

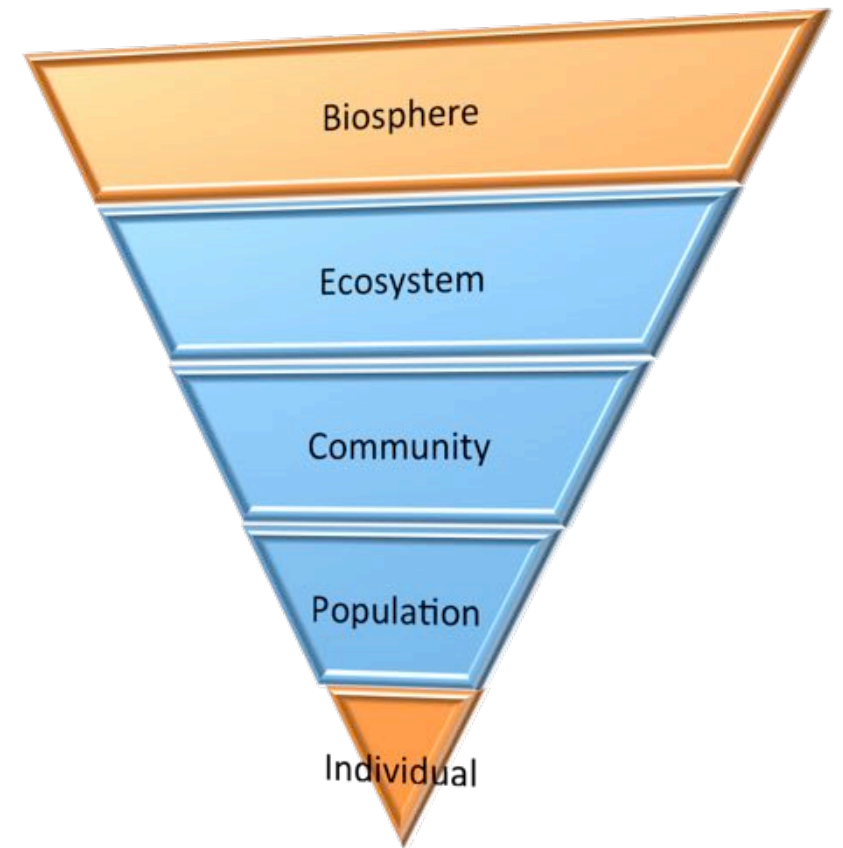
A review of the impacts of fisheries on open-ocean ecosystems

G. Ortuño Crespo,

D.C. Dunn & P.N. Halpin

Structure of the presentation

- Importance
 - Coast ecosystems
 - Deep sea ecosystems
 - Open-ocean ecosystems
- Three ecological levels of organization:
 1. Species-level impacts
 2. Community-level impacts
 3. Ecosystem-level impacts
- Acknowledgements
- References



Petition by the Commons to King Edward III, 1376



<http://www.southernfriedscience.com/bottom-trawling-and-the-importance-of-plaice/>

*“And that the great and long iron of the wondyrechaun runs so heavily and hardly over the ground when fishing that **it destroys the flowers of the land below water there, and also the spat of oysters, mussels and other fish upon which the great fish are accustomed to be fed and nourished.** By which instrument in many places, the fishermen take such quantity of small fish that they do not know what to do with them; and that they feed and fat their pigs with them, to the great damage of the commons of the realm and the destruction of the fisheries, and **they pray for a remedy.**”*

*From: The Unnatural History of the Sea
Dr. Callum Roberts*

Fisheries impacts on coastal ecosystems

□ Dayton et al., 1995 & Jennings and Kaiser, 1998

- “...profound effect on almost all components of associated communities and ecosystems.”
- “The most sensitive components are rare habitats that serve as nurseries, and species with low reproductive rates.”
- Trophic cascades (**Estes and Palmisano, 1974; Jackson et al., 2001; Bellwood et al., 2004**)
- Regime shifts – e.g. coral reefs (**de Young et al., 2008**)

(Estes and Palmisano, 1974)



Fisheries impacts on deep-sea ecosystems

□ Clark *et al.*, 2016

- “Recovery capacity of the benthos is highly limited and prolonged, predicted to take decades to centuries after fishing has ceased.”
- “Declines in faunal biodiversity, cover and abundance.”
- “These impacts translate into loss of biogenic habitat.”



