A size-based cascade in the Pacific subtropical pelagic ecosystem: observations and theory

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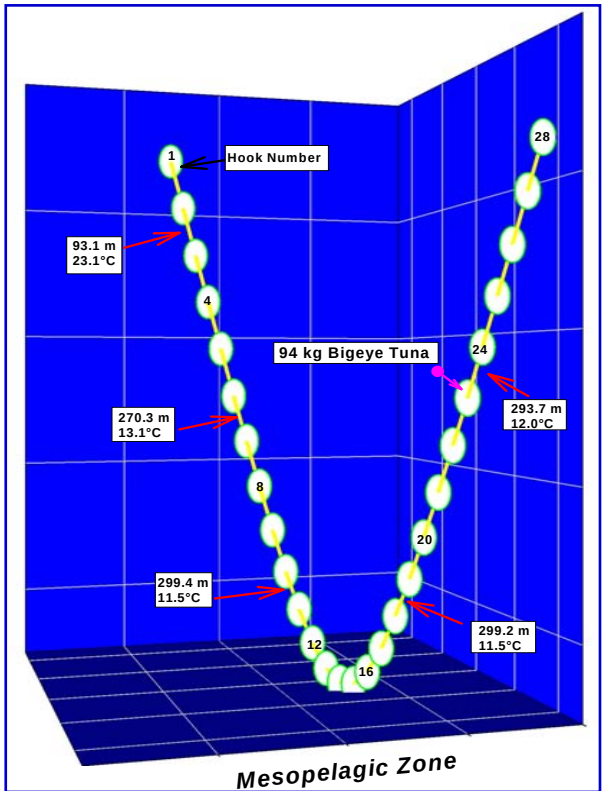
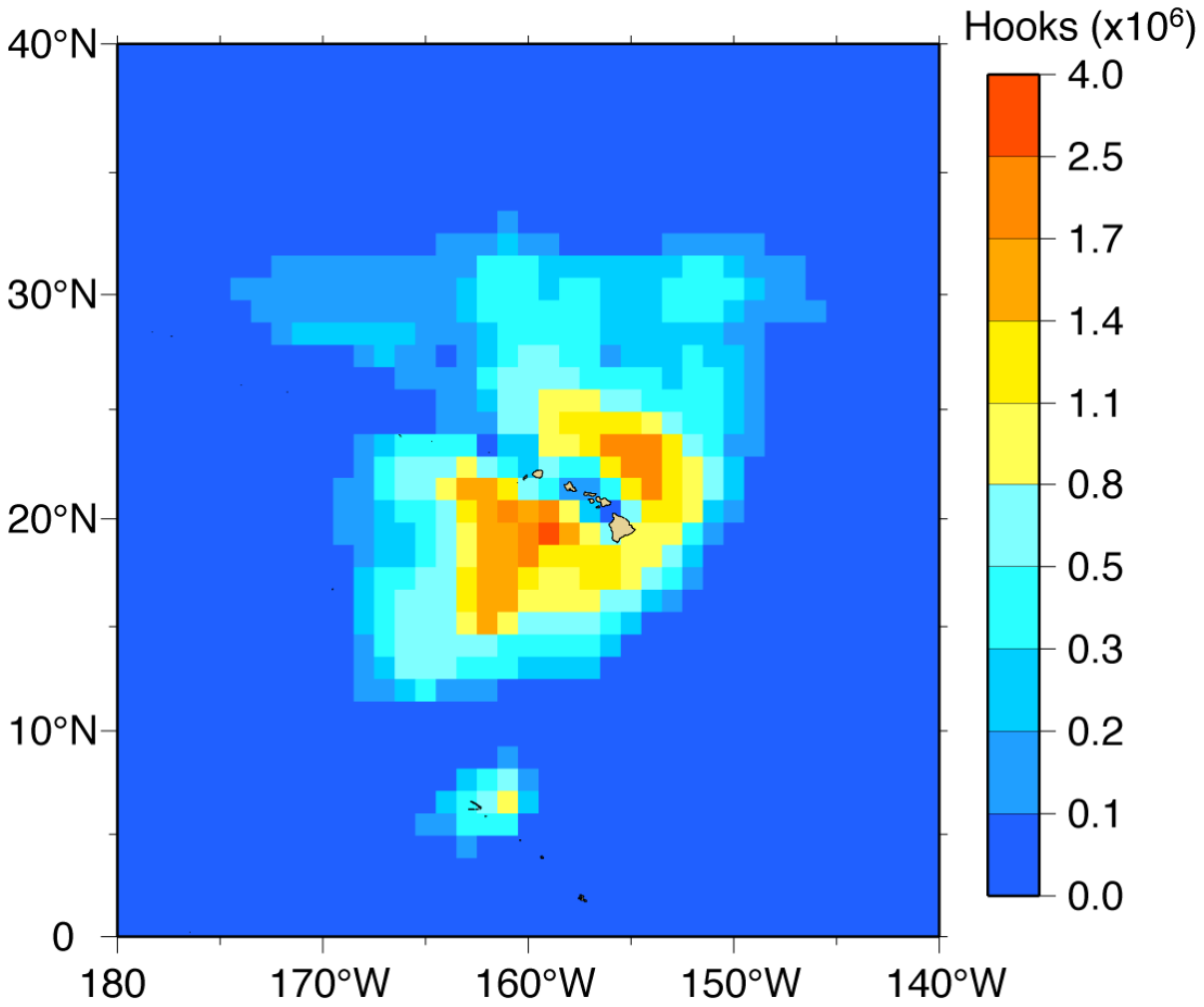
Hawaii-based pelagic longline fishery

