Selective Fishing, Balanced Harvest and EAF

Presented by
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Chair IUCN-CEM-FEG

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Selective Fishing and Balanced Exploitation in Relation to Fisheries and Ecosystem Sustainability

Organized by the IUCN Fisheries Expert Group (FEG)
In Nagoya (Japan) 14-16 October 2010

Convened by: S.M. Garcia, J. Rice, J. Kolding, M-J. Rochet, S. Zhou

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<th>PARTICIPANTS</th>
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<td>Arimoto, T. (Japan)</td>
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This presentation is made on their behalf
Outline

1. Relevant norms for fisheries policy
2. The conventional selectivity concept
3. The food chain concept
4. Management implications
«Stocks should be kept at biomass levels that can produce MSY»


Criticized by scientists since early 1970s but recognized in all summits
CBD norm

«A key feature of the ecosystem approach includes conservation of ecosystem structure and functioning»

CBD. 1998. Malawi principles for Ecosystem Approach:
FAO adopted EAF in 2001
Too Many Small Fish Are Caught, Report Says

By HENRY FOUNTAIN
Published: April 2, 2012

An international group of marine scientists is calling for cuts in commercial fishing for sardines, herring and other so-called fish whose use as food for fish farms is soaring. The catch should be cut in half for some fisheries, the scientists say, to protect populations of both the fish and the natural predators that depend on them.
Some discording voices

“In theory a food web could be maintained “in balance” by fishing each component in proportion to the rate of natural predation it is subjected to”.

Caddy and Sharp (1986) optimal, albeit ‘utopian’ strategy
Outline

1. Relevant norms for fisheries policy
2. The selectivity issues
Selectivity concept

- Selectivity is the process through which fishing obtains a catch with a composition (in size, sex, or species) that differs from that of the natural habitat on which it operates.
- It is the probability of a species, sex, size or age to be caught.
- It results from the appropriate selection of: (i) the fishing area and depth, (2) the fishing season and time, and (3) the fishing gear, its characteristics and operation.
- Usually defined at gear level, it can be defined at vessel, fishery, community and ecosystem levels.
- It is conventionally regulated to: (i) maximize long-term yield from each recruit of the target species and (ii) reduce catch of unwanted or protected species.
- It is used by fishers to maximize short-term economic returns.
- Conventional selectivity regulations ignore trophic relations and predation.
Dominant paradigm

“.. a fishery will yield its maximum physical returns if all fish are allowed to grow to the point where the rate of increase in weight just ceases to outstrip losses due to natural mortality and then harvested…"

Critical age!

Growth

Beverton and Holt, 1954

Mortality

Hillis and Arnason 1995

Growth over-fishing

Wildlife scientists have argued against it for decades in hunting reserves

But we all know there are problems with that paradigm!!

“leave a breeding stock"
Long-term change in landings (in %) when passing from 80mm to 120 mm mesh for Cod.

The difference is the result of the additional predation of large fish released by the larger mesh size.

Real results (since 2001) are different from both predictions (Graham, pers. Comm.)

What is the real predictive value of the conventional assessment?

Source: North Sea Cod. ICES 1989. Multispecies assessment working group
Natural uncertainty: Plaice

% plaice 15-27 cm in box

The young plaice had decided to change place!!

But the fishery improved nonetheless because …increases in fuel cost reduced fishing mortality!

Rijnsdorp et al 2010. FEG Nagoya meeting The plaice box
### Fishery response: Tuna

#### East Pacific Tuna Purse seining

<table>
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<tr>
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<th>Before dolphin protection</th>
<th>After dolphin protection</th>
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<tbody>
<tr>
<td>Yellowfin</td>
<td>18-22 Kg</td>
<td>3-6 Kg</td>
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<tr>
<td>Discard /set</td>
<td>0.1 t (1%)</td>
<td>4.6 t (10%)</td>
</tr>
<tr>
<td>Bycatch rate</td>
<td>1 dolphin</td>
<td>26 sharks</td>
</tr>
<tr>
<td></td>
<td>0.3 sailfish</td>
<td>1.8 marlins</td>
</tr>
<tr>
<td></td>
<td>0.2 manta ray</td>
<td>800 large bony fishes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1250 small fishes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.04 turtles</td>
</tr>
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This effect of selectivity was certainly not expected!
Change in mortality pattern...

