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Drivers of dynamics of small pelagic fish resources International Symposium
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Session 5: Future challenges for ecosystem-based management of highly variable fish populations

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Monitoring by direct surveys and integrated assessment of the Bay of Biscay anchovy (1989-2016)
To provide management advice

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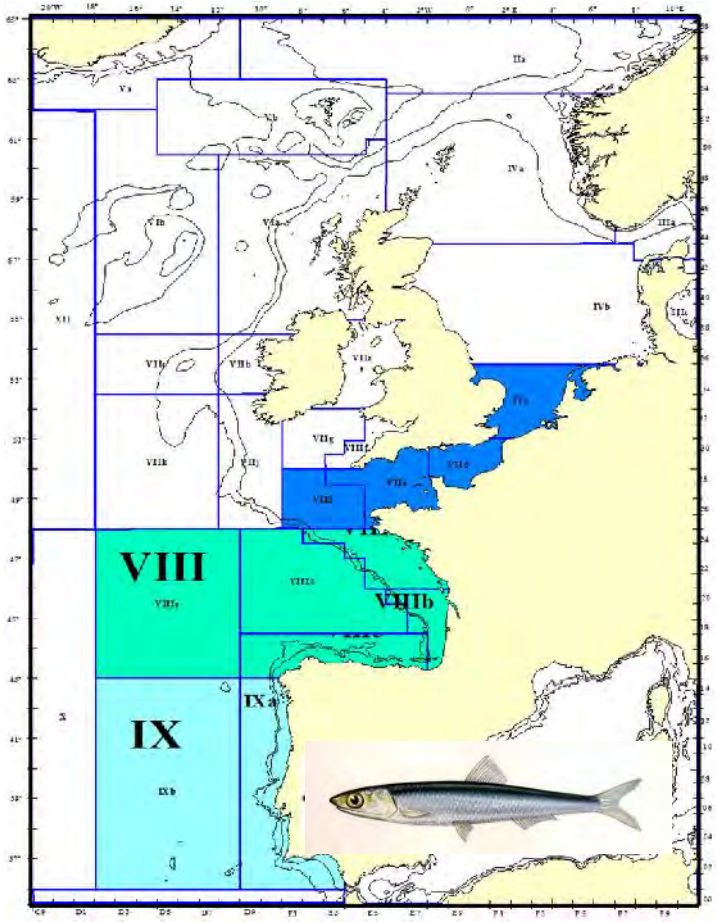
Index

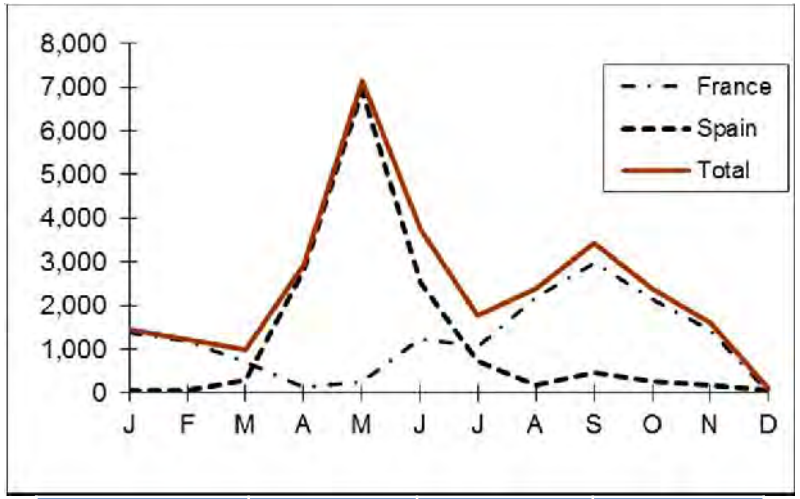
1- Introduction: biology

- Small pelagic species
- Aggregative behaviour
- Short-lived (3-5 years)
- Fast turn-over
- Mature at age 1
- Spawning in spring
- High and variable M
- Major predators on juveniles and adults are: tunidae, hake, monkfish, and demersal fishes, big mackerel, horse mackerel and jack mackerel