(*Hoplostethus atlanticus*)

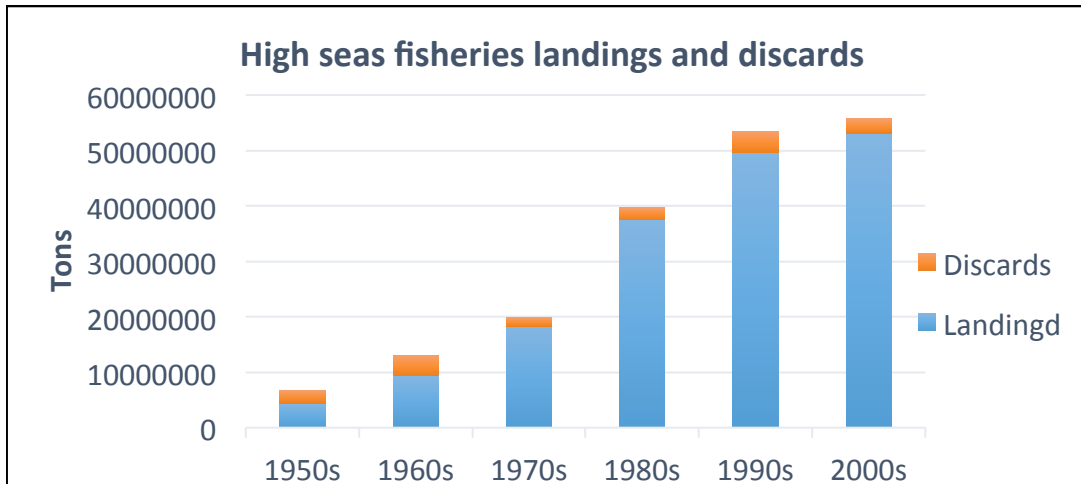
<http://www.fishtalesonline.com/recipes.php>

(*Hoplostethus atlanticus*) catch in a bottom trawl net. (Photo: Greenpeace nz)

- Most deep sea fishing is unregulated or poorly managed (**WWF/IUCN 2001**).
- Mortality is as high as 100% for fish brought up from great depths; both target and non-target species (**Gordon, 2001**).

Open-ocean ecosystems: Research, Fisheries & Management

- Include Exclusive Economic Zones & High Seas
- High Seas: 64% of the oceans – 45% of Earth
- Unassociated with benthic and coastal systems
- Commercial fisheries expanded into oceanic systems in the mid-XX



Data from: <http://www.seaaroundus.org/>

First session: 28 March – 8 April, 2016



Preparatory Committee (PrepCom) to establish an implementing agreement for the conservation of biodiversity in Areas Beyond National Jurisdiction.

Species-level impacts

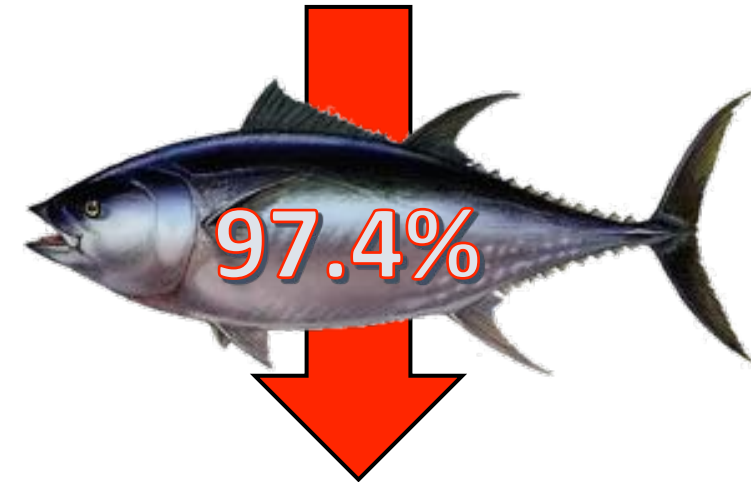
Much higher levels of overfishing and overfished stocks in ABNJ

- Estimates that straddling stocks are overfished or experiencing overfishing at twice the rate than stocks within national jurisdiction (64% vs 28.8%) (**FAO, 2009; FAO, 2014**).
- An assessment of the 48 highly-mobile fish stocks managed by the world's 18 Regional Fisheries Management Organizations (RFMO's) concluded that 67% of these were either overfished or depleted (**Cullis-Suzuki and Pauly, 2010**).

Increased extinction risk

- 36% of migratory or potentially migratory chondrichthyan fishes threatened with extinction (**Fowler, 2014**).
- 99% declines for species like the Oceanic whitetip shark in parts of their range (2004).
- Several species of pelagic sharks declined by 70% in the northwest Atlantic during 1986–2000 (**Baum et al., 2003**)

International Scientific Committee
for Tuna and Tuna-like Species in
the North Pacific Ocean (ISC)



Pacific Bluefin tuna (*Thunnus orientalis*)