Humans and natural predators “select” their targets differently!!
Growing big is not any more a good strategy!

Example from Arctic Cod
... leads to changes in maturation

- Selection of phenotypes
  - Reduced age and size at maturity
  - Reduces maximum body size
- Increased reproductive investment
- Increased resilience to high fishing
- Decreased resilience to environment
- Reduced resource productivity
- Reduced N° of subpopulations
- Reduced genetic variability
- Selection of genotypes

Modeling shows that a reduction of fishing pressure at both ends of the size spectrum reduces evolutionary response in a population

Source: Rijnsdorp. 2010; Mikko 2010. . FEG Nagoya meeting
… Changes in sizes at age …

Growth slows down if only large fish are targeted

Conover and Munch 2002
Selectively removing large adults decreases mean size and total yields.
Some conclusions

- The selectivity paradigm is 50-year old and non ecosystemic.
- It ignores trophic relations and predation.
- The paradigm is to avoid catching juveniles and protected species.
- There are recent calls to protect also old mature fish (BOFFFFs).
- By-catch and discards are hot issues.
- There is also increasing concern about fishery-induced evolution.
- Management seeks to optimize fisheries inputs/outputs.
- But: EAF seeks to maintain ecosystem structure and processes.
- But: any selective removal will change the population and the community in a non-intuitive manner.

Some questions

- Are present practices making things better or worse for the ecosystem?
- Could fishing selectivity be optimized at ecosystem level?
- Could selective harvest and selective protection be co-optimized?

The selectivity paradigm needs to be reassessed in an ecosystem perspective!
Outline

1. Relevant norms for fisheries policy
2. The conventional selectivity concept
3. The food chain concept
The food chain

Which are the two most similar fishes?

Conventional species-based approach

Ecosystem approach

Source: Jan Beyer. Nagoya FEG meeting presentation 2010
4. The food chain: ontogenic shift

Source: Jan Beyer. Nagoya FEG meeting presentation 2010
The food web is size structured...

- Primary producers
- Primary consumers
- Secondary consumers
- Tertiary consumers
- Top predators

... Abundance is inversely correlated with size
1. The distribution of biomass by body size follows regular patterns

2. Under conventional selective fishing slope and intercept will change
Changes in the North Sea Biomass

Garcia et al. 2012

Rice, Gislasson, 1996, 1998

Unfished
1983–1987
1998–2002

Garcia et al. 2012
Balanced harvesting

Fishing “all” sizes and species in proportion to their natural productivity

Reconciles objectives: maintains community structure; returns highest yields
Trophic cascades

Any positive or negative change in any compartment generates a cascade of direct consequences upwards and/or downwards and feed-back responses.

The end result is not easy to predict.

- Triggering change
- Induced change
4. The food chain: Trophic cascades

Source: Daskalov 2010
The food chain perspective

Balanced harvesting: a fishing strategy that maintains ecosystem structure by keeping fishing pressure moderate and distributing it across ecosystem components (species, sizes, and trophic levels) in proportion to their productivities.
Some comments

**Balanced harvesting**: a fishing strategy that maintains ecosystem structure by keeping fishing pressure moderate and distributing it across ecosystem components (species, sizes, and trophic levels) in proportion to their productivities.

