SOME INITIAL PROGRESS ON THE ECOSYSTEM MODELLING OF THE JARPN II SURVEY AREA USING ECOPATH-WITH-ECOSIM

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ABSTRACT

In order to evaluate the possible impact of whales (minke whales, bryde's whales, sei whales and sperm whales) migrating to the JARPN II survey area on Japanese commercially important fisheries resources, an initial ecosystem model of the JARPN II survey area is built using the Ecopath-with-Ecosim software, and is based on the newly collected provisional data sets obtained from the JARPN II survey. As for an initial test run, the impact of no harvesting of the minke whales for the coming 50 years on Japanese commercially important fishes was made. When running the harvesting scenario, uncertainties in the functional response curve and the trophic flow of the ecosystem are considered. In this test run, increase in minke whale biomass has some effect on pacific saury, though it has hardly any effect on other species considered in the model. The magnitude of the impact of the change in biomass of minke whales on pacific saury varies by the functional response curve assumed for minke whales and the magnitude of the trophic flow and the combination of the two. It is predicted that the biomass of pacific saury may decrease in maximum about 36% in the coming 50 years compared to the current level due to increase in predation pressure by the minke whales when this species were not harvested for the coming 50 years. Further work will take into account the effect of the equilibrium condition in Ecopath, will try to fit the model to available time-series data, and will consider the effect of quasi-decadal alternations in dominant species replacement (may be due to environmental forcing).

KEYWORD ECOPATH-WITH-ECOSIM, JARPN II SURVEY, ECOSYSTEM MODELLING, MINKE WHALE, PACIFIC SAURY

INTRODUCTION

This paper introduces some initial progress on the ecosystem modelling of the JARPN II survey area using Ecopath-with-Ecosim software (Christensen *et al*. 2005), and is based on the newly collected provisional data sets obtained from the JARPN II survey. The main objectives of the study are:

1) Evaluate the possible impact of whales migrating to the JARPN II survey area on Japanese commercially important fisheries resources, and
2) Estimate the difference between the MSY of a species calculated from single-species assessments to those calculated from multi-species assessment.

MODEL AND DATA TO BE USED

The model used is the Ecopath with Ecosim Ver.5.1（Christensen *et al*. 2005）, and the time-scale modelled is one year. The area to be modelled is the off-shore areas of sub-area 7, and sub-areas 8 and 9 of JARPN II survey areas (total area to be modelled is 2,775,043km^2) . The number of species considered is 30 species and are shown in Table 1a.

The data used in the model are shown in Tables 1a, 1b and 1c (an Appendix which explains the references/sources of data is in progress). Essentially, data on biomass, production, consumption, catch and diet-composition is required for each species, and most of these data for whales are obtained from the JARPNⅡsurvey.

METHODS

By using Ecopath, first a mass-balance model which reflects the current situation of the ecosystem (about from year 2000 to 2006) is built, and the connectivity of the species and the possible qualitative impact of an increase in one species may have on another is examined using mixed trophic-impact analysis. Next by using Ecosim, the possible impact of whales on their prey species, especially those that are commercially important for Japanese fisheries is evaluated. As for initial test runs, the impact of the following harvesting scenarios for minke whales and their main preys is evaluated:

Harvesting scenario ⅰ） No catch for the coming 50 years.

Harvesting scenario ⅱ） Double the size of the current catch for the coming 50 years.

When running the harvesting scenarios, the following three uncertainties are considered:

1) Uncertainties in the in-put parameters of Ecopath.
2) Uncertainties in the functional response curve (e.g. Hollying Type Ⅰ, Ⅱ, Ⅲ functional response).
3) Uncertainties in the trophic follow (e.g. top-down or bottom-up control).