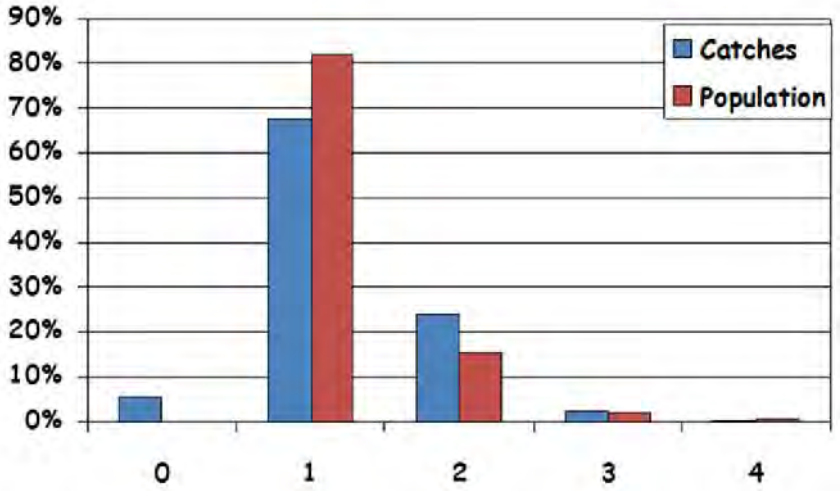
1- Introduction: The Fishery

Seasonal fishing 1992-2004



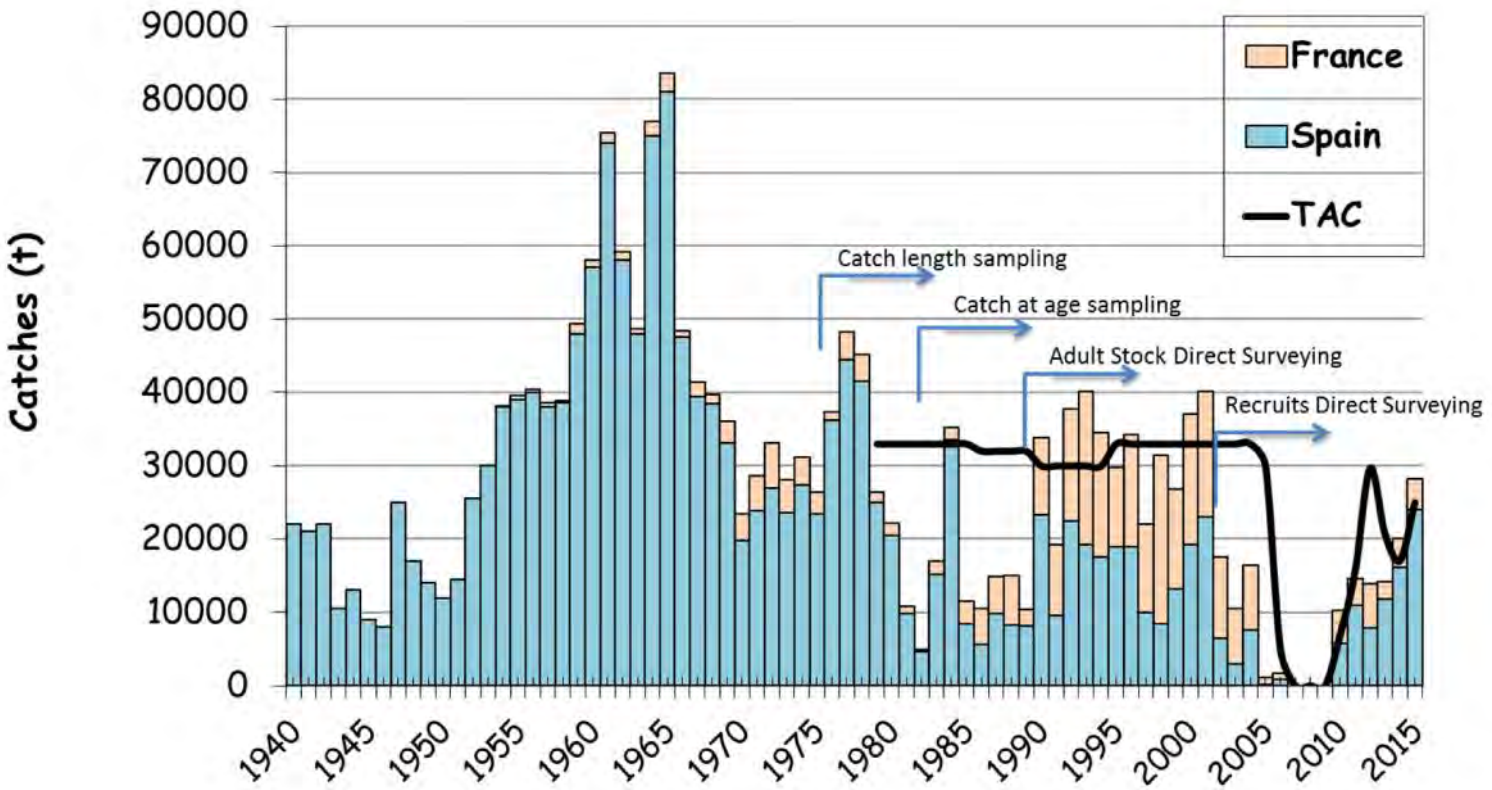
Country	1st Half	2nd half	TOTAL
Spain	87%	13%	100%
France	33%	67%	100%
International	60%	40%	100%

Age composition

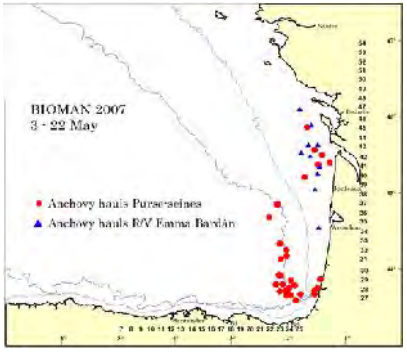


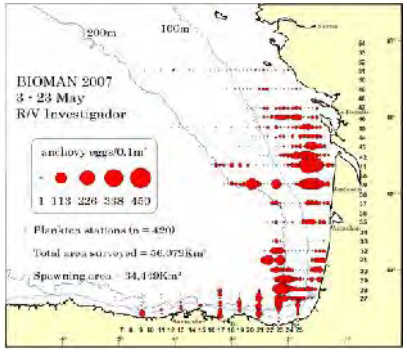
Population and catches mainly of Age 1 (~60%)

