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Second Interim Report of the Working Group on Integrated Assessments of the North Sea (WGINOSE)

10–13 March 2015

Hamburg, Germany

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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Contents

Executive summary

The Working Group on Integrated Assessments of the North Sea (WGINOSE) met in Hamburg, Germany, as guests of the Thünen-Institute of Sea Fisheries and Fishery Ecology from 10–13 March 2015. The meeting was chaired by Andrew Kenny, UK. There were eight participants representing three countries. Due to lack of participation it was not possible to up-date either the ecosystem trends analysis or ecosystem overview sections.

WGINOSE is a working group, which works to develop the science-base for Integrated Ecosystem Assessments (IEA) in the North Sea. The group works towards this goal in cooperation with similar groups within the ICES SCICOM Scientific Steering Group on Integrated Ecosystem Assessment Programme (SSGIEA). Specifically the group aims to provide:

1) Annual status reporting, through the application of statistical analyses, of the principal activties, pressures and state indicators operating at the sub-regional level of the ecoregion.
2) Probability based analysis of the inateractions between ‘key‘ components of the greater North Sea subregions using stochastic models, and;
3) an assessment of the possible outcomes of management actions at the ecosystem level through its contribution to the greater North Sea ecosystem overview.

This year the focus of the meeting was the continued development of a BBN model to explore the relationships between identified important ecosystem components of the North Sea and to make predictions of state changes in response to different management scenarios (Aim 2, above). While last year’s emphasis was on the development of conceptual models for the southern and northern North Sea (see ICES WGINOSE Report 2014; i.e. influence diagrams), this year’s meeting focused on the data quality and explorative data analysis of variable relationships. The specified relationships of influence diagrams have been tested with time-series data to determine the strength of the correlation between key variables. The explorative analysis revealed that most correlations have been rather weak. Therefore, the use of the data to convert the conceptual models into a BN for the northern and southern North Sea is also questionable.

To potentially overcome some of the weakness introduced by multiple fisheries operating in the same area, WGINOSE recommend targeting a single fishery, which consistently dominates the same area of the North Sea from one year to the next.

WGINOSE will continue to work in partnership with expertise from OSPAR ICG Cumulative Effects to demonstrate the modelling approach being developed to support cumulative effects assessments.

In summary, WGINOSE concludes:

1) The BN model structure has to be designed to answer specific questions – this allows the model complexity, spatial scale and performance to be optimized. It is no good trying to develop a BN model that replicates the real complexity of ecosystems – the BN is best applied to answer specific questions of management interest.
2) Whereas there may be some ecological justification in defining regional seas as coherent management and assessment units – this does not necessarily mean that such areas are the optimal spatial scale for developing a BN. The

appropriate spatial scale for a BN model should be based upon the spatial optimization of the data which underpin the structure of the model, which in turn relates to the assessment needs.

3) A data 'model' for the area of interest should therefore to be developed as a pre-cursor to defining the appropriate spatial boundary for the assessment model.

4) It is important not to over extend the spatial scale or utility of the BN model as this is likely to result in poor model results.

5) Not all assessment/advisory needs can be addressed by the same spatial model. There is therefore a need explore the nesting of BN models spatially to address multiple questions.

6) WGINOSE will explore during the next 12 months the development of a data model for the SNS with a view to optimizing the spatial scales at which BN model can operate to answer specific types of questions.

7) Specific assessment/advice questions should be defined before the model structure is developed – such questions are important in determining the scale on which the model should operate and these questions will be defined over the next 12 months in consultation with ICES.

1 Opening of the meeting

This year's meeting of WGINOSE was held at the Thünen-Institute of Sea Fisheries and Fishery Ecology, Hamburg, Germany, from the 10 – 13 March 2015. Participants of the meeting (Annex 1) were welcomed by Andy Kenny, Chair of WGINOSE.

2 Adoption of the agenda

The agenda (see Annex 2) was adopted by the group after a short discussion.

3 Introduction to meeting

WGINOSE is a working group, which develops the links between the science-base of Integrated Ecosystem Assessments (IEA) and ecosystem management advice in the ICES greater North Sea ecoregion. The group works towards this goal in cooperation with similar groups within the ICES SCICOM Scientific Steering Group on Integrated Ecosystem Assessment Programme (SSGIEA). Specifically the group aims to provide:

1) Annual status reporting, through the application of statistical analyses, of the principal activties, pressures and state indicators operating at the subregional level of the ecoregion.
2) Probability based analysis of the inateractions between 'key' components of the greater North Sea subregions using stochastic models, and;
3) an assessment of the possible outcomes of management actions at the ecosystem level through its contribution to the greater North Sea ecosystem overview.

This is the second year of working on a set of multi-annual ToRs (Annex 3) which essentially cover, i. up-dating the status and trend analysis; ii. reviewing and up-dating the ecosystem overview report; iii. develop and apply a dynamic BBN model to assess the cumulative effects of multiple human activities, and iv. reviewing the data needs and gaps for IEA of the ICES greater North Sea Ecoregion.

In addition to reviewing the data needs and gaps for IEA, the group focussed its efforts at this meeting on the continued development of a subregional dynamic BBN for the greater North Sea.

4 Develop and apply dynamic models as tools for integrated and combined effects assessments (ToR c)

4.1 BN structure development

Under ToR c) a Bayesian Belief Network (BNs) should be developed as a tool to assess both the relationships between key variables and the combined effects of their potential changes (see ICES WGINOSE Report 2014). (Kelly *et al.*, 2013) compared five approaches and model types suitable for integrated environmental assessment and management. Those models can accommodate multiple issues, values, scales, uncertainty measures and allow for stakeholder engagement comprising system dynamics, BNs, coupled component models, agent-based models and knowledge-based models. The adequate choice of the modelling approach should depend on the scope and purpose. For the purpose of WGINOSE, the modelling approach should allow to integrate multiple observed data and to reflect their causal relationship. Ultimately, the model should allow for the assessment of “what if”-scenarios to improve systems understanding.

