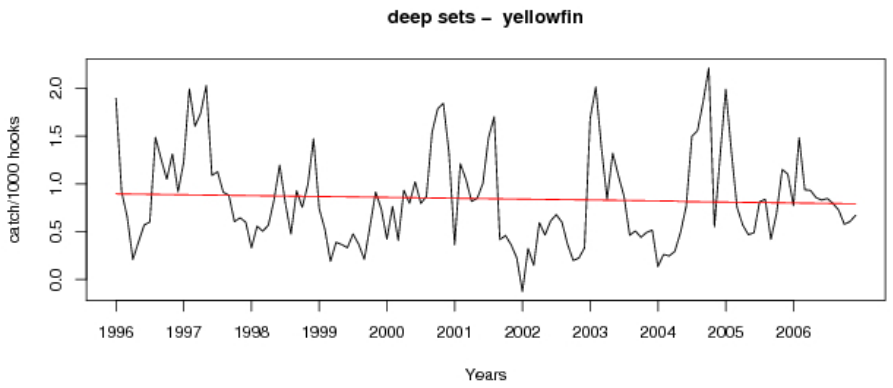

deep sets – albacore
catch/1000 hooks
0 2 4 6 8 10 12
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Years

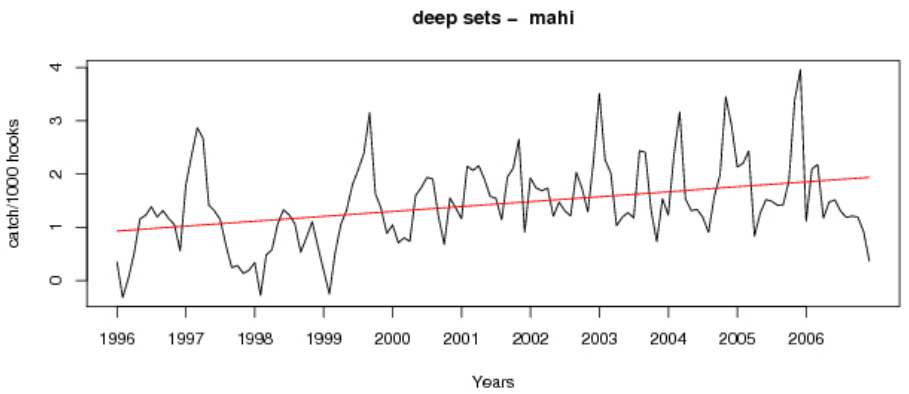

deep sets – bigeye
catch/1000 hooks
2 4 6 8
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Years

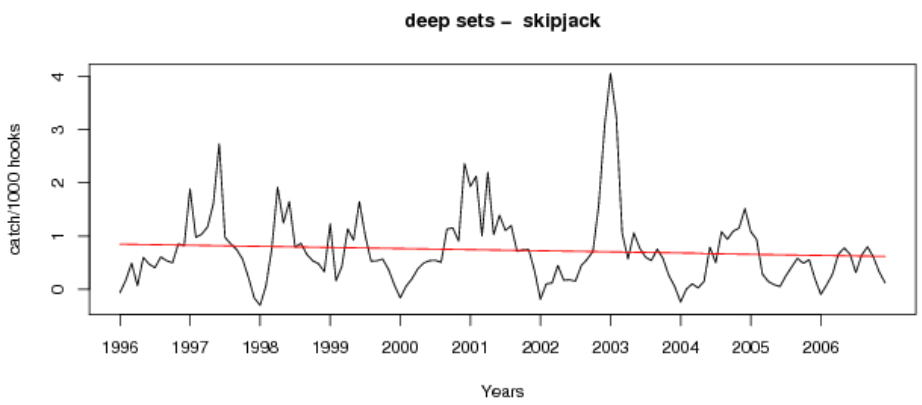

deep sets – striped marlin
catch/1000 hooks
0.0 0.5 1.0 1.5 2.0 2.5
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Years

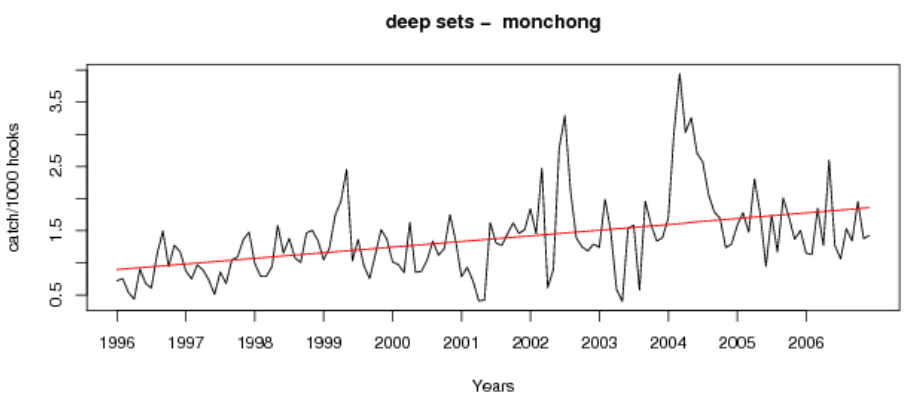

deep sets – blue shark
catch/1000 hooks
1.0 1.5 2.0 2.5 3.0 3.5
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Years