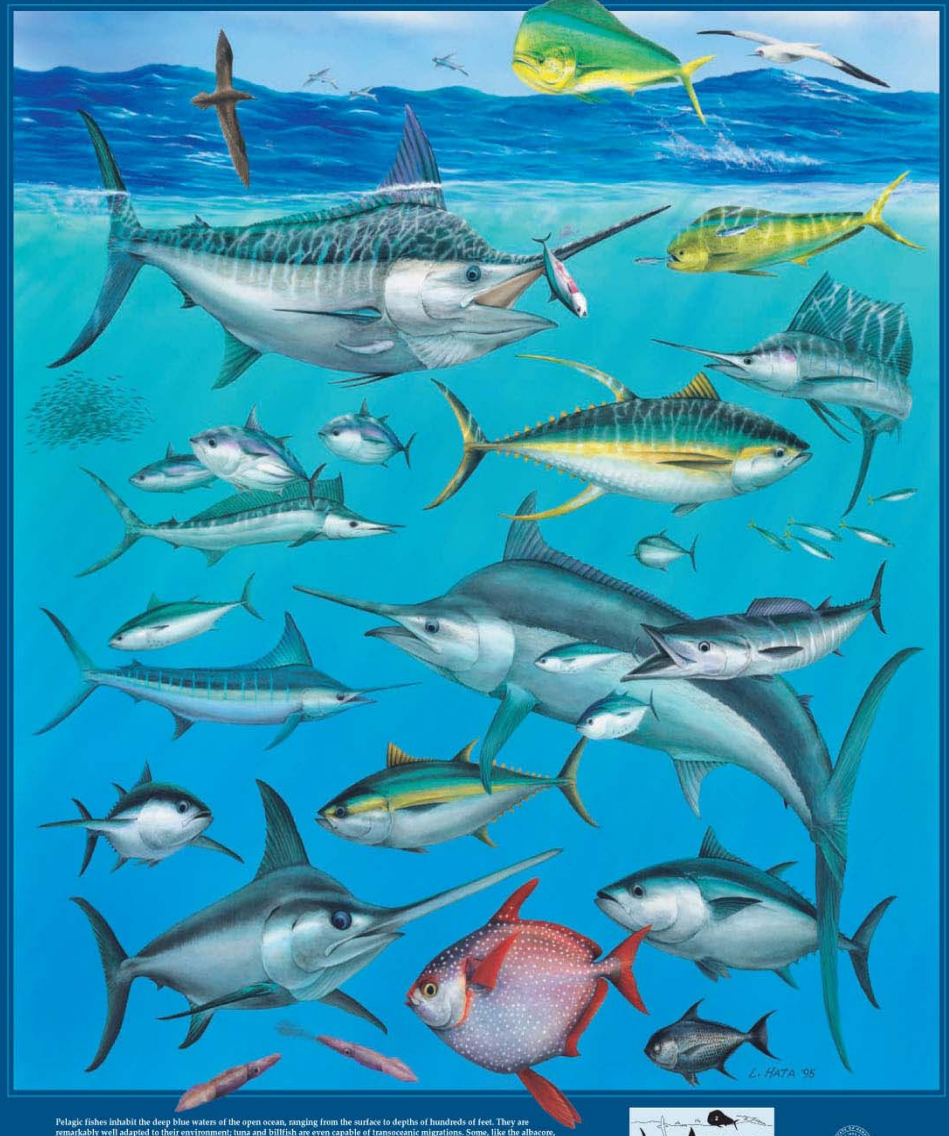
2010: 127 vessels, Ex-vessel value US$ 83 million



Total Effort of the Hawaii-based longline fishery 1990 - 2005



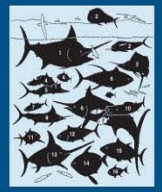
PELAGIC FISHES OF HAWAII



Pelagic fishes inhabit the deep blue waters of the open ocean, ranging from the surface to depths of hundreds of feet. They are remarkably well adapted to their environment; tuna and billfish are even capable of transoceanic migrations. Some, like the albacore, span the entire Pacific Ocean on their way to and from Hawaiian waters.

Tuna and billfish are top predators of the pelagic realm, feeding on almost all other creatures in the open ocean, including each other. Along with other large pelagic species, they are among the most popular fish for food and recreation. Their size and strength make them prized catches of sport fishers. They are also highly valued commercially, and command impressive prices on many international markets. From both an economic and social perspective, these are the most important fishes in Hawaii's waters.

1. **A'u** - *Makaira mazara*
Pacific blue marlin, kajiki
2. **Mahimahi** - *Coryphaena hippurus*
Dorado (male, shown jumping, and female)
3. **A'u lupe** - *Istiophorus platypterus*
Sailfish
4. **Aku** - *Katsuwonus pelamis*
Skipjack tuna
5. **A'u** - *Tetrapturus angustirostris*
Shortbill spearfish, hebi
6. **Ahi** - *Thunnus albacares*
Yellowfin tuna
7. **Kawakawa** - *Euthynnus affinis*
Eastern little tuna, mebachi
8. **A'u** - *Tetrapturus audax*
Striped marlin, nairagi
9. **A'u** - *Makaira indica*
Black marlin, hiida
10. **Ono** - *Acanthocybium solandri*
Wahoo
11. **'Ahi palaha** - *Thunnus alalunga*
Albacore, tombo
12. **'Ahi po'onui** - *Thunnus obesus*
Bigeye tuna, mebachi
13. **A'u ku** - *Xiphias gladius*
Broadbill swordfish, shutome
14. **Opah** - *Lampris guttatus*
Moonfish
15. **Maguro** - *Thunnus thynnus*
Northern bluefin tuna
16. **Monchong** - *Taractichthys steindachneri*
Pomfret