BNs are often applied in the context of decision-making and management and results represent probabilities of the occurrence of a certain event. Complex causal chains are represented by selected components and the uncertainty represented refers to the uncertainty of the model parameterization and not the model structure (Kelly *et al.*, 2013). This puts emphasis on the fact that BNs are not meant to be used as an analytical tool. Thus, in cases with limited knowledge of how a system functions a structure learning process might be used to define a BN model structure (Chen and Pollino, 2012). Following the good practice in BN modelling, after the conceptual model has been defined the refinement of the model components and structures has to be conducted (Chen and Pollino, 2012). Hence, all model nodes must affect the final output (in our case this refers to landings of selected fish species) and must represent either a node that is manageable, predictable or observable at the relevant scale of the model (Borsuk *et al.*, 2004). The integration of insignificant variables can increase the complexity of the BN and reduce the sensitivity of the model output.

While last year’s emphasis was on the development of conceptual models for the southern and northern North Sea (see ICES WGINOSE Report 2014; i.e. influence diagrams), this year’s meeting focused on the data quality and explorative data analysis of variable relationships. The specified relationships of influence diagrams have been tested with time-series data to determine the strength of the correlation between key variables. The explorative analysis revealed that most correlations have been rather week. Therefore, the use of the data to convert the conceptual models into a BN for the northern and southern North Sea is questionable. Thus, the derived conditional probability tables (CPTs) reflect the weak variable relationships and high level of variance (uncertainty) of observations.

At this stage of the BN modelling process the aim was to improve the model sensitivity by simplifying the model structure as recommended by (Chen and Pollino 2012). The simplified model structure in Figure 4.1.1 reflects a BN, which focused on the benthic components in the southern North Sea (see data in Annex 5). Table 4.1.1 contains a brief description of the nodes and respective data used. All model nodes represent either observed and/or manageable components.

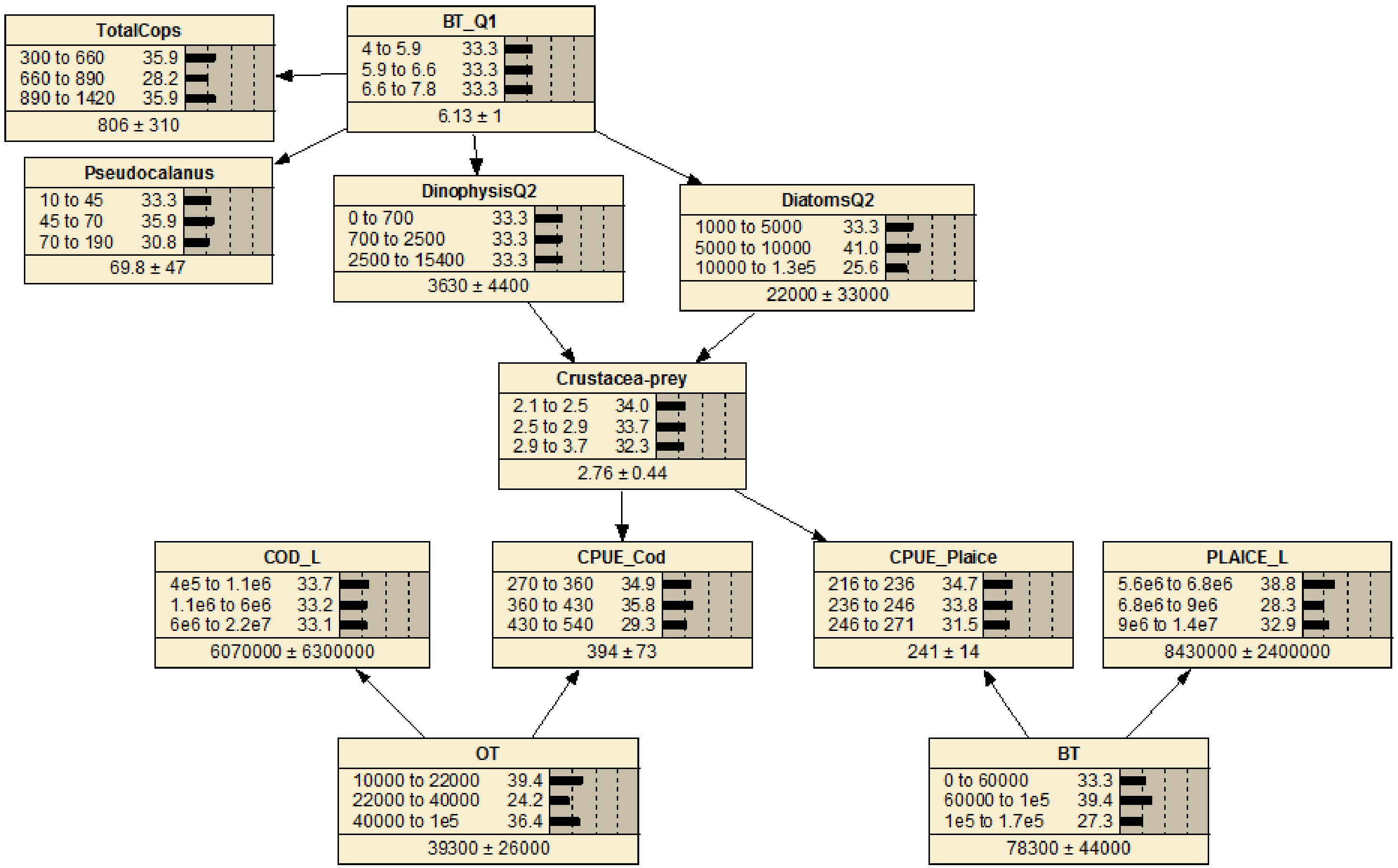

Figure 4.1.1. Refined structure of the BN model of the southern North Sea (baseline). Node states have been discretized by the equal-frequency method.