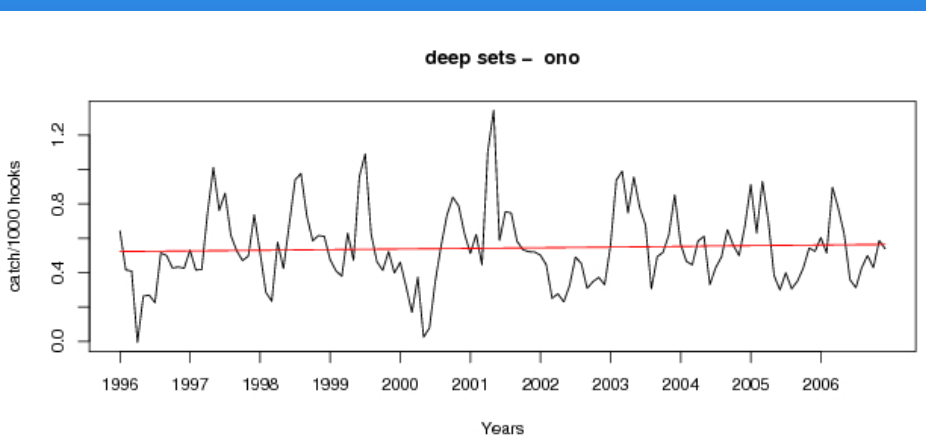

deep sets – shortbill spearfish
catch/1000 hooks
0.5 1.0 1.5 2.0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Years


deep sets – yellowfin
catch/1000 hooks
0.0
0.5
1.0
1.5
2.0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years

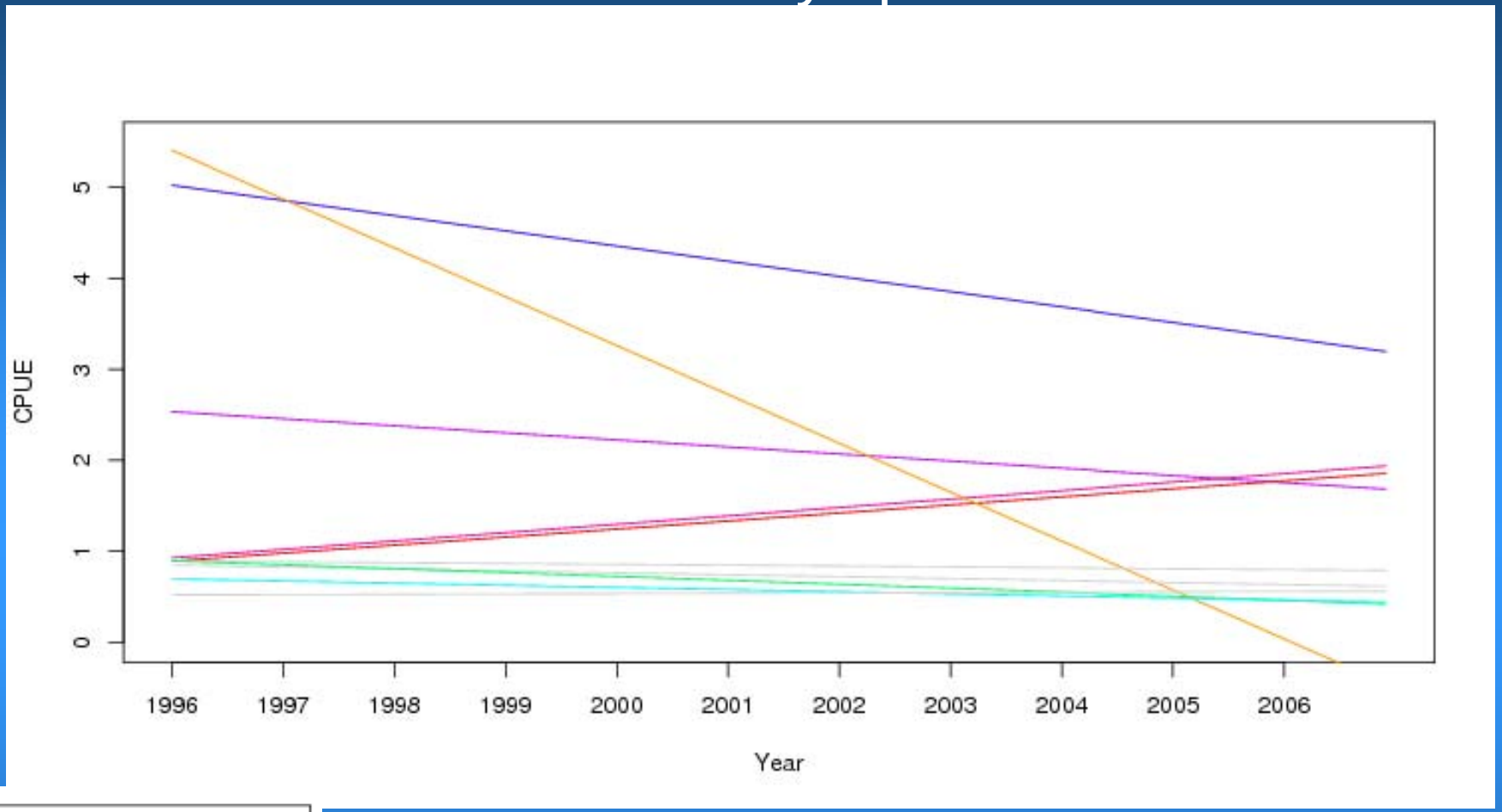

deep sets – mahi
catch/1000 hooks
0
1
2
3
4
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years


deep sets – skipjack
catch/1000 hooks
0
1
2
3
4
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years


deep sets – monchong
catch/1000 hooks
0.5
1.5
2.5
3.5
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years

