Fisheries Biology, Assessment & Management

John Shepherd

Southampton Oceanography Centre

Fisheries Science Three Major Themes

- 1) **Life Cycles in the Sea**
  - Biology & Population Dynamics
- 2) **How Many Fish in the Sea ?**
  - Assessment Methods (practical)
- 3) **Sustainable Management ?**
  - Biology versus Economics, Politics and all that....

3/10 January 2003 No.4631 An informa Publication Established 1913 £1

FISHING NEWS

www.fishingnews.co.uk

Boat sales 8-9 Safety 10 Markets re-open 16

EU fishermen's group call to Commission president:

SACK FISCHLER!

– UK is biggest loser in Council stitch up as Commission forces through days at sea limits

FISHERMEN'S leaders from across the EU called for Fisheries Commissioner Franz Fischler and his team of officials to be sacked following the final agreement at the end of the marathon December Council of Ministers, reports **Tim Oliver**.

The package, cobbled together after five days of intensive negotiations, set TACs for 2003, agreed a cod recovery plan and the reform of the CFP.

TACs on many species were slashed by more than half, and days at sea limits are to be introduced for cod and other 'recovery' stocks despite implacable opposition from the fishermen of almost every member state.

But fishermen's leaders said the deal was simply an exercise in political manipulation to force through an agreement that would ultimately do little for conservation.

The deal will devastate the

UK and Irish leaders at one of several meetings of the European Fishermen's Action Group held in Brussels during the five day Council negotiations. L-R: Bob Casson, Arnold Locker, Sam Lambourn (NFFO); Alex Smith (SFF), Jason Whooley (ISWFO), Hugh Allen, Hamish Morrison (SFF), Sean O'Donoghue

How Commission bribed each state

- IRELAND: No days at sea limit in Irish Box/Irish Sea (also seen as a possible ploy to split the UK opposition to days limits); subsidies for two more years; more herring quota in VIIg-k.
- DENMARK: Industrial fishery protected.
- SPAIN: hake dropped from recovery stock programme; subsidies for new building for another two years.
- FRANCE: allowed to use 80mm mesh in saithe/whiting fishery in southern North Sea (where there is plenty of juvenile cod); 25 days at sea per month for fleet using 80mm gear; no effort limits on threatened deep water fisheries.
- NETHERLANDS and BELGIUM: Proposed big North Sea plaice and sole cuts reduced to only 5% and 1% respectively.
- FINLAND and Mediterranean states GREECE and ITALY also benefited from new building subsidies

31 January 2003 No.4634 An informa Publication Established 1913 £1

FISHING NEWS

www.fishingnews.co.uk

New netter 8-9 Sweet Promise trip Pt II 10 Quota cuts 16

Industrial landings figures prove haddock slaughter

A FORMER top Scottish skipper says ICES figures for haddock and pout landings in the North Sea virtually prove that the industrial pout fishery catches huge amounts of juvenile haddock that are passed off as pout.

Davie Smith of Anstruther told *FN* that figures in a document released by the Danish Associations of Fish Meal and Fish Oil Manufacturers in 1993, in which the Danish manufacturers try to present evidence to refute allegations against the industrial fisheries in fact prove the opposite.

The report contains a graph of all the pout landings since 1960 and they show a perfect correlation between peak pout landings and the best haddock year classes, and the lowest pout landings and the weakest haddock year classes.

"I am staggered by the conclusions that I have come to. As far as I am concerned, this is the proof that we have all been looking for, right before our eyes, and none of us have made the connection before," said Davie Smith.

"The document quotes Roger Bailey, British fisheries scientist and Buckland Professor for 1992,who says that since records were kept in 1922, the pout stock shows fairly steady and relatively low recruitment levels until the pout landings started to increase from 1962 onwards. They peaked in 1968 at 400,000 tons and then peaked again in 1974 to 800,000 tons.

"This amazingly coincides with the ICES figures of two biggest haddock recruitment years of all time, 1967 and 1974. Conversely, the landings of pout in 1988 fell to their lowest level for 20 years – exactly matching the two poorest recruitment years of haddock in the last 20 years, 1987 and 1988; again ICES figures.

"I think we have all been hoodwinked by the scale of these landings of demersal fish in the name of pout, including the scientists, because the statistics were all based on total lies, and we all watched it happen."