The processes reflected in the model structure cover the influence of the winter bottom temperature on zooplankton and phytoplankton in the second quarter. The availability of phytoplankton triggers the density of crustaceans as a prey for cod (CPUE_Cod) and plaice (CPUE_Plaice). The otter (OT) and beam trawl (BT) effort reflect fishing mortality which in turn should influence the cpue of cod and plaice. In addition, there should be a positive and strong relationship between OT and cod landings and BT and plaice landings, respectively.

Table 4.1.1. Model nodes included in the refined BN for the southern North Sea.

Node	Description
BT	UK effort beam trawling (1986-2012)
OT	UK effort otter trawling (1986-2012)
COD_L	UK landings of cod (1986-2012)
PLAICE_L	UK landings of plaice (1986-2012)
CPUE_Cod	cpue of cod derived from the IBTS (1986-2012)
CPUE_Plaice	cpue of plaice derived from the IBTS (1986-2012)
Pseudocalanus	CPR, SAHFOS (1958 – 2014)
TotalCops	All stages CPR, SAHFOS (1958 – 2014)
DiatomsQ2	Sum of 8 taxa, CPR SAHFOS

4.2 BN sensitivity

In Figure 4.2.1, the influence of assumed high bottom temperatures is shown. The trained BN (using the data in Annex 5) showed that an assumed winter bottom temperature of 6.6 to 7.8 C would result in an increased average weighted density of phytoplankton (5270 +/-4900) and a slight increase of the expected weighted average of pseudocalanus density (84 +/- 50). However, due to the high standard error those predicted likely changes are not significant. Further, the assumed change in temperature does not affect the crustacean density or the cpue of cod or plaice. Therefore, the strength of the relationships in the data are very weak do to the high level of variance in the time-series (1986-2012).

Figure 4.2.2 shows the predicted influence of an increased average density of crustacean of 2.9 to 3.7. In contrast to the baseline BN, there are no predicted effects on the cpue of cod or plaice.

Finally, we inferred the BN by assuming an average high level of otter trawling and beam trawling (Figure 4.2.3). Accordingly, the high level of variance in the data did not show any effect on the cpue of cod or plaice. Thus in summary the strongest, although not significant, relationships are shown between the winter bottom temperature and spring phytoplankton nodes.

Additionally we evaluated the sensitivity of the crustacean node to the influence of the parent nodes by calculating the variance reduction (Marcot *et al.*, 2006). Results showed that node CPUE_Plaice has the greatest influence on the node crustacean-prey (9.01% variance reduction) followed by DinophysisQ2 (0.34 % variance reduction). This is also shown in Figure 4.2.4, where an assumed high average value of cpue of plaice of 246 to 271 could lead to a likely reduction of average crustacean prey density to 2.59 +/- 0.4). Accordingly, the greatest influence on the node CPUE_Plaice was predicted for crustacean-prey (9.5% variance reduction) and bottom trawling (0.84 % variance reduction).

From the results above, a high level of parameterization uncertainty can be concluded. Therefore, WGINOSE suggested to develop a BN error model to quantify the error of IBTS monitoring data further to ultimately improve the belief of the observed node values.