For the various functional response curves (Hollying Type Ⅰ, Ⅱ and Ⅲ), the parameter settings are as in the Appendix of Mackinson *et al*. (2003). Also an additional version of a Type Ⅲ functional response curve (called "Type Ⅲ+ other") is assumed. The difference in this and the usual Type Ⅲ functional response curve is that an additional assumption is made that the changes in the time spent foraging by a species proportionally affect their exposure to other sources of mortality that are not explicitly modelled, such as disease, starvation, collisions, or predation not accounted for (Mackinson *et al*. 2003).

The trophic flow in Ecosim is controlled by the vulnerability parameter (*v*). Low *v* means that the species is less vulnerable to its predator (bottom-up control) and high *v* means top-down control. If *v* is proportional to its trophic level (TL), it means that the lower trophic level species have more places to hide (thus less vulnerable to predation) compared to those of the higher trophic level species.

The difference between the MSY of a species calculated from single-species assessments to those calculated from multi-species assessment is estimated using the already developed routine in Ecosim.

PRESENT STATUS OF THE STUDY

1. Building a mass-balanced Ecopath model

At the first stage of the mass-balance model development, ecotrophic efficiency (EE) (EE: proportion of its production used by consumption or harvesting) for some species considered in Table 1a exceeded 1. If EE>1, this means that the species is harvested or consumed more than its production. Thus, by increasing the biomass or production of the species, or by reducing the predation mortality of the species, the parameters were adjusted to give a mass-balanced model. This was achieved manually by considering the level of uncertainty of each in-put parameter shown in Table 1a.

For most of the species that showed EE>1, this problem was solved by increasing the biomass of the species, which was the most uncertain parameter. The resultant mass-balanced model and its estimated parameters are shown in Table 3.

Figure 1 describes the food-web assumed in the model and the trophic level of each species calculated using Ecopath. Figure 2 shows the effect of a short-term increase in biomass of a species may have on another suggested by the output of Ecopath under the assumptions examined. The species on the vertical axis shows the species that give impact, and the species on the horizontal axis shows those that receive the impact. Upward bars represent positive impact, and downward bars represent negative impact. For example, Figure 2 indicates that a short-term increase in the biomass of pacific saury has positive impact on minke whales, while short-term increase in the biomass of anchovy has less positive impact on minke whales compared to those on bryde's whales or skipjack tuna. Thus by utilizing Figure2, one can qualitatively evaluate the relative impact of an increase in one species may have on another.

2. ECOSIM calculation

Table 4 shows output for the harvesting scenario, which no catch is assumed for minke whales for the coming 50 years (catch for other species are assumed same as the current level). The recent main preys of minke whales are pacific saury and anchovy (see the diet composition in Table 1b). In this test run, increase in minke whale biomass had some effect on pacific saury though it had hardly any effect on other species, thus in Table 4, only the relative change in biomass for minke whales and pacific saury are shown. The magnitude of the impact of the change in biomass of minke whales on pacific saury varies by the functional response assumed for minke whales and the magnitude of the trophic flow (controlled by the vulnerability parameter (v) in Ecosim) and the combination of the two. Largest impact of minke whales on pacific saury was found when the vulnerability of the species was assumed to be proportional to the trophic level, and when "Type III + other" functional response curve was assumed. The magnitude of the effect increased as year accumulates, and in 50 years, it was predicted that the biomass of pacific saury may decrease in maximum about 36% compared to the current level due to increase in predation pressure by the minke whales.

FUTURE WORK

Priority matters to be considered in future are:

1) the equilibrium condition assumed in Ecopath,
2) try fitting the model to available time-series data (and let v be estimated from the fit of the model),
3) effect of quasi-decadal alternations in dominant species replacement (may be due to environmental forcing) and prey switching by whales, and
4) revision of some in-put data due to updated information (e.g. diet composition of northern fur seals, split anchovy into immature and mature states etc.). An Appendix which describes all the references/sources of the in-put data will be prepared in due course.