Designed and illustrated by Lee Hata

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SPORT FISH RESTORATION

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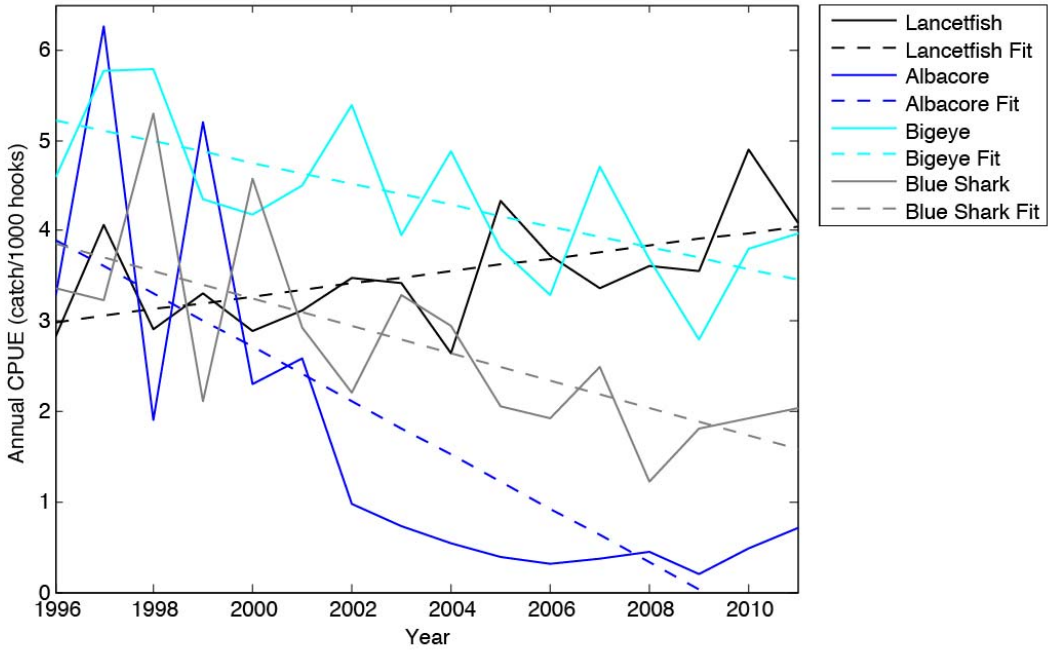
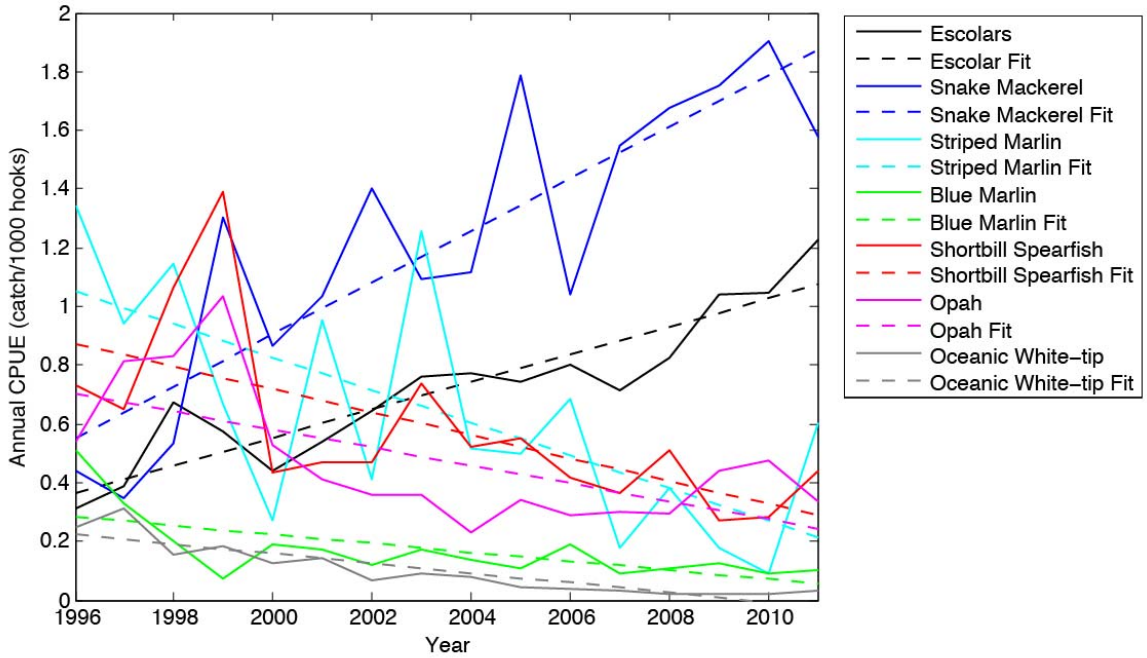
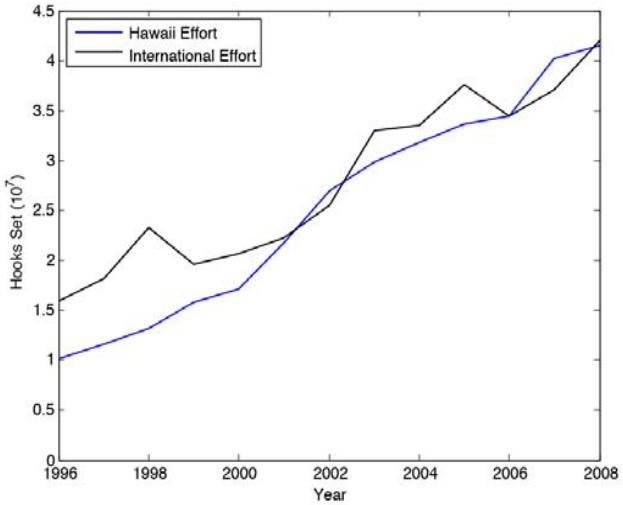




Annual CPUE for individual species/groups with significant linear trends
Top: High CPUEs
Bottom: Low CPUEs

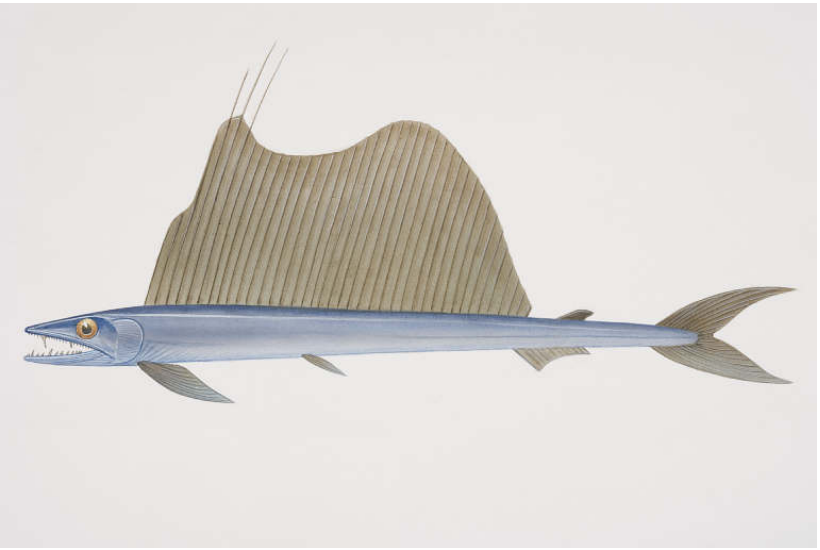


Fishing mortality in Central and Western Pacific for 1990-2010 increased by 4-5 fold for yellowfin and bigeye tunas