- It corresponds to Caddy and Sharp 1986 “Utopian management”
- I heard this from Garrod in the 1970s already
- Sydney Holt (pers. com.) considers it “intuitively obvious”
- Obtaining MSY from all stocks in the food chain would come close to it
- Ken Henderson: suggested to call it “Physiological Harvesting” as F is aimed to be proportional to M
- Wildlife scientist have already raised the issue (at population level) in conflict with hunters
Outline

1. Relevant norms for fisheries policy
2. The conventional selectivity concept
3. The food chain concept
4. The modeling contribution
Biomass-Size spectra

Size (8 orders of magnitude)

log(abundance)

plankton
zooplankton

bony fish

elasmobranchs
marine mammals

Fishery size range
Biomass-size spectra -2

Log Individual weight

Log Abundance

Beyer & Andersen 2010

Log body mass

Log Abundance

fixed plankton
dynamic spectrum

fixed spectrum

predation

growth

food

perturbation to
dynamic spectrum
Ecosystem models

Concentrated fishing

- Usual range
- Collapses
- Sizes
- Biomass
- Catch

Widespread fishing

- Usual range
- BH Range
- Collapses
- Biomass
- Sizes

Exploitation rate % of maximum

Source: Fulton et al.
1. Relevant norms for fisheries policy
2. The conventional selectivity concept
3. The food chain concept
4. Modeling results
5. What empirical evidence?
Empirical evidence: Lake Kariba

Lake Kariba ecosystem structure: 1980-1994

Unfished

- Mormyrus deliciosus
- Mormyrus longirostris
- Serranochromis condronotus
- Claris genipinus
- Herenobranchus longilirius
- Hydrocyamus vitulus
- Distichodus mossambicus
- Oreochromis mossambicus
- Synodontis zambesiensis
- Distichodus shanga
- Laboe altivelis
- Tilapia rendalli
- Laboe congara

- Serranochromis macrolepidaus
- Shib rele intermedius
- Laboe cylindricus
- Oreochromis niloticus
- Otophilus zambesiensis
- Oreochromis macrolepis
- Marunxenus macrolepidotus
- Hippopotamymus theocharis
- Breamus lateralis
- Varicorhinos nasurus
- Pseudocrenilabrus philander
- Pseudocrenilabrus seussi
- Barbus megalops
- Synodontis nebulosus
- Breamus
- Tilapia spastani
- Serranochromis robustus
- Phaeochromis bleheri

Heavily fished

- Unregulated and non enforced: 6000 t/y
- Regulated and enforced: 1000 t/y

Source: Jeppe Kolding, 2011 (unpublished yet)
Empirical evidence: Lake Kariba

Lake Kariba ecosystem structure: 1980-1994

Unfished

Heavily fished

Ongoing modeling work by J. Kolding and K. Andersen indicate that these patterns can be reproduced by a size-based model under a Balanced Harvest strategy.
Empirical evidence: Lake Kariba

Indirect proof
The patterns observed are easily simulated.
The results should be valid for large lakes and marine fish.

Source: Kolding, J.; Andersen, K. H.; Beyer, J.E. and van Zwieten, P.A.M. Maximizing fisheries yields while maintaining ecosystem structure (in preparation. Do not cite without permission)
BH in the North Atlantic

Norwegian and Barents Sea

North Sea

Unfished

Heavily fished

Kolding and colleagues, in preparation

\[
\begin{align*}
\text{Unfished} & : \quad \text{a} = -1.7327, \quad \text{b} = 0.8684, \quad r^2 = 0.6809, \quad p < 0.0001, \quad N = 28 \\
\text{Heavily fished} & : \quad \text{a} = -1.1105, \quad \text{b} = 0.8086, \quad r^2 = 0.5482, \quad p < 0.0001, \quad N = 39
\end{align*}
\]
Tentative conclusions

- In an ecosystem, there are robust relations between individual size (body mass, size, asymptotic size) and abundance that can be studied to analyze the impact of selective fishing on ecosystem structures and properties and develop appropriate indicators.

- Generally, models support the intuition that concentration of fishing on a narrow selection of species and sizes in an assemblage may not be the most sustainable way to use an ecosystem, maintaining its processes and properties.

- Spreading fishing pressure on the species and size spectrum appears theoretically preferable for ecosystem stability and, often, also for total yield.

- At population level, reducing pressure on both juveniles and old spawners, seems to stabilize the structure. To check!