REFERENCES

Christensen, V., Walters, C. J., and Pauly, D. 2005. Ecopath with Ecosim: a User's Guide. Fisheries Centre, University of British Columbia, Vancouver. November 2005 edition, 154p. (available onlie at www.ecopath.org)

Mackinson, S., Blanchard, J. L., Pinnegar, J. K. and Scott, R. 2003. Consequences of alternative functional response formulations in models exploring whale-fishery interactions. *Marine mammal Science*, 19 (4): 661-681.

Table1a. In-put parameters of B, P/B, Q/B used in the Ecopath model (the color of each cells reflect the reliability of the data – see Table 2 for the definition of the colors used; essentially, if the color is more towards red it means that the data is more reliable. Where as if the color is more towards light-blue it means that the data is less reliable). Q/B for the whales are mainly obtained from the JARPN II survey.

	Species	Habitat area (fraction)	Biomass in hab.area (t/km^2)	Production/biomass (/year)	Consumption/biomass (/year)	Ecotrophic efficiency
1	Minke whale	1	0.019	0.10	5.20	
2	Bryde's whale	1	0.016	0.09	4.38	
3	Sei whale	1	0.030	0.06	4.16	
4	Other baleen whales	1	0.068	0.06	3.90	
5	Sperm whale	1	0.342	0.10	4.20	
6	Baird's beaked whale	1	0.025	0.11	5.53	
7	Short-finned pilot whale	1	0.014	0.10	7.42	
8	Cuvier's beaked whale	1	0.014	0.10	7.06	
9	Other toothed whales	1	0.038	0.10	11.32	
10	Northern fur seal	1	0.001	0.24	20.30	
11	Marine birds	1	0.004	0.10	54.57	
12	Albacore juveniles	1	0.036	0.35	1.94	
13	Sword fish	1	0.001	0.60	2.05	
14	Skipjack tuna	1	0.036	2.90	20.00	
15	Blue shark	1	0.014	0.33	2.20	
16	Salmon shark	1	0.013	0.33	3.65	
17	Lanternfish	1	7.207	2.34	14.97	
18	Neon flying squid	1	0.144	2.56	21.60	
19	surface-mid water squid	1	0.330	2.56	21.60	
20	deep sea squid	1		2.56	21.60	0.95
21	Mackerel	1	0.252	1.07	7.15	
22	Pacific pomfret	1	0.053	0.75	3.75	
23	Sardine	1	0.047	1.50	10.00	
24	Anchovy	1	1.081	1.53	7.50	
25	Pacific saury	1	1.694	0.72	4.80	
26	Phytoplankton	1	26.58	194.36	-	
27	Euphausiids	1	1.982	11.12	12.05	
28	Copepods eaten by whales	1	21.30	5	10.00	
29	Other Copepods	1	21.30	5	10.00	
30	Detritus	1	132.92	-	-	

Table 1b. Diet composition matrix used in the Ecopath model (the color of each cells reflect the reliability of the data – see Table 2 for the definition of the colors used; essentially, if the color is more towards red it means that the data is more reliable. Where as if the color is more towards light-blue it means that the data is less reliable). Diet composition for the whales are mainly obtained from the JARPN Ⅱ survey.