Species-level impacts

Bycatch threatens non-target species

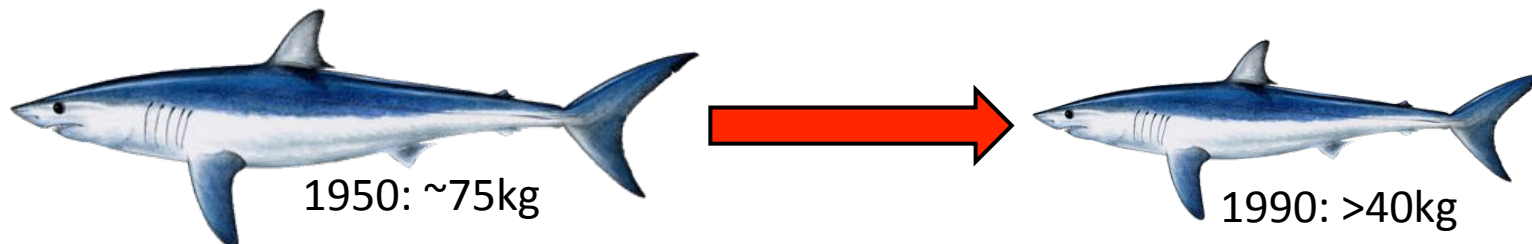
- Documented declines in >80% Pacific loggerhead and >95% decline in leatherback turtles (Spotila et al., 2000; Limpus and Limpus 2003)
- All 22 species of albatross & 19 of 21 oceanic elasmobranchs are listed as at least Near Threatened by the IUCN with bycatch cited as the main threat.

Contraction in species' ranges leads to change in community structure (Worm and Tittensor, 2011)

- 9 of the 13 species of tuna and billfish assessed exhibited reduced range with reduced abundances.
- Between 2% and 46% loss of observed range

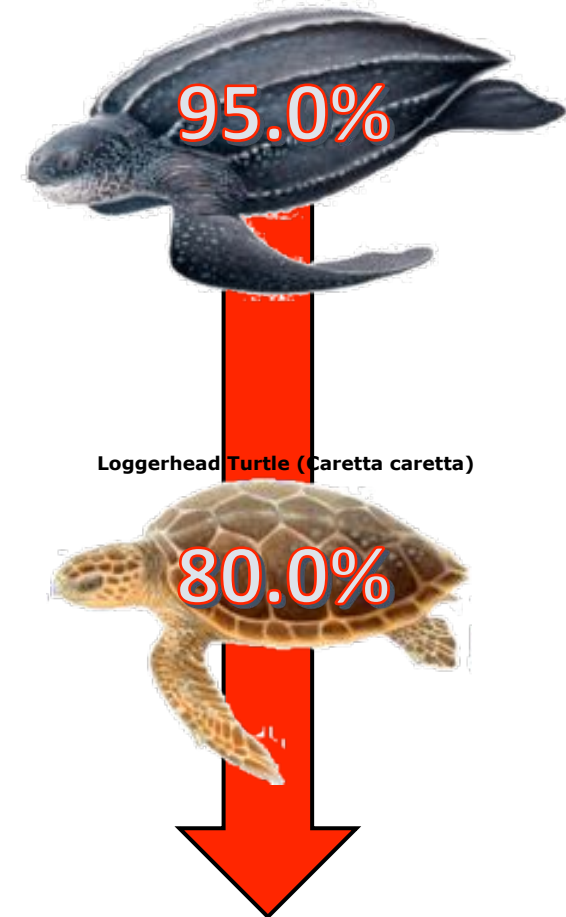
Changes in body mass (Ward and Myers, 2005)

- Predator body mass declines & body mass increases in lower TL species
- Reductions in body mass contributed 66% of the decline in the index of community biomass.



<http://www.massbayguides.com/Shark%20Fishing.htm>

<http://www.gulfleisure.com/turtlespecies.htm>
Leatherback Turtle (*Dermochelys coriacea*)



Species-level impacts

Reduction in the potential growth rate of the population

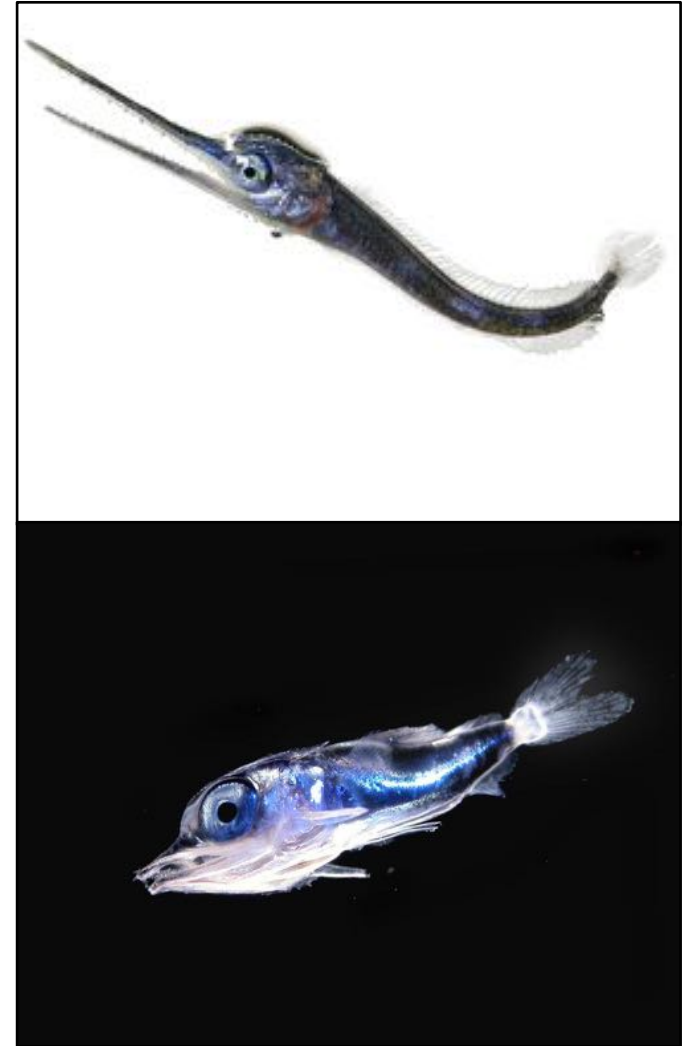
- Reductions in body size may lead to negative effect on population growth rate (**Hutchings and Reynolds, 2004**):
 - Reductions in potential fecundity of the population (Fish body size and fecundity are positively correlated (**Denney et al., 2002**)).
 - Smaller egg size
 - Increased variance in offspring survival