Mr Smith said he had been "a lone voice" in saying that he could never understand why the big 1974 year class of haddocks never made the impact on landings of demersal fish for human consumption that he thought it should have. "Alas, I know now – they were taken by the industrial fishery and landed as pout!"

Mr Smith said a letter in *FN* last week from David Hill from Esbjerg (24 January 'Only the tip of the iceberg' illustrated further what is really going on in the industrial fishing industry.

"I am sure no one knows the truth better than David Hill does, having worked in that industry for so long. He asks how much the Danish inspectorate sees when only 20% of the landings are inspected.

"The sad thing is, that in view of the recent landings infringements in Denmark, and quoting David Hill's figures of the increase in industrial fish landings of 1,057,555 tons in 2001, and 994,294 tons in 2002, unless someone puts a stop to this madness, it's an odds on bet that the very important 1999 year class of haddocks will suffer the same fate as the other two major year classes of the last 40 years."

Picture by Phil Lockley

£60m AID

THE GOVERNMENT is giving the UK fishing industry a £60m financial package in the wake of the huge TAC cuts and days at sea limits agreed at the December Fisheries Council, reports **Tim Oliver**.

Scots get £50m – including £10m interim cash

interim aid for England or Northern Ireland.

Details of how the money ...

and west of Scotland.

Scottish industry leaders initial reaction ...

Deas said the Federation was "bitterly disappointed" that there was no interim aid for its members.

"What is sauce for the goose is sauce for the gander – we have boats in exactly ...

14 February 2003 No.4636 An informa Publication Established 1913 £1

FISHING NEWS

FISHING 2003

For more information contact: Sue Hill
E-mail: sue.hill@informa.com
Fax: +44 (0)20 7017 4537
Tel: +44 (0)20 7017 4529

Lifeboats
Royal National Lifeboat Institution
RNLI Fishing Safety
FREEPHONE 0800 328 0600

www.fishingnews.co.uk

Fatalities reports 6 'Slipper skippers' 7 Netting trip 8-9 Industrial fishing 10

The damaged *De Vrouw Melanie* in Brixham after the collision.

Tanker collides with Brixham beamer

THE SIX strong crew of the Brixham beam trawler De *Vrouw Marie* had a lucky escape after she collided with the Panamanian registered chemical/oil tanker *Oriental Jasmin* on Saturday 8 February 33.5 miles off Start Point.

Brixham Coastguard was alerted after it overheard a conversation between two fishing vessels in the early hours of Saturday morning on Channel 16 and contacted the vessels for further information.

The 24m *De Vrouw Marie* was fishing and showing *Turn to page 2*

NFFO seeks a judical review

DAYS AT SEA LEGAL ACTION

MARINE ELECTRONIC DISTRIBUTION
Raymarine
Radars Fishfinder/Plotter Radar/Plotter
GARMIN

Aims

- To understand
  - real stock assessments (ICES WG reports)
  - the key issues in fisheries management (Shepherd, Lowestoft Lab Leaflet No 72)
  - why a TAC recommendation may go up when a stock is on the verge of collapse
  - the assessment of Cook et al (Nature 385, 521-522, 6 Feb 1997)

Requirements

- Fish Stock Assessment is **quantitative**
- One needs a little light mathematics
  - logarithms, exponentials, summations
  - mostly sums-of-products
- Use a scientific calculator, or a spreadsheet (e.g. Microsoft Excel)
- Lecture 2 is practical : **bring a calculator**
  - Cohort Analysis, Yield-per-recruit, Stock Recruitment Relationship, Catch Forecast

Books (1)

- Pitcher, T.J. & Hart, P.J.B., "Fisheries Ecology", Chapman & Hall,1982 (£25 p/b)
  - not bad, fairly cheap
  - Catch Equation : p90
  - von Bertalanffy & Logistic : pp140 -141
  - Stock & Recruitment : p182 et seq
  - Stock/Production Models : p 221 et seq
  - Yield-per-recruit : p252 ... 267 et seq
  - VPA/Cohort Analysis : pp 373 -377

Books (2)