Prey / Predator Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1 Minke whale																													
2 Bryde's whale																													
3 Sei whale																													
4 Other baleen whales																													
5 Sperm whale																													
6 Baird's beaked whale																													
7 Short-finned pilot whale																													
8 Cuvier's beaked whale																													
9 Other toothed whales																													
10 Northern fur seal																													
11 Marine birds																													
12 Albacore juveniles																													
13 Sword fish group ?																													
14 Skipjack tuna																													
15 Blue shark																													
16 Salmon shark																													
17 Lanternfish							0.1	0.05	0.1	0.12	0.1	0.19	0.01		0.02			0.28	0.2	0.2	0.02	0.03							
18 Neon flying squid					0.11	0.01	0.1	0.2	0.13	0.14	0.14		0.35		0.12			0.01			0.01	0.04							
19 surface-mid water squid	0.02				0.07	0.13	0.1	0.2	0.13	0.14	0.16	0.15	0.24	0.05	0.2	0.81		0.27	0.2	0.2	0.02	0.47							
20 deep water squid					0.81	0.18	0.2	0.2	0.13				0.15		0.55	0.04		0.2			0.01	0.22							
21 Mackerel		0.01					0.2	0.05	0.1	0.12	0.1																		
22 Pacific pomfret							0.2	0.05	0.1	0.12	0.1		0.05		0.07														
23 Sardine							0.03	0.05	0.1	0.12	0.1										0.02								
24 Anchovy	0.32	0.59	0.47	0.05		0.01	0.04	0.05	0.1	0.12	0.1	0.49		0.82	0.01			0.15	0.4	0.4	0.10	0.01							
25 Pacific saury	0.35		0.05	0.05			0.03	0.05	0.1	0.12	0.1										0.02	0.03							
26 Phytoplankton																							0.70				0.12	0.26	0.26
27 Euphausiids	0.17	0.35	0.23	0.65				0.1	0.01		0.1	0.07		0.09			0.24	0.01	0.2	0.2	0.5	0.03		0.2	0.1				
28 Copepods eaten by whales			0.24	0.26													0.18				0.15		0.15	0.4	0.45		0.09		
29 Other Copepods																	0.36				0.15		0.15	0.4	0.45		0.09		
30 Detritus																											0.7	0.74	0.74
Import	0.14	0.05	0.01		0.01	0.67						0.1	0.2	0.04	0.03	0.15	0.22	0.08				0.17							
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00

Table 1c. Catch data used in the Ecopath model (the color of each cells reflect the reliability of the data – see Table 2 for the definition of the colors used; essentially, if the color is more towards red it means that the data is more reliable. Where as if the color is more towards light-blue it means that the data is less reliable).

	Species	Whaling ($t/km^2/year$)	Fishery ($t/km^2/year$)
1	Minke whale	0.0002	
2	Brydes whale	0.0003	
3	Sei whale	0.0004	
4	Other baleen whales	0	
5	Sperm whale	6.84674E-05	
6	Baird's beaked whale	0.0003	
7	Short-finned pilot whale	5.98189E-06	
8	Cuvier's beaked whale	0	
9	Other toothed whales	0.0002	
10	Northern fur seal		0
11	Marine birds		0
12	Albacore juveniles		0.035
13	Sword fish group ?		0.001
14	Skipjack tuna		0.016
15	Blue shark		0.0002
16	Salmon shark		0.0003
17	Lanternfish		0
18	Neon flying squid		0.007
19	surface-mid water squid		0.076
20	deep water squid		0
21	Mackerel		0.083
22	Pacific pomfret		0
23	Sardine		0.018
24	Anchovy		0.137
25	Pacific saury		0.151
26	Phytoplankton		0
27	Euphausiids		0
28	Copepods eaten by whales		0
29	Other Copepods		0
30	Detritus		0

Tale 2. Criteria for the level of uncertainty used in the in-put parameters.

Biomass

Option	Index value	Conf. int.(+/- %)	Pattern
Estimated by Ecopath	0	80	
From other model	0	80	
Guesstimate	0	80	
Consumer: Approximate or indirect method Producer: Indirect method (remote sensing)	0.4	50	
Consumer: Sampling based, low precision Producer: Locally based, low precision	0.7	30	
Consumer: Sampling based, high precision Producer: Locally based, high precision	1	10	

P/B and Q/B

Option	Index value	Conf. int.(+/- %)	Pattern
Estimated by Ecopath	0	80	
Guesstimate	0.1	70	
From other model	0.2	60	
Empirical relationship	0.5	50	
Consumer: Similar group/species, similar system Producer: Similar system, low precision	0.6	40	
Similar group/species, same system Producer: Same system, low precision	0.7	30	
Consumer: Same group/species, similar system Producer: Similar system, high precision	0.8	20	
Consumer: Same group/species, same system Producer: Same system, high precision	1	10	