1- Introduction: Historical perspective and monitoring

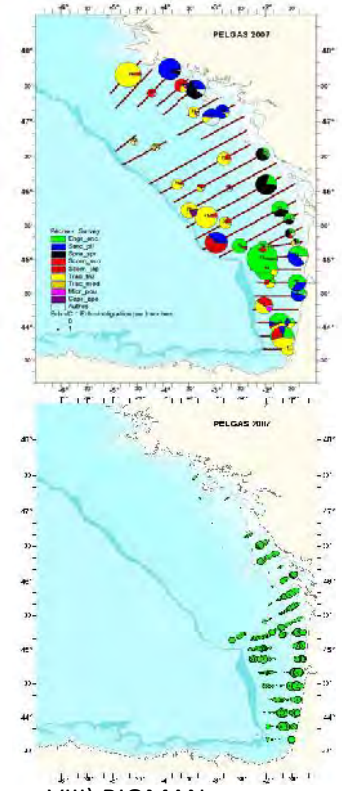


2- Spring surveys on the adult stock



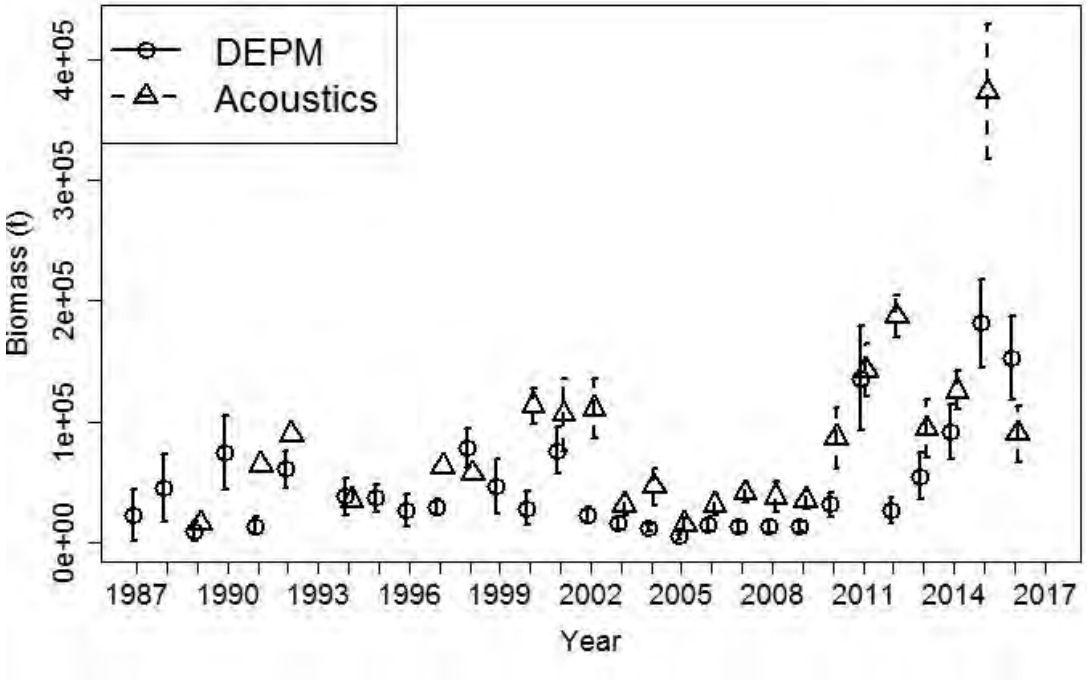


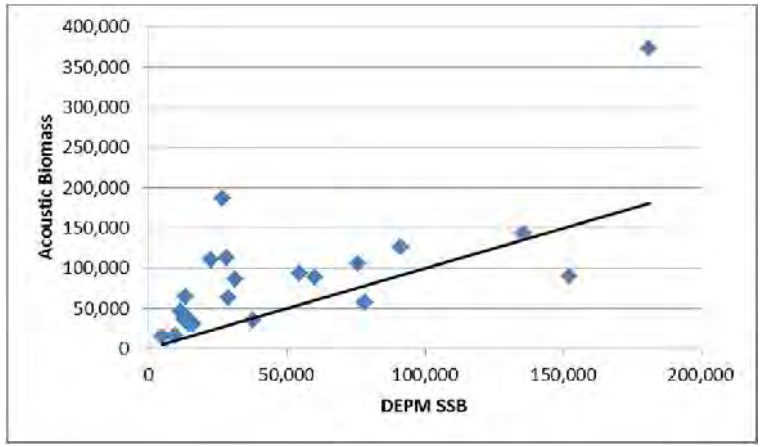
	BIOMAN*	PELGAS**
Time-series	1987-2016 (except 1993)	1989-2016 (some gaps before 2000)
Period	spring	spring
Type of survey	DEPM	acoustic
Estimates for assessment	SSB and Nage	SSB and Nage
Institute	AZTI-Tecnalia	IFREMER



* Santos M., Uriarte, A., Boyra G., and Ibaibarriaga L., *in press*. Anchovy DEPM surveys 2003 - 2012 in the Bay of Biscay (subarea VIII) BIOMAN.
** Masse J., Duhamel E., Petitgas P., Doray M., Huret M., *in press*. Spring Acoustic Surveys: Pelgas survey.
In Pelagic Surveys series for sardine and anchovy in ICES Areas VIII and IX (WGACEGG) - Towards an ecosystem approach. Edited by J. Masse, A. Uriarte, M.M. Angelico, and P. Carrera. ICES Cooperative Research Report (CRR) No 332. Copenhagen. Denmark

2- Spring surveys: Consistency of adult Biomass estimates



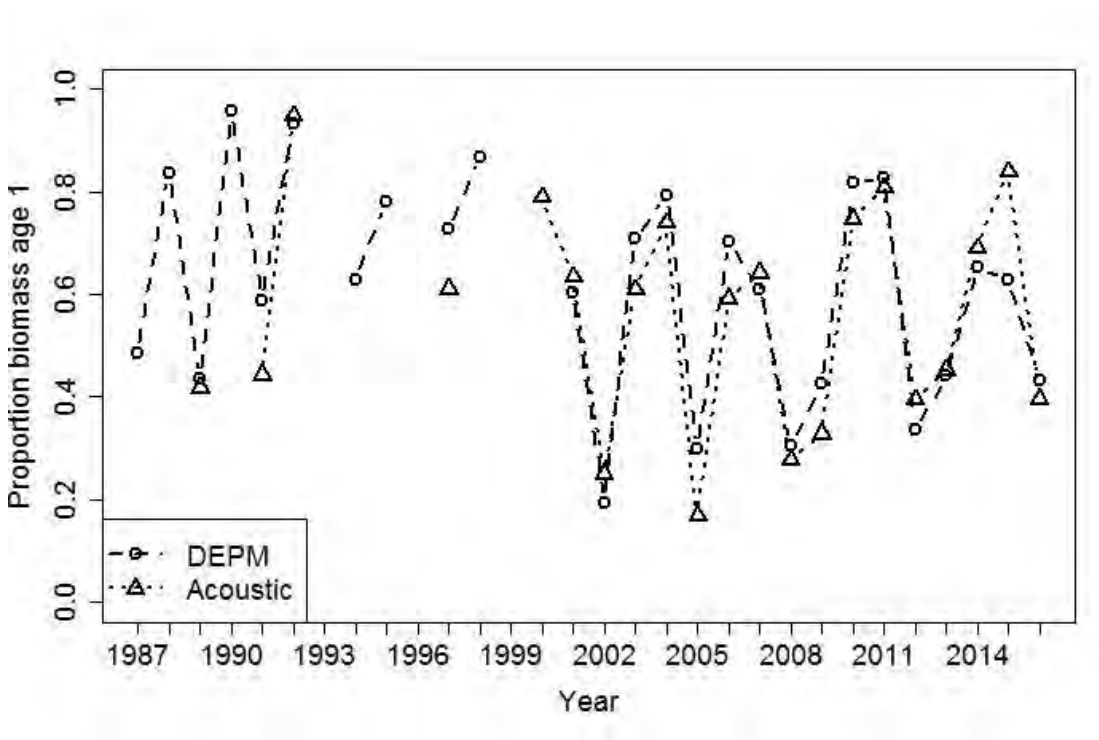


General good correlation (r= 0.71, r^2 = 51%, N=23, P=0.0013)

But $B_{acoustic} > B_{DEPM}$

→ Catchability assumption?