- Conversely, the depletion of large sizes (old spawners) could have a destabilizing impact on the ecosystem structure and the species relationships.
Tentative conclusions

- It has been difficult, however to verify empirically the ecosystem impacts predicted by the models but there are apparently some examples of sustainable ecosystem structures with widespread fishing pressure.

- Elements in favor of evolutionary forcing of stocks by fishing are slowly accumulating. Genetic evolution is likely but has not yet been proven. Applying a Dome-shaped fishing pressure vector on sizes may be beneficial. Sparing juveniles and old spawners seems promising.

How to combine all these conclusions in a coherent “balanced harvest” management strategy is not yet totally clear!
1. Relevant norms for fisheries policy
2. The conventional selectivity concept
3. The food chain concept
4. Management implications
Reconsidering the Consequences of Selective Fisheries

S. M. Garcia,1* J. Kolding,1,2* J. Rice,1,3* M.-J. Rochet,4,5† S. Zhou5* T. Arimoto,6 J. E. Beyer,7 L. Borges,8 A. Bundy,9 D. Dunn,10 E. A. Fulton,11 M. Hall,12 M. Heino,2,13,14 R. Law,15 M. Makino,1,16 A. D. Rijnsdorp,17 F. Simard,18 A. D. M. Smith19

Concern about the impact of fishing on ecosystems and fisheries production is increasing (1, 2). Strategies to reduce these impacts while addressing the growing need for food security (3) include increasing selectivity (1, 2): capturing species, sexes, and sizes in proportions that differ from their occurrence in the ecosystem. Increasing evidence suggests that more selective fishing neither maximizes production nor minimizes impacts (4–7). Balanced harvesting would more effectively mitigate adverse ecological effects of fishing while supporting sustainable fisheries. This strategy, which challenges present management paradigms, distributes a moderate mortality from fishing across the widest possible range of species, stocks, and sizes in an ecosystem, in proportion to their natural productivity (8), so that the relative size and species composition is maintained.

which are not going to be used,” i.e., by-catch (13). Fisheries worldwide have used species and size limits (9, 14), gear technology (5, 15), and spatial and temporal fishing restrictions (16) to reduce fishing impacts while pursuing human benefits.

But selective removals will inevitably alter the composition of a population or community and, consequently, ecosystem structure and biodiversity. Old individuals contribute the most to reproduction (17). Even moderate fishing reduces the proportion of species and individuals in the North Sea (22) (fig. S1). By contrast, in several African small-scale inland fisheries, the fish size spectrum (23) has been maintained under intense and diverse fishing activities that cause high mortality with low selectivity (5, 24) (fig. S1).

Results from models suggest that moderating fishing mortality across a wide range of species and sizes maximizes overall catch summed across species while better conserving biodiversity. Multispecies fishery models show that increased mesh sizes may reduce...
Management implications

Ecosystemic target: How to slice the pyramid?

- Strategies to be built around cumulative selectivity
- Evaluate performance of strategies already in place
- Define “Balance”: in relation to trophic levels? Sizes? Assemblages?
- Selection tool box: gear, time, area, market controls, rights, ecosystem tax, incentives, ecolabelling, novel food technology
- Strategy depends on starting point (ecological, economic conditions)
- Strategy depends on scale (small, large), area (coastal, offshore, high seas), domain (pelagic, demersal); culture (Asia, Africa, Europe)

Discuss use and protection strategies TOGETHER

- Role of MPAs and reserves
Management implications

- Need to add ecosystem-based strategic (long time) regulations to single-species (shorter time) regulations.
- Increase focus on diversity and diversification of harvest. Better distribute the impact across species and sizes. But also protect juveniles and old spawners.
- Reduce overall impact by eliminating overfishing as a prerequisite for implementing and benefiting from balanced harvest.
- Carefully examine modern management strategies that tend to increase target specialization and selectivity and, eventually, look for implementation or alternatives strategies to better balance overall pressure across the wider spectrum of species and sizes.
- Use incentives to convince fishers to broaden harvest diversity when appropriate.
Management implications

A tentative interpretation of “balance”

**Present: excessive & selective**

**Future: Right & balanced harvest?**
Thanks for your attention