Fishing and the Food Chain (Web)

- To assess this scientifically, we can assign a **trophic value** to each organism.
- **Sustainable** fisheries generally start with low values.
Demise of the Big Fish?

Number of Large Predators

Is everything driven by top-down impacts, primarily due to humans?
Towards Ecological Extinction

1. Fishing
2. Pollution
3. Mechanical habitat destruction
4. Introductions
5. Climate change

- Human expansion
- Altered ecosystems

"Then" ........................................ "Now"
Fishing and the Food Chain

- Given the “simple” view that humans are bad and are removing the apex predators, we could:
  - All become vegetarians
  - Fish at lower trophic levels
  - Eat more of the “undesirable” organisms

- But is this true?
Does “fishing down the food chain” exist?

Fishing through marine food webs

Timothy E. Essington1, Anne H. Beausoleil, and John Windermann2

School of Aquatic and Fishery Science, University of Washington, Box 353100, Seattle, WA 98195

Communicated by David W. Schindler, University of Alberta, Edmonton, Alta, Canada. December 29, 2005 (received for review March 16, 2005)

A recent pattern of declining mean trophic level of fisheries landings, termed “fishing down the food web,” is thought to be indicative of the net replacement of high-trophic-level fisheries with less valuable, low-trophic-level fisheries as the former become depleted to economic extinction. An alternative to this view, that declining mean trophic levels indicate the net addition of low-trophic-level fisheries (“fishing through the food web”), may be equally severe because it ultimately leads to conflicting demands for ecosystem services. By analyzing trends in fishery landings in all large marine ecosystems worldwide, we find that fishing down the food web was pervasive (present in 39 ecosystems) but that the sequential addition mechanism was by far the most common one underlying declines in the mean trophic level of landings. Specifically, only 1 ecosystem showed declining catches of upper-trophic-level species, compared with 21 ecosystems that exhibited either no significant change in mean trophic level or significant increases in mean trophic level in upper-trophic-level catches when fishing down the food web was occurring, only in the North Atlantic were changes in the proportion of high-trophic-level species significantly correlated with changes in the proportion of low-trophic-level species. In these ecosystems, we suggest that efforts to promote sustainable use of marine resources will benefit from a fuller consideration of all pressures leading to fishing down the food web.

ecosystem-based management | fisheries | marine conservation

The status of marine fisheries and their effects on marine ecosystems have become the subjects of intense scrutiny over the past decade (1–5). Arguably, one of the most influential works supporting this movement is that of Pauly et al. (6), who documented that the mean trophic level of fisheries landings around the world has been declining since the onset of industrial fishing. The scientific literature has been nearly unanimous in emphasizing this trend, termed “fishing down the food web,” as being symptomatic of overfishing, unsustainable harvests, and species substitution. In one notable exception, however, sequential addition of low-trophic-level species has been observed in a number of ecosystems. The present study seeks to explore alternative explanations for fishing down the food web, quantifying the contributions of these alternatives, and considering their implications for marine conservation and fisheries management.

There are at least two ways that fishing down the food web could occur. The first is through the sequential replacement of high-value upper-trophic-level species with less valuable lower-trophic-level species as the former are depleted to economic extinction. The second mechanism is through the sequential addition of low-trophic-level fisheries within an ecosystem. We refer to the latter model as “fishing through the food web” to emphasize that fisheries for high-trophic-level species are maintained despite a decline in the overall mean trophic level of landings.

The policy implications of the sequential collapse/replacement mechanism are severe: detrimentally overfished apex predator guilds (7–9), with poor prospects for recovery (8, 9), and dramatic restructuring of marine ecosystems with concomitant loss of ecosystem services and biodiversity (10, 11). The sequential addition model of fishing through the food web appears at first glance to be more benign, because it allows the possibility of sustainable catches of high-trophic-level fisheries. Yet, from a policy standpoint, fishing through the food web process gives rise to potentially irreparable harm, because developing fisheries that demand different ecosystem services (e.g., productive apex predator stocks vs. productive forage fish stocks) will ultimately force policy makers to make judgments and assign values to these alternative fisheries. History has shown that most policy makers struggle to make effective decisions when facing trade-offs between user groups (12). Navigating these conflicts is moving to the forefront of contemporary marine fisheries management and conservation (13), and such conflicts have been implicated in the sequential collapse of capelin in the Barents Sea (13). Moreover, multiple-trophic-level fisheries are rarely an optimal policy on the basis of maintaining yield or economic return (14). Finally, if the sequential addition model is prevalent, then it is a need to develop management plans that explicitly account for intertrophic species. These considerations are rarely present in traditional single-species management schemes.

In this study, we evaluated the consequences of each of these alternative mechanisms giving rise to fishing down the food web from the temporal dynamics of upper-trophic-level fishery catches when fishing down the food web was occurring. Under the sequential collapse/replacement model, a decline in the mean trophic level should be accompanied by declining catches of high-trophic-level species as these species become economically extinct. Under the sequential addition model, however, we expect catches of upper-trophic-level species to be maintained or even increase.

