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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

Marine ecosystem of the western North Pacific mainly focusing of top predators and forage fish is modelled as a part of exercises under JARPNII using the ecosystem modelling framework, “Ecopath with Ecosim (EwE)”. Firstly, Ecopath in 2013 is constructed as available data for the modelling is relatively rich. Ecopath in 1994 is then constructed based on the model in 2013. Finally, Ecosim is constructed based on Ecopath in 1994 using available time series data from 1994 to 2013. Regime of the period is relative stable in comparison with previous periods. A series of pre-balance diagnostics, “PREBAL” (Link, 2010) is conducted for both the 2013 and 1994 models to evaluate the initial satanic energy budget of Ecopath. An ecosystem network analysis indicator, mixed trophic impact (MTI) is used to assess the positive or negative effect of changes in the biomass of a species/group on the biomass of the other species/groups in the steady state ecosystem. Order of Trophic level (TL) of baleen whales is as follows (from high to low): common minke (4.1), Bryde’s (3.9), sei (3.7), humpback (3.5), fin (3.3) and blue (3.2) whales. These species are in intermediate TL in the ecosystem. MTIs suggested that changes in biomass of forage fish impact most of species/groups from low to high trophic levels. Baleen whales impact forage fish negatively but the magnitude is weak. The Ecosim model with forced biomass time series of 4 forage fish species (Japanese sardine and anchovy, and chub and spotted mackerels) having 10 predator and prey search blocks attains the lowest AIC. Estimated time series of biomasses and total mortality by using the model are reasonably fitted to input time series data especially for cetaceans targeted by JARPNII. The result might indicate strong linkage between cetaceans and forage fish. Overall results appear to be reasonable but it is still preliminary largely because of incompleteness of input data. The followings are points to be improved in the further excises: (1) consistency of spatial resolution of input data, (2) development of regional models within our EwE area, (3) collection of diet composition data in regular interval, (4) resolution and quality of data on non-commercial and lower trophic level species and (5) evaluation of the sensitivity of Ecopath models to input data.

INTRODUCTION

The western North Pacific around Japan serves as an important fisheries ground for various species (Yatsu *et al.*, 2013). The Oyashio (a subarctic western boundary current with cold, low-salinity water) influences the northern part while the Kuroshio (the subtropical western boundary current with warm high-salinity water) influences the southern part (Fig. 1). The area between the Oyashio and the Kuroshio is called the Kuroshio-Oyashio transition (inter-frontal) zone (area). The zone is also called as the subarctic-subtropical transition zone. Small pelagic fish such as Japanese sardine, Japanese anchovy, chub and spotted mackerels and Pacific saury play important role in the ecosystem of the western North Pacific as they transfer energy from lower to higher trophic levels. In addition, they are important target of commercial fisheries. Such an ecosystem can be termed as “wasp-waist ecosystem” where many species exist at the top and the bottom but a few dominant species (mostly small pelagic fishes) occupied the middle (analogous to body shape of wasp in terms of number of species in an ecosystem) (Bakun, 2006; Cury *et al.*, 2000). Small pelagic fish also called as forage fish and their roles in marine ecosystems is actively studied in recent years by using whole ecosystem models such as Ecopath with Ecosim (EwE) (Christensen and Walters, 2004) in recent years (Pikitch *et al.*, 2012; Pikitch *et al.*, 2014). The Working Group on Ecosystem Modelling (EM) of the Scientific Committee of the International Whaling Commission (IWC/SC) reviewed the related work with focus on relationship between forage fish and whales (IWC, 2014). The Working Group recognized the ecosystem models used in the studies to date were useful for their broad-scale strategic conclusions, but were not suitable guides for short-term tactical management decisions.

Spawning area of Japanese sardine and anchovy in the western North Pacific is located in the coastal area of southern part of Japan where the influence of Kuroshio is strong. They are mainly distributed in the coastal area but it is well documented that they expand their distribution area to as far as 180° longitude when the stocks are abundant (Giannoulaki *et al.*, 2014). They are transported from the spawning area to the Kuroshio-Oyashio transition zone by the Kuroshio and its extension. The transition zone serves as their feeding ground but they also subject to predation by top predators including whales. They then return to the spawning area. Chub and spotted mackerels and Pacific saury have same kind of migration patterns. Spatial heterogeneity has to be considered when ecosystem models targeting on forage fish in this area are constructed because they utilize large area as their habitat.

These forage fish species showed drastic fluctuation and quasi-decadal species alterations so-called species replacement or biological regime shift from 1956 to 2012 (Fig. 2). Notably, rapid increase and decrease in abundance of Japanese sardine was observed in 1980's and the magnitude of the change was an order of magnitude larger than previous and subsequent periods of 1980's.The study group of fisheries and ecosystem responses to recent regime shift under PICES defined regime shift as "a relative rapid change from one decadal-scale period of a persistent state to another decadal-scale period of persistent state" (King, 2005). Climate indices such as the Pacific Decadal Oscillation (PDO) indicated that significant climatic regime shifts were occurred around 1976, 1989 and 1998 in recent decades (Overland *et al.*, 2008). No assessment on the regime after 1998 has been available. It was indicated that the species replacement was related to the climate regime shift (Takasuka *et al.*, 2008; Tian *et al.*, 2004; Yatsu *et al.*, 2008). Simple interpretation of interaction between climatic and biological regime shifts was provided based on spawning temperature optima theory among forage fish (Takasuka *et al.*, 2008) but the exact mechanism is yet to be determined. These studies focused on interaction among forage fish, their prey and climate, and interaction between predators and forage fish has not been considered fully although changes in prey compositions of top predators in response to the species replacement have been documented (Kasamatsu and Tanaka, 1992; Ohizumi *et al.*, 2000; Yonezaki *et al.*, 2015b).

Ecosystem modelling in the western North Pacific using EwE was attempted as a part of exercises under "the second phase of the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN II)" (Mori *et al.*, 2009) and it was reviewed in the "Expert Workshop to review the ongoing JARPN II Programme" held by IWC/SC in 2009 (IWC, 2010). The Panel provided a number of constructive suggestions to improve the modelling work (Table 1).

In this paper, some preliminary results of EwE modelling in the western North Pacific are presented. We mainly focus on interaction between forage fish and their predators including target species of JARPNII (common minke, sei, Bryde's and sperm whales). Firstly, Ecopath in 2013 is constructed as available data for the modelling is relative rich. Ecopath in 1994 is then constructed based on the model in 2013. Finally, Ecosim is constructed based on Ecopath in 1994 using available time series data from 1994 to 2013. Initially, we intended to construct Ecopath in 1980's when abundance of Japanese sardine was enormously high to capture ecosystem regime shift since then. However, it was proved that such an excise was difficult at this stage because of lack of basic input parameters. Instead, we focus on the period (1994-2013) when the regime appears to be stable but changes in biomass of forage fish are still observed (Fig. 3). The suggestions provided by the Panel is considered fully in the present model (Table 1).

MATERIALS AND METHODS

In this modelling exercise, the western North Pacific is divided into 3 geographical blocks considering bottom topography and oceanography: coastal Oyashio (OYC), coastal Kuroshio (KC) and offshore (OF) (Fig. 1). OYC is mainly under the influence of Oyashio while KC is under the influence of Kuroshio. OYC and KC is corresponding to the areas where offshore bottom trawl fisheries are conducted and the catch statistics are available. OF is corresponding to the Oyashio-Kuroshio transition zone. Species/groups considered in the modelling are summarized in Table 2. It is assumed that some species are endemic to a block (e.g. bottom fish) while migrating species are distributed 2 or 3 blocks. The blocks are connected by these migrating species. Similar approach attempted in the Mediterranean Sea (Piroddi *et al.*, 2015) is adopted in the study.

EwE mainly consists of two modules: Ecopath and Ecosim. Ecopath deals with mass balance modelling while Ecosim deals with time-dynamic modelling based on the result of Ecopath. Initially, a mass balance model in 2013 is constructed by using Ecopath. Ecopath has two basic equations. The first equation describes production term which ensure mass balance in the ecosystem:

$$P_i = Y_i + M2_i + B_i + E_i + BA_i + P_i \cdot (1 - EE_i)$$

(1)

where P_i is the total production rate of species *i*, Y_i is the total fishery catch rate of *i*, $M2_i$ is the total predation rate for *i*, B_i it the biomass of *i*, E_i is the net migration rate (emigration and immigration) of *i*, BA_i is the biomass accumulation rate for *i* and $P_i(1\text{-}EE_i)$ is the other mortality rate for *i* ($M0_i$). EE_i is ecotrophic efficiency of *i* which can be described as the proportion of the production utilized in the ecosystem. $M2_i$ links between predator *j* of *i*:

$$M2_i = \sum_{j=1}^{n} Q_j DC_{ji}$$

(2)

where *n* is a total number of *j* feeding on *i*, Q_j is the total consumption rate for *j* and DC_{ji} is proportion *i* as the diet of *j*. Equation (1) can be re-expressed as:

$$B_i \cdot \left(\frac{P}{B}\right)_i \cdot EE_i - \sum_{j=1}^{n} B_j \cdot \left(\frac{Q}{B}\right)_j \cdot DC_{ji} - Y_i - E_i - BA_i = 0$$

(3)

where $(P/B)_i$ is the ratio of production and biomass ratio and $(Q/B)_j$ is the ratio of consumption and biomass. Production and biomass ratio (*P/B*) is generally corresponding to total mortality rate, *Z* (fishing mortality rate [*F*] plus natural mortality rare [*M*]) (Allen, 1971). If either 3 parameters from following 4 parameter are supplied along with *DC* to Ecopath, rest of a parameter is estimated by Ecopath: *B*, *P/B*, *Q/B* and *EE*. The second basic equation ensures balances within each species/groups:

$$Q_i = P_i + R_i + GS_i \cdot Q_i$$

(4)

where R_i is respiration for *i*, GS_i is proportion of food that is not assimilated for *i*. Wet weight (t) is used as currency in the modelling. Another mass balance model in 1994 is then constructed based on the 2013 model. Basic input parameters for the 2013 and 1994 models are summarized in Table 3 and 4 Diet compositions are summarized in Table 5. Same diet compositions are assumed in both 2013 and 1994 models. Fishery landings used in the models are summarized in Table 6. No fleet type is considered. Proportion of unassimilated consumption is set as 0.2 for all species/groups. No detritus import is assumed. Details of input parameters are described in Appendix 1. A series of pre-balance diagnostics, "PREBAL" (Link, 2010) is conducted for both the 2013 and 1994 models to evaluate the initial satanic energy budget of Ecopath. A ecosystem network analysis indicator, mixed trophic impact (MTI) (Ulanowicz and Puccia, 1990), calculated by Ecopath based on the balanced models is used to assess the positive or negative effect of changes in the biomass of a species/group on the biomass of the other species/groups in the steady state ecosystem. Both direct and indirect effect are taken account by the MTI. The MTI for species/groups is calculated by constructing an *n* by *n* matrix where the *i*th and *j*th elements representing the interaction between the impacting group *i* and the impacted group *j*:

$$MTI_{i,j} = DC_{i,j} - FC_{j,i}$$

(5)

where $DC_{i,j}$ is the diet composition term expressing how much *j* contributes to the diet of *i*, and $FC_{j,i}$ is a host composition term giving the proportion of the predation on *j* that is due to *i* as a predator.