Increased variability in biomass of exploited species

- Selective fishing for adults results in **age-truncated fish stocks**, which magnify fluctuations in population levels and can contribute to stock collapses (**Rochet and Benoit, 2012**).

Genetic Diversity

- The steep declines in abundance of many of these open-ocean taxonomic groups may be translating into reductions in genetic variation at the population and subpopulation levels (**Allendorf et al., 2008**).
- Loss of genetic diversity can increase extinction risk, increase recovery time and decrease adaptability to changing climates (**Olsen et al., 2004; Walsh et al., 2006**).

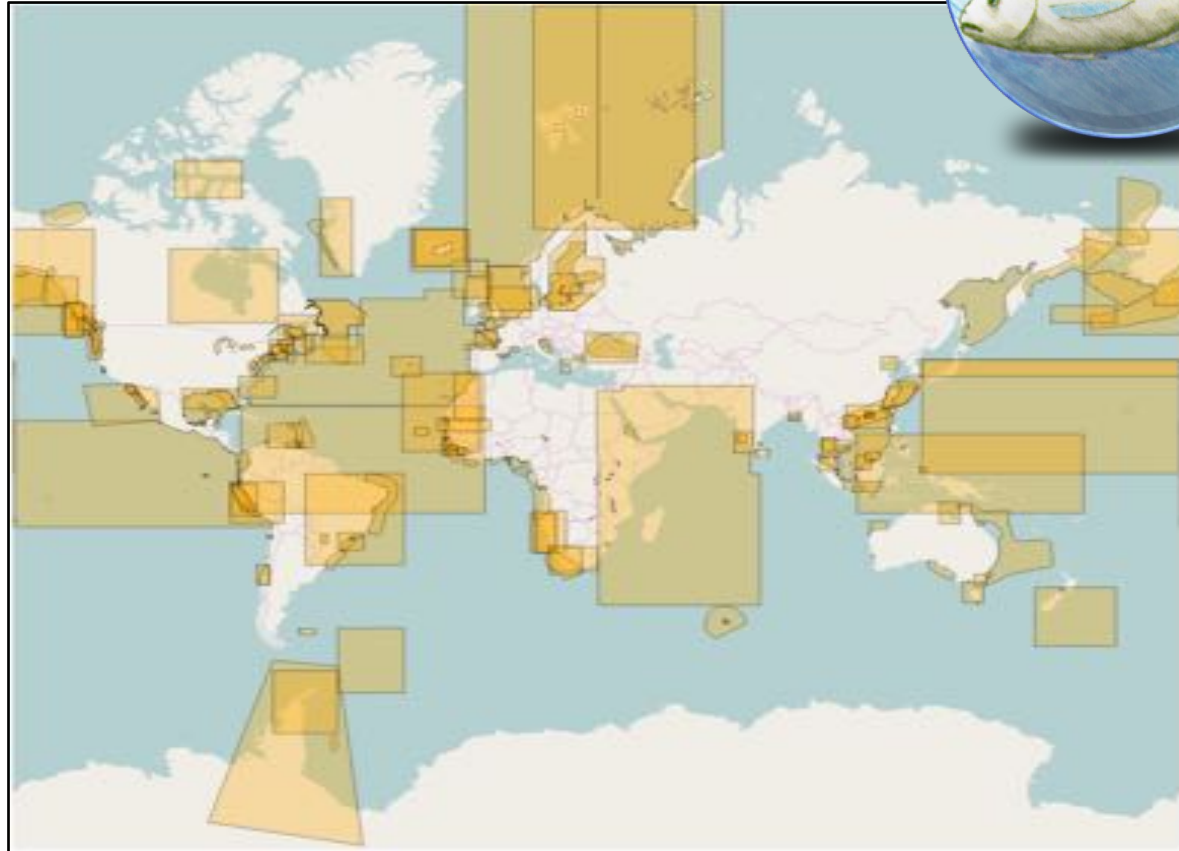


Community-level impacts: trophic imbalances

Species-level impacts propagate

<http://ecobase.ecopath.org/index.php?action=base> – 434 EwE models

- Fisheries time series data
- Data on trophic dynamics
- Advancements in modeling