Results

We detected declines in mean trophic level of >0.17 to be evidence of ecologically significant fishing down the food web. From an energetic perspective, this decline in trophic level represents an ≈30% decrease in the primary productivity required to sustain a given amount of catch (15). Of the 68 large marine ecosystems (LMEs) worldwide that had suitable data, the proportion of substantial fishing down the food web, with an average decline of 0.42 trophic level. These declines were substantially larger than those originally documented in the analysis of more spatially aggregated datasets (15), consistent with the notion that regional estimates from poorer-quality data generally underestimate the magnitude and frequency of fishing down the food web (16).

Visual exploration of catch data revealed evidence for both mechanisms underlying fishing down the food web (Fig. 1). The Scotian Shelf provides a typical example of the sequential collapse/replacement model (Fig. 1A). The mean trophic level in fisheries landings declined markedly beginning in 1987, corresponding with the initial collapse of groundfish stocks. This collapse was succeeded by a decline in herring (Clupea harengus) landings, ultimately leading to increased exploitation of northern pike (Esox lucius). In contrast, the Patagonian Shelf exhibited a similar decline in mean trophic level between 1980 and 2000, but landings of high-trophic-level species (namely,
Illustrative examples of the sequential collapse/replacement (A) and sequential addition (B) mode of fishing down the food web.

- Collapse of Cod
- Decline of herring
- Northern prawns

- Argentinian hake
- Squid

Essington T. E. et al. PNAS 2006;103:3171-3175
Comparison of the mean (±SE) instantaneous rate of change in apex predator catches (trophic level > 4; solid bars) and all upper-trophic-level catches (trophic level > mean trophic level; open bars) among ocean regions.

![Graph showing the change in catch over time for different ocean regions.]

Text: Essington T. E. et al. PNAS 2006;103:3171-3175
Does “fishing down the food chain” exist?

“The observed frequencies of these alternative mechanisms may not be accurately reflected in the scientific community’s interpretation of fishing down the food web. We analyzed >200 peer-reviewed publications and did not find a single article claiming that fishing down the food web was associated with the sequential addition of new fisheries (Table 1). Instead, our review revealed a scientific community that has embraced the view that fishing down the food web is evidence of unsustainable fishing and human alteration of food web structure and “… is clear evidence of ineffective management” (17). This disconnect between perception and reality, which places undue emphasis on the less common sequential collapse/replacement mechanism, is dangerous because it leads us to ignore the policy implications of the more common sequential addition mechanism.”
Changes in MTL relative to unfished ecosystem MTL.

Authors argue that catch-based statistics tell you almost nothing about how the ecosystem actually responds--argue that we need to directly measure or model ecosystems.
Why fishing magnifies fluctuations in fish abundance

Christian N. K. Anderson¹, Chih-hao Hsieh¹,²,³,⁴, Stuart A. Sandin¹, Roger Hewitt⁵, Anne Hollowed⁶, John Beddington⁷, Robert M. May⁸ & George Sugihara¹

It is now clear that fished populations can fluctuate more than unharvested stocks. However, it is not clear why. Here we distinguish among three major competing mechanisms for this phenomenon, by using the 50-year California Cooperative Oceanic Fisheries Investigations (CalCOFI) larval fish record. First, variable fishing pressure directly increases variability in exploited populations. Second, commercial fishing can decrease the average body size and age of a stock, causing the truncated population to track environmental fluctuations directly. Third, age-truncated or juvenescent populations have increasingly unstable population dynamics because of changing demographic parameters such as intrinsic growth rates. We find no evidence for the first hypothesis, limited evidence for the second and strong evidence for the third. Therefore, in California Current fisheries, increased temporal variability in the population does not arise from variable exploitation, nor does it reflect direct environmental tracking. More fundamentally, it arises from increased instability in dynamics. This finding has implications for resource management as an empirical example of how selective harvesting can alter the basic dynamics of exploited populations, and lead to unstable booms and busts that can precede systematic declines in stock levels.
a, The size distribution and maturation profile of an unexploited population, which shows a certain level of variability in abundance over time. 
b, The age-truncation — juvenescence — effect caused by fishing leads to a population with a lower average age, and is often associated with individuals attaining maturity at younger ages. The result is increased variability in abundance. If the change is phenotypic (ecological) only, recovery is possible. 
c, A more permanent (evolutionary) change in the demographics leads to potentially irreversible increased variability in abundance, unless there is a high degree of genetic variability left in the population to return it to the unexploited state.
How do you make a map like this?