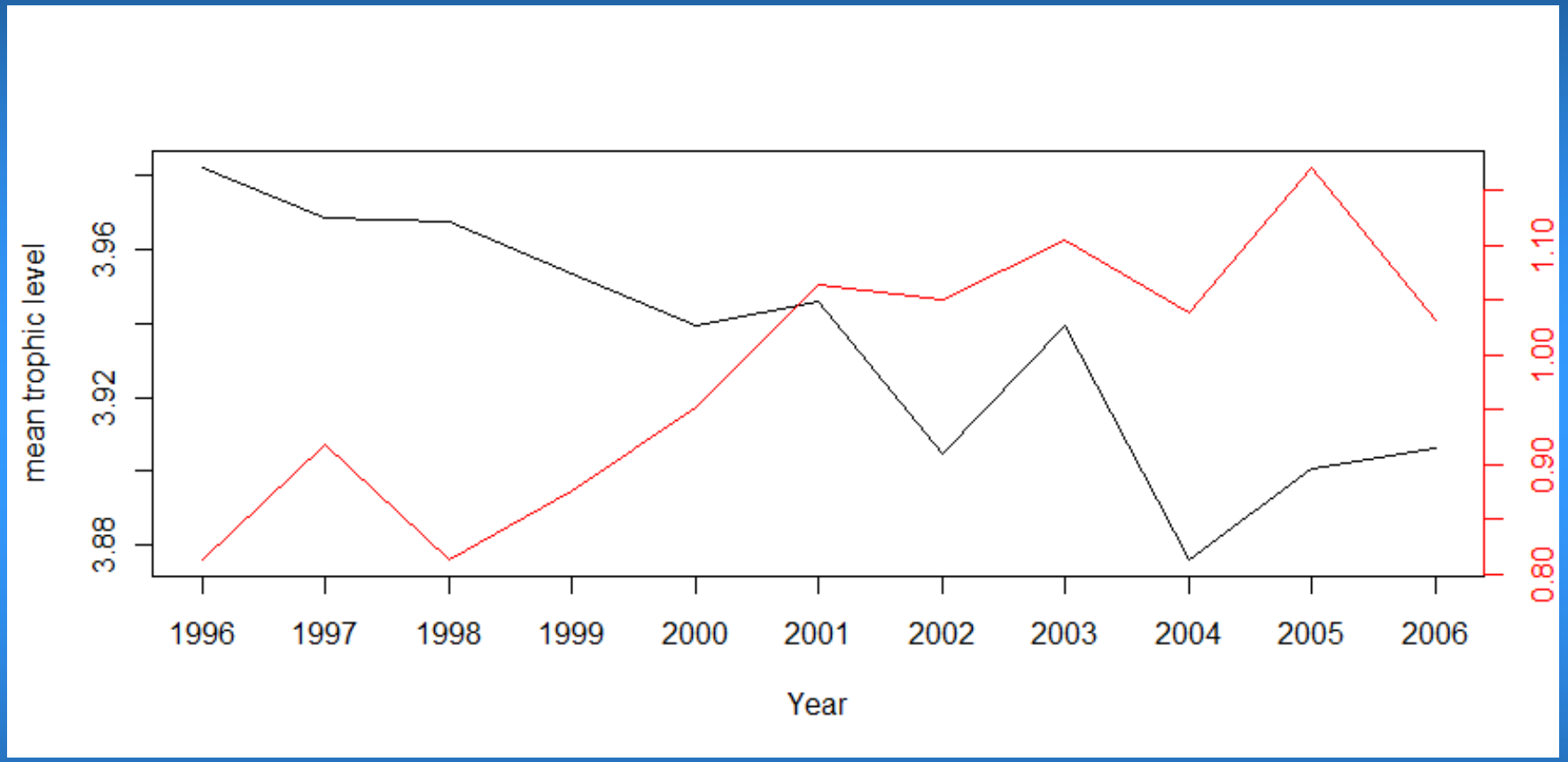

deep sets – ono
catch/1000 hooks
0.0
0.4
0.8
1.2
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
Years