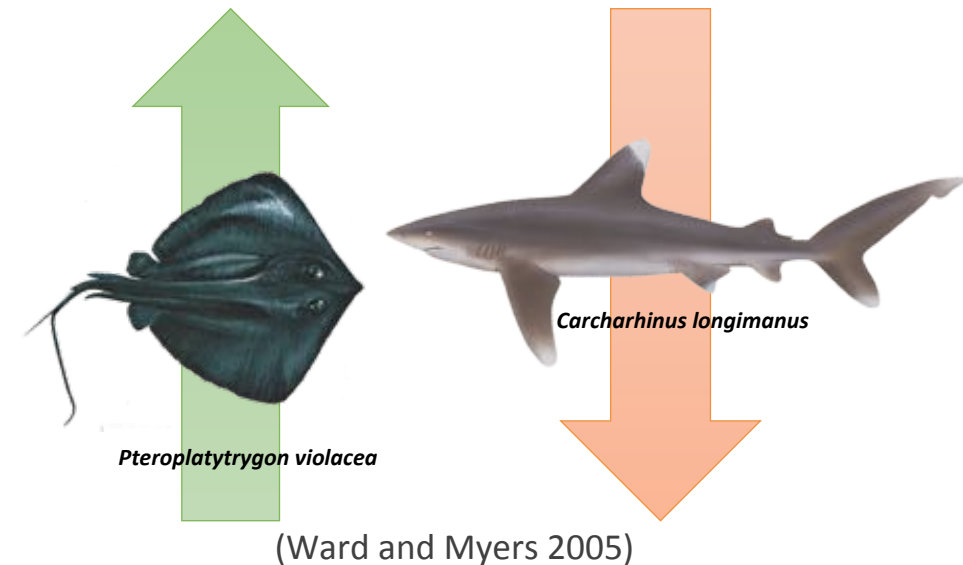
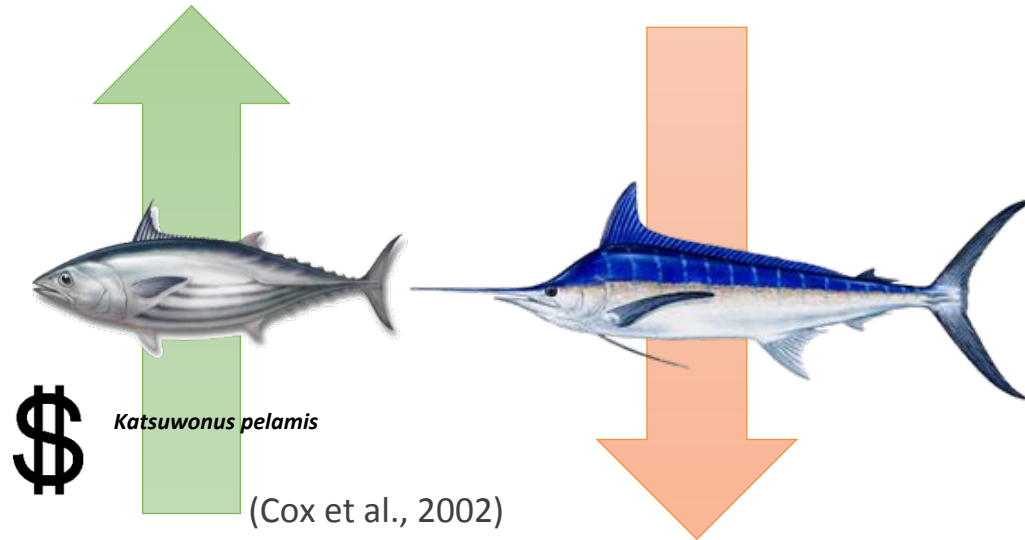


Community-level impacts: trophic imbalances

Removal of top predators leads to mesopredator release and changes in community structure.

Mesopredator release → increases in the biomasses of lower trophic levels caused by the reduction in abundance of their predators

- **Hinke et al., (2004):** Two tuna fisheries in the Central North and Eastern Pacific Ocean (**Cox et al., 2002 ;Olson and Watters, 2003**)
Abundance of predatory species was reduced by a factor of 10 → abundance of lower TL species was maintained or increased.



Community-level impacts: trophic imbalances

- Discards can alter foraging behavior and trophic relationships (2007)
- Reduction in mean trophic level.
- Decreases in body size can affect trophic relationships (diet composition changes between age classes).