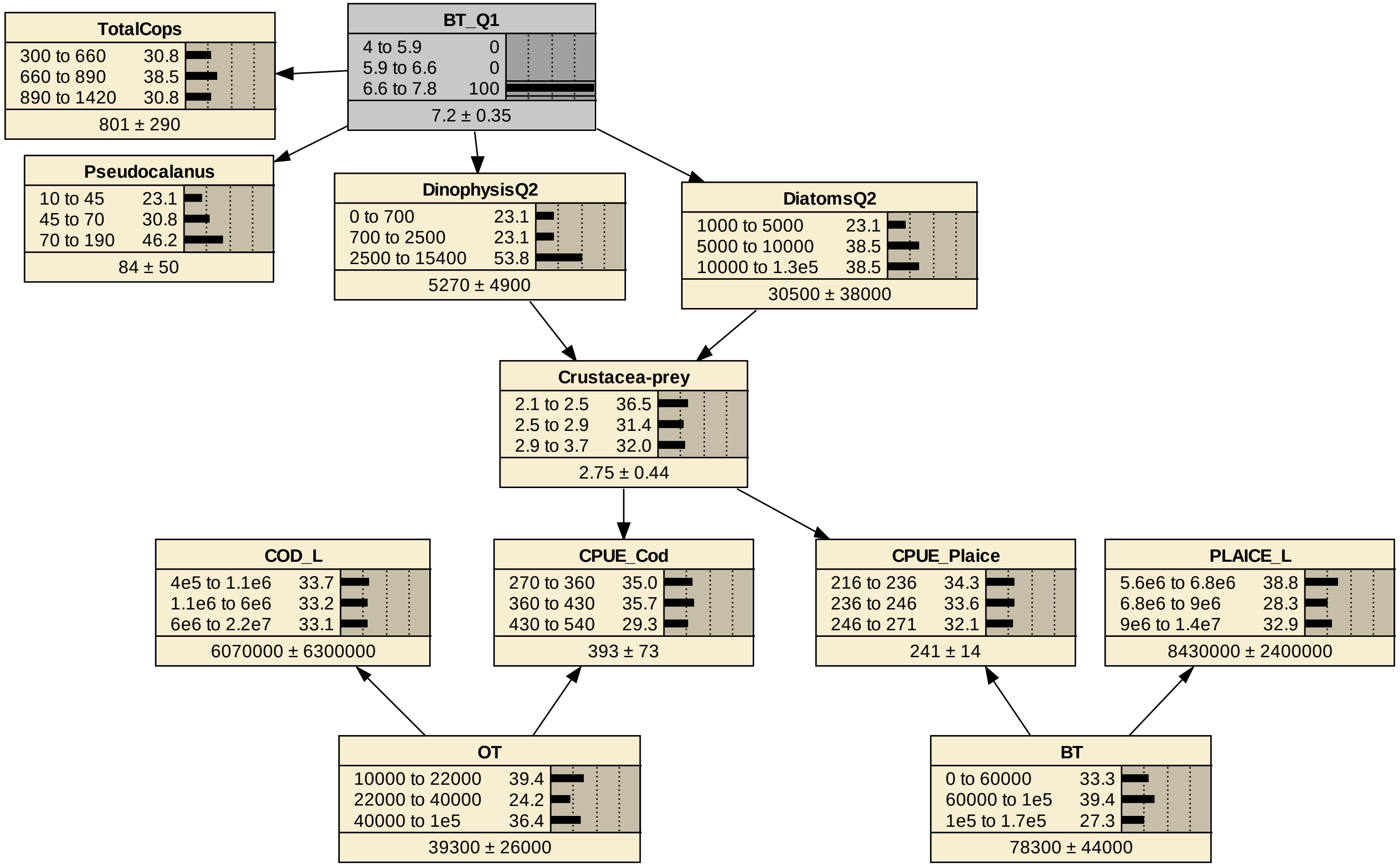

Figure 4.2.1. Inferred BN of the southern North Sea assuming annual average winter bottom temperature of 6.6 to 7.8° C.

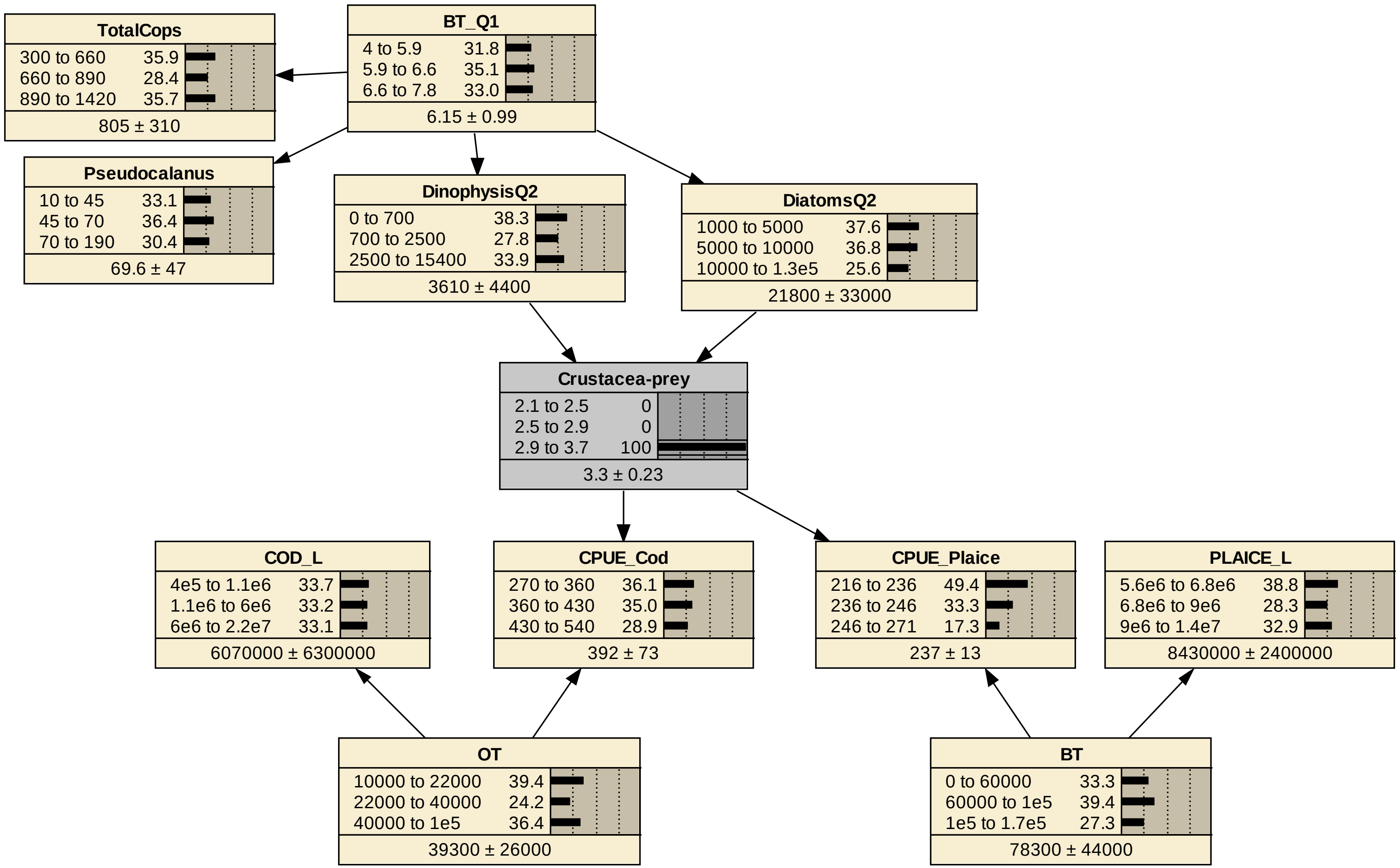

Figure 4.2.2. Inferred BN of the southern North Sea assuming annual average crustacean density of 2.9 to 3.7.

