Ecological metrics of biomass removed by 3 methods of purse-seine fishing for tunas in the eastern tropical Pacific Ocean

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3 methods of purse-seine fishing for tunas in the eastern tropical Pacific Ocean

- **Dolphin sets**
  - Landings: large yellowfin
  - Discards (low): small yellowfin, dolphins

- **Floating-object sets**
  - Landings: bigeye, skipjack and yellowfin
  - Discards (large): misc. fish, sharks, billfishes

- **Unassociated sets**
  - Landings: skipjack and yellowfin
  - Discards (medium): small target fish, sharks
Ecosystem-based management

- Effects of fishery depend on **total removals** (landings + discards)
- Reduction of bycatch is a goal, but not the only goal
- Animals removed differ in size, life history, and ecological role
- Removals vary in **type** and **amount**, and can be measured as
  - Number
  - Weight
  - Trophic level (1+ weighted average TLs of prey)
  - Replacement time ( = inverse of $P/B$ )
  - Diversity ( Shannon = $- \sum_i p_i \ln p_i$ )
- Trophic levels and $P/B$ ratios from model of Olson & Watters (2003)
TOTAL ANNUAL BIOMASS REMOVALS
eastern tropical Pacific

Data from ~94% of trips during 1993-2008
### Target Catch

- **Small yellowfin tuna**
- **Large yellowfin tuna**
- **Skipjack tuna**
- **Large bigeye tuna**
- **Small bigeye tuna**
- **Pacific bluefin tuna**
- **Albacore tuna**
- **Large marlins**
- **Small marlins**
- **Large sailfish**
- **Small sailfish**
- **Large swordfish**
- **Small swordfish**
- **Large wahoo**
- **Small wahoo**
- **Small dorado**
- **Bullet & frigate tuna**
- **Misc. piscivores**
- **Misc. epipelagic fish**
- **Large sharks**
- **Small sharks**
- **Rays**
- **Sea turtles**
- **Spotted dolphins**
- **Other dolphins**
- **Toothed whales**

### Bycatch

- **Misc. epipelagic fish**
- **Misc. piscivores**
- **Bullet & frigate tuna**
- **Small sailfish**
- **Large swordfish**
- **Small swordfish**
- **Small wahoo**
- **Small dorado**
- **Large wahoo**
- **Misc. epipelagic fish**
- **Large sharks**
- **Small sharks**
- **Rays**
- **Turtles**
- **Sea turtles**
- **Spotted dolphins**
- **Toothed whales**
- **Other dolphins**
- **Cetaceans**
- **Cetaceans**

### Catch type

- **95%** Landings
- **5%** Discards

### Target species

- **98% of landings**
- **81% of discards**
MEAN TOTAL REMOVALS PER SET

5% discards

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean Catch per Set (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolphin</td>
<td>10</td>
</tr>
<tr>
<td>Floating object</td>
<td>30</td>
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<tr>
<td>Unassociated</td>
<td>5</td>
</tr>
</tbody>
</table>

2% bycatch

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean Catch per Set (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dolphin</td>
<td>20</td>
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<tr>
<td>Floating object</td>
<td>40</td>
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<tr>
<td>Unassociated</td>
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</tr>
</tbody>
</table>

Legend:
- Blue: Landings
- Red: Discards
- Green: Target
- Orange: Bycatch
TROPHIC LEVEL

Landings

Discards

Mean trophic level

1995 2000 2005

Dolphin sets
Floating-object sets
Unassociated sets
BIOMASS REPLACEMENT TIME

Landings

Biomass replacement time (years)

1995 2000 2005

Discards

Biomass replacement time (years)

1995 2000 2005

- Dolphin sets
- Floating-object sets
- Unassociated sets

0.8 0.6 0.4 0.2 0.0

0 2 4 6 8 10
## 4 Metrics of Total Amount of Removals

<table>
<thead>
<tr>
<th>Removal Category</th>
<th>Number (millions)</th>
<th>Biomass (1000 tons)</th>
<th>Trophic level x biomass (1000s)</th>
<th>Replacement time x biomass (1000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowfin</td>
<td>80</td>
<td>300</td>
<td>150</td>
<td>250</td>
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<tr>
<td>Skipjack</td>
<td>40</td>
<td>200</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Bigeye</td>
<td>20</td>
<td>100</td>
<td>50</td>
<td>50</td>
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<tr>
<td>Other fishes</td>
<td>10</td>
<td>50</td>
<td>25</td>
<td>25</td>
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<tr>
<td>Sharks</td>
<td>5</td>
<td>25</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Turtles</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Cetaceans</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
4 METRICS OF TOTAL AMOUNT OF REMOVALS

- **Number**
  - Landings
  - Discards

- **Biomass**
  - Weight (1000 t)
  - Trophic level x biomass

- **Replacement time x biomass**
  - Year-tons (1000s)

**Removal category**
- Yellowfin
- Skipjack
- Bigeye
- Other fishes
- Sharks
- Turtles
- Cetaceans

**Fishing method**
- D = Dolphin sets
- F = Floating-object sets
- U = Unassociated sets
Concluding remarks

• EBFM takes account of total removals by fishery: landings + discards
• EBFM needs ecologically informative metrics
• Dolphin, floating-object and unassociated methods of fishing have different ecological consequences.
• Effects on individual populations may still be necessary for conservation reasons (e.g., dolphins, sharks, bigeye tuna).
• EBFM is about what remains, not what is removed.
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