Various times series from 1994 to 2013 are fitted to the balanced Ecpath model in 1994 by using Ecosim. Biomass dynamics are expressed through a series of coupled differential equations in Ecosim and the equations are derived from the first basic equation of Ecopath:

$$\frac{dB_i}{dt} = g_i \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - \left(M0_i + F_i + e_i\right)B_i$$

(6)

where dB_i/dt is the biomass growth rate during the time interval dt of i, g_i is the net growth efficiency (production/consumption ratio), F_i is fishing mortality rate for i, e_i is emigration rate for i, I_i is immigration rate for i, (hence $e_i \cdot B_i$- I_i is the net migration rate). The first summation is the first expressing the total consumption by i, and the second is the predation by all predators on i. Consumption rate, Q_{ji}, in Ecosim is based on the foraging arena theory (Ahrens *et al.*, 2012) and expressed as:

$$Q_{ij} = \frac{a_{ij} \cdot v_{ij} \cdot B_i \cdot P_j \cdot T_i \cdot T_j \cdot S_{ij} \cdot M_{ij} / D_j}{v_{ij} + v_{ij} \cdot T_i M_{ij} + a_{ij} \cdot M_{ij} \cdot P_j \cdot S_{ij} \cdot T_j / D_j}$$

(7)

where, a_{ij} is the effective search rate for predator i feeding on prey j, v_{ij} is base vulnerability expressing the rate with which prey move between being vulnerable and not vulnerable, B_i is biomass of prey, P_j is biomass of j, T_i is prey relative feeding time, T_j is predator relative feeding time, S_{ij} is user-defined seasonal or long term forcing effects, M_{ij} mediation forcing effects, and D_j represents effects of handling time of predator. Parameters v, T, S, M and D can be set by modellers but it is assumed that v has the strongest effect on biomass dynamics in Ecosim. High value of v indicates top-down control while the low value indicates bottom-up control. Direct assessment of vulnerability based on field observation is difficult for most of species. Instead, it can be estimated through time series fitting implemented in Ecosim. Goodness of fit to time series is measured by a weighted sum of squared deviations (SS) of log biomasses from log predicted biomasses, scaled in the case of relative abundance data by the maximum likelihood estimate of the relative abundance scaling factor q in the equation $y=qB$ (y=relative abundance, B=absolute abundance). In this paper, biomass dynamics from 1994 to 2013 (20 years) are modelled based on Ecopath in 1994. A total of 29 time series data are used in the analysis (Table 7). Equal weight is assigned to all time series. Procedures for the time series fitting are as follows. Firstly, sensitives of SS to v by predator and prey blocks are determined by changing each one slightly (1%) then rerunning the model to see how much SS is changed. Secondly, v estimates that give better fits to the time series data (lower SS) with vulnerabilities blocks is searched. Number of predator and prey blocks which are used to estimate v are increased from 5 until the smallest AIC (Akaike information criteria). Default value of v is set as 2. In this exercise, effect of changes in biomass of small forage fish (Japanese sardine, Japanese anchovy and, chub and spotted mackerel) on changes in biomass of top predators is mainly investigated. The model attained the smallest AIC is considered as the best model.

RESULTS AND DISCUSSION

Estimated basic parameters for Ecopath in 2013 and 1994 are summarized in Tables 8 and 9. The results of PREBAL are summarized in Appendices 2 and 3. The balanced models are considered to be reasonable based on the results of PREBAL although some parameters might need to be revisited in the future for further check. The food webs in 2013 and 1994 estimated by Ecopath are shown in Figs. 4 and 5. Baird's beaked whale attains the highest trophic level (TL) followed by sperm and pilot whales, mesopelagic sharks and tunas in both 2013 and 1994. Order of TL of baleen whales is as follows (from high to low): common minke (4.1), Bryde's (3.9), sei (3.7), humpback (3.5), fin (3.3) and blue (3.2) whales. These species are in intermediate TL. MTIs in 2014 and 1993 are shown in Figs. 6 and 7. MTIs suggested that changes in biomass of forage fish impact most of species/groups from low to high trophic levels. Baleen whales impact forage fish negatively but the magnitude is weak. Overall, outputs from Ecopath between 2013 and 1994 are similar. The results are not surprising as both years are under similar regime.

Results of time series fitting from 1994 to 2013 are summarized in Table 10. The model with forced biomass time series of 4 forage fish species (Japanese sardine and anchovy, and chub and spotted mackerels) having 10 predator and prey search blocks attain the lowest AIC (model number 19 in Table 10). Estimated vulnerability parameters for the selected model are summarized in Table 11. Strong top-down controls are expected for the following predator/prey in the modelled period: blue shark/Japanese anchovy, Japanese anchovy/zooplankton (OF), chub mackerel (all)/Japanese anchovy (all), chub mackerel (all)/krill (OF), chub mackerel (all)/zooplankton (OF), spotted mackerel (all)/krill (OF) and spotted mackerel (all)/zooplankton (OF). The vulnerability parameters for the rest of predator and prey blocks are estimated as 2 and this suggested intermediate interactions between predator and prey. Estimated time series of biomass, total mortality and catch are shown in Figs. 8-10. Estimated time series for the model without forcing on biomass time series of 4 forage fish species (model number 7 in Table 1) are also shown in the figures for comparison. Reasonable results of time series fitting for biomass and total mortality are obtained especially for cetaceans if the biomass time series of forage fish are forced. The result might indicate strong linkage between cetaceans and forage fish. There are discrepancies for catch data even if the biomass time series of forage fish are forced.

We consider that results obtained by this exercises are reasonable but it is still preliminary largely because of incompleteness of input data. Following are points to be improved:

(1) Consistency of spatial resolution of input data

Spatial resolutions of input data are varied from data to data. Some data are recorded within our EwE area (e.g. JAPRNII) but some are not. For instance, biomass of highly migrating fish (e.g. tunas) are estimated in much wider area than our EwE area for the purpose of the stock assessment (e.g. the entire Pacific). It is assumed that biomass density is same for these two areas. However, the assumption might not be valid because spatial heterogeneity of spatial distribution of target species is expected. Such inconsistencies of spatial resolutions are also occurred within our EwE area. Only a point estimate of biomass is available for most of species. Spatial estimation of biomass of some of the species in our EwE area are undergoing by using either statistical models (e.g. generalized additive model, GAM) (Murase *et al.*, 2016: SC/F16/JR7) or spatial ecosystem models such as individual based ecosystem models (Okunishi *et al.*, 2012) and SEAPODYM (Lehodey *et al.*, 2011). Integration or coupling with these models could be one of the future solutions along with preparation of appropriate raw data.

(2) Development of regional models within our EwE area

Regional details are largely overlooked in our EwE model because it covers quite large area. The Ecopath model developed in the southern part of the OYC block (Yonezaki *et al.*, 2015a) acts as a good source of basic input of our EwE. Development of regional EwE models especially in the coastal area of Japan (e.g. northern part of OYC and KC blocks) will be helpful to improve our EwE model.

(3) Collection of diet composition data in regular interval

Some of the diet composition data used in our model are old qualitative data and/or obtained outside of the modelled area. Collection of diet composition data especially for top predators in the area in regular interval must be conducted to improve the model performance. It is especially true if the aim of the modelling is to investigate mechanism of regime shift in the area.

(4) Resolution and quality of data on non-commercial and lower trophic level species

Resolution (in terms of number of species/groups) and quality of data on non-commercial and lower trophic level species are not satisfactory in our model. Effort on assembling existent data and collection of new data (if necessary) should be made further.

(5) Evaluation of the sensitivity of Ecopath models to input data

Although the initial satanic energy budget of Ecopath was evaluated in this paper applying a series of pre-balance diagnostics, sensitivity of Ecopath models to input data (Essington, 2007) should also be evaluated in the future excises.

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Table 1. Suggestions by the Panel of the expert workshop to review the ongoing JARPNII programme (IWC, 2010) to improve Ecopath and Ecosim modelling in the western North Pacific (left column). Improvement in the modelling in this paper based on these suggestions are also listed (right column).

