Sensitivity study of the Icelandic Atlantis model

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Introduction

- Sensitivity analysis of an ecosystem model can give insight into what parameters contribute to uncertainty in the output.
- It can also be helpful in understanding behaviour and functioning of the system.
- Sensitivity study of recruitment and growth parameters in the Icelandic Atlantis model was carried out.
- The Atlantis model
  - Oceanograpic, biology and fisheries model
  - 52 functional groups and 10 age classes
  - 52 spatial boxes and 7 layers

Methods

- Maximum recruitment (α) in the Beverton-Holt function was altered by ±20%

$$Rec = \frac{\alpha * SSB}{\beta + SSB}$$

- The maximum growth rate (mum) in Holling II was altered by ±20% for zooplankton.

$$Cons = \frac{C \cdot B}{1 + \frac{C}{mum}[B \cdot E]}$$

- Growth rate for phytoplankton altered by ±20%.
- Interactions between ZL, PS and PL studied.

Measure of sensitivity

- Average biomass over the whole simulated period (65 years) used to measure sensitivity.
- Sensitivity of recruitment parameters measured with:

$$S_{ij} = \frac{V_i(1.2\alpha_j) - V_i(0.8\alpha_j)}{0.4V_i(\alpha_j)}$$

- Sensitivity of growth parameters and their interactions measured with percentage change in biomass.

Sensitivity of recruitment parameters

Sensitivity of fish groups

	Blue whiting	Capelin	Cod	Commercial	Flatfish	Gr. halibut	Haddock	Herring	Large pelagic	Long Lived	Mackerel	Other Codfish	Other dem	Redfish	Saithe	Sandeel Fish	Small pelagic
Small pelagic	-0.18	-0.1	0	-0.07	-0.02	-0.02	0.02	-0.04	-0.17	0.01	0	-0.03	0.02	-0.26	0.03	-0.05	0.85
Sandeel Fish	-1.09	-0.04	0.03	0.06	-0.4	0.08	0.03	0.06	0.06	0	0.01	0.01	-0.01	-0.86	0.57	1.91	0.08
Saithe	-0.05	-0.01	0	0.01	-0.03	-0.01	0	0	0	-0.01	0	-0.02	0	-0.28	0.8	0.13	0
Redfish	-0.08	-0.03	-0.01	-0.02	-0.03	-0.02	0	0.01	0.02	-0.01	-0.01	0.01	-0.01	0.28	0.04	0.1	-0.03
Other dem	0	0	-0.01	0	-0.01	-0.14	0	0	0	-0.01	0	0	0.57	0	0	0	0
Other Codfish	0.01	0	0.01	0	-0.01	0	0	-0.02	0.01	-0.01	0	0.78	0	0.06	-0.35	-0.02	0
Mackerel	-0.21	-0.27	-0.04	-0.31	0.01	0.2	0.37	-0.23	0.16	0.04	1.59	-0.41	0.3	0.05	0.09	-0.2	-0.17
Long Lived	-0.01	0	0	0.01	0	-0.1	0	0.01	0	0.32	0	0	0.01	-0.01	0	0	0
Large pelagic	-0.01	-0.08	0	-0.04	-0.02	-0.05	0.01	0.04	0.48	-0.02	0	-0.02	0	-0.07	-0.02	-0.02	0.17
Herring	-0.02	-0.04	-0.06	0.02	-0.03	-0.03	-0.04	1.19	-0.08	-0.02	0.02	-0.02	-0.02	-0.16	0	0.11	-0.04
Haddock	-0.02	0	-0.04	0	-0.02	-0.02	0.99	-0.01	0.01	-0.01	0.01	-0.01	0.01	-0.07	-0.34	0.03	0.01
Gr. halibut	0.03	0.01	0	0	-0.01	0.52	0	0	0	-0.01	0	0	0.02	-0.02	-0.01	0	0.01
Flatfish	0.1	0.02	-0.1	-0.06	0.94	-0.02	-0.13	-0.07	-0.08	-0.01	0	-0.03	-0.01	0.35	-0.98	-0.33	-0.02
Commercial	0	0	-0.04	0.68	0	-0.01	0	0	0	-0.01	0	-0.02	0	0.02	-0.06	-0.01	0
Cod	-0.03	-0.01	0.42	0	-0.01	-0.03	0	0.01	0	0	0	0	0	-0.08	0.01	0.03	0
Capelin	-0.01	0.11	-0.05	-0.01	-0.05	-0.08	-0.01	0.01	0.01	-0.01	-0.03	0.01	-0.02	-0.12	-0.05	0.01	-0.02
Blue whiting	0.91	-0.03	-0.01	-0.03	-0.01	-0.05	-0.02	-0.03	-0.06	0.01	0	-0.03	-0.01	-0.06	-0.31	0.01	-0.03