- Beverton, R.J.H. & Holt, S.J., "On the Dynamics of Exploited Fish Populations" (1957) : reprinted by Chapman & Hall 1993
  - the "bible", but dated (and £65 h/b !)
- Hilborn, R & Walters, C.J. "Quantitative Fisheries Stock Assessment", Chapman & Hall 1992
  - A good modern text, with software
  - Has N. American (West Coast) approach

Books (3)

- Gulland, J.A.(ed) "Fish Population Dynamics", 2nd edition, Wiley 1988
  - good general review (multi-author)
- Rothschild, B.J. "Dynamics of Marine Fish Populations", Harvard U.P. 1986
  - Good wide-ranging text
  - not too mathematical !
- Cushing, D.H. "Key Papers on Fish Populations", IRL Press 1983
  - collected original papers

More (New) Books

- Jennings S, Kaiser MJ & Reynolds JD, "**Marine Fisheries Ecology**", Blackwell Science (2001) [ecological]
- Haddon, M "**Modelling & Quantitative Methods in Fisheries**" Chapman & Hall (2001) [mathematical/statistical]
- Quinn TJ & Deriso RB, "**Quantitative Fish Dynamics**", Oxford UP (1999) [serious, professional, the best modern text]
- P. J. B. Hart and J. D. Reynolds: (2002). **Handbook of Fish Biology and Fisheries (Volume II): Fisheries**. [Chapters 7 & 8 by J. G. Shepherd & J. G. Pope]

Fisheries Biology, Assessment & Management

Lecture 1

Life and Death in the Sea

Population Dynamics
a simple science ...

- Birth
- Growth
- Reproduction
- Death

Concepts

- The Population (or Stock)
  - a group of individuals, forming a self-contained (closed) breeding unit
    - e.g. North Sea cod, or Celtic Sea sole
- A Cohort (or Yearclass)
  - all those fish (of a single stock) spawned in a particular year
- Population number-at-age (of a cohort)
  - P(a), P(t), N(a) or N(t)

Stock Identity

- Physical Separation
- Genetic Separation ?

Fish Migration

- Spawning (on defined grounds)
- Egg & Larval Drift (to Nursery grounds)
- Feeding, Growth & Maturation
- Return for Spawning

Recruitment

- the number of young fish joining the stock (each year)
- **and** the process of them doing so
- **also** the size (abundance) of a yearclass
- may have **recruitment**
  - to the spawning stock (at ages ~ 1 to 6)
  - to the fishable stock (at ages ~ 0 to 3)
  - at some reference age (often age 0 or 1)

Sustainability

- depends on maintaining adequate recruitment
- and therefore on an adequate **spawning stock biomass**
  - (zero spawning stock means zero recruits)
- may be affected by
  - natural causes
    - (fluctuations, regime shifts)
  - exploitation
    - (increased death rate and reduced SSB)

Fish Life History

a quick summary of the essential
facts-of-life

Fish Eggs

- “Birth” as eggs : several millions per fish
  - Usually planktonic
  - Cell division -> embryos (using yolk)
  - Unable to swim !
  - Death rate ~50% per day
  - Biomass of cohort declines
  - Duration about 10 days
  - 99.9 % die : 1 in 1000 survives

Fish Larvae

- Eggs hatch into larvae
  - First feeding is crucial
    - can now swim and hunt for food
  - Size is 10 to 30 mm (length)
  - Growth (in weight) at ~30% per day
  - Death rate is also ~30% per day
  - Biomass of cohort is roughly constant
  - Duration : weeks to months
  - 99.9% die : 1 in 1000 survives

Juvenile Fish

- Larvae metamorphose into juvenile fish
  - size about 3cm to 30cm (varies)
  - growth : about 10 cm per year
  - death rate about 70% per year
  - duration : a few years
  - 90% die : about 1 in 10 survives
  - biomass of cohort increases

Summary : Early Life-history

- Several distinct stages : mainly planktonic
- Several trophic levels
  - non-feeding eggs
  - herbivorous zooplankton
  - carnivorous zooplankton
  - carnivorous nekton (pelagic or demersal)
- Few survive to maturity
  - 99.99999 % die : 1 in 10 million survives