Percent change in CPUE over 16-year period ordered by mean fish size

Species	% Change in CPUE from Linear Fit over 16 yr period	Mean Wt (kg)
Blue Marlin	-80.30	224.0
Blue Shark	-59.18	106.4
Striped Marlin	-79.63	93.5
Shortbill Spearfish	-67.03	75.7
Opah	-65.36	30.2
Bigeye	-33.77	22.5
Oceanic White-tip	-110.37	19.0
Albacore	-114.37	17.1
Escolars	194.5	12.1
Lancetfish	35.3	7.1
Snake Mackerel	240.8	0.8

Lancetfish (*Alepisaurus ferox*)



Escolar, walu, (*Lepidocybium flavobrunneum*)

Snake mackerel (*Gempylus serpens*)

Small fishes: 8 Fishes with mean weight < 15 kg

Skipjack: 7.92 kg	Pomfrets: 4.87 kg
Escolars: 12.12 kg	Molas: 8.78 kg
Mahi: 7.44 kg	Snake mackerel: 0.82 kg
Great barracuda: 5.92 kg	Lancetfish: 7.07 kg

Large fishes: 14 Fishes with mean weight ≥ 15 kg

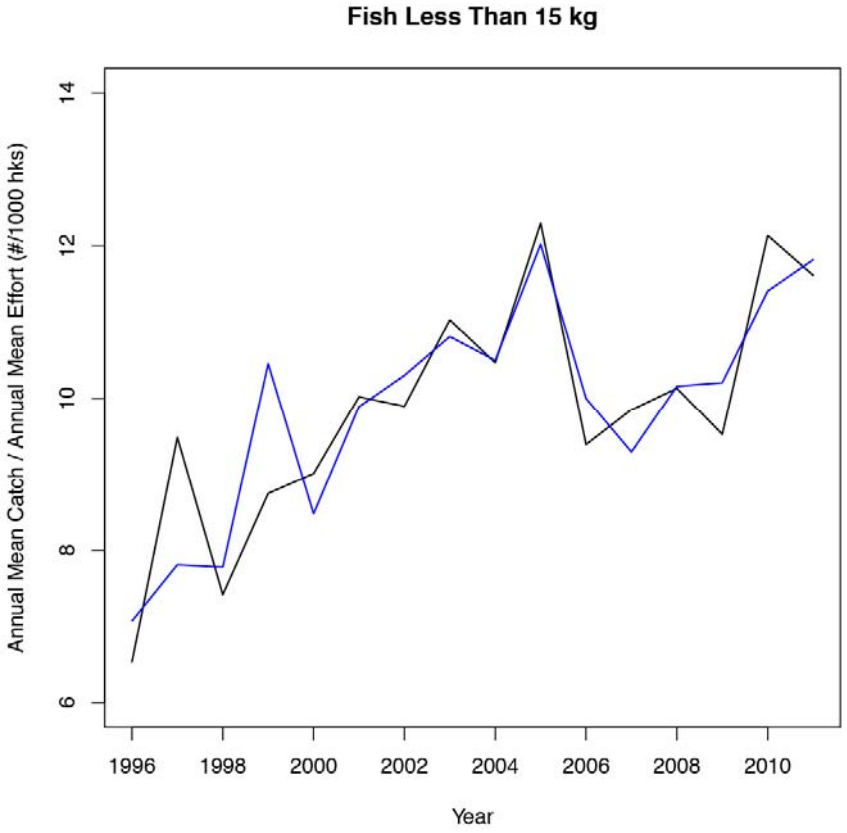
Yellowfin: 33.5 kg	Shortbill spearfish: 93.49 kg
Albacore: 17.14 kg	Wahoo: 16.38 kg
Unid. tuna: 23.89 kg	Opah: 30.17 kg
Bigeye: 22.50 kg	Oceanic White-tip: 18.96 kg
Swordfish: 41.97 kg	Bigeye thresher: 23.91 kg
Striped marlin: 93.49 kg	Shortfin mako: 48.27 kg
Blue marlin: 224.03 kg	Blue shark: 106.42 kg

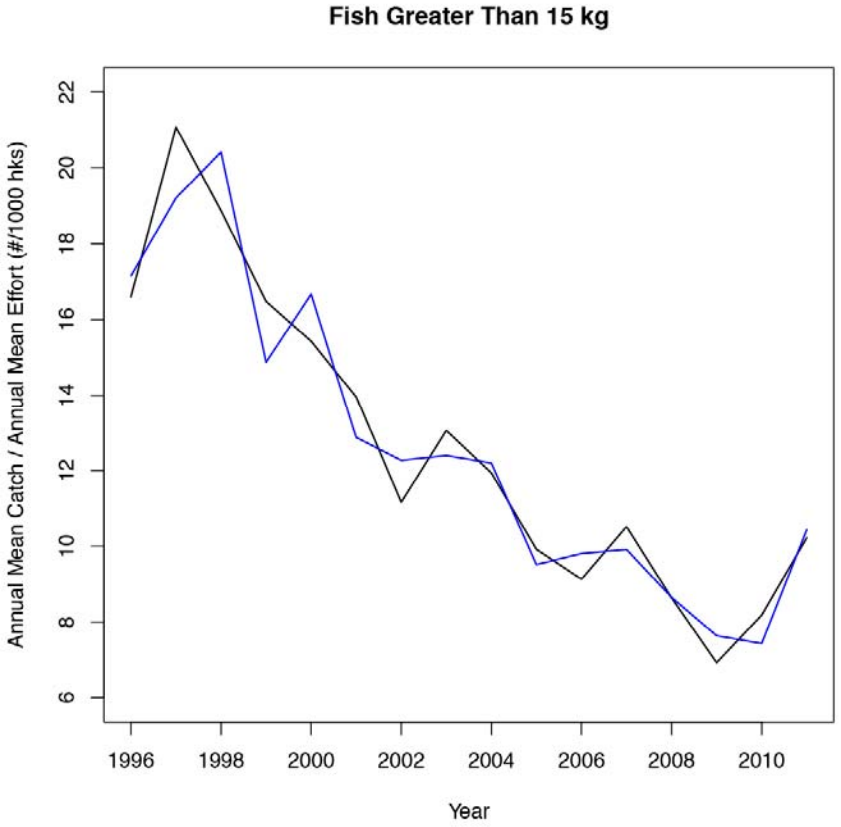
Observed and GAM fitted CPUE

Observed

GAM

		Intercept	year	Hooks set	longitude	latitude	sst
GAM	**Catch (<15kg)**	0.9676	0.0265	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$
	Catch (≥15kg)	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$	$<2\times10^{-16}$