Groups with altered recruitment

Sensitivity of invertebrates and primary producers

	Blue whiting	Capelin	Cod	Commercial	Flatfish	Gr. halibut	Haddock	Herring	Large pelagic	Long Lived	Mackerel	Other Codfish	Other dem	Redfish	Saithe	Sandeel Fish	Small pelagic
Zoo	-0.04	-0.3	0.01	-0.01	-0.01	0	-0.03	0	0.01	0	0	0.02	-0.02	0.02	0.04	0.02	-0.02
Shrimp	-0.32	0.02	-0.01	0	0	0.01	0	0.02	0.02	0	0	0	0	-0.02	0.11	0	0.01
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scallop	-0.01	0.01	0.01	0	-0.01	0	0	0.01	0	0	0	-0.01	0	-0.01	0.01	0.01	0.01
Quahog	0	0	0	0	-0.01	0	0	0	0	0	0	0	0	0	0	0	0
PicoPhytopl	-0.13	0.59	0.17	-0.81	-0.62	0.7	1.43	-0.84	0.08	-0.06	-0.36	-0.95	0.57	0.01	-0.04	-1.29	0.1
MicroZoo	0	0.99	-0.03	0	0.07	-0.18	0.07	-0.09	0	-0.05	0.01	-0.11	0.04	-0.22	-0.2	0.02	0.02
Meiobenth	0	0.02	0	0	0	-0.01	0	0	-0.01	0	0.01	0	0	0	0	-0.01	0.01
Megazoobenthos	-0.01	0	-0.01	0	0	0	0	-0.01	0	0	0	0	0	0.01	0	-0.02	0
MacroZoo	0.04	-0.02	-0.01	-0.01	-0.02	-0.02	-0.03	0.01	0.01	-0.02	-0.01	0	0	-0.01	0.02	0.01	0.01
Macroalgae	0.1	0.01	-0.06	0.01	0	0	-0.15	-0.02	0	0	0	0	0	0.2	0.05	-1.72	-0.01
Lobster	-0.02	0	0	0	0.01	-0.01	0	-0.03	0	0	0.01	0	0	-0.01	0.01	-0.01	0.01
Gelat Zoo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.01	-0.01
Filter Other	-0.03	0	-0.01	0	0	0	0	-0.03	0	0	0.01	0	-0.01	0	0.01	-0.01	0
DinoFlag	-0.12	-0.07	0.36	-0.04	0.01	0.03	0.05	0.03	-0.02	0.04	-0.05	0.01	0.02	-0.12	0.07	0.77	0.03
Diatom	0.11	0.4	-0.01	0.12	0.09	-0.13	-0.02	-0.01	-0.05	0.09	-0.17	0.04	0	-0.13	-0.04	0.11	0.02
Deposit Feeder	-0.01	0.03	0.01	0	0.01	0	0	0.01	-0.01	0	0.01	0	0	0	0	0	0.01
Cucumbers	-0.01	0.01	0	0	-0.01	0	0	-0.01	0	0	0	0	0	-0.01	0.02	0.02	0
Cephalopod	-0.04	-0.19	0	-0.01	0	0	-0.01	0	0	0	-0.01	0	-0.01	0.02	0.03	0	-0.03
Benthic grazer	0.05	0	-0.02	0	-0.03	0	-0.12	-0.03	0	0	0	0	0	0.08	0.01	-0.43	0
Benthic Carniv	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.01	-0.01	-0.02	0

S: 1.0, 0.5, 0.0, -0.5, -1.0

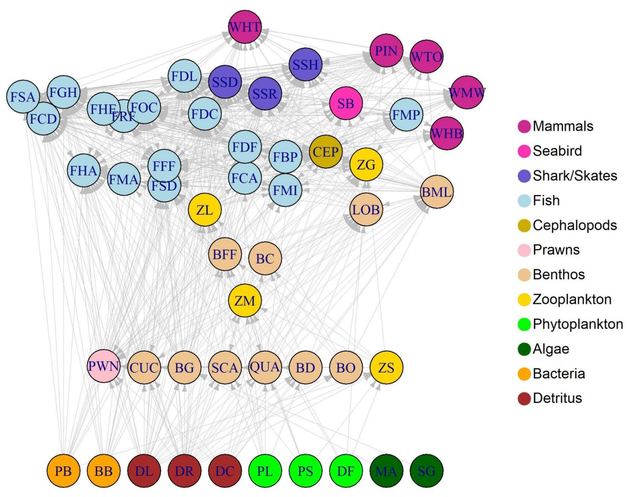
Groups with altered recruitment

Results

- Changing the recruitment of a group had usually the most effect on themselfs.
- Mackerel and sandeel were sensitive to changes in recruitment of other groups.
- Redfish and saithe had strong effects on many of the other groups.
- Cod which is a top predator with large population size did not have much effect on other groups.
- Capelin and sandeel had the most effect on the lower trophic levels
- Pico-phytoplankton was very sensitive to changes in recruitment.