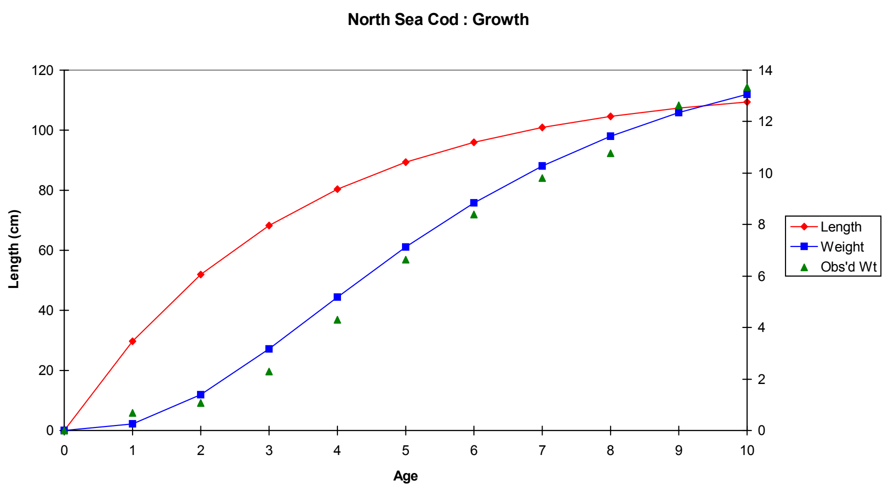
Pre-recruit Mortality and Variability of Recruitment

- pre-recruit mortality (during the first year) is **enormous**
  - about 16 in usual (logarithmic) units
  - compare with
    - ~ 0.2 per year (natural, post-recruitment)
    - ~ 1 per year (adults, heavily fished)
- slight variations (~ 10 %) in rates can lead to massive variations (by factors of up to ten) in survival, and thus in recruitment

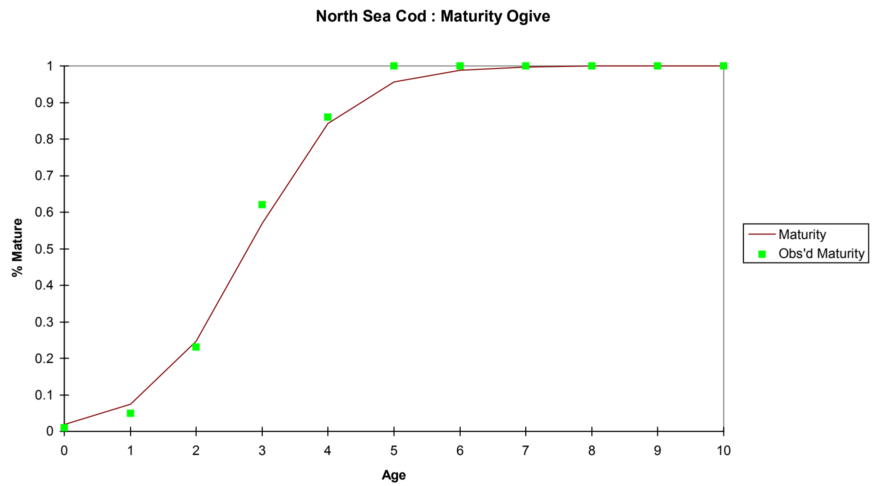
"Adult" Fish Growth & Maturation

- Growth in Length : the von Bertalanffy curve
  - $L(t) = L_{inf} [1 - \exp\{ - K (t-t_0) \}]$
- Growth in Weight
  - proportional to $(\text{length})^3$, so
    - $W(t)= W_{inf} [1 - \exp\{ - K (t-t_0) \}]^3$
  - similar to the Logistic curve ...
- Maturation : the Logistic curve
  - $M(t) = 1 / [1 + \exp\{ - K' (t-t_{50}) \}]$