There are also non-consumptive effects including

- Changes in prey behavior, growth or development

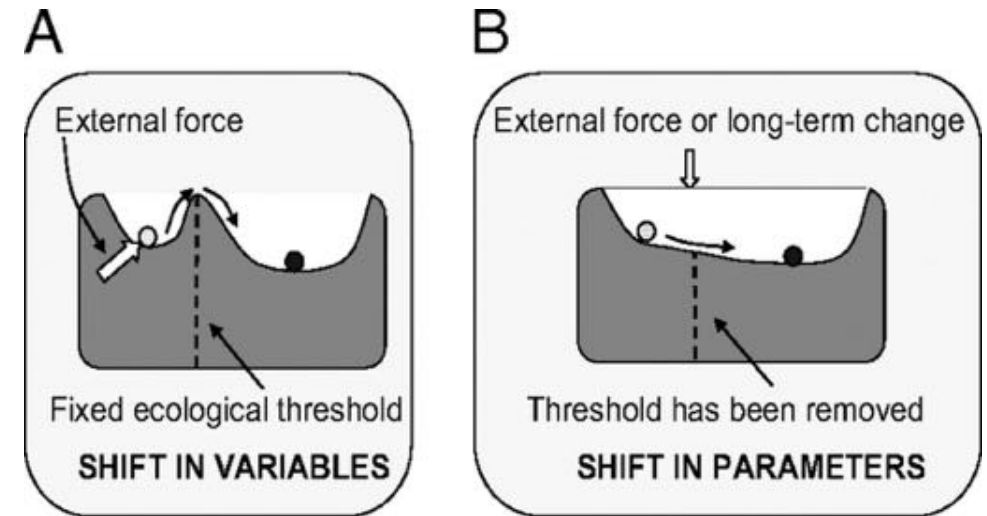
e.g. foraging relationship between seabirds and tuna in tropical regions, where decreases in density or abundance of tuna may lead to decreases in foraging success for associated seabirds.



Ecosystem-level impacts

Transitions between alternative states of the ecosystem, which affect both the system's dynamics and functionality; these are known as **regime shifts** (Scheffer and Carpenter, 2003; Daskalov *et al.*, 2007; de Young *et al.*, 2008; Beaugrand *et al.*, 2015).

- Changes at this level are mostly expressed as bottom-up biophysical changes, often linked to climatic changes: Pacific decadal oscillation, or North Atlantic oscillation (Pershing *et al.*, 2015).
- Top down trophic forcing's (e.g. trophic cascades) can also induce regime shifts in pelagic systems: **Black Sea; Baltic Sea; North Sea; Scotian Shelf**.