Linear trends in CPUE by species from GAM

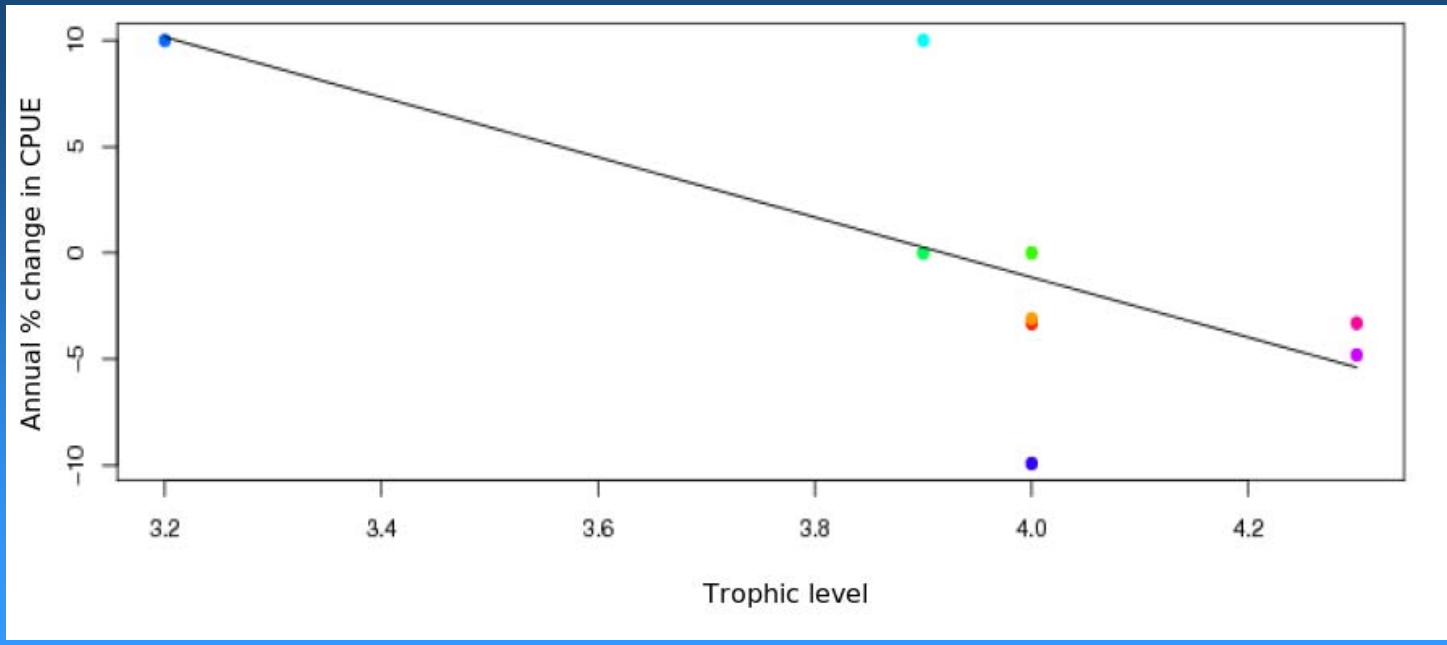


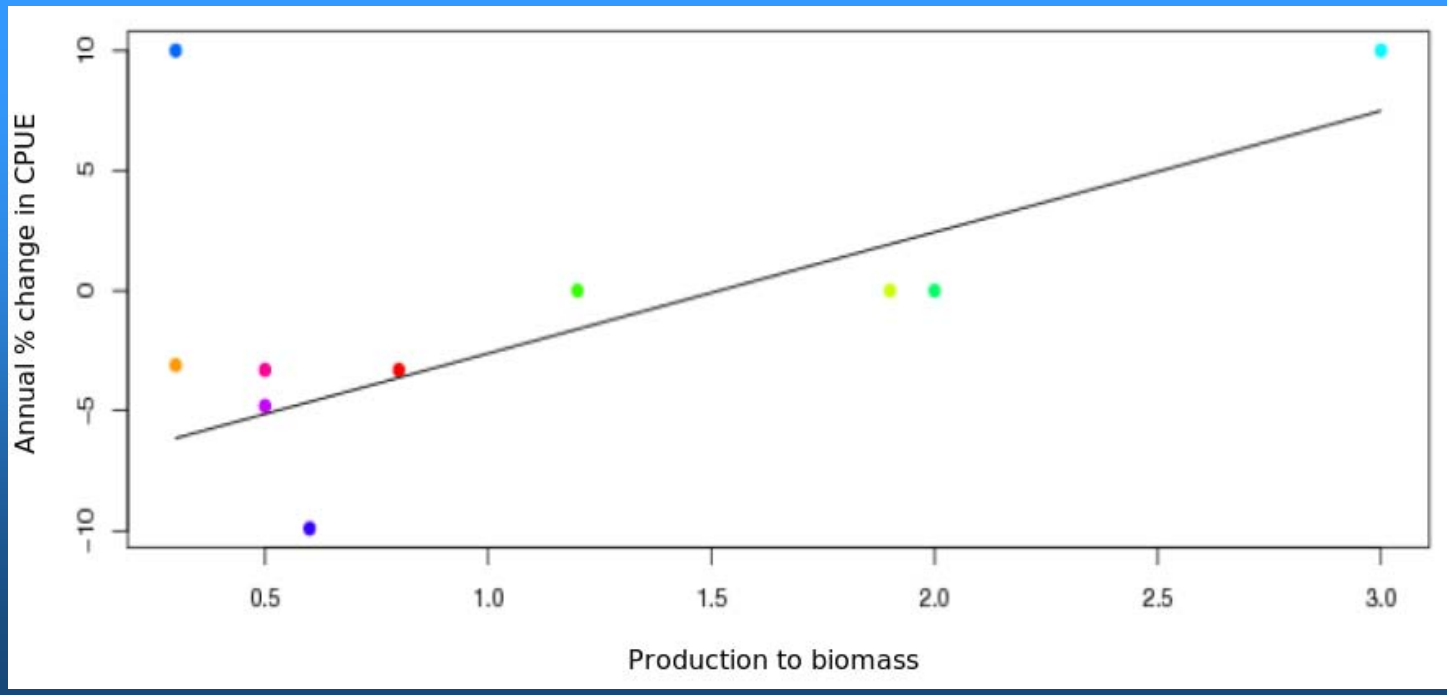
species	% of total catch		annual percent change in CPUE	Production/biomass	Trophic level
	1996	2006			
albacore tuna	24	3	-9.9	0.6	4.0
striped marlin	7	5	-4.8	0.5	4.3
shortbill spearfish	3	3	-3.3	0.5	4.3
bigeye tuna	24	24	-3.3	0.8	4.0
blue shark	14	14	-3.1	0.3	4.0
skipjack tuna	3	4	0.0	1.9	3.9
yellowfin tuna	5	7	0.0	1.2	4.0
ono	2	5	0.0	2.0	3.9
mahi	4	10	10.0	3.0	3.9
Monchong	5	12	10.0	0.3	3.2
Total	91	87	-3.7	-	-