Suggestion	Improvement in response to the suggestion
Considerably more resources must be allocated to the modelling work – without this, the likelihood that the objective of the programme will be reached in a reasonable timeframe will be minimal. The models developed should be used to identify the areas of uncertainty with the greatest impact on model outputs of relevance to management, and hence to guide the prioritisation of future data collection and the associated sample size/sampling design.	Collaboration with specialists in other disciplines (e.g. oceanography, pelagic fish and highly migratory fish [sharks and tunas]) has been strengthened for EwE modelling.
A wider range of models needs to be considered if the objectives of the programme are to be met. Further work should aim towards fitting dynamic models to time series of data, especially abundance indices.	Time series data from 1994 to 2013 is fitted in Ecosim to estimate vulnerability parameters which is one of important parameters in the model
The area covered by JARPN II is not spatially homogeneous, and serious consideration should be given to developing separate models for three regions distinguished by the inshore or shelf region, the sub-Arctic oceanic region of the Oyashio current and the sub-tropical region of the Oyashio and Kuroshio transition zone.	A quasi sub-model structure is established in EwE considering bottom topography and oceanography the modelled area.
There is a need to take much wider account of uncertainty at all stages of the modelling process, including that associated with the prey consumption rates of whales	Uncertainty is not addressed fully in EwE although vulnerability parameters is estimated in Ecosim.
The importance, ultimately, of developing models which incorporate natural variability in dynamic processes was emphasised, although it was recognised that this might not be possible for certain ecosystem modelling ‘packages’. This is in addition to taking account of uncertainty in model structure and parameter values. The complexity of ecosystems and the difficulty of modelling species interactions adequately might mean that management actions based on such models are more likely to induce unexpected instabilities than current single-species based approaches; this suggests a more cautious approach will be needed on the part of decision makers.	A climate index, the Pacific the Pacific Decadal Oscillation (PDO) index, is initially considered whether it can be used as forcing function in Ecosim. However, it is not considered in actual modelling because it appear that influence of PDO on biomass dynamics in the modelling period (1994-2013) is not strong. But it is still on the to-do list in the further modelling especially if the modelling period is expanded to the past.
It is important to concentrate first on improving the Ecopath component of this EwE analysis before moving on to the next step of extending the modelling effort from a static to a dynamic model such as Ecosim.	A series of pre-balance diagnostics, “PREBAL” (Link, 2010) is conducted for both the 2013 and 1994 models to evaluate the initial satanic energy budget of Ecopath before Ecosim modelling is conducted.
The species included in the Ecopath analysis should be reviewed giving attention to Ecopath models developed for other regions; in particular the inclusion of gelatinous zooplankton should be considered. Furthermore the values of the parameters of this Ecopath analysis should be compared with values for those others, with attention directed towards any instances of major discrepancies.	Because EwE mainly focuses on offshore instead of near shore area, it appears that gelatinous zooplankton is not key species in the modeled area. In addition, such data scarce so far. Presented EwE modelling mainly focus on interaction between forage fish and their predators and the number of predators in the model is increased from the previous one. Values of basic parameters are compared with other models qualitatively.
The need to rebalance the Ecopath model. Alternative approaches to doing so should be considered. For example, rather than use values for some parameters drawn from other regions, placing a bound on some relationship (e.g. P/C<0.6) may lead to an improved result overall.	A series of pre-balance diagnostics, “PREBAL” (Link, 2010) is conducted for both the 2013 and 1994 models to evaluate the initial satanic energy budget of Ecopath before Ecosim modelling is conducted.
Further analyses must take full account of the uncertainties associated with model inputs e.g. using Ecoranger	Ecoranger is not used in the modelling as the development is little so far.

Table 2. Species/groups considered in Ecopath and Ecosim in the western North Pacific in 2013 and 1994. Allocations to the 3 geographic blocks (OYC, KC and OF) are also shown. Migrating species are allowed to be distributed in 2 or 3 blocks.

Category		Species/group	Allocation to the geographical blocks				
			Coastal Oyashio (OYC)	Coastal Kuroshio (KC)	Offshore (OF)	OYC/OF	All blocks
Baleen whales	1	Blue whale (OYC, OF)				x	
	2	Fin whale (OYC, OF)				x	
	3	Sei whale (OYC, OF)				x	
	4	Bryde's whale (OYC, OF)				x	
	5	Common minke whale (OYC, OF)				x	
	6	Humpback whale (OYC, OF)				x	
Toothed whales	7	Sperm whale (all)				x	
	8	Killer whale (all)					x
	9	Large dolphins (all)					x
	10	Small dolphins (all)					x
	11	Dall's porpoise (OYC, OF)					x
	12	Pilot whale (all)					
	13	Baird's beaked whale (OYC)	X				
	14	Beaked whales (all)					x
Seabirds	15	Seabirds (all)					x
Elasmobranch	16	Blue shark (all)					x
	17	Mesopelagic sharks (OYC)	X				
Tunas	18	Tunas (all)					x
	19	Skipjack (all)					x
Billfish	20	Swordfish (all)					x
Miscellaneous piscivores	21	Miscellaneous piscivores (all)					x
Small pelagic fish	22	Japanese sardine (all)					x
	23	Japanese anchovy (all)					x
	24	Pacific saury (all)					x
	25	Chub mackerel (all)					x
	26	Spotted mackerel (all)					x
Bottom fish	27	Righteye flounders (OYC)	X				
	28	Alaska pollock (OYC)	X				
	29	Miscellaneous bottom fish (OYC)	X				
	30	Righteye flounders (KC)		x			
	31	Seabreams (KC)		x			
	32	Miscellaneous bottom fish (KC)		x			
Mesopelagic fish	33	Mesopelagic fish (OYC)	X				
	34	Mesopelagic fish (KC)		x			
	35	Mesopelagic fish (OF)			x		
Squids	36	Surface squids (all)					x
	37	Mesopelagic squids (all)					x
Benthos	38	Benthos (OYC)	X				
	39	Benthos (KC)		x			
Krill	40	Krill (OYC)	X				
	41	Krill (OF)		x			
Miscellaneous zooplankton	42	Zooplankton (OYC)	X				
	43	Zooplankton (KC)		x			
	44	Zooplankton (OF)			x		
Phytoplankton	45	Phytoplankton (OYC)	X				
	46	Phytoplankton (KC)		x			
	47	Phytoplankton (OF)			x		
Detritus	48	Detritus (OYC)	X				
	49	Detritus (KC)		x			
	50	Detritus (OF)			X		

Table 3. Basic input parameters for Ecopath in the western North Pacific in 2013. OYC: coastal Oyasio block, KC: coastal Kuroshio block, OF: offshore block, B in habitat: biomass (t/km^2) in distributed blocks, P/B: production/biomass ratio, Q/B: consumption/biomass ratio EE: ecotrophic efficiency and P/Q: production/consumption ratio.

	Species/group	Habitat area (fraction)	B in habitat	P/B	Q/B	EE	P/Q
1	Blue whale (OYC, OF)	0.950	0.022	0.040	4.220		
2	Fin whale (OYC, OF)	0.950	0.053	0.052	4.548		
3	Sei whale (OYC, OF)	0.950	0.034	0.099	4.384		
4	Bryde's whale (OYC, OF)	0.950	0.035	0.087	7.372		
5	Common minke whale (OYC, OF)	0.950	0.006	0.120	4.581		
6	Humpback whale (OYC, OF)	0.950	0.009	0.072	4.634		
7	Sperm whale (OYC, OF)	0.950	0.160	0.061	8.696		
8	Killer whale (all)	1.000	0.002	0.100	4.381		
9	Large dolphins (all)	1.000	0.003	0.120	7.778		
10	Small dolphins (all)	1.000	0.025	0.143	10.777		
11	Dall's porpoise (OYC, OF)	1.000	0.002	0.138	11.492		
12	Pilot whales (all)	0.950	0.002	0.147	14.287		
13	Baird's beaked whale (OYC)	0.050	0.049	0.105	4.872		
14	Beaked whales (all)	1.000	0.004	0.100	7.855		
15	Seabirds (all)	1.000	0.003	0.120	36.667		
16	Blue shark (all)	1.000	0.089	0.464	1.325		
17	Mesopelagic sharks (OYC)	0.050	0.107	0.330	2.900		
18	Tunas (all)	1.000	0.036	0.326	6.754		
19	Skipjack (all)	1.000	0.027	0.458	16.200		
20	Swordfish (all)	1.000	0.001	0.490	2.500		
21	Miscellaneous piscivores (all)	1.000		2.250	7.700	0.950	
22	Japanese sardine (all)	1.000	0.446	0.517			0.200
23	Japanese anchovy (all)	1.000	1.156	2.180			0.200
24	Pacific saury (all)	1.000	0.851	1.523			0.200
25	Chub mackerel (all)	1.000	1.240	0.513			0.200
26	Spotted mackerel (all)	1.000	1.009	0.486			0.200
27	Righteye flounders (OYC)	0.050	0.946	0.446	2.893		
28	Alaska pollock (OYC)	0.050	4.889	0.840	2.212		
29	Miscellaneous bottom fish (OYC)	0.050	14.138	0.393	3.182		
30	Righteye flounders (KC)	0.050	0.001	0.446	2.893		
31	Seabreams (KC)	0.050	0.003	0.490	2.450		
32	Miscellaneous bottom fish (KC)	0.050	0.025	0.346	2.832		
33	Mesopelagic fish (OYC)	0.050		1.500		0.900	0.250
34	Mesopelagic fish (KC)	0.050		1.500		0.900	0.250
35	Mesopelagic fish (OF)	0.900		1.500		0.900	0.250
36	Surface squids (all)	1.000		2.555	7.300	0.950	
37	Mesopelagic squids (all)	1.000		2.979	13.641	0.938	
38	Benthos (OYC)	0.050	64.534	3.030	10.102		
39	Benthos (KC)	0.050		2.530	8.430	0.915	
40	Krill (OYC)	0.050	114.489	2.555	12.045		
41	Krill (OF)	0.900	23.392	2.555	12.045		
42	Zooplankton (OYC)	0.050	29.730	23.160	45.350		
43	Zooplankton (KC)	0.050	8.067	23.160	45.350		
44	Zooplankton (OF)	0.900	11.643	23.160	45.350		
45	Phytoplankton (OYC)	0.050	13.555	153.776			
46	Phytoplankton (KC)	0.050	10.012	128.274			
47	Phytoplankton (OF)	0.900	9.036	153.776			
48	Detritus (OYC)	0.050	47.911				
49	Detritus (KC)	0.050	30.184				
50	Detritus (OF)	0.900	47.499				

Table 4. Basic input parameters for Ecopath in the western North Pacific in 1994. OYC: coastal Oyasio block, KC: coastal Kuroshio block, OF: offshore block, B in habitat: biomass (t/km^2) in distributed blocks, P/B: production/biomass ratio, Q/B: consumption/biomass ratio EE: ecotrophic efficiency and P/Q: production/consumption ratio. Parameters changed from the 2013 model are in italic with underline.