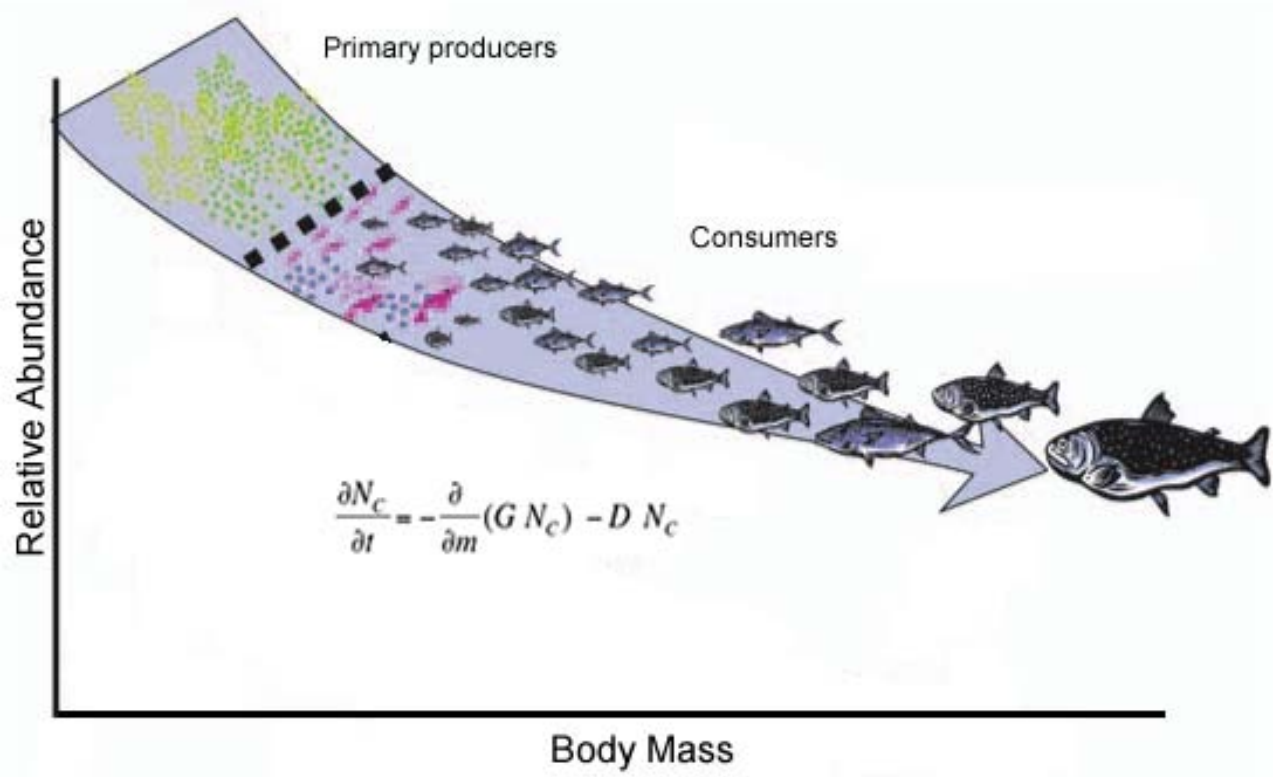


Size-based model

Assumes size-based predation, and size-specific growth and mortality are functions of food availability and SST

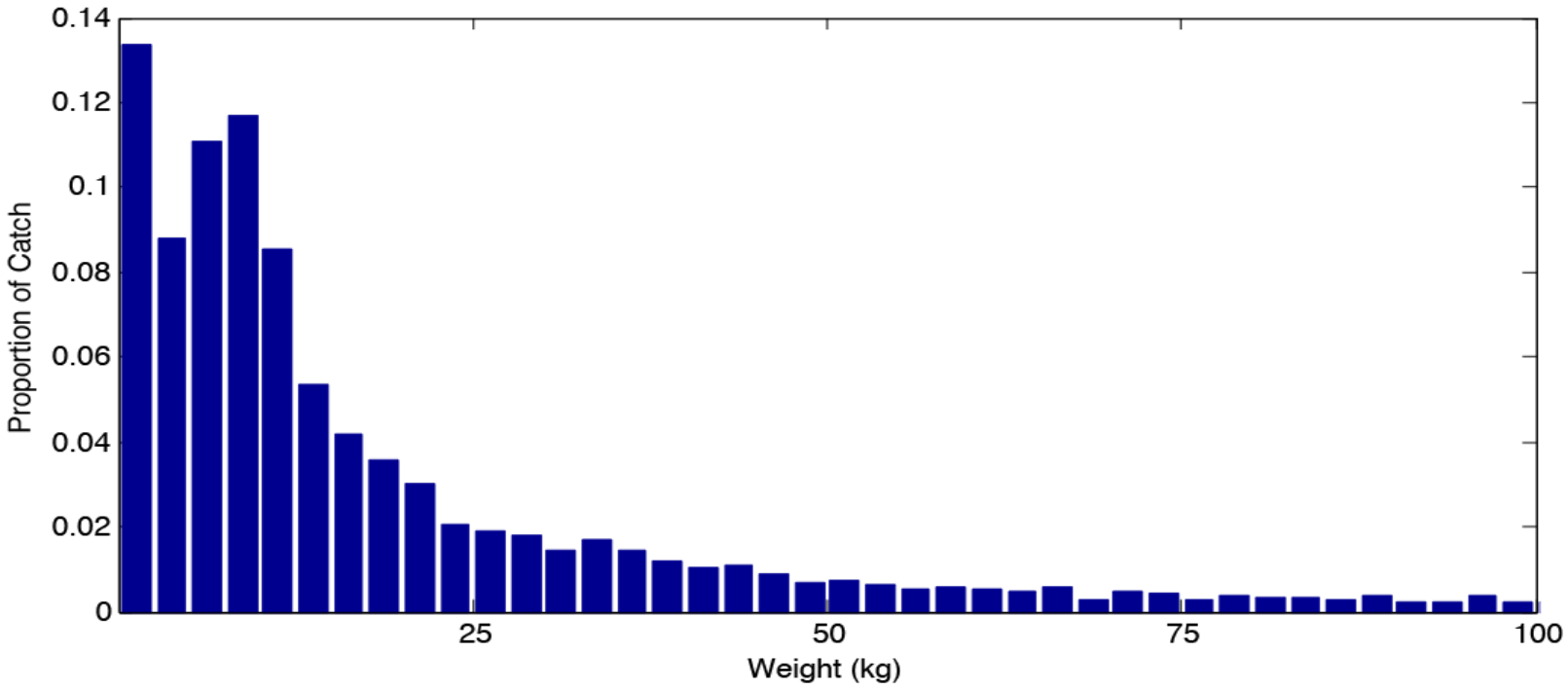
Input: monthly plankton size spectrum and SST