Mean annual trophic level and P/B ratio of the catch of the top 10 species in the deep-set longline fishery

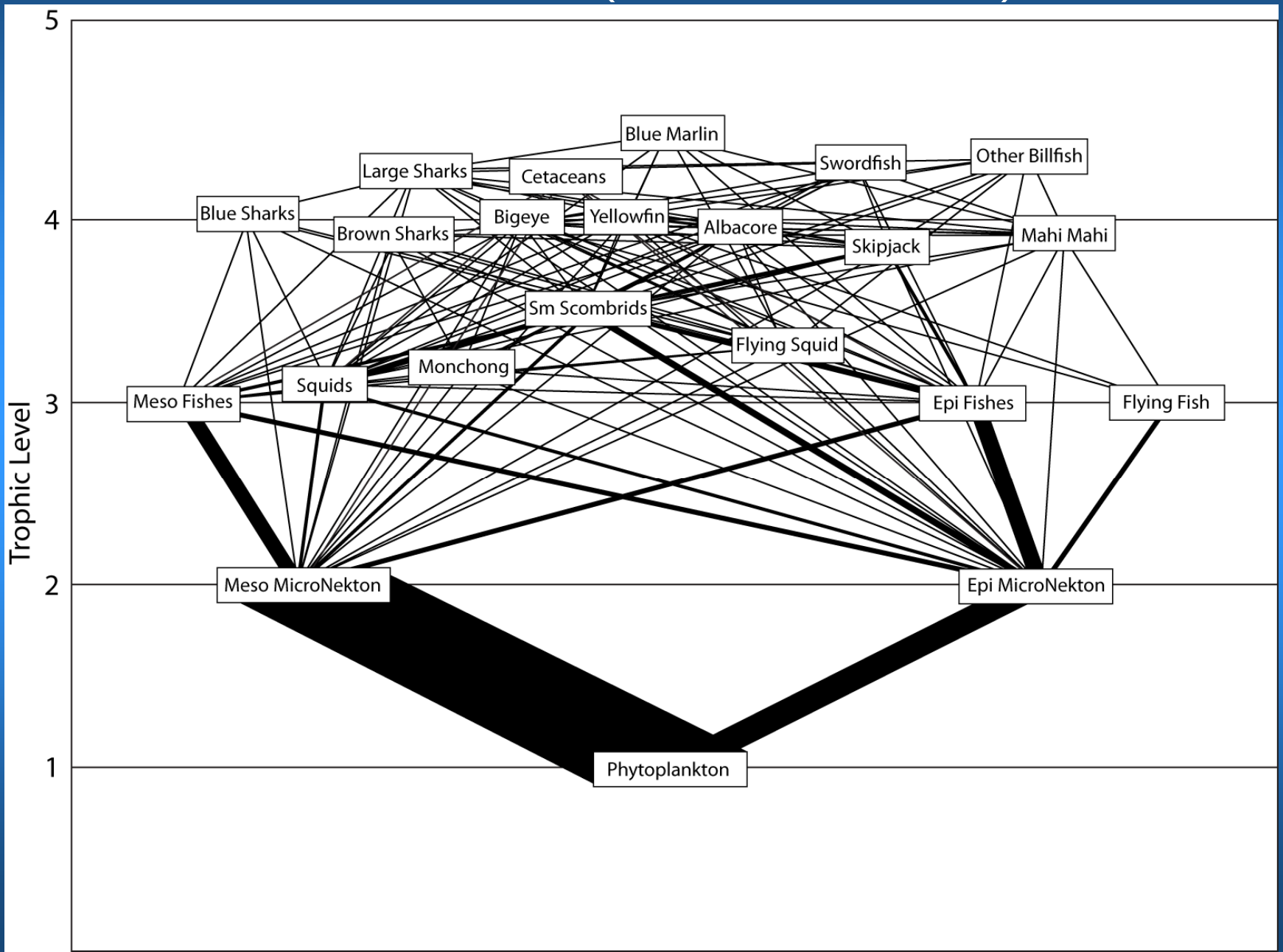


P/B and Trophic level estimates from Ecopath Model in Kitchell et al. (2002)