	Species/group	Habitat area (fraction)	B in habitat	P/B	QB	EE	P/Q
1	Blue whale (OYC, OF)	0.950	0.022	0.040	4.220		
2	Fin whale (OYC, OF)	0.950	0.053	0.052	4.548		
3	Sei whale (OYC, OF)	0.950	*0.024*	0.099	4.384		
4	Bryde's whale (OYC, OF)	0.950	*0.038*	0.087	7.372		
5	Common minke whale (OYC, OF)	0.950	*0.006*	0.120	4.581		
6	Humpback whale (OYC, OF)	0.950	0.009	0.072	4.634		
7	Sperm whale (OYC, OF)	0.950	0.136	0.061	8.696		
8	Killer whale (all)	1.000	0.002	0.100	4.381		
9	Large dolphins (all)	1.000	0.003	0.120	7.778		
10	Small dolphins (all)	1.000	0.025	0.143	10.777		
11	Dall's porpoise (OYC, OF)	1.000	0.002	0.138	11.492		
12	Pilot whales (all)	0.950	0.002	0.147	14.287		
13	Baird's beaked whale (OYC)	0.050	0.049	0.105	4.872		
14	Beaked whales (all)	1.000	0.004	0.100	7.855		
15	Seabirds (all)	1.000	0.003	0.120	36.667		
16	Blue shark (all)	1.000	*0.077*	*0.727*	1.325		
17	Mesopelagic sharks (OYC)	0.050	0.107	0.330	2.900		
18	Tunas (all)	1.000	*0.051*	*0.299*	6.754		
19	Skipjack (all)	1.000	*0.037*	*0.468*	16.200		
20	Swordfish (all)	1.000	0.001	0.490	2.500		
21	Miscellaneous piscivores (all)	1.000		2.250	7.700	0.950	
22	Japanese sardine (all)	1.000	*1.276*	*0.613*			0.200
23	Japanese anchovy (all)	1.000	*0.920*	*2.019*			0.200
24	Pacific saury (all)	1.000	0.851	1.523			0.200
25	Chub mackerel (all)	1.000	*0.494*	*0.497*			0.200
26	Spotted mackerel (all)	1.000	*0.494*	*0.497*			0.200
27	Righteye flounders (OYC)	0.050	0.946	0.446	2.893		
28	Alaska pollock (OYC)	0.050	*4.889*	0.840	2.212		
29	Miscellaneous bottom fish (OYC)	0.050	14.138	0.393	3.182		
30	Righteye flounders (KC)	0.050	0.001	0.446	2.893		
31	Seabreams (KC)	0.050	0.003	0.490	2.450		
32	Miscellaneous bottom fish (KC)	0.050	0.025	0.346	2.832		
33	Mesopelagic fish (OYC)	0.050		1.500		0.900	0.250
34	Mesopelagic fish (KC)	0.050		1.500		0.900	0.250
35	Mesopelagic fish (OF)	0.900		1.500		0.900	0.250
36	Surface squids (all)	1.000		2.555	7.300	0.950	
37	Mesopelagic squids (all)	1.000		2.979	13.641	0.938	
38	Benthos (OYC)	0.050	64.534	3.030	10.102		
39	Benthos (KC)	0.050		2.530	8.430	0.915	
40	Krill (OYC)	0.050	114.489	2.555	12.045		
41	Krill (OF)	0.900	23.392	2.555	12.045		
42	Zooplankton (OYC)	0.050	*23.450*	23.160	45.350		
43	Zooplankton (KC)	0.050	8.487	23.160	45.350		
44	Zooplankton (OF)	0.900	*11.643*	23.160	45.350		
45	Phytoplankton (OYC)	0.050	13.555	153.776			
46	Phytoplankton (KC)	0.050	10.012	128.274			
47	Phytoplankton (OF)	0.900	9.036	153.776			
48	Detritus (OYC)	0.050	47.911				
49	Detritus (KC)	0.050	30.184				
50	Detritus (OF)	0.900	47.499				

Table 5. Diet compositions (*DC*s, expressed in proportions) for Ecopath in the western North Pacific in 2013 and 1994. OYC: coastal Oyasio block, KC: coastal Kuroshio block, OF: offshore block

	Prey/Predator	Blue whale (OYC, OF)	Fin whale (OYC, OF)	Sei whale (OYC, OF)	Bryde's whale (OYC, OF)	Common minke whale (OYC, OF)	Humpback whale (OYC, OF)	Sperm whale (OYC, OF)	Killer whale (all)	Large dolphins (all)	Small dolphins (all)	Dall's porpoise (OYC, OF)
		1	2	3	4	5	6	7	8	9	10	11
1	Blue whale (OYC, OF)								0.001			
2	Fin whale (OYC, OF)								0.001			
3	Sei whale (OYC, OF)								0.001			
4	Bryde's whale (OYC, OF)								0.001			
5	Common minke whale (OYC, OF)								0.001			
6	Humpback whale (OYC, OF)								0.001			
7	Sperm whale (OYC, OF)								0.001			
8	Killer whale (all)											
9	Large dolphins (all)								0.001			
10	Small dolphins (all)								0.001			
11	Dall's porpoise (OYC, OF)								0.001			
12	Pilot whales (all)								0.001			
13	Baird's beaked whale (OYC)								0.001			
14	Beaked whales (all)								0.001			
15	Seabirds (all)											
16	Blue shark (all)								0.001			
17	Mesopelagic sharks (OYC)								0.001			
18	Tunas (all)								0.010			
19	Skipjack (all)								0.010			
20	Swordfish (all)								0.010			
21	Miscellaneous piscivores (all)					0.013			0.020			
22	Japanese sardine (all)		0.010	0.010	0.010	0.010	0.010		0.022	0.011	0.010	0.001
23	Japanese anchovy (all)		0.050	0.424	0.726	0.407	0.300		0.076	0.028	0.056	0.016
24	Pacific saury (all)		0.020	0.043		0.315	0.070		0.022	0.011	0.010	0.001
25	Chub mackerel (all)		0.010	0.048	0.017	0.002	0.010		0.040	0.010	0.010	0.002
26	Spotted mackerel (all)		0.010	0.048	0.017	0.002	0.010		0.040	0.010	0.010	0.002
27	Righteye flounders (OYC)								0.010	0.010		
28	Alaska pollock (OYC)					0.107			0.010	0.030		0.020
29	Miscellaneous bottom fish (OYC)					0.010		0.003	0.020	0.048	0.226	
30	Righteye flounders (KC)									0.000		
31	Seabreams (KC)									0.000		
32	Miscellaneous bottom fish (KC)									0.000	0.000	
33	Mesopelagic fish (OYC)								0.010	0.020	0.016	0.044
34	Mesopelagic fish (KC)								0.010	0.020	0.016	0.044
35	Mesopelagic fish (OF)				0.009			0.019	0.180	0.030	0.292	0.792
36	Surface squids (all)			0.010		0.030		0.001	0.001	0.002	0.003	0.001
37	Mesopelagic squids (all)					0.004		0.977	0.494	0.730	0.330	0.077
38	Benthos (OYC)									0.020	0.011	
39	Benthos (KC)									0.020	0.010	
40	Krill (OYC)	0.052	0.034	0.009	0.012	0.005	0.021					
41	Krill (OF)	0.948	0.616	0.157	0.209	0.088	0.379					
42	Zooplankton (OYC)		0.013	0.013			0.010					
43	Zooplankton (KC)											
44	Zooplankton (OF)		0.237	0.238		0.007	0.190					
45	Phytoplankton (OYC)											
46	Phytoplankton (KC)											
47	Phytoplankton (OF)											
48	Detritus (OYC)											
49	Detritus (KC)											
50	Detritus (OF)											

Table 5. (Continued)

	Prey/Predator	Pilot whales (all)	Baird's beaked whale (OYC)	Beaked whales (all)	Seabirds (all)	Blue shark (all)	Mesopelagic sharks (OYC)	Tunas (all)	Skipjack (all)	Swordfish (all)	Miscellaneous piscivores (all)	Japanese sardine (all)
		12	13	14	15	16	17	18	19	20	21	22
1	Blue whale (OYC, OF)											
2	Fin whale (OYC, OF)											
3	Sei whale (OYC, OF)											
4	Bryde's whale (OYC, OF)											
5	Common minke whale (OYC, OF)											
6	Humpback whale (OYC, OF)											
7	Sperm whale (OYC, OF)											
8	Killer whale (all)											
9	Large dolphins (all)											
10	Small dolphins (all)											
11	Dall's porpoise (OYC, OF)											
12	Pilot whales (all)											
13	Baird's beaked whale (OYC)											
14	Beaked whales (all)											
15	Seabirds (all)											
16	Blue shark (all)											
17	Mesopelagic sharks (OYC)											
18	Tunas (all)							0.002	0.001	0.000	0.001	
19	Skipjack (all)							0.001	0.001	0.013	0.001	
20	Swordfish (all)											
21	Miscellaneous piscivores (all)	0.079			0.008	0.005		0.242	0.077	0.001	0.005	
22	Japanese sardine (all)	0.010			0.010	0.010	0.001	0.010	0.010	0.010	0.005	
23	Japanese anchovy (all)	0.040			0.070	0.371	0.007	0.139	0.104	0.126	0.020	
24	Pacific saury (all)	0.010			0.067	0.010	0.001	0.090	0.070	0.100	0.010	
25	Chub mackerel (all)	0.020			0.010	0.010	0.001	0.090	0.070	0.100	0.005	
26	Spotted mackerel (all)	0.020			0.010	0.010	0.001	0.090	0.070	0.100	0.005	
27	Righteye flounders (OYC)						0.139					
28	Alaska pollock (OYC)						0.039					
29	Miscellaneous bottom fish (OYC)	0.100	0.956	0.074			0.503					
30	Righteye flounders (KC)											
31	Seabreams (KC)											
32	Miscellaneous bottom fish (KC)	0.000		0.000								
33	Mesopelagic fish (OYC)	0.005		0.009	0.017	0.001	0.011	0.007	0.009	0.003	0.016	
34	Mesopelagic fish (KC)	0.005		0.009	0.017	0.001		0.007	0.009	0.003	0.016	
35	Mesopelagic fish (OF)	0.090		0.158	0.299	0.026		0.121	0.158	0.050	0.284	
36	Surface squids (all)	0.001	0.001	0.001	0.001	0.001	0.044	0.001	0.001	0.001	0.001	
37	Mesopelagic squids (all)	0.620	0.043	0.699	0.335	0.535	0.167	0.184	0.302	0.412	0.315	
38	Benthos (OYC)			0.025			0.080					
39	Benthos (KC)			0.025								
40	Krill (OYC)				0.004	0.001	0.006	0.001	0.003	0.002	0.008	0.002
41	Krill (OF)				0.072	0.019		0.007	0.056	0.038	0.150	0.004
42	Zooplankton (OYC)				0.004			0.001	0.003	0.002	0.008	0.025
43	Zooplankton (KC)				0.004			0.001	0.003	0.002	0.008	0.025
44	Zooplankton (OF)				0.072			0.006	0.053	0.037	0.142	0.447
45	Phytoplankton (OYC)											0.025
46	Phytoplankton (KC)											0.025
47	Phytoplankton (OF)											0.447
48	Detritus (OYC)											
49	Detritus (KC)											
50	Detritus (OF)											