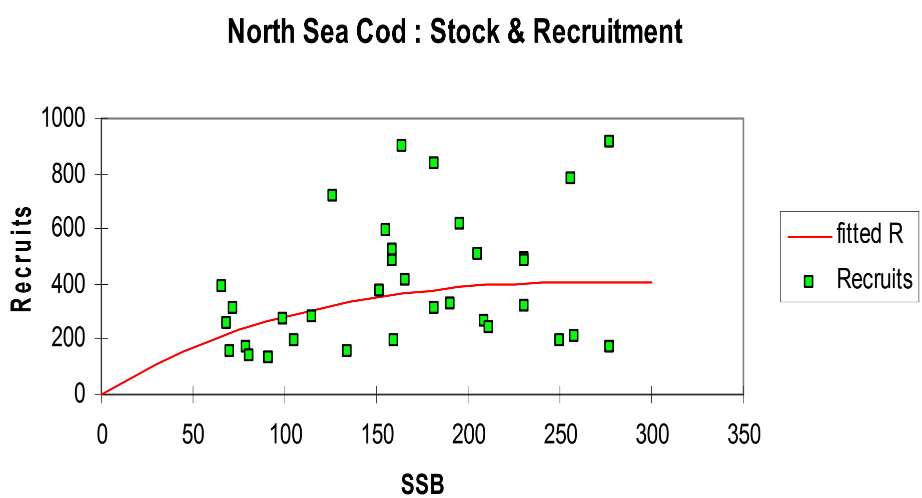
Fish Growth



Fish Maturation



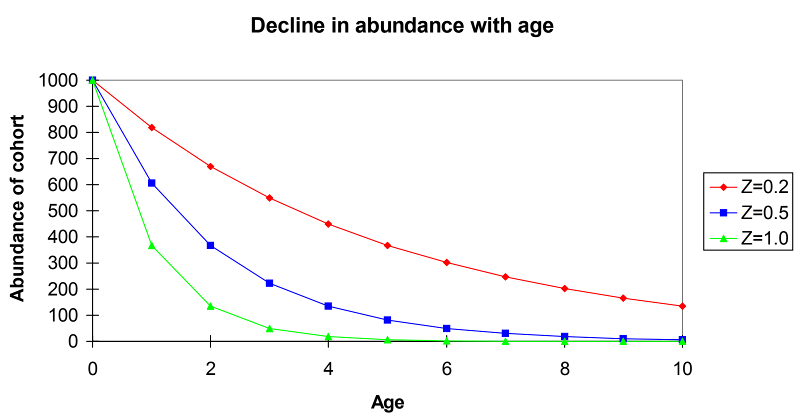
Stock & Recruitment



Death in the Sea

- IF a constant fraction Z of fish die per unit time (usually per year), then
- $dP/dt = - Z P(t)$
- which is a classic differential equation with the solution :
- $P(t) = P(0) \exp\{ -Zt \}$
- i.e. an exponential decline in number with time (and thus also with age)
- Z is the **total mortality rate** (coefficient)

Effect of mortality on a cohort



The Effects of Fishing

- increases the death rate (mortality)
- which reduces the stock size (biomass)
  - (and the average age and size of fish)
- and therefore probably also reduces:
  - the catch-rate (CPUE)
  - profitability
  - stability of catches
  - recruitment
- which may lead to stock collapse

Sources of mortality

- Z = Total mortality (rate)
- Z = F + M, where...
- F = Fishing mortality (rate)
  - the fraction which die (per unit time) due to fishing
  - typically F ~ 0.2 to 1.0 (per year)
- M = Natural mortality (rate)
  - the fraction which die (per unit time) due to natural causes (disease, predation etc)
  - typically M ~ 0.1 to 0.3 (per year)

Types of fish

- Pelagic : Living & feeding in mid-water
  - shoaling, fast swimming species
    - herring, mackerel, anchovy, sardine
- Demersal : on or near the bottom
  - more evenly distributed, but still migrate
    - cod, haddock, flatfish (plaice, sole, etc)
- Benthic : on or in the bottom
  - sessile (mostly static)
    - shellfish (scallops, nephrops, lobsters, crabs)

Fishing effort & catchability

- Fishing effort
  - Days fished, hours trawled, hooks set etc
- For demersal fish only ...
  - Each unit of effort catches some roughly constant proportion of the fish present
    - so fishing mortality is proportional to effort
    - $F = q E$
    - where q = catchability coefficient

Pictures of Fishing Gears

CPUE & Abundance

- Catch-per-unit-effort (CPUE) is an index of stock abundance (for demersal fish)
  - $C = F\ P_{bar}$
  - $F = q\ E$
  - $C = q\ E\ P_{bar}$
  - $CPUE = C/E = q\ P_{bar}$
- For pelagic fish CPUE is not a good index
  - depends on handling capacity etc
    - CPUE ~ constant
    - catchability ~ 1 / abundance