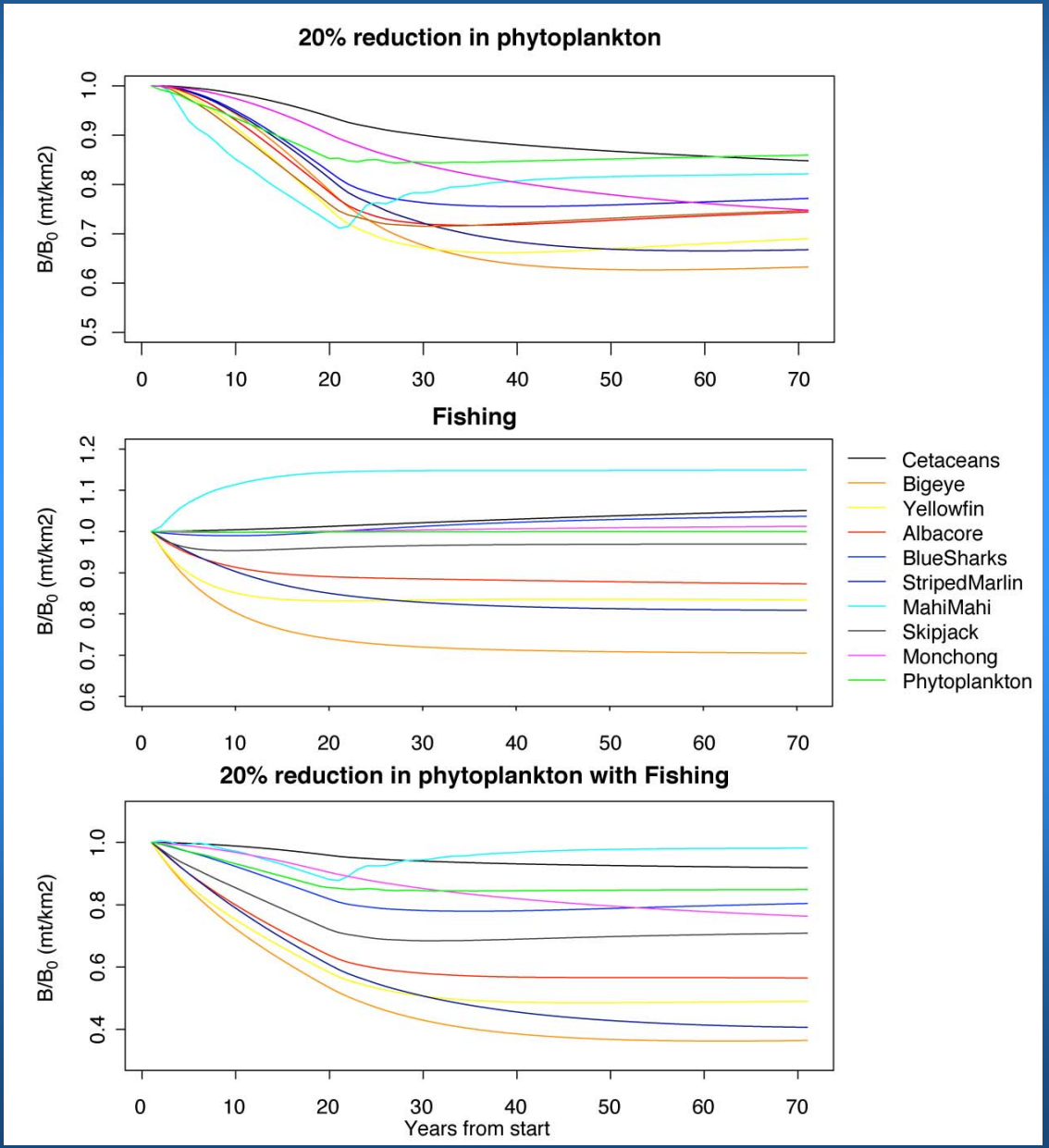




Schematic energy flow in Ecopath/Ecosim pelagic model based on CNP8(Kitchell et al. 2002)



Application of Ecopath with Ecosim for central North Pacific
Kitchell et al. 2002, Model CNP8



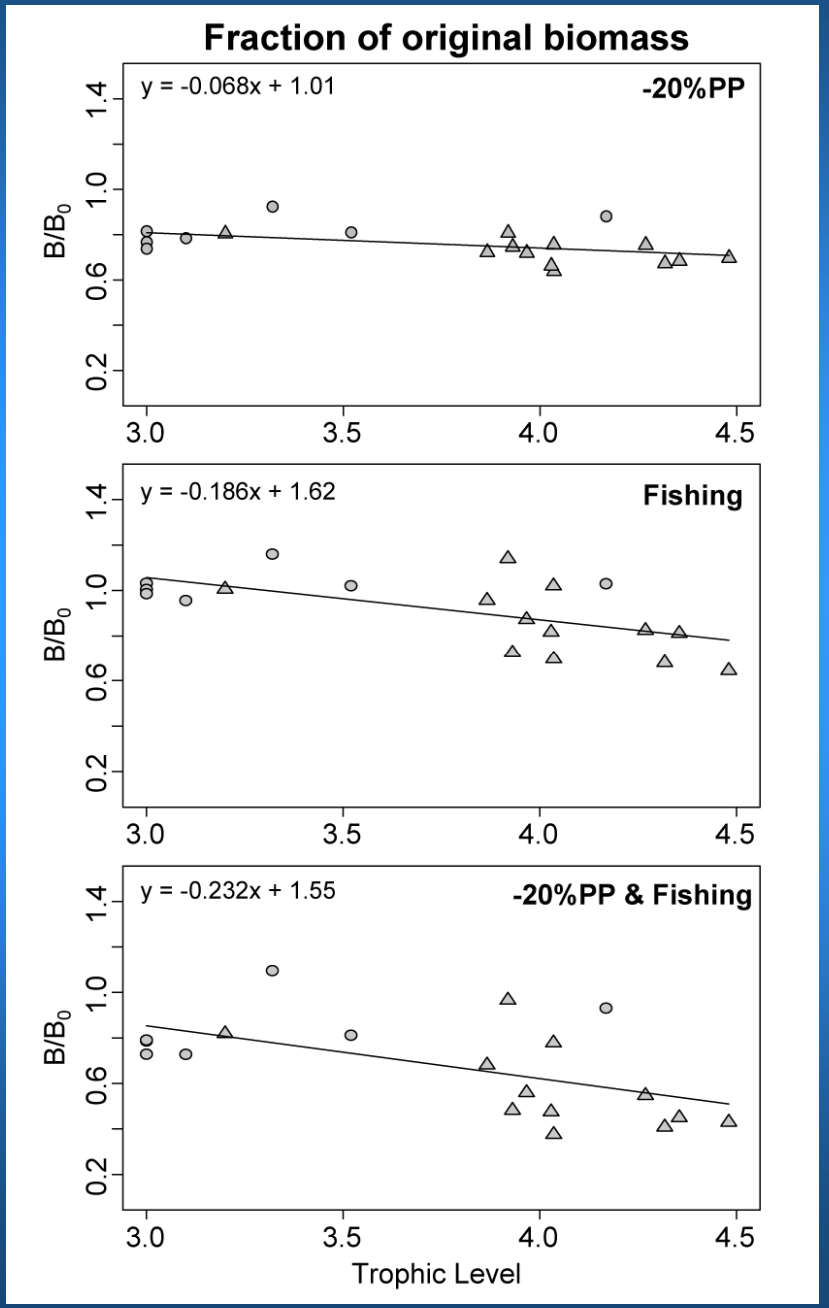
Ecosim Model Results (CNP8, Kitchell et al. 2002)