Output: monthly population size spectrum



Jennings et al. 2008, *Proc. R. Soc. B;* Blanchard et al. 2009 *J Anim Ecol*; Blanchard et al. 2010 *Theor. Ecol.*

Weight-Frequency Distribution from Catch data, all years pooled, 1996 – 2011

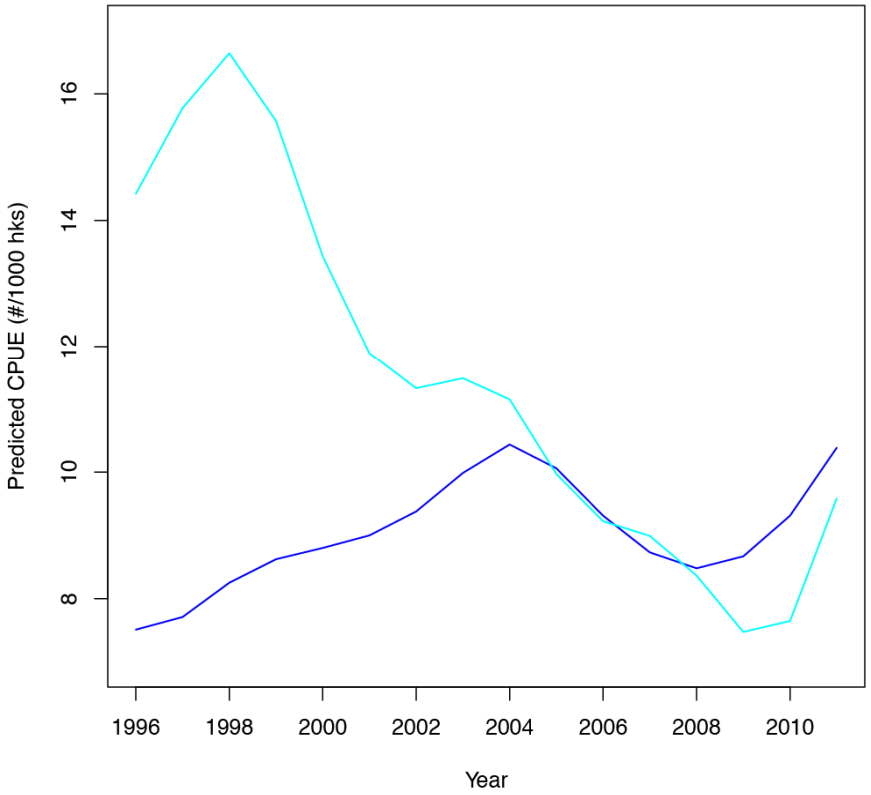


Size of entry to fishery 1 kg (1 – 15 kg: F = 0.25F) and size full selective by gear is 15 kg.

1 – 15 kg size category

> 15 kg size category

GAM standardized fishery CPUE



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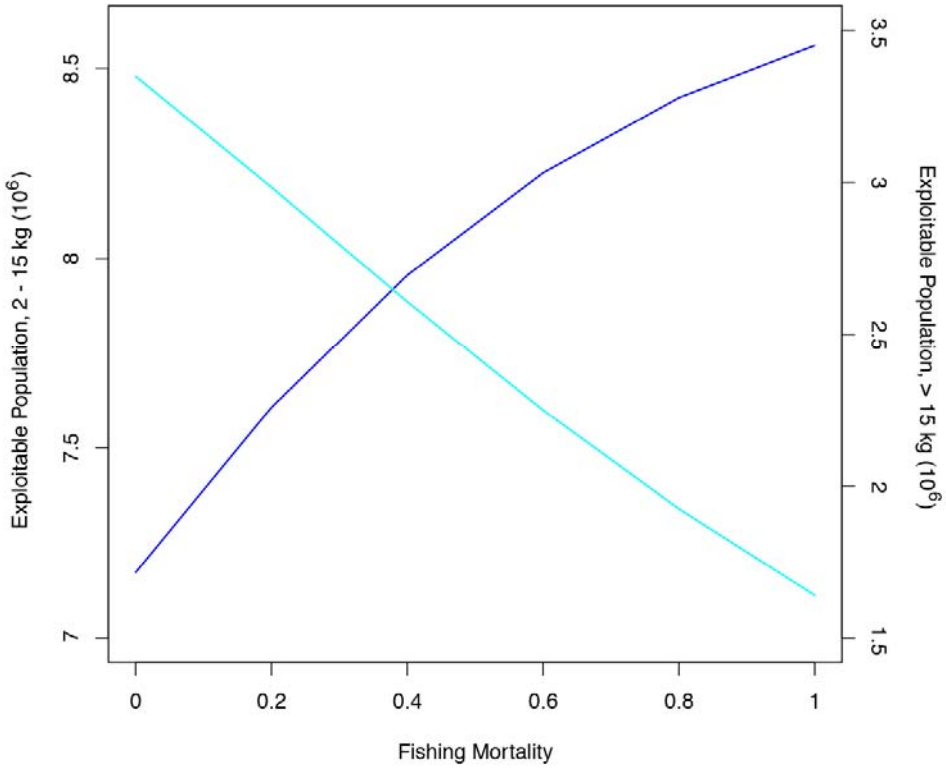
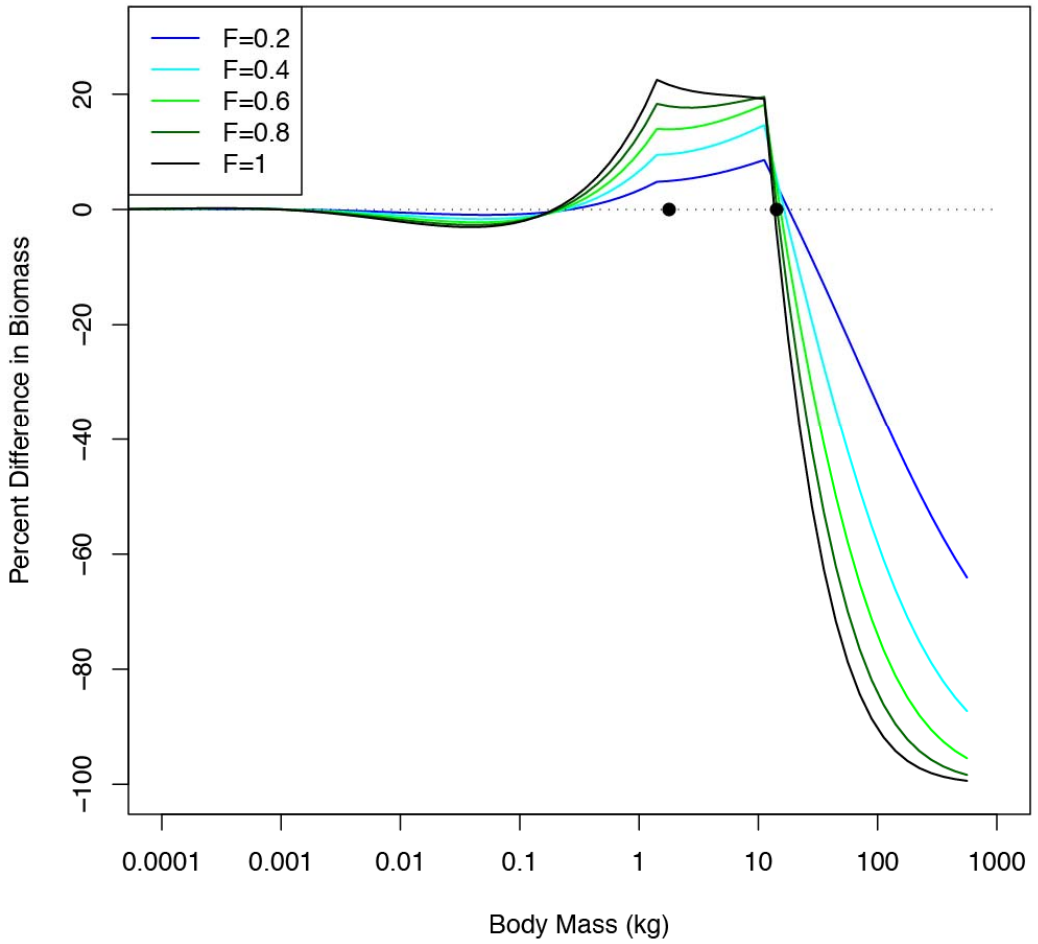