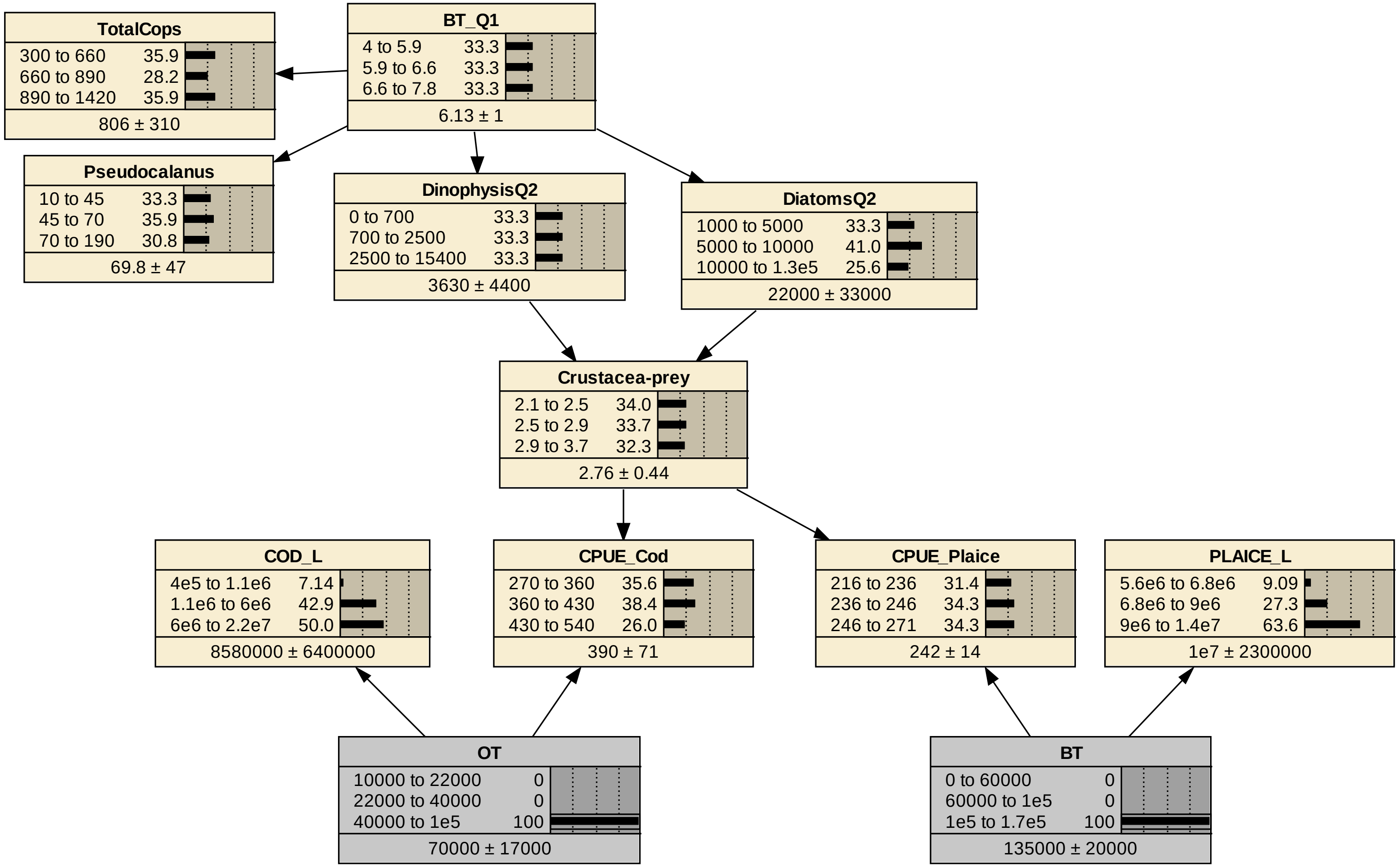

Figure 4.2.3. Inferred BN of the southern North Sea assuming annual average otter trawl effort of 70000 h and a beam trawl effort if 135000 h.