2- Spring surveys: Consistency of adult Biomass estimates



General good correlation (r= 0.918, r^2 = 82%, N=20, P>0.000001)

3- First assessment: Integrate Catch at age Analysis ICA (1995-2004)

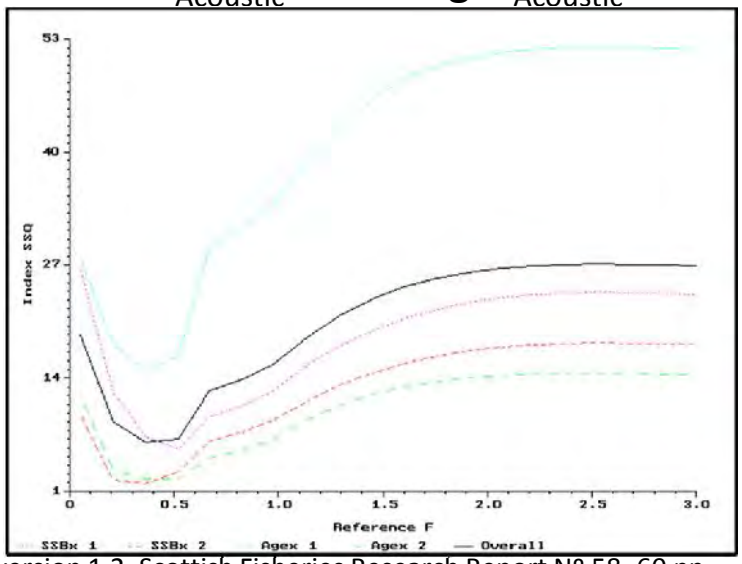
	MODELS	ICA
	Source	(Patterson & Melvin,1996)
	Time steps	Year
Model	Population Dynamics (Age structure) (errors)	Numbers at age (0-5+)
Param	Natural Mortality	M=1.2 (explicit)
Param	Growth	Observed Mean W@age
Inputs	Biomass indices Spring Adult surveys (errors)	PELGAS, BIOMAN (Biomass 1+) (lognorm)
Inputs	Abundance at age indices Spring Adult Surveys (errors)	PELGAS, BIOMAN (Nages 1-3+) (lognorm)
Inputs	Total Catch (tons)	NO
Inputs	Catch at age (errors & modelling)	(C@age0-5+) (LogNormal) (Separability assumption)
Inputs	Recruitment index for Y+1?	NO
Priors	PRIORS	NO
Estimat.	Estimation Proc.	Min(SSQ) Fortran

Objective function: Weighted sum of SSQ of residuals to

Cages +

$SSBindex_{DEPM}$ + $Numages_{DEPM}$ +

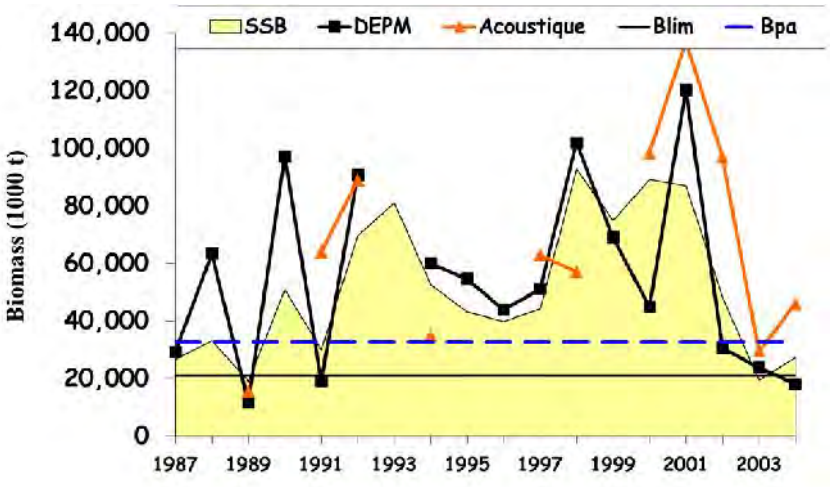
$SSBindex_{Acoustic}$ + $Numages_{Acoustic}$



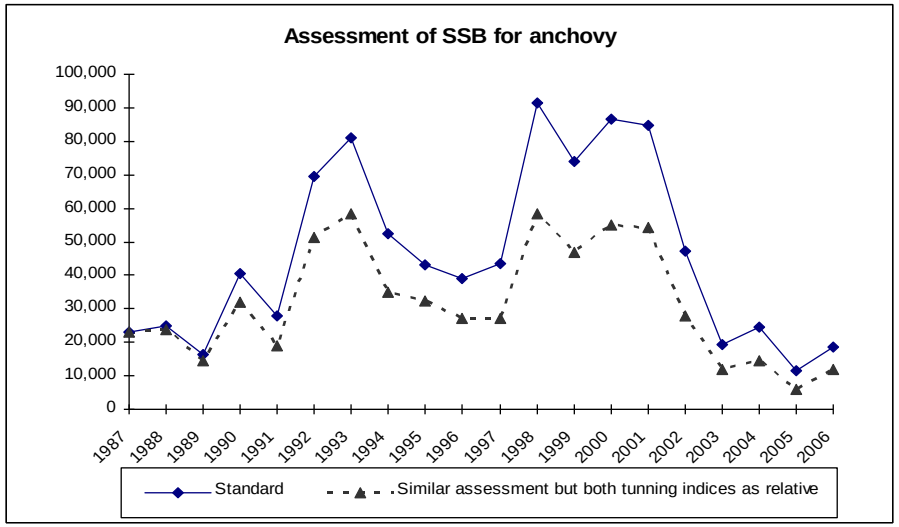
Patterson, K.R. and G.D. Melvin 1996: Integrated Catch at age Analysis, version 1.2. Scottish Fisheries Research Report № 58, 60 pp

3- First assessment: ICA

Deterministic Biomass estimates:



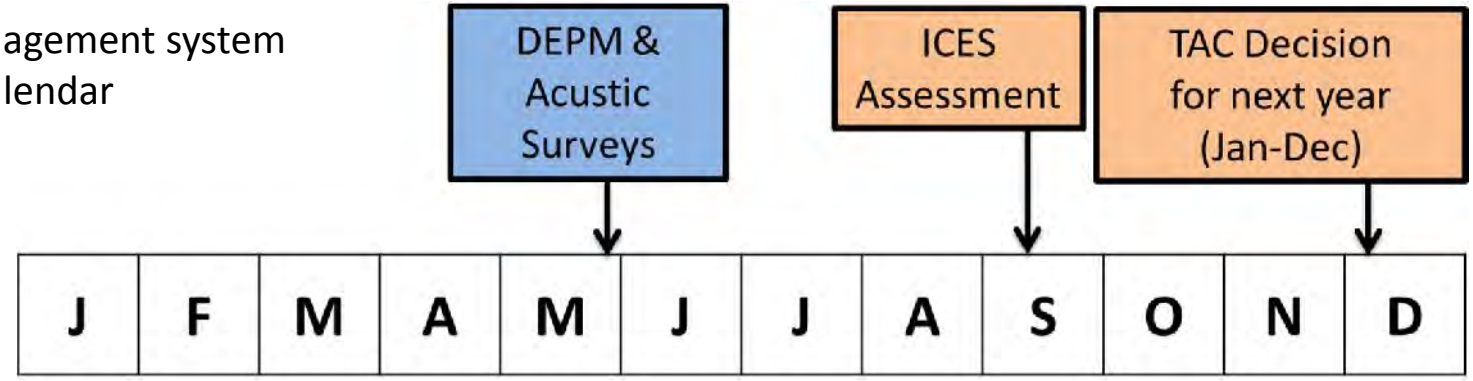
Sensitive to catchability assumptions



Standard assessment assuming DEPM absolute (catchability Q=1)