Nature of the Size-Based Cascade in Subtropical Pelagic Ecosystem

Model estimated percent change in size frequency distribution for various levels of fishing mortality relative to the unfished population. Size of entry to fishery 1 kg (1 – 15 kg: F = 0.25F) and size of full selectivity 15 kg.



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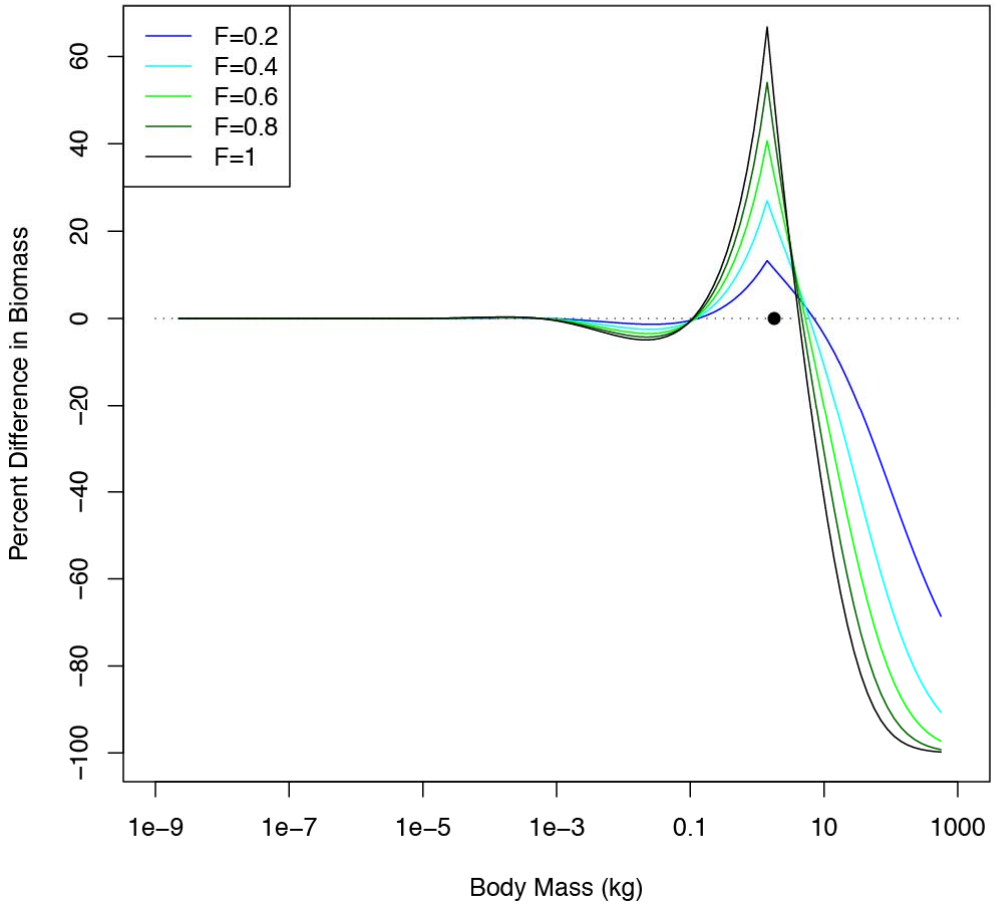
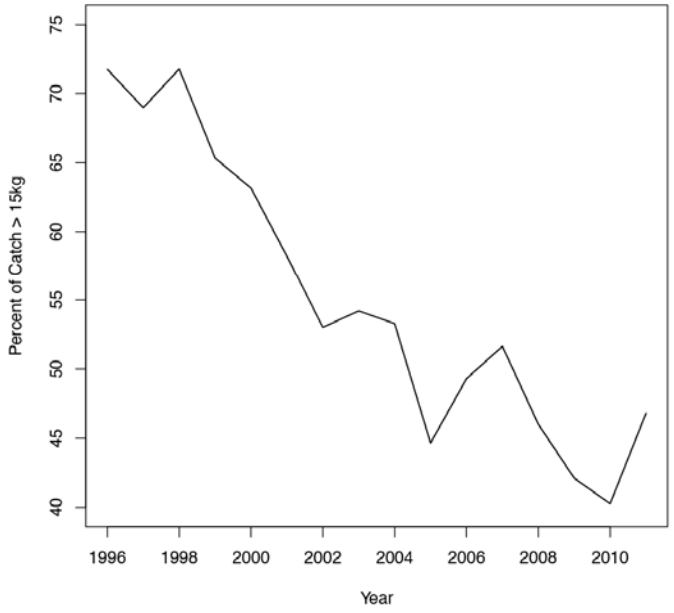
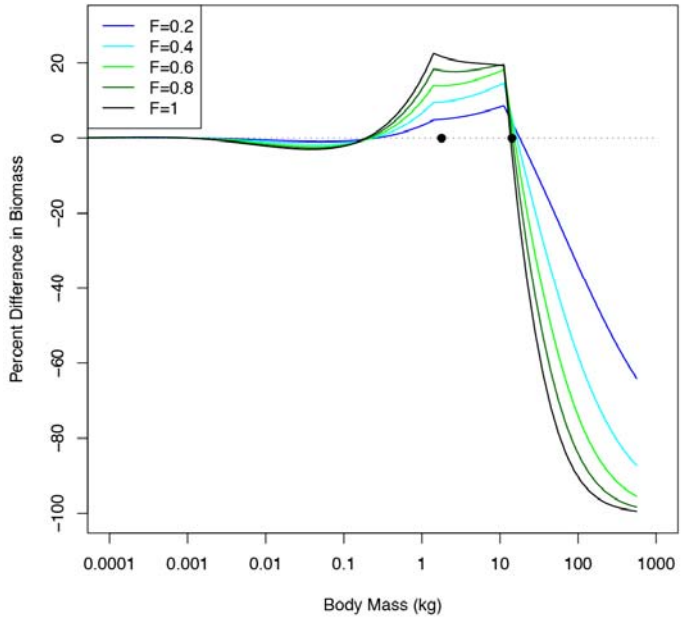