TL

	p
FF	**0.04**
FF Fish	**0.01**
Fish No FF	**0.005**

	r2
FF	**0.17**
FF Fish	**0.28**
Fish No FF	**0.34**

TL > 4
Blue Marlin (4.48)
Str. Marlin (4.32)
Swordfish (4.32)
Large Sharks (4.27)
Cetaceans (4.17)
Bigeye (4.04)
Blue Sharks (4.03)
Yellowfin (4.03)

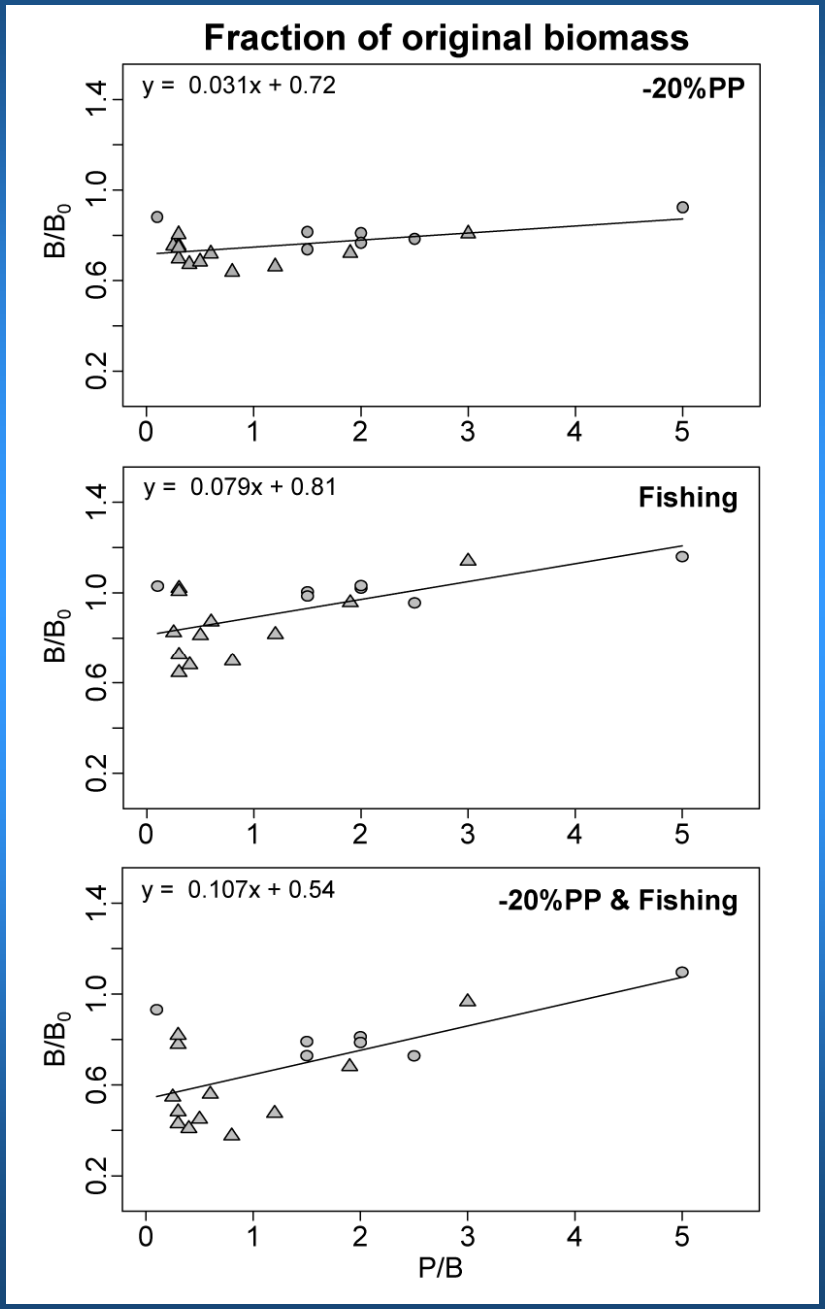


Ecosim Model Results (CNP8, Kitchell et al. 2002)