Diet

Option	Index value	Conf. int.(+/- %)	Pattern
General knowledge of related group/species	0	80	
From other model	0	80	
General knowledge for same group/species	0.2	60	
Qualitative diet composition study	0.5	50	
Quantitative but limited diet composition study	0.7	30	
Quantitative, detailed, diet composition study	1	10	

Catch

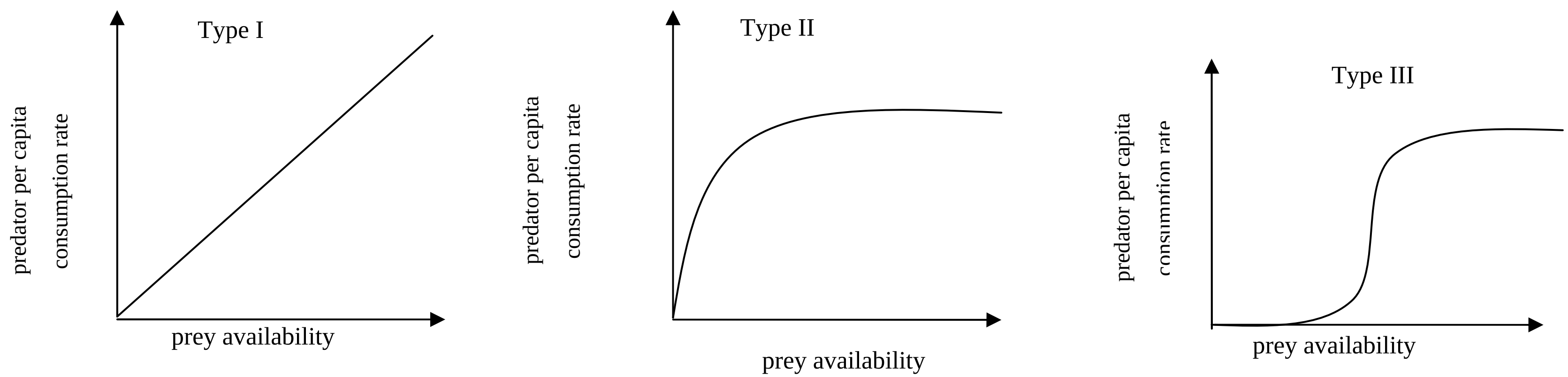
Option	Index value	Conf. int.(+/- %)	Pattern
Guesstimate	0.1	70	
From other model	0.1	70	
FAO statistics	0.2	60	
National statistics	0.5	50	
Local study, low precision/incomplete	0.7	30	
Local study, high precision/complete	1	10	

Table 3. Parameters of the mass-balanced Ecopath model (the values indicated in grey are estimated by the model).

Group name	Trophic level	Biomass (t/km2)	Prod./ biom. (/year)	Cons./ biom. (/year)	Ecotrophic efficiency
Minke whale	3.88	0.019	0.10	5.20	0.11
Brydes whale	3.72	0.016	0.09	4.38	0.21
Sei whale	3.59	0.030	0.06	4.16	0.22
Other baleen whale	3.22	0.068	0.06	3.90	0.00
Sperm whale	5.08	0.342	0.10	4.20	0.00
Bairds beaked whale	4.95	0.025	0.11	5.53	0.11
Short-finned pilot whale	4.86	0.014	0.10	7.42	0.00
Cuivers beaked whale	4.68	0.014	0.10	7.06	0.00
Other toothed whale	4.59	0.038	0.10	11.32	0.05
Northern fur seal	4.52	0.001	0.24	20.30	0.00
Marine birds	4.42	0.004	0.10	54.57	0.00
Albacore (juvenile)	4.02	0.110	0.35	1.94	0.91
Sword fish	5.23	0.002	0.60	2.05	0.83
Skipjack tuna	4	0.036	2.90	20.00	0.15
Blue shark	5.08	0.014	0.33	2.20	0.04
Salmon shark	4.88	0.013	0.33	3.65	0.07
Lantern fish	3.06	7.207	2.34	14.97	0.18
Neon flying squid	4.51	0.144	2.56	6.20	0.92
surface-water squid	3.87	1.000	2.56	6.20	0.93
mid to deep-sea squid	4.04	0.661	2.56	6.20	0.95
Mackerel	3.32	0.252	1.07	7.15	0.66
Pacific pomfret	4.81	0.130	0.75	3.75	0.98
Sardine	2.3	0.090	1.50	10.00	0.96
Anchovy	3.04	2.500	2.00	7.50	0.98
Pacific saury	3.02	1.694	0.72	4.80	0.27
Phytoplankton	1	26.580	194.36	-	0.02
Euphausiids	2.18	3.500	11.12	12.05	0.88
Copepods (eaten by whales)	2	21.300	5.00	10.00	0.33
Other copepods	2	21.300	5.00	10.00	0.51
Detritus	1	132.920	-	-	0.01