Table 5. (Continued)

	Prey/Predator	Japanese anchovy (all) 23	Pacific saury (all) 24	Chub mackerel (all) 25	Spotted mackerel (all) 26	Righteye flounders (OYC) 27	Alaska pollock (OYC) 28	Miscellaneous bottom fish (OYC) 29	Righteye flounders (KC) 30	Seabreams (KC) 31	Miscellaneous bottom fish (KC) 32	Mesopelagic fish (OYC) 33
1	Blue whale (OYC, OF)											
2	Fin whale (OYC, OF)											
3	Sei whale (OYC, OF)											
4	Bryde's whale (OYC, OF)											
5	Common minke whale (OYC, OF)											
6	Humpback whale (OYC, OF)											
7	Sperm whale (OYC, OF)											
8	Killer whale (all)											
9	Large dolphins (all)											
10	Small dolphins (all)											
11	Dall's porpoise (OYC, OF)											
12	Pilot whales (all)											
13	Baird's beaked whale (OYC)											
14	Beaked whales (all)											
15	Seabirds (all)											
16	Blue shark (all)											
17	Mesopelagic sharks (OYC)											
18	Tunas (all)											
19	Skipjack (all)											
20	Swordfish (all)											
21	Miscellaneous piscivores (all)											
22	Japanese sardine (all)			0.010	0.010	0.001		0.003	0.001		0.003	
23	Japanese anchovy (all)			0.242	0.226	0.003		0.010	0.003		0.010	
24	Pacific saury (all)					0.001		0.003	0.000		0.003	
25	Chub mackerel (all)					0.001		0.003	0.001		0.003	
26	Spotted mackerel (all)					0.001		0.003	0.001		0.003	
27	Righteye flounders (OYC)					0.002		0.004				
28	Alaska pollock (OYC)					0.010	0.005	0.004				
29	Miscellaneous bottom fish (OYC)					0.041		0.035				
30	Righteye flounders (KC)								0.001		0.001	
31	Seabreams (KC)								0.000		0.001	
32	Miscellaneous bottom fish (KC)								0.001	0.001	0.001	
33	Mesopelagic fish (OYC)					0.006	0.188	0.166				
34	Mesopelagic fish (KC)								0.006		0.166	
35	Mesopelagic fish (OF)											
36	Surface squids (all)			0.001	0.001	0.002		0.002	0.002		0.002	
37	Mesopelagic squids (all)			0.013	0.032	0.019	0.153	0.102	0.019		0.102	
38	Benthos (OYC)					0.688	0.029	0.566				0.250
39	Benthos (KC)								0.688	0.600	0.566	
40	Krill (OYC)	0.015	0.010	0.018	0.019	0.159	0.488	0.043				0.500
41	Krill (OF)	0.285	0.190	0.352	0.365							
42	Zooplankton (OYC)	0.033	0.040	0.018	0.017	0.066	0.137	0.056				0.250
43	Zooplankton (KC)	0.033	0.040	0.018	0.017				0.277	0.399	0.139	
44	Zooplankton (OF)	0.604	0.720	0.328	0.313							
45	Phytoplankton (OYC)	0.01										
46	Phytoplankton (KC)	0.01										
47	Phytoplankton (OF)	0.01										
48	Detritus (OYC)											
49	Detritus (KC)											
50	Detritus (OF)											

Table 5. (Continued)

	Prey/Predator	Mesopelagic fish (KC)	Mesopelagic fish (OF)	Surface squids (all)	Mesopelagic squids (all)	Benthos (OYC)	Benthos (KC)	Krill (OYC)	Krill (OF)	Zooplankton (OYC)	Zooplankton (KC)	Zooplankton (OF)
		34	35	36	37	38	39	40	41	42	43	44
1	Blue whale (OYC, OF)											
2	Fin whale (OYC, OF)											
3	Sei whale (OYC, OF)											
4	Bryde's whale (OYC, OF)											
5	Common minke whale (OYC, OF)											
6	Humpback whale (OYC, OF)											
7	Sperm whale (OYC, OF)											
8	Killer whale (all)											
9	Large dolphins (all)											
10	Small dolphins (all)											
11	Dall's porpoise (OYC, OF)											
12	Pilot whales (all)											
13	Baird's beaked whale (OYC)											
14	Beaked whales (all)											
15	Seabirds (all)											
16	Blue shark (all)											
17	Mesopelagic sharks (OYC)											
18	Tunas (all)											
19	Skipjack (all)											
20	Swordfish (all)											
21	Miscellaneous piscivores (all)											
22	Japanese sardine (all)			0.005								
23	Japanese anchovy (all)			0.036								
24	Pacific saury (all)			0.005								
25	Chub mackerel (all)			0.005								
26	Spotted mackerel (all)			0.005								
27	Righteye flounders (OYC)											
28	Alaska pollock (OYC)											
29	Miscellaneous bottom fish (OYC)											
30	Righteye flounders (KC)											
31	Seabreams (KC)											
32	Miscellaneous bottom fish (KC)											
33	Mesopelagic fish (OYC)			0.015	0.015	0.003						
34	Mesopelagic fish (KC)			0.015	0.015		0.003					
35	Mesopelagic fish (OF)			0.270	0.270							
36	Surface squids (all)			0.004	0.005							
37	Mesopelagic squids (all)			0.005	0.005	0.001	0.001					
38	Benthos (OYC)					0.143						
39	Benthos (KC)	0.250					0.143					
40	Krill (OYC)			0.015	0.015	0.003						
41	Krill (OF)		0.300	0.285	0.285							
42	Zooplankton (OYC)			0.017	0.019	0.099		0.200		0.100		
43	Zooplankton (KC)	0.750		0.017	0.019		0.102				0.100	
44	Zooplankton (OF)		0.700	0.301	0.352				0.200			0.100
45	Phytoplankton (OYC)					0.121		0.500		0.600		
46	Phytoplankton (KC)						0.121				0.600	
47	Phytoplankton (OF)								0.500			0.600
48	Detritus (OYC)					0.630		0.300		0.300		
49	Detritus (KC)						0.630				0.300	
50	Detritus (OF)											

Table 6. Fishery landings in the western North Pacific in 2013 and 1994 used in Ecopath. Values changed from the 2013 to 1994 are in italic with underline.

	Species/groups	Landing (t/km^2/year)	
		2013	1994
1	Blue whale (OYC, OF)	-	-
2	Fin whale (OYC, OF)	-	-
3	Sei whale (OYC, OF)	0.00050	-
4	Bryde's whale (OYC, OF)	0.00018	-
5	Common minke whale (OYC, OF)	0.00009	*0.00003*
6	Humpback whale (OYC, OF)	-	-
7	Sperm whale (OYC, OF)	0.00002	-
8	Killer whale (all)	-	-
9	Large dolphins (all)	0.00003	*0.00004*
10	Small dolphins (all)	0.00002	*0.00003*
11	Dall's porpoise (OYC, OF)	0.00002	*0.00026*
12	Pilot whales (all)	0.00003	*0.00004*
13	Baird's beaked whale (OYC)	0.00005	*0.00005*
14	Beaked whales (all)	-	-
15	Seabirds (all)	-	-
16	Blue shark (all)	0.00052	*0.00062*
17	Mesopelagic sharks (OYC)	0.00006	*0.00010*
18	Tunas (all)	0.00247	*0.00180*
19	Skipjack (all)	0.00050	*0.00104*
20	Swordfish (all)	0.00006	0.00006
21	Miscellaneous piscivores (all)	-	-
22	Japanese sardine (all)	0.01890	*0.11300*
23	Japanese anchovy (all)	0.06270	*0.02900*
24	Pacific saury (all)	0.12080	*0.08600*
25	Chub mackerel (all)	0.04540	*0.03100*
26	Spotted mackerel (all)	0.04280	*0.01900*
27	Righteye flounders (OYC)	0.00041	*0.00044*
28	Alaska pollock (OYC)	0.08313	*0.11090*
29	Miscellaneous bottom fish (OYC)	0.00647	*0.00235*
30	Righteye flounders (KC)	0.00001	0.00001
31	Seabreams (KC)	0.00004	0.00004
32	Miscellaneous bottom fish (KC)	0.00037	0.00037
33	Mesopelagic fish (OYC)	-	-
34	Mesopelagic fish (KC)	-	-
35	Mesopelagic fish (OF)	-	-
36	Surface squids (all)	0.02516	0.02516
37	Mesopelagic squids (all)	-	-
38	Benthos (OYC)	0.00002	0.00002
39	Benthos (KC)	0.00002	0.00002
40	Krill (OYC)	0.00699	0.00699
41	Krill (OF)	-	-
42	Zooplankton (OYC)	-	-
43	Zooplankton (KC)	-	-
44	Zooplankton (OF)	-	-
45	Phytoplankton (OYC)	-	-
46	Phytoplankton (KC)	-	-
47	Phytoplankton (OF)	-	-
48	Detritus (OYC)	-	-
49	Detritus (KC)	-	-
50	Detritus (OF)	-	-

Table 7. Time series data used for time series fitting in Ecosim in the western North Pacific from 1994 to 2013.

Species/group	Time series	Year
Sei whale	Biomass Catch Fishing mortality	1994-2013 (20 years)
Bryde's whale	Biomass Catch Fishing mortality	1994-2013 (20 years)
Common minke whale	Biomass Catch Fishing mortality	1994-2013 (20 years)
Sperm whale	Biomass Catch Fishing mortality	1994-2013 (20 years)
Blue shark	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years) *Same value as in 2012 was allocated to 2013
Tunas	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years) *Same value as in 2012 was allocated to 2013
Skipjack	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years) *Same value as in 2012 was allocated to 2013
Japanese sardine	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years)
Japanese anchovy	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years)
Pacific saury	Biomass	2003-2013 (11 years)
	Catch	1994-2013 (20 years)
Chub mackerel	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years)
Spotted mackerel	Biomass	1994-2013 (20 years) *Same value as chub mackerel in 1994 was allocated to 1994
	Catch	1994-2013 (20 years)
	Fishing mortality Total mortality	1994-2013 (20 years) *Same value as chub mackerel in 1994 was allocated to 1994
Alaska pollock	Biomass Catch Fishing mortality Total mortality	1994-2013 (20 years)
Zooplankton (OYC)	Biomass	1994-2013 (20 years)
Zooplankton (KC)	Biomass	1994-2013 (20 years)
Phytoplankton (OYC)	Biomass	2003-2013 (11 years)
Phytoplankton (KC)	Biomass	2003-2013 (11 years)
Phytoplankton (OF)	Biomass	2003-2013 (11 years)

Table 8. Estimated basic parameters for Ecopath in the western North Pacific in 2013. OYC: coastal Oyasio block, KC: coastal Kuroshio block, OF: offshore block, B in habitat: biomass (t/km^2) in distributed blocks, B: biomass (t/km^2) in the entire modelled area, P/B: production/biomass ratio, Q/B: consumption/biomass ratio, EE: ecotrophic efficiency and P/Q: production/consumption ratio.