The Catch Equation

- The rate at which fish are caught is
  - $dC/dt = F\ P(t)$
- If F is constant, integration over one year leads to the Catch Equation (for each age)
  - $C(a) = F(a)\ P(a)\ [\ 1 - \exp\{ -Z(a)\}\ ]\ /\ Z(a)$
    - where N.B. P(a) is the population number at the **beginning** of the year
  - in fact $C(a) = F(a)\ P_{bar}(a)$
    - where $P_{bar}(a)$ is the average over the year
    - because $[\ 1 - \exp\{ -Z(a)\}\ ]\ /\ Z(a)$ is just the ratio of average to initial numbers for each year (~ 0.6)

Derivation of the catch equation

$$\frac{dC}{dt} = F(t)P(t)$$

$$\therefore C(a) = \int_{t=a}^{t=a+1} F(t)P(t)dt$$

$$\therefore C(a) = F(a)P(a) \int_{t=0}^{t=1} \exp\{-Z(a)t\}dt$$

$$\therefore C(a) = F(a)P(a)\frac{[1-\exp\{-Z(a)\}]}{Z(a)}$$

Ambiguity of Catch Data

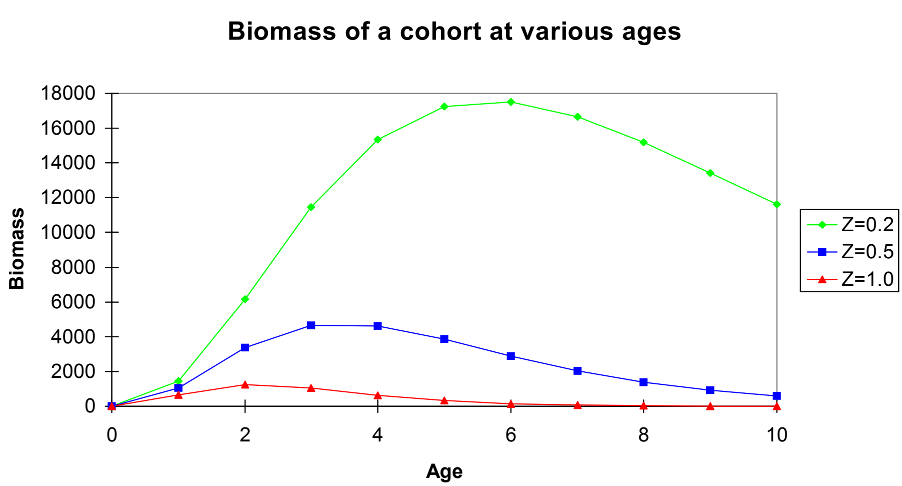
- $C = F\ P_{bar}$
- i.e. Catch = Fishing mortality x stock size
- Increased catches may be due to :
  - increased fishing mortality (effort) [bad]
  - or increased stock size [good]
  - or both
- and vice versa
- **Catch data alone is not enough**

The Gadoid Outburst

The Biomass of a Cohort

- Numbers-at-age decline with age
  - $P(a) = P(0) \exp\{ -Za \}$
- but weight-at-age increases
  - $W(a) = W_{inf} [1 - \exp\{ - K a\}]^3$
- and biomass-at-age is the product of these
  - $B(a) = P(a) W(a)$
- which is a maximum at some intermediate age

Biomass as a function of age



“Optimum” Fishing Strategy ?

- There is an age (about 6 yrs for N. Sea cod) at which the biomass is maximum
- So, to maximise the yield from any cohort ...
- Do not catch fish younger than this age at all
- Try to catch them all just at this age
  - deploy infinite fishing effort, using a very large mesh size (about 300 mm !!)
- But ... this is difficult in practice
  - and what about the spawning stock ??

Next Lecture

- Better ways to assess the effects of fishing
- and the potential effects of management
- using real data and assessment calculations
  - cohort analysis
  - yield-per-recruit
  - stock-recruitment relationships
  - catch forecasts
- to derive “advice to managers”
- in forms which are (hopefully) practicable

Reminder

- Bring a scientific calculator
- Be prepared to use
  - (natural) logarithms
  - exponentials
  - summations