Percent of fish > 15 kg in catch from fishery data

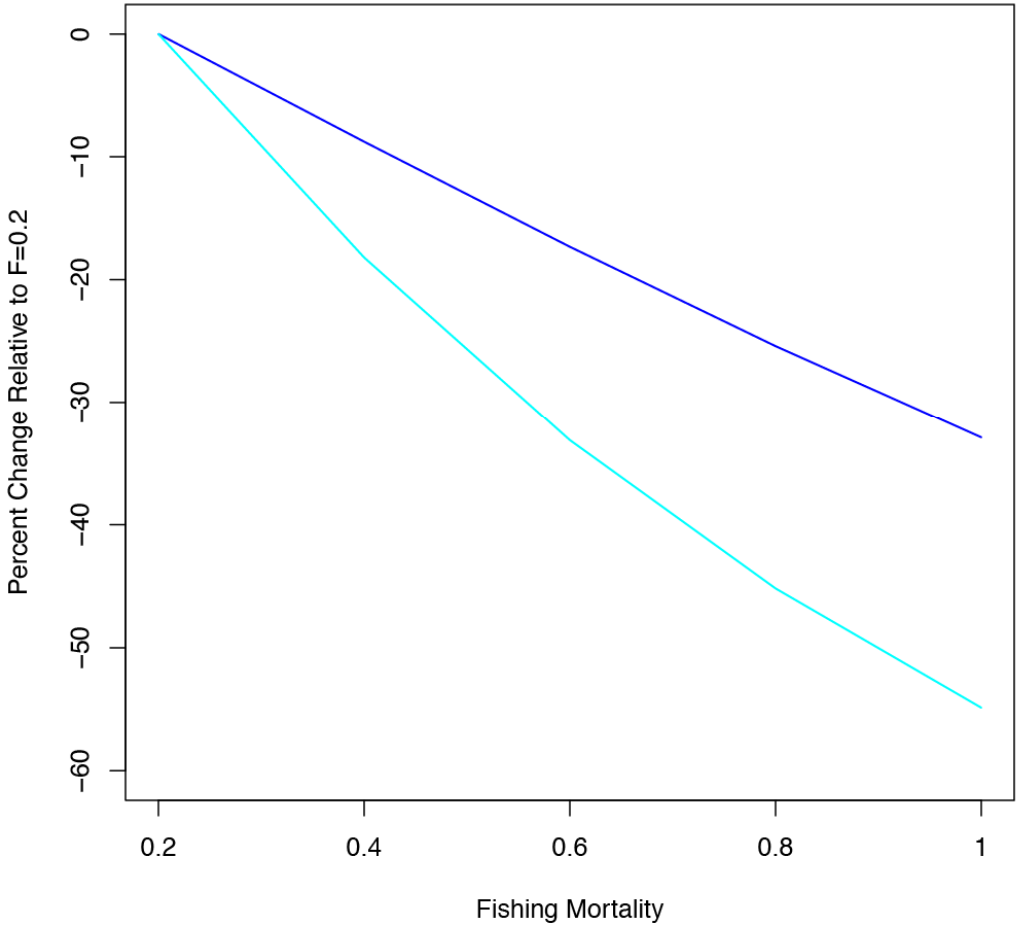




Percent of catch ≥ 15 kg

Percent of fish> 15 kg
relative to fish > 0.1 kg

Change in catch and number of fish > 15 kg from size-based model as a function of F



Summary

- A size-based model captures temporal dynamics of subtropical pelagic ecosystem suggesting the system may be regulated largely by size-based predation.

- The reach of a size-based cascade is limited – for example, a decline in the abundance of fishes larger than 15 kg results in an increase in abundance of animals from 15 to 0.1 kg but with minimal further cascading to sizes smaller than 0.1 kg.

- When a size-based cascade occurs, fishery data alone underestimates fishing impacts on ecosystem size structure.