	Species/group	TL	Habitat area (fraction)	B in habitat	B	P/B	Q/B	EE	P/Q
1	Blue whale (OYC, OF)	3.222	0.950	0.022	0.021	0.040	4.220	0.010	0.009
2	Fin whale (OYC, OF)	3.285	0.950	0.053	0.050	0.052	4.548	0.003	0.011
3	Sei whale (OYC, OF)	3.742	0.950	0.034	0.032	0.099	4.384	0.159	0.023
4	Bryde's whale (OYC, OF)	3.920	0.950	0.035	0.033	0.087	7.372	0.065	0.012
5	Common minke whale (OYC, OF)	4.106	0.950	0.006	0.006	0.120	4.581	0.144	0.026
6	Humpback whale (OYC, OF)	3.558	0.950	0.009	0.009	0.072	4.634	0.014	0.016
7	Sperm whale (OYC, OF)	4.464	0.950	0.160	0.152	0.061	8.696	0.003	0.007
8	Killer whale (all)	4.395	1.000	0.002	0.002	0.100	4.381	0.000	0.023
9	Large dolphins (all)	4.389	1.000	0.003	0.003	0.120	7.778	0.108	0.015
10	Small dolphins (all)	4.347	1.000	0.025	0.025	0.143	10.777	0.008	0.013
11	Dall's porpoise (OYC, OF)	4.183	1.000	0.002	0.002	0.138	11.492	0.104	0.012
12	Pilot whales (all)	4.464	0.950	0.002	0.002	0.147	14.287	0.139	0.010
13	Baird's beaked whale (OYC)	4.633	0.050	0.049	0.002	0.105	4.872	0.228	0.022
14	Beaked whales (all)	4.368	1.000	0.004	0.004	0.100	7.855	0.022	0.013
15	Seabirds (all)	4.106	1.000	0.003	0.003	0.120	36.667	0.000	0.003
16	Blue shark (all)	4.292	1.000	0.089	0.089	0.464	1.325	0.013	0.350
17	Mesopelagic sharks (OYC)	4.445	0.050	0.107	0.005	0.330	2.900	0.039	0.114
18	Tunas (all)	4.426	1.000	0.036	0.036	0.326	6.754	0.327	0.048
19	Skipjack (all)	4.221	1.000	0.027	0.027	0.458	16.200	0.134	0.028
20	Swordfish (all)	4.259	1.000	0.001	0.001	0.490	2.500	0.301	0.196
21	Miscellaneous piscivores (all)	3.945	1.000	0.046	0.046	2.250	7.700	0.950	0.292
22	Japanese sardine (all)	2.560	1.000	0.446	0.446	0.517	2.585	0.454	0.200
23	Japanese anchovy (all)	3.111	1.000	1.156	1.156	2.180	10.900	0.733	0.200
24	Pacific saury (all)	3.133	1.000	0.851	0.851	1.523	7.615	0.169	0.200
25	Chub mackerel (all)	3.418	1.000	1.240	1.240	0.513	2.565	0.202	0.200
26	Spotted mackerel (all)	3.429	1.000	1.009	1.009	0.486	2.430	0.256	0.200
27	Righteye flounders (OYC)	3.388	0.050	0.946	0.047	0.446	2.893	0.576	0.154
28	Alaska pollock (OYC)	3.594	0.050	4.889	0.244	0.840	2.212	0.491	0.380
29	Miscellaneous bottom fish (OYC)	3.640	0.050	14.138	0.707	0.393	3.182	0.653	0.124
30	Righteye flounders (KC)	3.291	0.050	0.001	0.000	0.446	2.893	0.614	0.154
31	Seabreams (KC)	3.232	0.050	0.003	0.000	0.490	2.450	0.592	0.200
32	Miscellaneous bottom fish (KC)	3.565	0.050	0.025	0.001	0.346	2.832	0.865	0.122
33	Mesopelagic fish (OYC)	3.216	0.050	11.423	0.571	1.500	6.000	0.900	0.250
34	Mesopelagic fish (KC)	3.161	0.050	3.009	0.150	1.500	6.000	0.900	0.250
35	Mesopelagic fish (OF)	3.144	0.900	2.935	2.642	1.500	6.000	0.900	0.250
36	Surface squids (all)	3.525	1.000	0.042	0.042	2.555	7.300	0.950	0.350
37	Mesopelagic squids (all)	3.470	1.000	0.846	0.846	2.979	13.641	0.938	0.218
38	Benthos (OYC)	2.310	0.050	64.534	3.227	3.030	10.102	0.706	0.300
39	Benthos (KC)	2.310	0.050	4.181	0.209	2.530	8.430	0.915	0.300
40	Krill (OYC)	2.222	0.050	114.489	5.724	2.555	12.045	0.189	0.212
41	Krill (OF)	2.222	0.900	23.392	21.053	2.555	12.045	0.286	0.212
42	Zooplankton (OYC)	2.111	0.050	29.730	1.487	23.160	45.350	0.751	0.511
43	Zooplankton (KC)	2.111	0.050	8.067	0.403	23.160	45.350	0.398	0.511
44	Zooplankton (OF)	2.111	0.900	11.643	10.479	23.160	45.350	0.529	0.511
45	Phytoplankton (OYC)	1.000	0.050	13.555	0.678	153.776	0.000	0.758	
46	Phytoplankton (KC)	1.000	0.050	10.012	0.501	128.274	0.000	0.177	
47	Phytoplankton (OF)	1.000	0.900	9.036	8.132	153.776	0.000	0.330	
48	Detritus (OYC)	1.000	0.050	47.911	2.396			0.728	
49	Detritus (KC)	1.000	0.050	30.184	1.509			0.104	
50	Detritus (OF)	1.000	0.900	47.499	42.749			0.190	

Table 9. Estimated basic parameters for Ecopath in the western North Pacific in 1994. OYC: coastal Oyasio block, KC: coastal Kuroshio block, OF: offshore block, B in habitat: biomass (t/km2) in distributed blocks, B: biomass (t/km2) in the entire modelled area, P/B: production/biomass ratio, Q/B: consumption/biomass ratio, EE: ecotrophic efficiency and P/Q: production/consumption ratio.

	Species/group	TL	Habitat area (fraction)	B in habitat	B	P/B	Q/B	EE	P/Q
1	Blue whale (OYC, OF)	3.222	0.950	0.022	0.021	0.040	4.220	0.010	0.009
2	Fin whale (OYC, OF)	3.285	0.950	0.053	0.050	0.052	4.548	0.003	0.011
3	Sei whale (OYC, OF)	3.742	0.950	0.024	0.023	0.099	4.384	0.004	0.023
4	Bryde's whale (OYC, OF)	3.920	0.950	0.038	0.036	0.087	7.372	0.003	0.012
5	Common minke whale (OYC, OF)	4.106	0.950	0.006	0.006	0.120	4.581	0.057	0.026
6	Humpback whale (OYC, OF)	3.558	0.950	0.009	0.009	0.072	4.634	0.014	0.016
7	Sperm whale (OYC, OF)	4.464	0.950	0.136	0.129	0.061	8.696	0.001	0.007
8	Killer whale (all)	4.395	1.000	0.002	0.002	0.100	4.381	0.000	0.023
9	Large dolphins (all)	4.389	1.000	0.003	0.003	0.120	7.778	0.135	0.015
10	Small dolphins (all)	4.347	1.000	0.025	0.025	0.143	10.777	0.011	0.013
11	Dall's porpoise (OYC, OF)	4.183	1.000	0.002	0.002	0.138	11.492	0.974	0.012
12	Pilot whales (all)	4.464	0.950	0.002	0.002	0.147	14.287	0.175	0.010
13	Baird's beaked whale (OYC)	4.633	0.050	0.049	0.002	0.105	4.872	0.228	0.022
14	Beaked whales (all)	4.368	1.000	0.004	0.004	0.100	7.855	0.022	0.013
15	Seabirds (all)	4.106	1.000	0.003	0.003	0.120	36.667	0.000	0.003
16	Blue shark (all)	4.292	1.000	0.077	0.077	0.727	1.325	0.011	0.549
17	Mesopelagic sharks (OYC)	4.445	0.050	0.107	0.005	0.330	2.900	0.062	0.114
18	Tunas (all)	4.426	1.000	0.051	0.051	0.299	6.754	0.240	0.044
19	Skipjack (all)	4.221	1.000	0.037	0.037	0.468	16.200	0.150	0.029
20	Swordfish (all)	4.259	1.000	0.001	0.001	0.490	2.500	0.301	0.196
21	Miscellaneous piscivores (all)	3.945	1.000	0.064	0.064	2.250	7.700	0.950	0.292
22	Japanese sardine (all)	2.560	1.000	1.276	1.276	0.613	3.065	0.217	0.200
23	Japanese anchovy (all)	3.111	1.000	0.920	0.920	2.019	10.095	0.587	0.200
24	Pacific saury (all)	3.133	1.000	0.851	0.851	1.523	7.615	0.158	0.200
25	Chub mackerel (all)	3.418	1.000	0.494	0.494	0.497	2.485	0.542	0.200
26	Spotted mackerel (all)	3.429	1.000	0.494	0.494	0.497	2.485	0.493	0.200
27	Righteye flounders (OYC)	3.388	0.050	0.946	0.047	0.446	2.893	0.578	0.154
28	Alaska pollock (OYC)	3.594	0.050	5.211	0.261	0.840	2.212	0.588	0.380
29	Miscellaneous bottom fish (OYC)	3.640	0.050	14.138	0.707	0.393	3.182	0.636	0.124
30	Righteye flounders (KC)	3.291	0.050	0.001	0.000	0.446	2.893	0.614	0.154
31	Seabreams (KC)	3.232	0.050	0.003	0.000	0.490	2.450	0.592	0.200
32	Miscellaneous bottom fish (KC)	3.565	0.050	0.025	0.001	0.346	2.832	0.865	0.122
33	Mesopelagic fish (OYC)	3.216	0.050	11.413	0.571	1.500	6.000	0.900	0.250
34	Mesopelagic fish (KC)	3.161	0.050	2.897	0.145	1.500	6.000	0.900	0.250
35	Mesopelagic fish (OF)	3.144	0.900	2.822	2.539	1.500	6.000	0.900	0.250
36	Surface squids (all)	3.525	1.000	0.039	0.039	2.555	7.300	0.950	0.350
37	Mesopelagic squids (all)	3.470	1.000	0.790	0.790	2.979	13.641	0.938	0.218
38	Benthos (OYC)	2.310	0.050	64.534	3.227	3.030	10.102	0.706	0.300
39	Benthos (KC)	2.310	0.050	4.030	0.201	2.530	8.430	0.915	0.300
40	Krill (OYC)	2.222	0.050	114.489	5.724	2.555	12.045	0.182	0.212
41	Krill (OF)	2.222	0.900	23.392	21.053	2.555	12.045	0.240	0.212
42	Zooplankton (OYC)	2.111	0.050	23.450	1.173	23.160	45.350	0.896	0.511
43	Zooplankton (KC)	2.111	0.050	8.487	0.424	23.160	45.350	0.374	0.511
44	Zooplankton (OF)	2.111	0.900	11.643	10.479	23.160	45.350	0.518	0.511
45	Phytoplankton (OYC)	1.000	0.050	13.555	0.678	153.776	0.000	0.677	
46	Phytoplankton (KC)	1.000	0.050	10.012	0.501	128.274	0.000	0.186	
47	Phytoplankton (OF)	1.000	0.900	9.036	8.132	153.776	0.000	0.331	
48	Detritus (OYC)	1.000	0.050	47.911	2.396			0.677	
49	Detritus (KC)	1.000	0.050	30.184	1.509			0.108	
50	Detritus (OF)	1.000	0.900	47.499	42.749			0.190	