3- ICES advice within PA approach 2001-2004

management system & calendar



- Catch Advice provided for Y+1 with unknown Recruits at age 1 (about 60% of catches unknown)
- ICES Precautionary approach (PA) Strategy: Two phase approach for advise:
  - I. Initial TAC advise based on poor Recruit assumption to start the year (January)
  - II. Revised TAC advise (in June) after Recruit estimates from May Surveys
- Caveats: Most of the catches (60%) in 1st half of the year governed under PA
  - Unbalanced PA affection by Countries (Spain 87%; France 33% during 1st half the year)
  - PA approach → Precautionary but Suboptimal exploitation strategy due to the unknown Recruits
- → The advice was not followed / Fixed TAC around 30 to 33 000 t

3- ICES advice within PA approach 2001-2004

Outlook for 2005:

The forecast is based on a catch constraint equal to the expected outtake in 2004. The forecast assumes that the recruitment in 2005 is the geometric mean of those equal to or below the median in the historical series (GM of 1987, 88, 90, 93, 94, 98, 2001, 2002 and 2003), i.e. 7.1 billions.

Basis: SSB(2004) = 24 024 t; catch (2004) = 16 200 t.
The maximum fishing mortality which would be in accordance with precautionary limits (F (precautionary limits)) is 1.0.

Catch options for 2005
for a low recruitment scenario

Rationale	Landings(2005)	F(2005)	Basis	SSB(2005)	SSB(2006)
Zero catch	0	0	F=0	31220	37730
Status quo	2383	0.10	$F = F_{sq} * 0.2$	30318	35571
	4616	0.19	$F = F_{sq} * 0.4$	29447	33617
	6711	0.29	$F = F_{sq} * 0.6$	28606	31843
	8680	0.39	$F = F_{sq} * 0.8$	27794	30228
	10532	0.48	$F = F_{sq}$	27010	28755
	12277	0.58	$F = F_{sq} * 1.2$	26252	27408

Exploitation boundaries in relation to precautionary limits

Advice

A preliminary TAC for 2005 should be set to 5 000 t. A catch of this size will, even in the case of poor recruitment, allow the SSB to rebuild in 2005. The TAC could be re-evaluated in the middle of the year 2005, based on the development of the fishery and on the results from the acoustic and egg surveys in May-June 2005.

4- Keep it simple: Bayesian Biomass model (BBM) (2005-2013)

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	MODELS	ICA	BBM
	Source	(Patterson & Melvin,1996)	(Ibaibarriaga et al, 2008)
	Time steps	Year	Half year
Model	Population Dynamics (Age structure) (errors)	Numbers at age (0-5+)	Two-stage biomass at age (1-2+)
Param	Natural Mortality	M=1.2 (explicit)	**g** (M-G) (implicit M=1.2 - Growth)
Param	Growth	Observed Mean W@age	**g** (M- Growth)
Inputs	Biomass indices Spring Adult surveys (errors)	PELGAS, BIOMAN (Biomass 1+) (lognorm)	PELGAS, BIOMAN (Biomass 1+) (lognorm)
Inputs	Abundance at age indices Spring Adult Surveys (errors)	PELGAS, BIOMAN (Nages 1-3+) (lognorm)	PELGAS, BIOMAN (% Nages 1-2+) (Beta)
Inputs	Total Catch (tons)	NO	Tons (offsets - removals)
Inputs	Catch at age (errors & modelling)	(C@age0-5+) (LogNormal) (Separability assumption)	NO input (No modelling)
Inputs	Recruitment index for Y+1?	NO	NO
Priors	PRIORS	NO	YES
Estimat.	Estimation Proc.	Min(SSQ) Fortran	Bayesian (WinBUGS/JAGS)

- Bayesian state space model
- A two-stage biomass dynamic model (Ibaibarriaga et al. 2008) (ages 1 – 2+)
- Change in mass rate by **g** = G-M
- Same Inputs as in ICA
- No modelling of catches (just removals)
- Bayesian inference of the posterior distribution of states & parameters given the observations

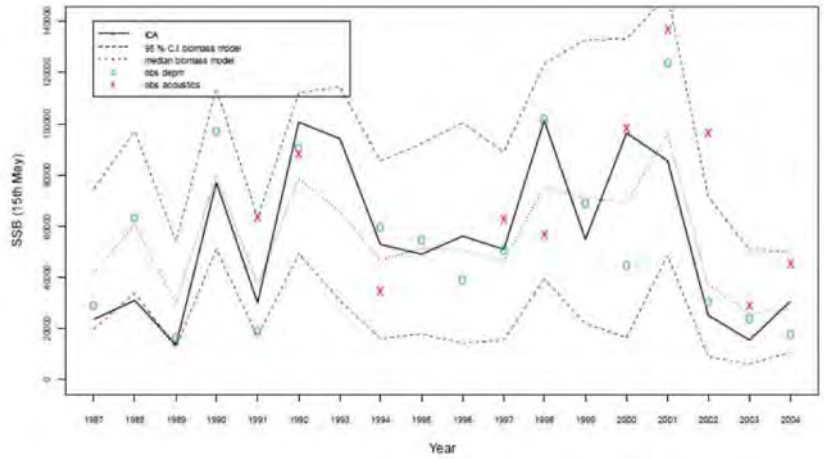
$$p(\text{param}, \text{states}|\text{observ}) \propto p(\text{observ}|\text{param}, \text{states})p(\text{states}|\text{param})p(\text{param})$$