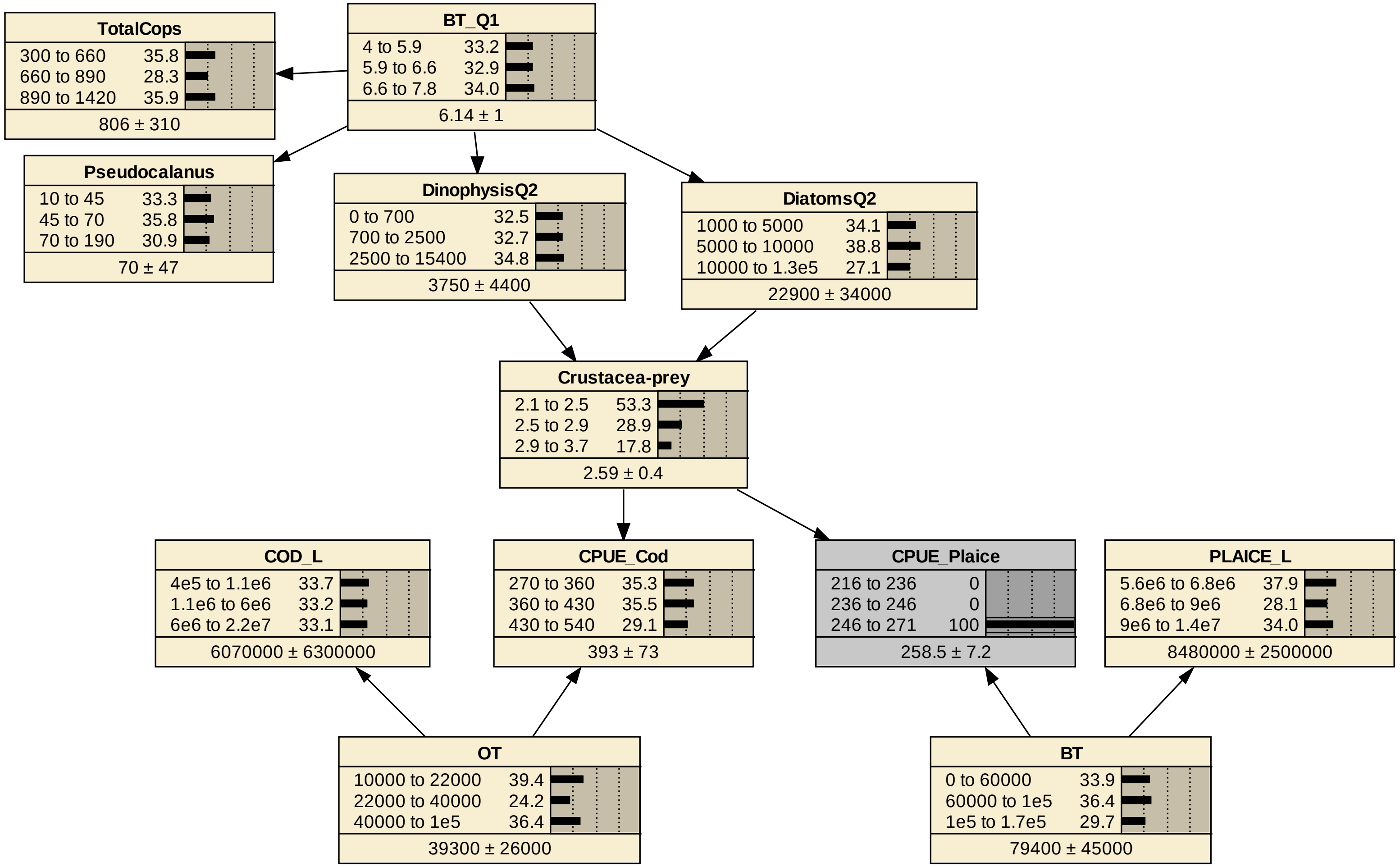

Figure 4.2.4. Inferred BN of the southern North Sea assuming annual average cpue of plaice of 258.5.

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4.3 Refining the spatial scope of the BBN

It was agreed that the spatial scope of the model probably needs to be further refined in order to reflect better the spatial trends in the ecosystem dynamics across the southern North Sea. For example, within the area defined as the southern North Sea (Figure 4.3.1a) there is a well-defined spatial footprint of beam trawling fishing effort (Figure 4.3.1b) which can be used to define the extent of the BBN mode to be developed. The spatial extent of the BBN to be developed for the beam trawl fishery in the southern North Sea is shown in Figure 4.3.1.

4.4 Data needs for the BBN

The data needs for the development of a Bayesian model for the demersal ecosystem of the southern North Sea is given in Table 4.4.1.

Table 4.4.1. Data needs applicable for the refined spatial extent of the model.

Variable	Data type	Data source	Available Period	Temporal resolution	Spatial resolution	Aggregation level	Future needs
Bottom Temperature	Geo-statistical model of observed data	AHOI-Model (Nunez-Riboni et al. in review)	1960-2013	monthly	0.2°*0.2°	to Q1 and ICES rectangle	
Bottom Silicate conc. Bottom total nitrogen conc. Bottom phosphate conc.	Observed	ICES	-2013	Sampling time	Sampling location	to Q1 and ICES rectangle	Include further data sources for better spatial-temporal coverage*
Pseudocalanus spp. (CVI) Total copepods (all stages) Dinophysis spp. Diatoms: Sum of 8 taxa	Observed	CPR, SAHFOS	1958-2013	monthly	Sampling location	Q2, entire SNS	Spatial predictions while neglecting temporal changes
Benthic invertebrate abundance	Observed	IMARES (BTS Survey)	1985-2014	Q3	Sampling location	ICES rectangle	classification into functional groups
Gadus morhua CPUE *Pleuronectes platessa* CPUE *Solea solea CPUE*	Observed	IBTS	1983-2014	Q1	Sampling location	ICES rectangle	Disaggregate to size classes
Gadus landings *Solea* landings *Pleuronectes* landings	Logbook data	UK	1983-2013	annual	ICES rectangle	ICES rectangle	
Otter trawl effort Beam trawl effort	Logbook data	UK	1983-2013	annual	ICES rectangle	ICES rectangle	Groundtruthing with VMS data

[1]

[1] In relation to silicate, nitrogen and phosphate concentrations, request to CliSAP of the University of Hamburg, that collate a database of biochemical data.