Sensitivity of growth parameters

Food web of the system



Sensitivity of fish groups

	PSb_PLd_ZLb	PSb_PLi_ZLb	PSd_PLb_ZLb	PSd_PLd_ZLb	PSd_PLi_ZLb	PSi_PLb_ZLb	PSi_PLd_ZLb	PSi_PLi_ZLb
Small pelagic	-25	47	22	-2	77	27	8	51
Sandeel Fish	-29	44	-19	-48	57	-19	-49	17
Saithe	-11	15	5	-11	16	4	-14	20
Redfish	-33	64	20	-7	84	22	-6	54
Other dem	-3	5	2	-1	6	2	0	4
Other Codfish	-5	3	3	-2	6	4	1	5
Mackerel	12	-44	26	27	-48	69	89	60
Long Lived	-1	3	2	0	4	3	1	5
Large pelagic	-11	26	26	12	34	37	29	47
Herring	-6	2	0	-12	0	-6	-19	8
Haddock	0	-7	-3	-4	-5	-4	-4	-5
Gr. halibut	-7	17	10	3	23	9	5	16
Flatfish	-8	3	9	9	12	16	25	10
Commercial	-1	3	2	0	4	2	1	3
Cod	-5	3	2	-5	4	1	-5	5
Capelin	-13	24	51	20	55	59	43	78
Blue whiting	-7	-22	15	10	-25	46	50	28

Model run

Sensitivity of invertebrates and primary producers

	PSb_PLd_ZLb	PSb_PLi_ZLb	PSd_PLb_ZLb	PSd_PLd_ZLb	PSd_PLi_ZLb	PSi_PLb_ZLb	PSi_PLd_ZLb	PSi_PLi_ZLb
Zoo	13	-28	41	49	10	28	29	13
Shrimp	-4	4	-8	-15	6	-4	-5	2
Seagrass	0	0	0	0	0	0	0	0
Scallop	-6	6	-7	-14	0	5	-5	6
Quahog	-2	2	-2	-4	0	1	-2	2
PicoPhytopl	17	-23	-84	-85	-95	312	349	260
MicroZoo	-12	-15	502	505	399	-20	-13	-9
Meiobenth	-7	17	-8	-14	10	5	-3	12
Megazoobenthos	-1	2	-1	-1	1	1	0	1
MacroZoo	-35	116	51	32	118	5	-21	49
Macroalgae	19	-57	0	26	-59	3	27	-43
Lobster	-8	20	-5	-12	14	4	-4	11
Gelat Zoo	0	0	1	1	1	1	1	1
Filter Other	-4	5	3	0	6	6	1	7
DinoFlag	-12	30	12872	12837	10243	-13	-26	5
Diatom	12	28	3	18	5	-19	-34	-20
Deposit Feeder	-10	22	-11	-23	16	5	-2	17
Cucumbers	-5	4	-6	-10	0	2	-2	4
Cephalopod	-26	173	81	48	255	40	18	119
Benthic grazer	3	-13	0	7	-13	2	9	-11
Benthic Carniv	-2	4	-2	-4	2	1	-1	3

% : 100, 50, 0, -50, -100

Model run

Results

- Altering the growth parameter of ZL did not have much effect (not shown).
- Fish groups feeding on zooplankton were sensitive to changes in phytoplankton growth rate.
- Increasing the growth rate of PL had positive effects on all fish groups except mackerel and blue whiting.
- Decreasing the growth rate of PS had positive effects on dino-flagellates that otherwise became extinct.
- The sensitivity study shows the functioning of the system and will be helpful for further work with the Atlantis model.

Description of code for model runs

ZL = Large zooplankton
PL = Diatoms
PS = Pico-phytoplankton
b = growth parameter as in the base run
d = growth parameter decreased
i = growth parameter increased
Example:
PSd_PLi_ZLb = Model run where growth parameter decreased for pico-phytoplankton, increased for diatoms and unchanged for large zooplankton.

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