- Probabilistic forecast for Rec scenarios

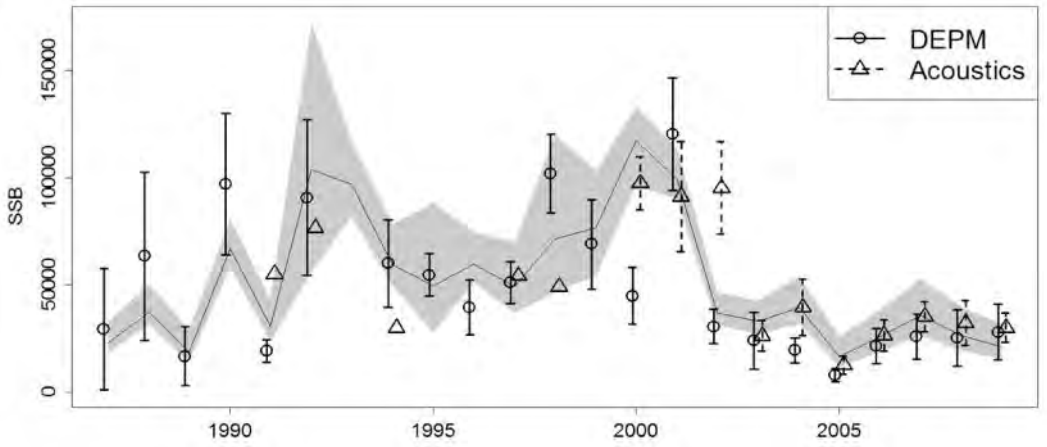
Ibaibarriaga, L., Fernández, C., Uriarte, A., and Roel, B. A. 2008. A two-stage biomass dynamic model for Bay of Biscay anchovy: a Bayesian approach. – ICES Journal of Marine Science, 65: 191–205.

4- Bayesian Biomass model (BBM) (2005-2013)

Consistent results ICA & BBM

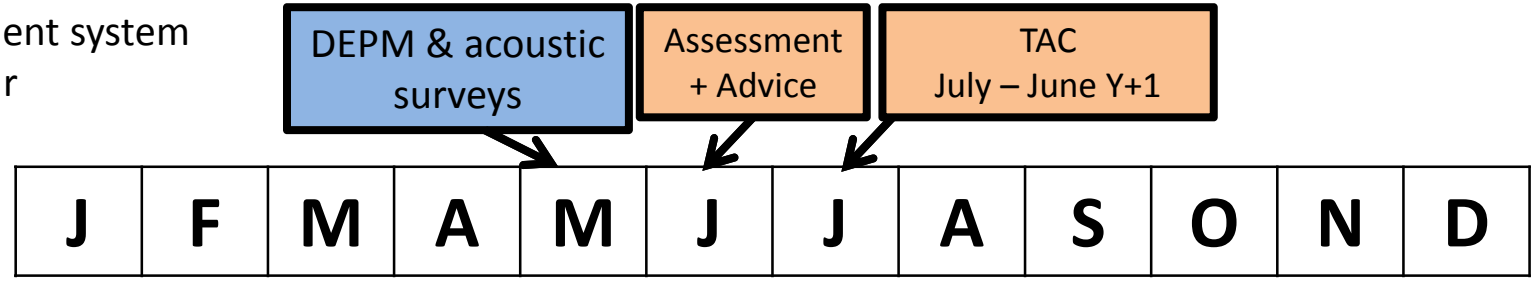


Estimates with confidence intervals



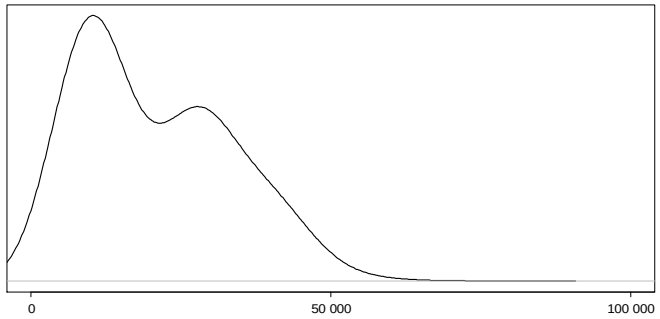
4- ICES advice within PA approach 2005-2012 (after 2005 fishery crash)

management system & calendar

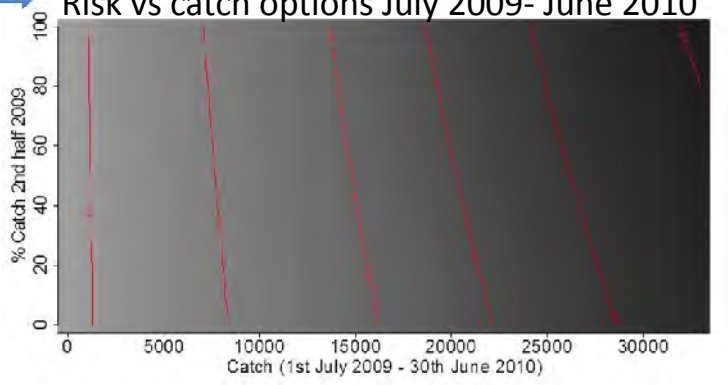


- Advice informed by Surveys on about 67% managed Catches but less than 40% Managed Population in Y+1)
- ICES Precautionary approach (PA): Probabilistic forecast for a Scenario based Recruitment in Y+1 (low/ unknown)
- Example: In 2010 the Sum of all recent low recruitment posterior distributions (since 2002) was selected as the most likely scenario to forecast Population to asses