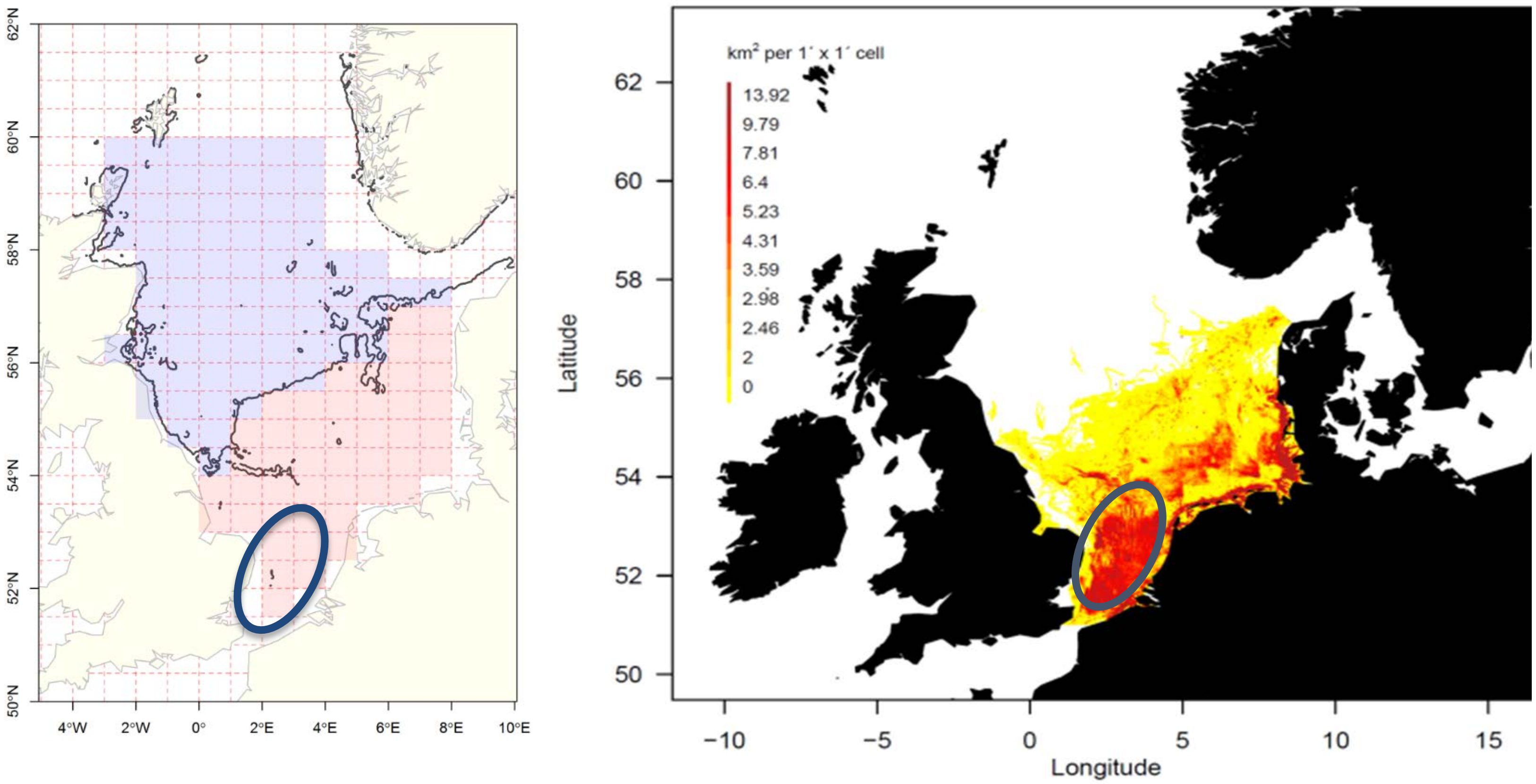

Figure 4.3.1a. The division between Northern and Southern North Sea used to identify corresponding ICES rectangles. Figure 4.3.1b. The distribution of beam trawling effort in the southern North Sea using swept-area calculations based upon 3 years of VMS data (courtesy of FP7 project BENTHIS). The area identified by the 'blue' oval represents the spatial extent for the development and refinement of a BBN to be developed.

4.5 Conclusions

In summary, WGINOSE concludes:

1) The BN model structure has to be designed to answer specific questions – this allows the model complexity, spatial scale and performance to be optimized. It is no good trying to develop a BN model that replicates the real complexity of ecosystems – the BN is best applied to answer specific questions of management interest.

2) Whereas there may be some ecological justification in defining regional seas as coherent management and assessment units – this does not necessarily mean that such areas are the optimal spatial scale for developing a BN. The appropriate spatial scale for a BN model should be based upon the spatial optimization of the data, which underpin the structure of the model, which in turn relates to the assessment needs.

3) A data 'model' for the area of interest should therefore to be developed as a pre-cursor to defining the appropriate spatial boundary for the assessment model.

4) It is important not to over extend the spatial scale or utility of the BN model as this is likely to result in poor model results.

5) Not all assessment/advisory needs can be addressed by the same spatial model. There is therefore a need explore the nesting of BN models spatially to ad-dress multiple questions.

6) WGINOSE will explore during the next 12 months the development of a data model for the SNS with a view to optimizing the spatial scales at which BN model can operate to answer specific types of questions.

7) Specific assessment/advice questions should be defined before the model structure is developed – such questions are important in determining the scale on which the model should operate and these questions will be defined over the next 12 months in consultation with ICES.

4.6 References

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Chen, S. H., Pollino, C. A. 2012. Good practice in Bayesian network modelling. Environmental Modelling & Software, 37:134–145.

Kelly, R. A., Jakeman, A. J., Barreteau, O., Borsuk, M. E., ElSawah, S., Hamilton, S. H., Henriksen, H. J., Kuikka, S., Maier, H. R., Rizzoli, A. E., van Delden, H., Voinov, A. A. 2013. Selecting among five common modelling approaches for integrated environmental assessment and management. Environmental Modelling & Software, 47:159–181.

Marcot, B. G., Steventon, J. D., Sutherland, G. D., McCann, R. K. 2006. Guidelines for developing and updating Bayesian belief networks applied to ecological modelling and conservation. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere, 36:3063–3074.

Annex 1: List of WGINOSE participants

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Annex 2: Agenda

ICES Working Group Integrated Ecosystem Assessment of the North Sea(WGINOSE)

March, 2015; Hamburg

Agenda - ToRs

I. up-date the integrated ecosystem trend analysis

II. up-date the ecosystem overview

III.develop a BBN model for the North Sea

IV.Review the data needs, issues and approaches

Agenda

Tuesday PM (13:00 – 17:00)

1. Development of the NS BBN – discussion
    i. Model parameters/structure?
    ii. Demersal/benthic model?
    iii. Pelagic model?
    iv. Benthos time series?

2. Work plan for the next two days?

Agenda

<u>Wednesday AM (09:00 – 12:30)</u>

1. Development of the NS BBN – work plan analysis
2. IEA trend analysis – work plan

Lunch (12:30 – 13:30)

<u>Wednesday PM (13:30 – 17:00)</u>

1. Plenary – progress reporting
2. Development of the NS BBN – work plan
3. IEA trend analysis - work plan?

Agenda

<u>Thursday AM (09:00 – 12:30)</u>

1. Development of the NS BBN – work plan analysis
2. IEA trend analysis – work plan

Lunch (12:30 – 13:30)

<u>Thursday PM (13:30 – 17:00)</u>

1. Plenary – progress reporting
2. Writing-up results NS BBN
3. Writing-up results IEA trend analysis

Agenda

<u>Friday AM (09:00 – 12:30)</u>

1. Plenary – review of work/text drafted
2. Finalising report text

Lunch (12:30 – 13:30)

<u>Close of meeting</u>

Annex 3: Multi-Annual ToRs

The **Working Group on Integrated Assessments of the North Sea** (WGINOSE), chaired by Andy Kenny, UK, will meet at ICES Headquarters, Copenhagen, Denmark, from 14–18 March 2016, to work on their ToRs and generate deliverables as listed in the Table below.