Table 4. Relative biomass of minke whales and pacific saury for the coming 10, 20, 30, 40 and 50 years, when minke whales are not harvested for the coming 50 years. *V* is the vulnerability parameter in Ecosim which controls the trophic impact of the ecosystem. Description on different functional response curve is detailed in the text.

Scenario: Minke whale catch is 0 for the coming 50 yrs		$(B_{current+10})/B_{current}$		$(B_{current+20})/B_{current}$		$(B_{current+30})/B_{current}$		$(B_{current+40})/B_{current}$		$(B_{current+50})/B_{current}$	
V	Functional response / Species	minke whale	pacific saury	minke whale	pacific saury	minke whale	pacific saury	minke whale	pacific saury	minke whale	pacific saury
2 (mixed trophic impact)	Type I	1.09	1.00	1.15	1.00	1.19	1.00	1.22	1.00	1.24	1.00
	Type II	1.13	1.00	1.23	0.99	1.30	0.99	1.35	0.99	1.38	0.99
	Type III	1.11	1.00	1.23	1.00	1.34	1.00	1.45	1.00	1.54	1.00
	Type III + other	1.14	1.00	1.20	1.00	1.21	1.00	1.22	1.00	1.22	1.00
20 (top-down)	Type I	1.11	1.00	1.22	0.98	1.33	0.97	1.43	0.96	1.53	0.96
	Type II	1.18	0.98	1.37	0.96	1.58	0.93	1.81	0.91	2.03	0.89
	Type III	1.12	1.00	1.26	0.99	1.41	0.98	1.58	0.97	1.76	0.97
	Type III + other	1.22	0.99	1.46	0.98	1.72	0.96	1.99	0.95	2.24	0.95
prop. to TL (V_{max}=20)	Type I	1.10	0.99	1.21	0.98	1.31	0.97	1.40	0.95	1.48	0.94
	Type II	1.17	0.98	1.36	0.95	1.55	0.93	1.74	0.90	1.92	0.87
	Type III	1.12	0.99	1.26	0.97	1.41	0.95	1.57	0.92	1.74	0.89
	Type III + other	1.21	0.98	1.44	0.95	1.65	0.91	1.83	0.88	1.96	0.85
prop. to TL (V_{max}=10000)	Type I	1.11	0.99	1.22	0.97	1.33	0.94	1.44	0.90	1.53	0.87
	Type II	1.18	0.97	1.38	0.92	1.60	0.85	1.82	0.78	2.03	0.71
	Type III	1.12	0.99	1.26	0.95	1.41	0.90	1.58	0.84	1.75	0.78
	Type III + other	1.22	0.97	1.48	0.91	1.73	0.83	1.97	0.73	2.13	0.64