Recruitment scenario: **Recent years**

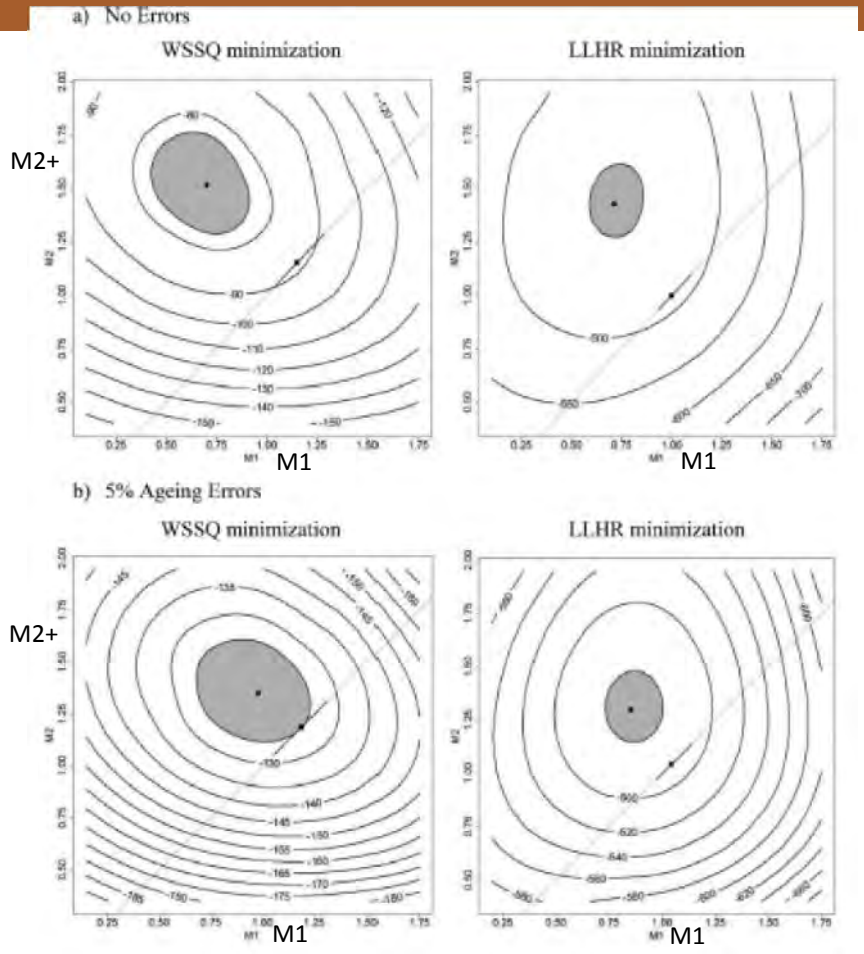


Risk vs catch options July 2009- June 2010



5- Recent Advances: Natural mortality

- Assumming flat catchability by ages in Spring Surveys (compatible with the data)
- All analysis of abundance indexes and integrated assessments leads to M1<M2+ (senescence?)
- ICES: M1=0.8 &M2+=1.2

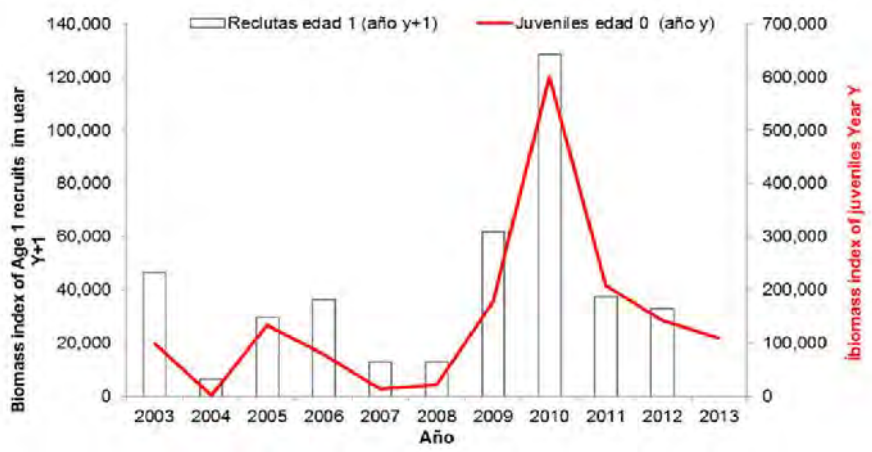


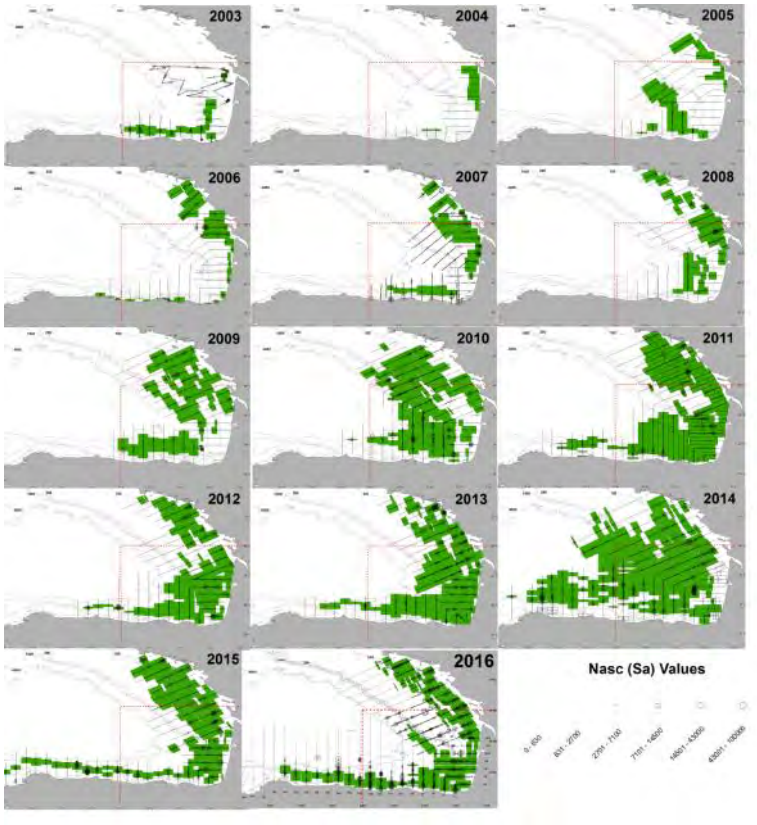
Uriarte A., Ibaibarriaga L., Pawlowski L., Massé J., Petitgas P., Santos M., and Skagen D. 2016. Assessing natural mortality of Bay of Biscay anchovy from survey population and biomass estimates. Canadian Journal of Fisheries and Aquatic Sciences (Can. J. Fish. Aquat. Sci.) 73(2): 216-234.

6- Recent Advances: Recruitment surveys

Autumn acoustic survey JUVENA: Estimates of Juveniles since 2003

- Good Correlation with Age 1 recruits of the assessment in year Y+1
- Incorporated into assessment in 2013





Boyra G., U. Martinez, U. Cotano, M. Santos, X. Irigoien, and A. Uriarte, 2013: Acoustic surveys for juvenile anchovy in the Bay of Biscay: abundance estimate as an indicator of the next year's recruitment and spatial distribution patterns. ICES J Mar Sci (2013) 70 (7): 1354-1368

7- Merging all & back to Catches at age: New Assessment (CBBM)

- **2013 Benchmark process in ICES based on Integrated Catch Bayesian Biomass Model (CBBM)**
- **Separates the growth and natural mortality processes** and allows estimations by age class. New M values incorporated. Assessment less sensitive to catchability assumption (now Q for both surveys are estimated)
- **Modelling the fishery**: Continuous process separating F into year and age-class effects in each semester
- → observation equations for total catch and catch proportions by age class (in biomass 1 and 2+) by semesters
- **Recruitment index**: Inclusion of a the acoustic survey on Juveniles and an observation of Recruitment age 1 in Y+1 → Output: starting Biomass in January Y+1
- **Incorporation of the variances reported by surveys** + additional component of unexplained Variance ()