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Update the integrated ecosystem trend analysis for the North Sea using as many of the 'core'variables as identified by WGINOSE in 2013	a) Science Requirements b) Advisory Requirements c) Requirements from other EGs	1.1, 2.1 Input from relevant EWG as highlighted WGINOSE in 2013	Years 1, 2 & 3	Regional sea state trend analysis for inclusion in ecoregion overviews annually.
b	Update the North Sea ecosystem overview report using findings from ToR a and ToRc where possible	a) Science Requirements b) Advisory Requirements	1.1, 2.1 To facilitate the provision of IEA advice	Years 1, 2 & 3	North Sea ecosystem overview updated annually
c	Develop and apply a dynamic Bayesian Belief Network model as a tool for integrated and combined effects assessments.	a) Science Requirements	2.2, 2.3, 3.2, 3.3	Years 1, 2 & 3	Results which explore the balance of trade-offs between ecosystem protection and sustainable resource use
d	Review the data needs and approaches to support the operational implementation of ToRa and ToRb (above)	a) Science Requirements	4.1	Years 1, 2 & 3	Recommedations and actions giving rise to the ongoing improvement to flow of data between EWG, the data centre and WGINOSE

Summary of the Work Plan

Year 1.	In terms of delivery, the first year will focus on developing links between relevant expert groups (ICES and others external to ICES) and the ICES data centre to compile a core set of IEA variables for the North Sea. An update of the North Sea trends analysis will be performed and the results will be used to update the North Sea ecosystem overview.
Year 2.	In addition to the annual update of the trend analysis and ecosystem overview, the focus for the second year delivery will be to demonstrate the utility of the developed dBBN North Sea model, espceially in answering the 'key' questions around the balance of trade-offs between ecosystem protection and sustainable resource use for a range of human activities.

Year 3.	In addition to the annual update of the trend analyses and ecosystem overview, the focus for the 3rd year will be a review of comparative performance of WGINOSE, especially in relation to the uptake and use of model results and trend analyses in the advisory and management processes.

'Supporting information

Priority	The current activities of this Group will lead ICES into issues related to the development of Integrated Ecosystem Assessments for the North Sea (a data rich ecosystem) as a step towards implementing the ICES Science Plan and the ecosystem approach, these activities are considered to have a very high priority.
Resource requirements	Assistance of the Secretariat in maintaining and exchanging information and data to potential partcipants, especially the services of the ICES data centre to generate data tables for analysis from selected variables held in the database.
Participants	The Group is normally attended by some 10–20 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	Relevant to the work of ACOM and SCICOM
Linkages to other committees or groups	There is a very close working relationship with all the groups of SSGIEA. It is also very relevant to the EWG identified in WGHAME 2013 report..
Linkages to other organizations	OSPAR, EU, NAFO, NEAFC

Annex 4: Recommendations

Recommendation	For follow up by:
WGINOSE recommends that the ICES data centre provide IBTS Q1 CPUE data for the demersal, benthic and pelagic species already selected by the end of April, or as soon after as possible.	ICES Data Centre

Annex 5: Data used for BBN model evaluation

Year	BT	OT	COD_L	PLAICE_L	CPUE_Cod	CPUE_Plaice	Pseudocalanus	TotalCops	DiatomsQ2	DinophysisQ2	BT_Q1
1983	9120	10063	21152985	6051229	430	260	49.10	713.47	2697.20	217.39	5.94
1984	21052	32401	13533928	6623673	345	247	26.01	500.13	5542.93	1250.00	5.69
1985	38497	37752	11904985	6459770	445	247	109.70	1164.07	5605.16	1704.37	4.80
1986	52150	44278	9280812	6902201	291	246	55.51	731.48	4151.32	3798.25	4.45
1987	71640	83326	13597168	6805475	358	244	44.64	1061.31	2619.05	714.29	4.13
1988	79381	91377	12196180	8250703	427	250	100.77	741.78	31854.20	7446.81	6.71
1989	94349	73183	8539185	9375765	419	262	92.71	821.45	129614.41	15338.76	7.23
1990	99997	62676	6063339	8715447	534	271	180.04	1417.85	5393.03	7434.99	7.44
1991	135861	61611	5209314	10978469	453	260	97.07	893.72	1463.74	688.41	5.56
1992	144791	60650	4560116	13474362	304	239	87.02	1017.46	8094.63	0.00	6.53
1993	161510	61726	4731788	12954927	426	249	45.24	1226.19	29523.81	8000.00	6.16
1994	159141	56208	4686953	10910092	303	243	40.16	1044.88	6076.96	1157.08	5.79
1995	151875	53263	5993576	9602497	384	246	66.01	1335.95	37232.61	2985.41	6.78
1996	129838	40459	6747813	10053490	410	239	51.44	645.82	2199.66	476.19	4.04
1997	106783	38334	5266983	8726375	270	233	82.46	906.16	16129.79	758.55	5.53
1998	91607	34532	6171341	6795638	417	230	109.58	837.43	9885.80	2287.32	6.86
1999	92808	29064	5052857	6073015	455	234	47.34	694.97	7925.21	128.21	6.55
2000	98782	30264	2471632	7812095	403	236	85.56	891.39	9673.51	719.46	6.60
2001	104630	19912	1512683	8376687	334	235	67.33	904.22	5639.18	523.05	6.07
2002	92540	14064	1023645	6782951	337	216	41.55	685.56	34380.07	2540.97	7.30
2003	70875	19973	954304	5825382	377	224	55.37	606.86	7434.97	1228.07	6.33
2004	67658	20484	660659	6630854	376	232	56.49	448.65	2098.37	476.19	6.60
2005	63416	16873	464050	5743896	316	222	29.64	309.58	3663.97	354.07	6.53
2006	52037	21518	544775	5703601	311	233	64.35	707.80	5848.26	277.96	5.90
2007	56577	16740	520023	5611210	334	230	51.79	604.03	5403.44	3101.85	7.72
2008	45404	26194	882512	6002067	389	239	17.43	659.38	1553.52	253.88	7.00
2009	58098	21722	1148707	7572296	468	241	10.97	654.99	4157.14	4188.28	6.15
2010	63213	14751	926145	10514238	441	245	17.63	512.78	11791.79	1226.85	5.18
2011	34033	18064	570571	10206202	396	240	34.33	467.05	9501.53	2606.52	5.34
2012	30496	18118	547567	12383829	466	239	15.51	331.00	4980.65	1093.75	6.46