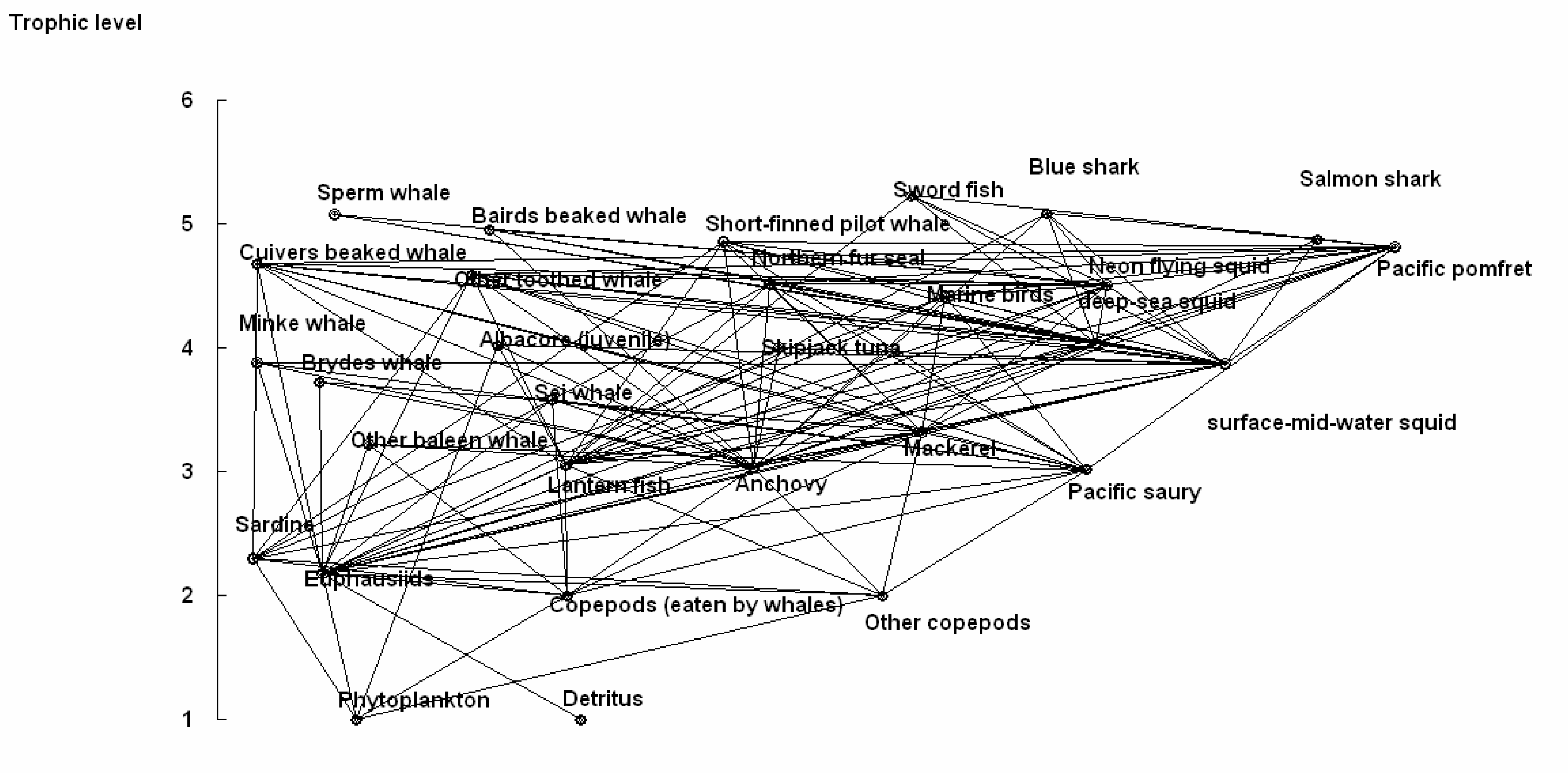


Figure 1. Food-web assumed in the model and the trophic level estimated for each species.

Figure 2. An example of output showing that effect of the short-term increase in the vertical axis species on the horizontal axis species obtained by Ecopath. Upward bars represent positive impact, and downward bars represent negative impact.