Introduction to population dynamics and stock assessments

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Introduction to population dynamics and stock assessments

Part 1
Factors that affect fish populations

Part 2
Surplus production and the maximum sustainable yield

Part 3
Stock assessment models and data requirements

Part 4
Role of Stock Assessment Scientists and Purpose of ACLS
What is a model?

- A model is a simplified version of a real world system
- Models cannot capture the full complexity of real systems
- The goal is to capture the general trends as accurately as possible
Biological populations (humans, fish, trees, bacteria...) are regulated by four primary factors:

- Birth
- Death
- Immigration
- Emigration
A population is the same over time when:

Birth + Immigration = Death + Emigration
US Population 1900-2013

Number of People over Time

Rate of Change

Population (millions)

% Change per year
What would you want to know to understand changes in the populations of fish?

How long do the fish live?  
When do the fish reproduce?  
Do the offspring survive to become adults?  
Is there movement to or from other populations?

All of these questions require some type of approach to estimate quantities that are not easily observed.

We do not need to count every fish…
Why are fish population dynamics important?

With **population dynamics** and **models** we can estimate something we cannot see:

The **number** of fish in the sea
Stock Assessment
Math Made Simple
Stocking the Pond
The Survey
Beginning of year dip:
8 fish per dip

End of year dip:
2 fish per dip
Conclusion
3 out of 4 fish died

What else do we know about this system?
The Catch
\[ \frac{3}{4} \text{ of the fish are gone} \]

(Determined from survey)

We know that the friendly neighbor caught and removed 300 fish this year

We can figure out how many we started with.
The 300 fish caught and removed count as the fish that are missing (3 out of every 4)

Therefore we had to have had 400 fish at the beginning of the year.

And there should be 100 left in the pond.
Natural Mortality
Now we also know:

1 out of 4 fish in this region dies of natural mortality (predators, etc.)
We know $\frac{3}{4}$ of the fish are missing
(Determined from survey)

and $\frac{1}{4}$ died due to natural causes
(natural mortality assumed for the species)

We can figure out how many we started with.
Natural mortality counts for \( \frac{1}{4} \)

The 300 fish caught and removed count as the rest of the fish that are missing.

Therefore we had to have had 600 fish at the beginning of the year.

And there should be 150 left in the pond.
The confession
What if your catch data were wrong?

What if 400 fish were caught and removed by the neighbor?
Natural mortality counts for ¼

The 400 fish caught and removed count as the rest of the fish that are missing.

Therefore we had to have had 800 fish at the beginning of the year.

And there should be 200 left in the pond.
All stock assessments are based on the idea that if an action is taken on a population (e.g., catch), then there will be a reaction.

If we know an action was taken and can measure the reaction, then we will have learned something about the population.

If we learn enough, we can anticipate how the population will react to certain management actions.
Stock assessments work in a similar way except with more data inputs and more complicated models.
Introduction to population dynamics and stock assessments

Part 2
Let’s explore an example that will help us understand sustainable yield.
Compound interest on a bank account

Calculate the money in your bank account in 13 years with a 5% interest rate if you start with $1000.

You could multiply $1,000 x 1.05 for the first year and 1,050 x 1.05 for the second year, and so on for 13 years and get $1,885.65.
Compound interest on a bank account

The interest rate does not change...

...but the bank account increases by more when the amount of money in the bank is larger.
The amount of money accrued is higher when there is more money in the account. The number of new fish is highest at an intermediate population size.
Density Dependence

**Production** = New fish in the population

As density increases individuals compete for resources and the rate of production slows.

At carrying capacity there is no production.
Density Dependence

Production = New fish in the population

- Few Babies, High Survival, Fast Growth
- Many Babies, Low Survival, Slow Growth
- Balance Between Making Babies and Keeping Them Alive
- Low Density
- High Density
- Carrying Capacity
- Many Babies
- Low Survival
- Slow Growth
Sustainable Yield

**Production** = New fish in the population

How much can we catch without causing the biomass to change from one year to the next?

It depends on the size of the population!

If removals can be replaced by stock production each year, the fishery is sustainable.
What is MSY?

The Maximum Sustainable Yield is the highest yield that can be extracted repeatedly year after year.