Table 10. Results of time series fitting using Ecosim in the western North Pacific from 1994 to 2013. Number of predator/prey blocks

Search category	Assignment of time series data	Model number	Number of predator/prey blocks	SS	AIC
Base case (v=2), time series loaded	All relative biomass and catch time series are used as reference	1	-	93.4	-
	All but biomass of anchovy is used as forced time series	2	-	74.8	-
	All but biomass of anchovy and sardine is used as forced time series	3	-	47.6	-
	All but biomasses of anchovy, sardine and chub mackerel are used as forced time series	4	-	36.8	-
	All but biomasses of anchovy, sardine and, chub and spotted mackerel are used as forced time series	5	-	34.1	-
Search by predator/prey	All relative biomass and catch are used as reference	6	5	66.4	438
		7	10	63.3	443.1
		8	20	63.0	462.6
	All but biomass of anchovy is used as forced time series	9	5	64.9	435.7
		10	10	61.8	440.6
		11	20	60.9	459.1
	All but biomass of anchovy and sardine is used as forced time series	12	5	37.5	379.8
		13	10	37.4	389.5
		14	20	36.5	407
	All but biomasses of anchovy, sardine and chub mackerel are used as forced time series	15	5	30.6	359
		16	10	29.1	363.9
		17	20	27.1	376.6
	All but biomasses of anchovy, sardine and, chub and spotted mackerel are used as forced time series	18	5	27.4	347.8
		19	10	22.9	339.2
		20	20	22.0	355.2

Table 11. Estimated vulnerability parameters (*v*) based on model number 19 in Table 10.

Predator / prey	Estimated *v*
Blue shark (all) / Japanese anchovy (all)	>10
Blue shark (all) / Mesopelagic squids (all)	1
Skipjack (all) / Mesopelagic squids (all)	1
Japanese anchovy (all) / Zooplankton (OF)	>10
Chub mackerel (all) / Japanese anchovy (all)	>10
Chub mackerel (all) / Krill (OF)	>10
Chub mackerel (all) / Zooplankton (OF)	>10
Spotted mackerel (all) / Japanese anchovy (all)	1
Spotted mackerel (all) / Krill (OF)	>10
Spotted mackerel (all) / Zooplankton (OF)	>10

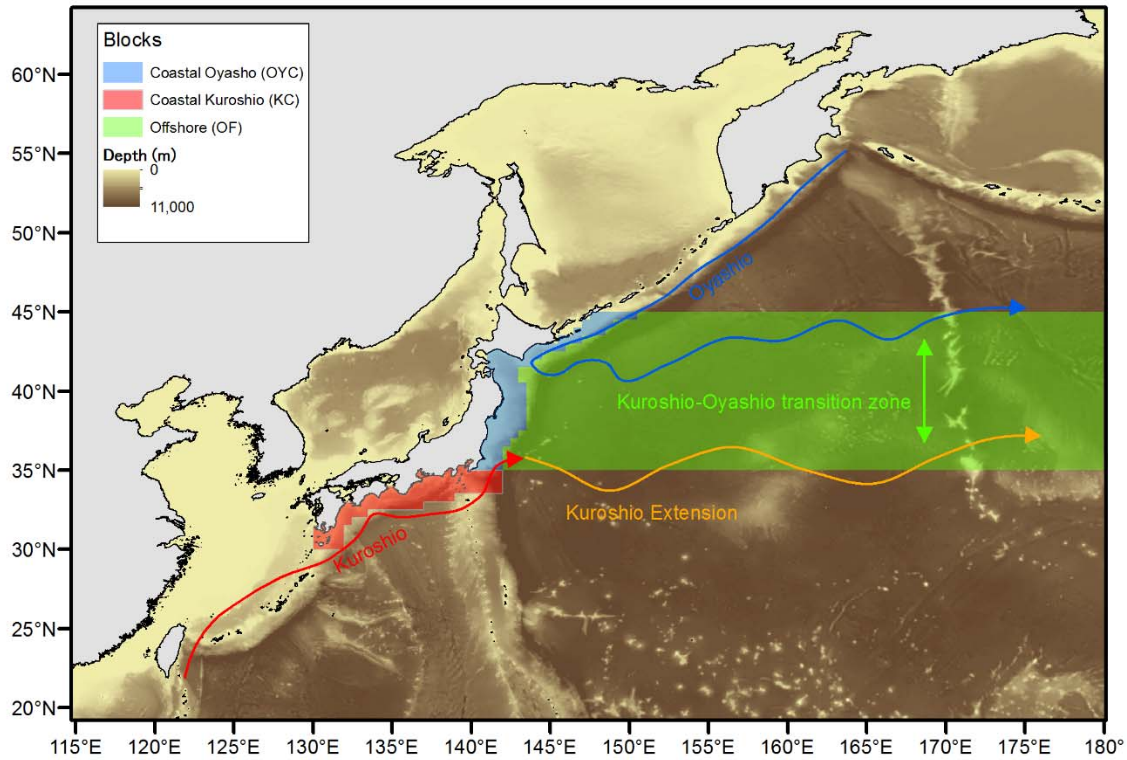

Fig. 1. Schematic map of Ecopath with Ecosim modelling area in the western North Pacific.