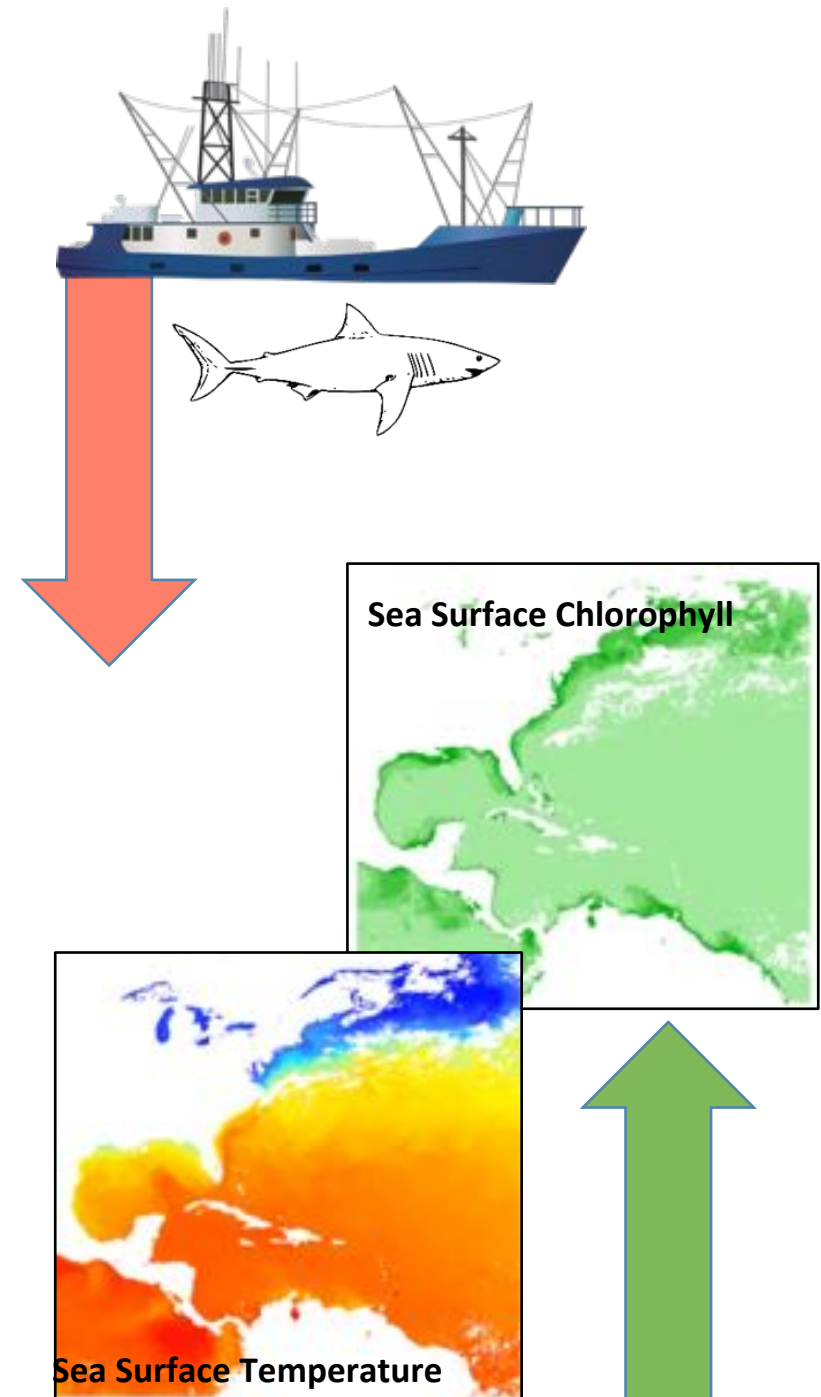


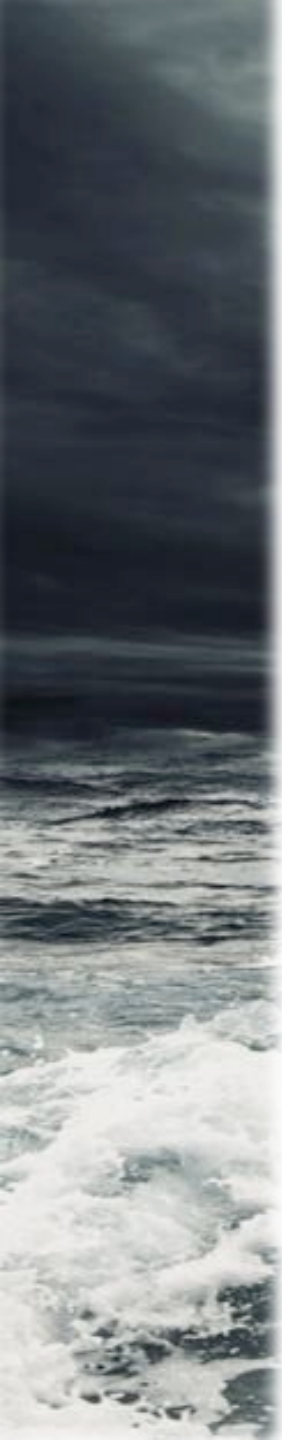
(Horan *et al.*, 2011)



Ecosystem-level impacts

- Research suggests (**Folke *et al.*, 2004; Worm *et al.*, 2005; Worm *et al.*, 2006**) that regime shifts are more likely to occur when the resilience of an ecosystem is reduced by:
 - removal of functional groups or trophic levels from a community
 - reductions of biodiversity (species richness and density)
- Losses in marine biodiversity could compromise the ability that oceanic ecosystems have to provide ecosystem services (**Worm *et al.*, 2006**)
- Potentially changing the system from being top-down regulated to bottom-up regulated.