P/B

	p
FF	0.02
FF Fish	0.03
Fish No FF	0.003

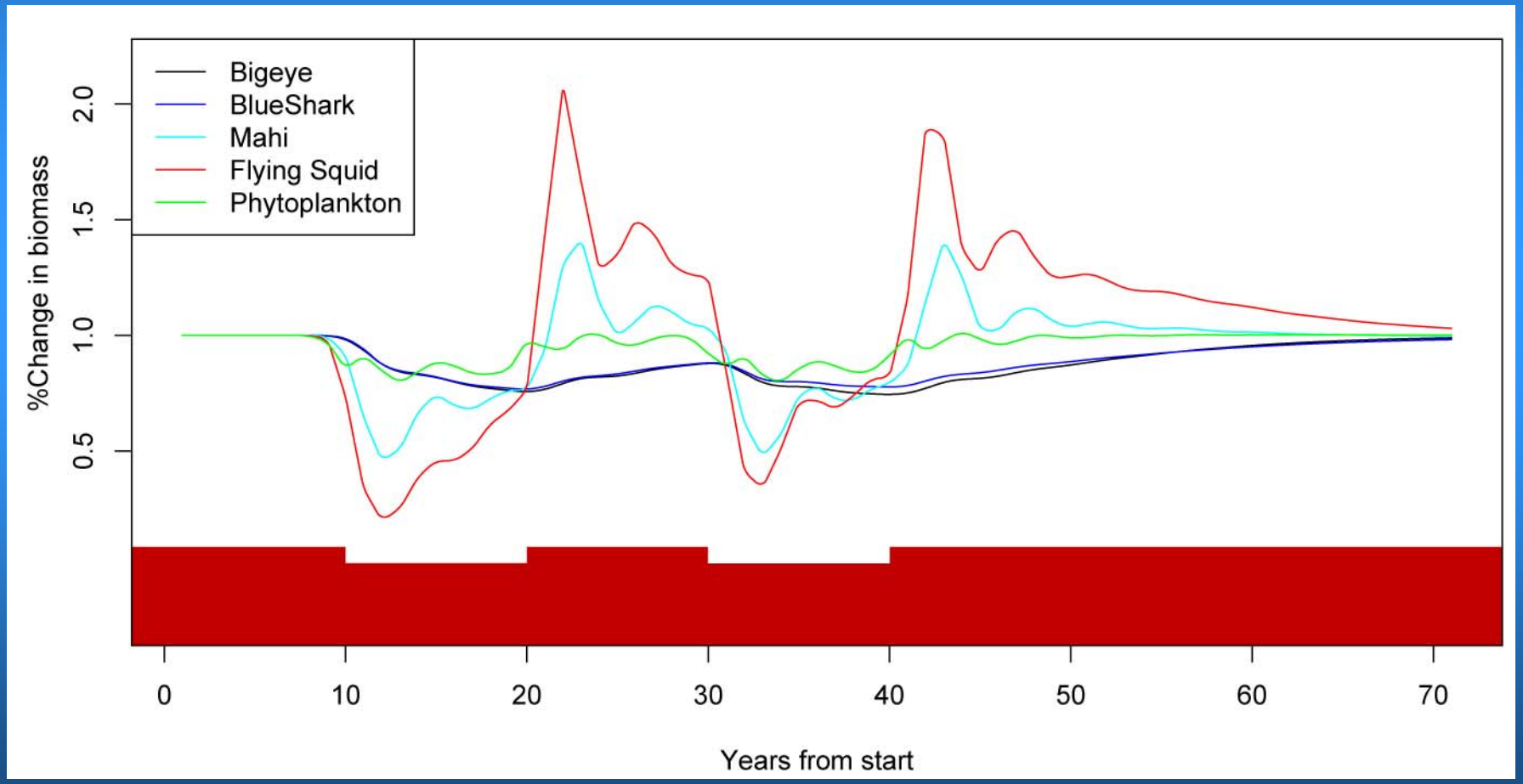
	r^2
FF	0.24
FF Fish	0.38
Fish No FF	0.37



Comparisons between CPUE trends and Ecosim

- Both model and CPUE data suggests that fishing and lower productivity results in a increase in high P/B species and a decline in high TL species.
- Both model and CPUE exhibit declines at top trophic level (bill fishes, sharks, tunas) and an increase in mahi mahi.
- Model doesn’t show collapse of albacore or increase in monchong as seen in CPUE trends.
- Species that do best in model simulation are flying squids (TL=3.3, P/B=5.0) that increase in biomass and mahi (TL=3.9 and P/B= 3.0) and cetaceans (TL=4.1, P/B=0.1) both which maintain initial biomass.

Changes in biomass of species with various P/B ratios in response to decadal changes of 10% in phytoplankton biomass



Summary

SeaWiFS data suggests that there has been an expansion of the least productive areas in the ocean's subtropical gyres over past decade.

Fishery data and model simulations suggest that in response to climate change lowering productivity and continued fishing, the subtropical gyre will see:

i) a continued decline in fished species with low P/B and high trophic levels (billfishes, sharks, large tunas)

ii) an increase in mid-trophic level species especially those with high P/B ratios (mahi, squids, monchong(?))

iii) an increase in high trophic level species not caught in fisheries (sperm whales, beaked whales, pilot whales)

iv) due to the increase in high P/B species, the ecosystem will be more sensitive to climate forcing – making mean P/B of the catch a useful indicator

Seasonal pattern in recruitment to the fishery for those species with substantial seasonality