The maximum sustainable yield (MSY) is equal to the maximum production.
**Overfished**: Stock smaller than the size that can provide MSY

**Overfishing**: Fishing yield that is greater than sustainable production

“Overfishing” and “Overfished” mean a level of fishing mortality that jeopardizes the ability of fishery to produce MSY on a long-term basis.
Example 1:

Is the stock **overfished**?

Is the stock undergoing **overfishing**?
Example 2:

Is the stock **overfished**?

Is the stock undergoing **overfishing**?
Example 3:

Is the stock overfished?

Is the stock undergoing overfishing?
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Part 3
Stock assessments use models and data to

• determine if fishing yield is sustainable
• determine if stock size is above or below the level that can provide MSY
• quantify the uncertainty in the status of the stock
• provide management advice for optimizing resource utilization

No model can capture the full complexity of the system. **The goal is to capture the general trends as accurately as possible!**
The right tool for the job

Example: Ferry Schedule

A good model is as simple as it can be while still getting the job done.
## Examples of assessment models and their data requirements

### Increasing model complexity and information requirements

<table>
<thead>
<tr>
<th>Data requirements</th>
<th>Mean length estimator</th>
<th>Depletion-based methods</th>
<th>Surplus production</th>
<th>Integrated stock assessment</th>
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<td>Age composition</td>
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| Outcomes                | Total mortality       | OFL                     | MSY                | MSY                        |

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**NOAA Fisheries**

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | NOAA Fisheries | Page 43
Indices of Abundance

Indices of abundance are often calculated using CPUE (Catch-per-unit-effort).

Changes in an index of abundance are assumed proportional to changes in the actual stock abundance.

Recall the pond example…
Time series of CPUE can tell us about relative changes in the population abundance!

Beginning of year dip: 8 fish per dip
End of year dip: 2 fish per dip
Conclusion: 3 out of 4 fish are gone
Mean Length and Total Mortality Rate

Analyzing mean length over time can provide advice about overfishing status.
How can we develop advice on how to optimize utility, even when we have limited data?
Data-Limited Methods Toolkit

• Collaboration between the University of British Columbia and the National Resources Defense Council

• A set of peer reviewed data-limited assessment models

• Increased usage for developing management advice
## Subset of data-limited methods in DLM Toolkit

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Part 4
Stock assessment scientists work in partnership with constituents to provide reliable scientific advice that enhances the stewardship of our living marine resources.
Conservation and management measures shall...

• **prevent overfishing** while achieving, on a continuing basis, the optimum yield.

• be based upon the **best scientific information available**.

• **consider efficiency in the utilization of fishery resources**; except that no such measure shall have economic allocation as its sole purpose.

• **take into account and allow for variations**.
How many fish are out there and how many can we take out of the population on a continuing basis?

Fisheries are managed so that our grandchildren and great-grandchildren can also fish.
Purpose of stock assessments in the US

1. **Determine Overfishing Limit (OFL)**
   - **Who:** Federal (NMFS) or State
   - **How:**
     - Data-moderate: stock assessment
     - Data-limited: MSY proxy (e.g., reproductive potential)

2. **Determine Acceptable Biological Catch (ABC)**
   - **Who:** Scientific and Statistical Committee (SSC)
   - **How:**
     - Harvest control rule – predefined control rule that is intended to account for scientific uncertainty in the OFL estimate
       - e.g., ABC = 0.75 x OFL

3. **Determine Annual Catch Limit (ACL)**
   - **Who:** Fishery Management Council
   - **How:**
     - Based upon scientific recommendations which account for various ecological, social and economic factors

4. **Determine Annual Catch Target (ACT)**
   - **Who:** Fishery Management Council
   - **How:**
     - Accounts for management uncertainty
Current assessment approach in US Caribbean

Mean length estimator
• Used in past SEDAR assessments
• Has provided advice about overfishing status
• Has not provided advice about the OFL

DLM Toolkit
• Used in most recent assessment (SEDAR 46)
• Provides catch advice. CFMC SSC is developing a control rule that will allows us to "map" this advice to produce estimates of OFL and ABC
**Future Outlook**

- Continue to measure average lengths
- Continue to collect landings and effort data
- Manage to avoid overfishing and stocks becoming overfished
- Make informed adjustments to ACLs