NEREUS
PROGRAM
Predicting Future Oceans

Supported by



THE NIPPON
FOUNDATION



Marine Geospatial
Ecology Lab

Duke University

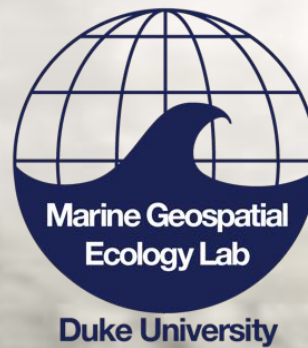
References

- Beaugrand, G., Conversi, A., Chiba, S., Edwards, M., Fonda-Umani, S., Greene, C., Mantua, N., Otto, S.A., Reid, P.C., Stachura, M.M. and Stemmann, L., 2015. Synchronous marine pelagic regime shifts in the Northern Hemisphere. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 370(1659): 20130272.
- Bellwood, D.R., Hughes, T.P., Folke, C. and Nyström, M., 2004. Confronting the coral reef crisis. *Nature*, 429(6994), pp.827-833.
- Clark, M.R., Althaus, F., Schlacher, T.A., Williams, A., Bowden, D.A. and Rowden, A.A., 2016. The impacts of deep-sea fisheries on benthic communities: a review. *ICES Journal of Marine Science: Journal du Conseil*, 73(suppl 1), pp.i51-i69.
- Cox, S.P., Essington, T.E., Kitchell, J. F., Martell, S. J. D. , Walters, C. J., Boggs, C., and Kaplan, I., 2002. Reconstructing ecosystem dynamics in the central North Pacific Ocean, 1952-1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. *Canadian Journal of Fisheries and Aquatic Sciences* 59:1736-1747.
- Cullis-Suzuki, S. and Pauly, D., 2010. Failing the high seas: a global evaluation of regional fisheries management organizations. *Marine Policy*, 34(5):1036-1042.
- Daskalov, G.M., Grishin, A.N., Rodionov, S. and Mihneva, V., 2007. Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. *Proceedings of the National Academy of Sciences*, 104(25), pp.10518-10523.
- Dayton, P. K., Thrush, S. F., Agardy, M. T., and Hofman, R. J. 1995. Environmental effects of marine fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 5: 205–232.
- de Young, B., Barange, M., Beaugrand, G., Harris, R., Perry, R.I., and Scheffer, M., 2008. Regime shifts in marine ecosystems: detection, prediction and management. *Trends in Ecology & Evolution*, 23:402–409.
- Denney NH, Jennings S, Reynolds JD. 2002. Life-history correlates of maximum population growth rates in marine fishes. *Proceedings of the Royal Society of London, B*. 269: 2229-2237.
- Estes, J.A. & Palmisano, J.F. (1974) Sea otters: their role in structuring nearshore communities. *Science*, 185, 1058–1060.
- Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S., 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics*, 35:557-581.
- Fowler, S., 2014. The Conservation Status of Migratory Sharks. UNEP/CMS Secretariat, Bonn, Germany.
- Gordon, J.D.M., 2001. Deep-water fisheries at the Atlantic Frontier. *Continental Shelf Research*, 21(8), pp.987-1003.
- Hinke, J.T., Kaplan, I.C., Aydin, K., Watters, G.M., Olson, R.J. and Kitchell, J.F., 2004. Visualizing the food-web effects of fishing for tunas in the Pacific Ocean. *Ecology and Society*, 9(1):10.
- Horan, R.D., Fenichel, E.P., Drury, K.L. and Lodge, D.M., 2011. Managing ecological thresholds in coupled environmental–human systems. *Proceedings of the National Academy of Sciences*, 108(18), pp.7333-7338.

References

- Hutchings, J.A. and Reynolds, J.D., 2004. Marine fish population collapses: consequences for recovery and extinction risk. *BioScience*, 54(4), pp.297-309.
- Jackson, J.B., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A. and Hughes, T.P., 2001. Historical overfishing and the recent collapse of coastal ecosystems. *science*, 293(5530), pp.629-637.
- Jennings, S., and Kaiser, M.J. 1998. The effects of fishing on marine eco- systems. In *Advances in Marine Biology*, Vol 34. *Advances in Marine Biology*, 34:201–220. J.H.S. Blaxter, A. J. Southward, and P. A. Tyler. Academic Press Ltd-Elsevier Science Ltd, London
- Limpus, C. and Limpus, D. J., 2003. The loggerhead turtle, *Caretta caretta*, in the Equatorial and Southern Pacific Ocean: a species in decline. pp.199–209 in A. B. Bolten and B. E. Witherington (eds). 2003. *Loggerhead sea turtles*. Smithsonian Institution Press, Washington, D.C. 352p.
- Olson, R.J. and Watters, G.M., 2003. A model of the pelagic ecosystem in the eastern tropical Pacific Ocean. *Inter-American Tropical Tuna Commission Bulletin*, 22(3):135-218.
- Pershing, A.J., Mills, K.E., Record, N.R., Stamieszkin, K., Wurtzell, K.V., Byron, C.J., Fitzpatrick, D., Golet, W.J. and Koob, E., 2015. Evaluating trophic cascades as drivers of regime shifts in different ocean ecosystems. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 370(1659), p.20130265.
- Rochet, M.-J., Benoit, E., 2012. Fishing destabilizes the biomass flow in the marine size spectrum. *Proceedings of the Royal Society B*, 279:284–292.
- Scheffer, M. and Carpenter, S.R., 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. *Trends in Ecology & Evolution*, 18(12):648-656.
- Spotila, J.R., Reina, R.D., Steyermark, A.C., Plotkin, P.T., Paladino, F. V, 2000. Pacific leatherback turtles face extinction. *Nature*, 405:529–30.
- Ward, P. and Myers, R.A., 2005. Shifts in open-ocean fish communities coinciding with the commencement of commercial fishing. *Ecology*, 86(4):835-847.
- Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B., Lotze, H.K., Micheli, F., Palumbi, S.R. and Sala, E., 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science*, 314(5800):787-790.
- Worm, B., Sandow, M., Oschlies, A., Lotze, H.K. and Myers, R.A., 2005. Global patterns of predator diversity in the open oceans. *Science*, 309(5739):1365-1369.
- Worm, B., Tittensor, D. P., 2011. Range contraction in large pelagic predators. *Proceedings of the National Academy of Sciences U.S.A.*, 108:11942–11947.
- WWF/IUCN (2001) *The Status of Natural Resources on the High-seas*, World Wide Fund for Nature and World Conservation Union

NEREUS
PROGRAM
Predicting Future Oceans



Supported by

THE NIPPON
FOUNDATION

Thank you

Questions or Comments

G. Ortuño Crespo, D.C. Dunn & P.N. Halpin

Twitter: @G_Oceans

Email: gortunocrespo@gmail.com