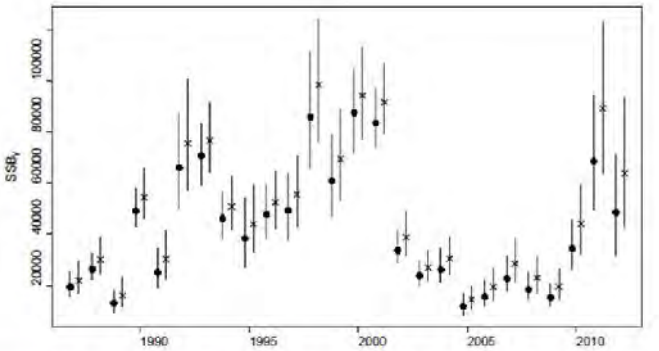
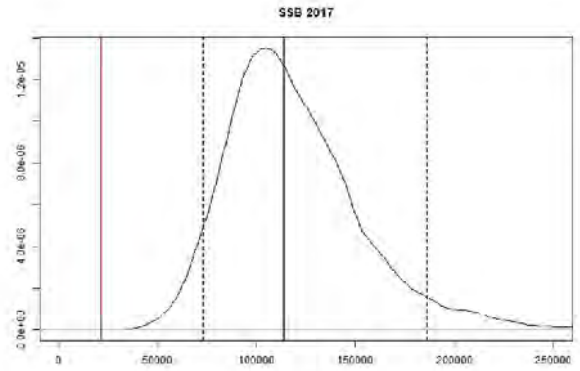


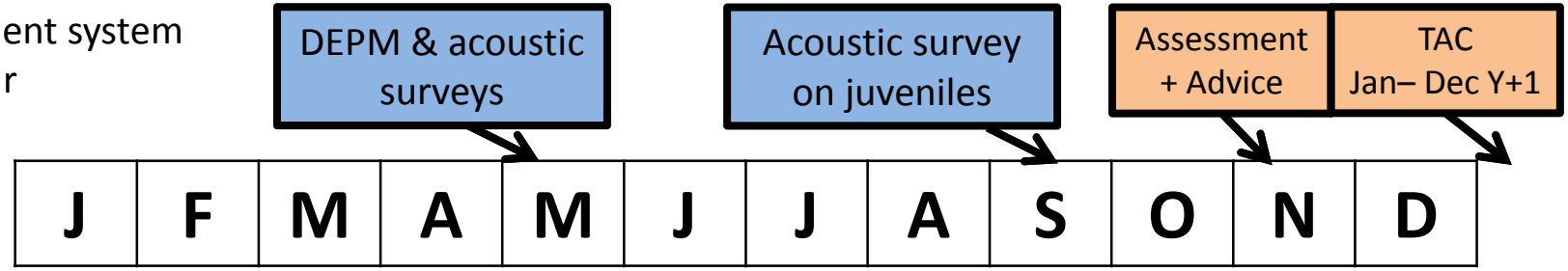
Figure 3.6.4.1.16. Comparison of SSB estimates from the CBBM when the DEPM is taken as absolute (bullet) and relative (cross). Natural mortality rates are fixed at M1=0.8 and M2+=1.2.



Ibaibarriaga, L., Fernández, C. and Uriarte, A., 2011. Gaining information from Commercial Catch for a Bayesian two-stage biomass dynamic model: Application to Bay of Biscay anchovy– ICES Journal of Marine Science, 68: 1435–1446.

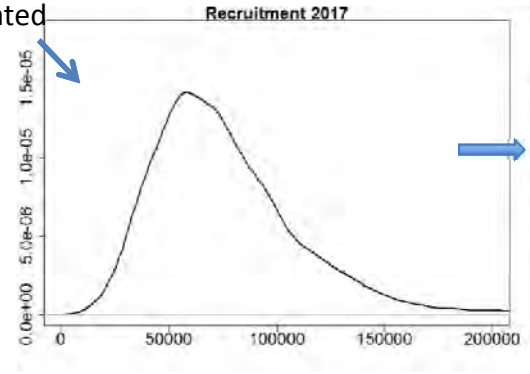
7- ICES advice within PA approach 2013-2016

management system & calendar

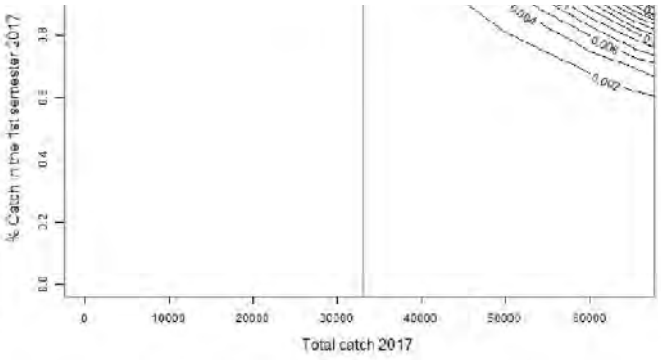


- Advice informed by Surveys (adults & juveniles) on 98% managed Catches and 100% Managed Population in Y+1
- ICES Precautionary approach (PA): Assessment of risk in management year for an informed level of Recruitment
- Example: In 2016 The assessment reported the posterior distribution of Recruitment at age in 2017 (according to the autumn recruitment survey)

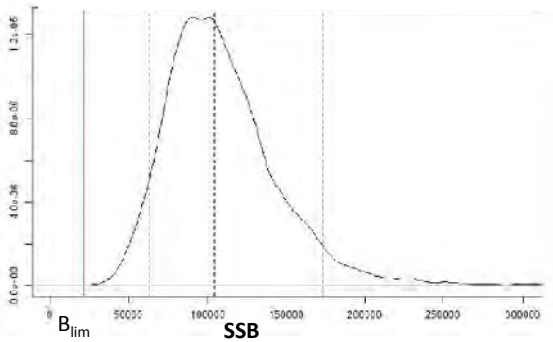
Estimated



Risk vs catch options for 2017



Expected SSB (2017) at TAC=33000 t



8 - CONCLUSIONS

- Coherent monitoring through independent surveys
  - Independent surveys can filter yearly noise estimations
- Assessment are mainly driven by Direct Survey inputs (given M)
- Natural Mortality matters to scale the assessments
- Two stage models are enough to capture Population dynamics of short lived species
- Catch at age modelling is not as relevant for these species as for long lived species (modest contribution to the SSB outcomes) when direct surveys are available.
- Major improvement in advice from recruitment surveys
  - More accurate forecasts to produce the advice
- In the absence of a recruitment index → reduce the lag between surveys, advice and management to reduce the uncertainties
- Bayesian context
  - Incorporation of prior knowledge on any parameters
  - Improved realization of uncertainties
  - Easier Probabilistic forecasts & better assessment of risks for the catch options in the advice

Thank you very much!

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