- Fishing Activity determined by Sea Around Us Program (SAUP) at 1/2 degree scale
- Fish Landings from FAO
- “Pressure” determined as catch density divided by (satellite) primary productivity
- Assumes more pressure if equivalent fish are removed from low-productivity environments
Fig. 1. Quarterly distributions (½° latitude by 1° longitude) of catches from the northeast Atlantic mackerel stock for 2006 [data from (14)].
The Rise of “Slime”

Interaction strength combinations and the overfishing of a marine food web

Jordi Bascompte*, †, Carlos J. Melián*, and Enric Sala†

Author Affiliations

Communicated by Robert T. Paine, University of Washington, Seattle, WA, February 25, 2005
(received for review October 15, 2004)

Abstract

The stability of ecological communities largely depends on the strength of interactions between predators and their prey. Here we show that these interaction strengths are structured nonrandomly in a large Caribbean marine food web. Specifically, the cooccurrence of strong interactions on two consecutive levels of food chains occurs less frequently than expected by chance. Even when they occur, these strongly interacting chains are accompanied by strong omnivory more often than expected by chance. By using a food web model, we show that these interaction strength combinations reduce the likelihood of trophic cascades after the overfishing of top predators. However, fishing selectively removes predators that are overrepresented in strongly interacting chains. Hence, the potential for strong community-wide effects remains a threat.
• Large Quantitative Food Web:
  - 249 species/groups
  - 3,313 interactions
  - 1000 square km, Carribean Reef system
  - All benthic and pelagic communities from 0-100 m depth
  - detritus, 4 primary producers, 35 invertebrates, 208 fish species, turtles, birds, apex predators (such as sharks)
Letters to Nature

Nature **427**, 727-730 (19 February 2004) | doi:10.1038/nature02315; Received 12 December 2003; Accepted 5 January 2004

Changes in fisheries discard rates and seabird communities

Stephen C. Votier†1, Robert W. Furness†1, Stuart Bearhop1,2, Jonathan E. Crane1, Richard W. G. Caldw2, Paulo Catry4, Kenny Ensor1, Keith C. Hamer5, Anne V. Hudson1, Ellen Kalmbach6, Nicholas I. Klomp7, Simone Pfeiffer1,8, Richard A. Phillips9, Isabel Prieto1 & David R. Thompson10

It is clear that discards from commercial fisheries are a key food resource for many seabird species around the world1, 2, 3, 4, 5, 6, 7, 8. But predicting the response of seabird communities to changes in discard rates is problematic and requires historical data to elucidate the confounding effects of other, more 'natural' ecological processes. In the North Sea, declining stocks, changes in technical measures, changes in population structure9 and the establishment of a recovery programme for cod (Gadus morhua10) will alter the amount of fish discarded. This region also supports internationally important populations of seabirds11, some of which feed extensively, but facultatively, on discards, in particular on undersized haddock (Melanogrammus aeglefinus) and whiting (Merlangius merlangus)1, 2, 3. Here we use long-term data sets from the northern North Sea to show that there is a direct link between discard availability and discard use by a generalist predator and scavenger—the great skua (Stercorarius skua). Reduced rates of discarding, particularly when coupled with reduced availability of small shoaling pelagic fish such as sandeel (Ammodytes marinus), result in an increase in predation by great skuas on other birds. This switching of prey by a facultative scavenger presents a potentially serious threat to some seabird communities.
The Impact of United States Recreational Fisheries on Marine Fish Populations

Felicia C. Coleman,1* Will F. Figueira,2† Jeffrey S. Ueland,3† Larry B. Crowder2

We evaluated the commercial and recreational fishery landings over the past 22 years, first at the national level, then for populations of concern (those that are overfished or experiencing overfishing), and finally by region. Recreational landings in 2002 account for 4% of total marine fish landed in the United States. With large industrial fisheries excluded (e.g., menhaden and pollock), the recreational component rises to 10%. Among populations of concern, recreational landings in 2002 account for 23% of the total nationwide, rising to 38% in the South Atlantic and 64% in the Gulf of Mexico. Moreover, it affects many of the most-valued overfished species—including red drum, bocaccio, and red snapper—all of which are taken primarily in the recreational fishery.
Recreational Fishing Alliance challenges red snapper closure
Timing of the interim snapper ban makes it tough to stop, group’s lawyer says.

Posted: December 6, 2009 - 3:19am

By Jim Sutton

The Recreational Fishing Alliance wasted no time in mounting a legal challenge to an interim red snapper closure, announced Thursday by the federal government and entered into the Federal Registry on Friday.

RFA attorney Dave Heil said from his Orlando office that the complaint “is sitting in the clerk’s office” in the U.S. District Court’s Jacksonville Division.

“We had the paperwork ready,” Heil said.

The RFA had anticipated an earlier closure.
Summary:

• The global fisheries show increasing signs of distress

• It’s a much more complicated problem than simply “fishing down the food chain”, although that is part of it

• There are no simple solutions, but we do know that some species are more “connected” than others in the food web

• Get used to eating jellyfish! (or deer, or horses…)

June 25, 2007

Waiter, There’s Deer in My Sushi

By MARTIN FACKLER

TOKYO, June 24 — Sushi made with deer meat, anyone? How about a slice of raw horse on that rice?

These are some of the most extreme alternatives being considered by Japanese chefs as shortages of tuna threaten to remove it from Japan’s sushi menus — something as unthinkable here as baseball without hot dogs or Texas without barbecue.

In this seafood-crazed country, tuna is king. From maguro to otoro, the Japanese seem to have almost as many words for tuna and its edible parts as the French have names for cheese. So when global fishing bodies recently began lowering the limits on catches in the world’s rapidly depleting tuna fisheries, Japan fell into a national panic.