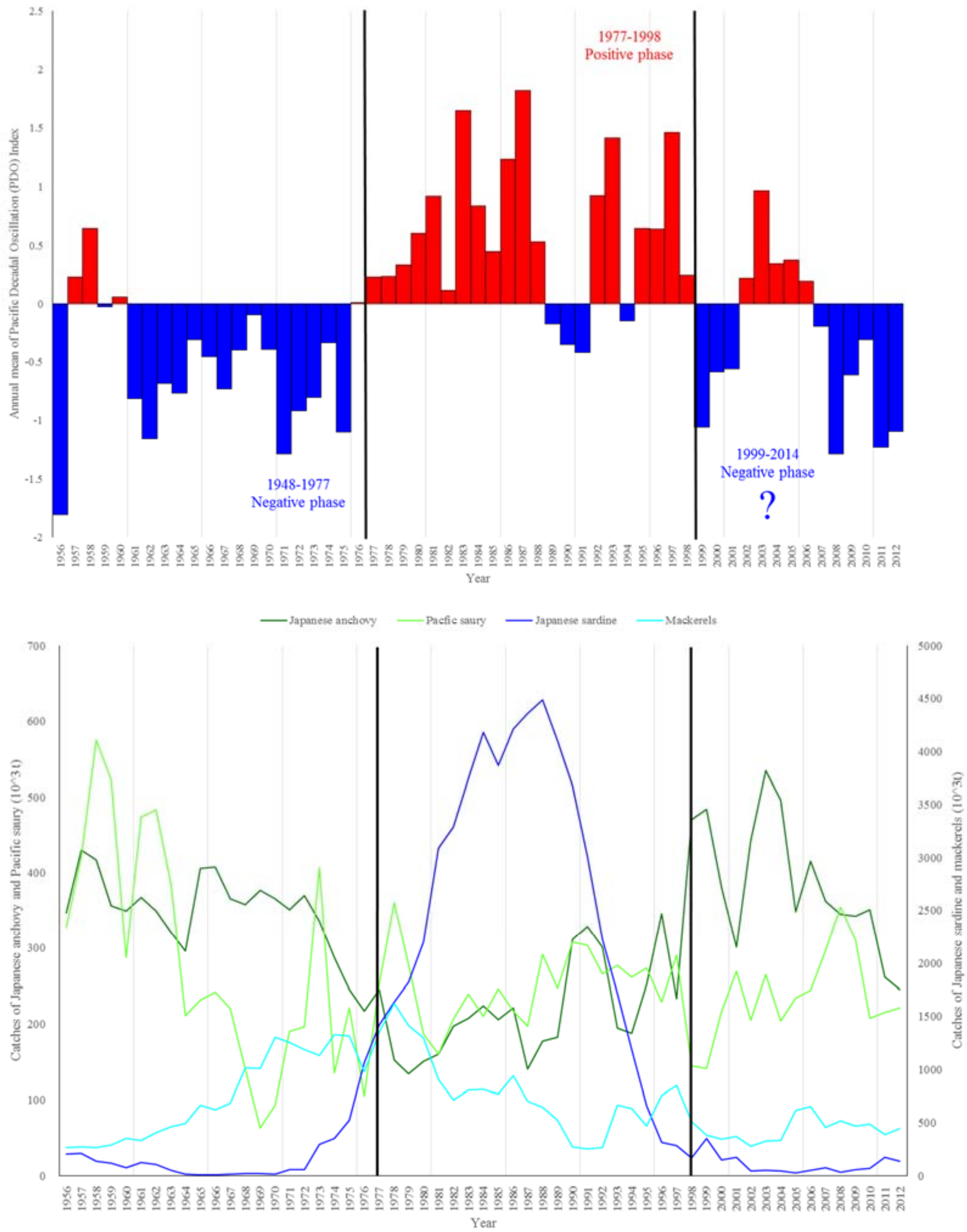

Fig. 2. Annual mean of Pacific Decadal Oscillation (PDO) index from 1956 to 2012 (top) and landing of small pelagic fish (Japanese sardine, Japanese anchovy, mackerels and Pacific saury) from 1956 to 2012 (bottom). Monthly PDO data available from "http://research.jisao.washington.edu/pdo/" (accessed on 6 October 2015) are used to calculate annual mean. Landing data are extracted from "Statistics of Agriculture, Forestry and Fisheries" (available http://www.e-stat.go.jp; accessed on 28 November 2015). Climate regime shift indicated in several published papers are also shown in the figure as black lines. Sea surface temperature in the eastern Pacific is high in the positive phase while that in the western Pacific is low. Vice versa is true for the negative phase. Scales of landing are different from Japanese anchovy and Pacific saury (left axis) and Japanese sardine and mackerels (right axis).

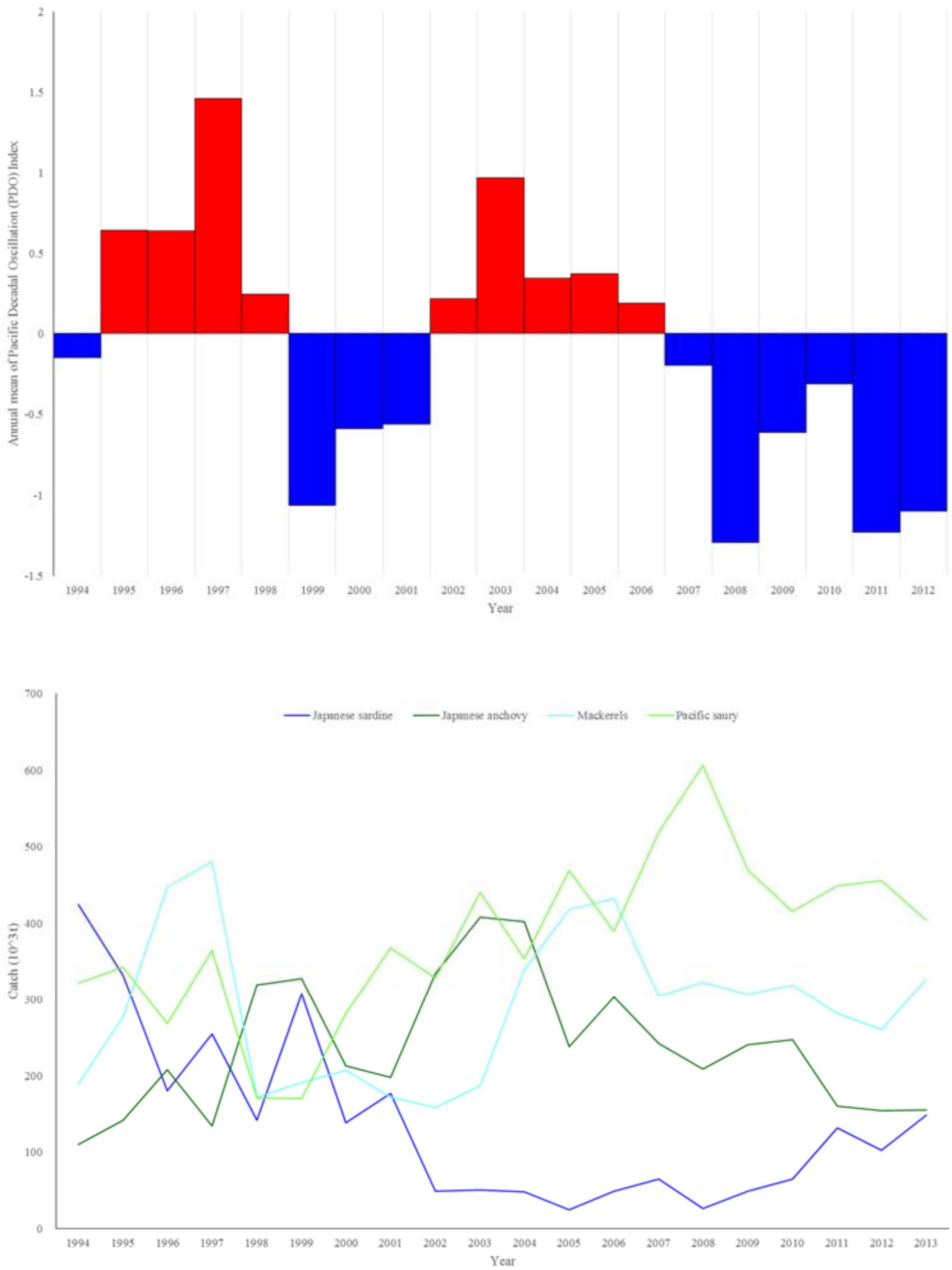

Fig. 3. Annual mean of Pacific Decadal Oscillation (PDO) index from 1994 to 2013 (top) and landing of small pelagic fish (Japanese sardine, Japanese anchovy, mackerels and Pacific saury) from 1994 to 2013 (bottom). Monthly PDO data available from "http://research.jisao.washington.edu/pdo/" (accessed on 6 October 2015) are used to calculate annual mean. Landing data in the stock assessment report (Fisheries Agency and Fisheries Research Agency of Japan, 2015) are used.

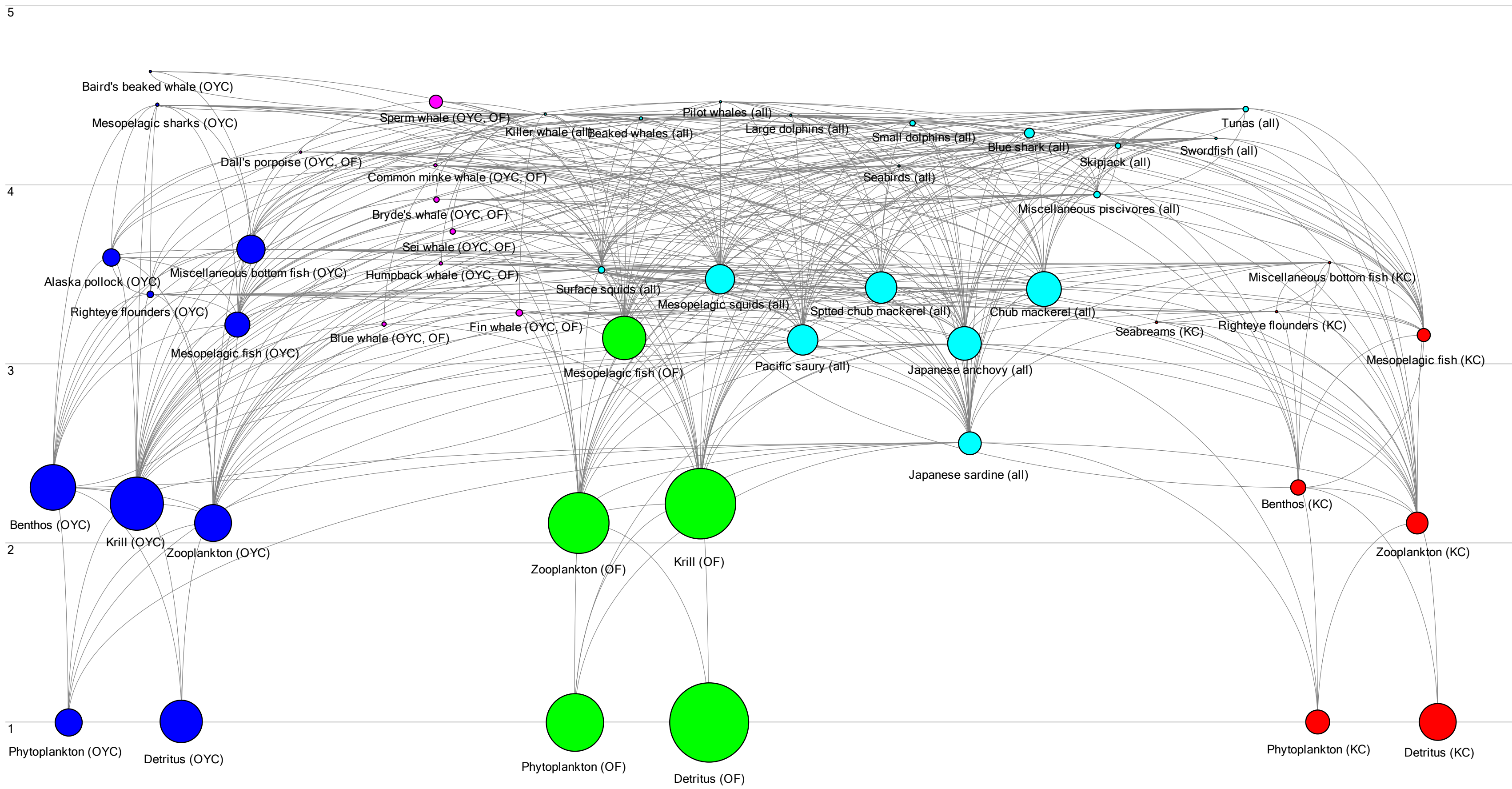

Fig. 4. Food web of the western North Pacific in 2013 estimated by Ecopath. Numbers (1-5) in the left indicate trophic levels. Size of bubbles represents biomass of each species/group. Colours of bubble indicate allocation of spatial blocks for species/groups. Blue: coastal Oyashio block, red: coastal Kuroshio block, light green: offshore block (OF), purple: OYC and OF blocks and sky blue: all blocks.

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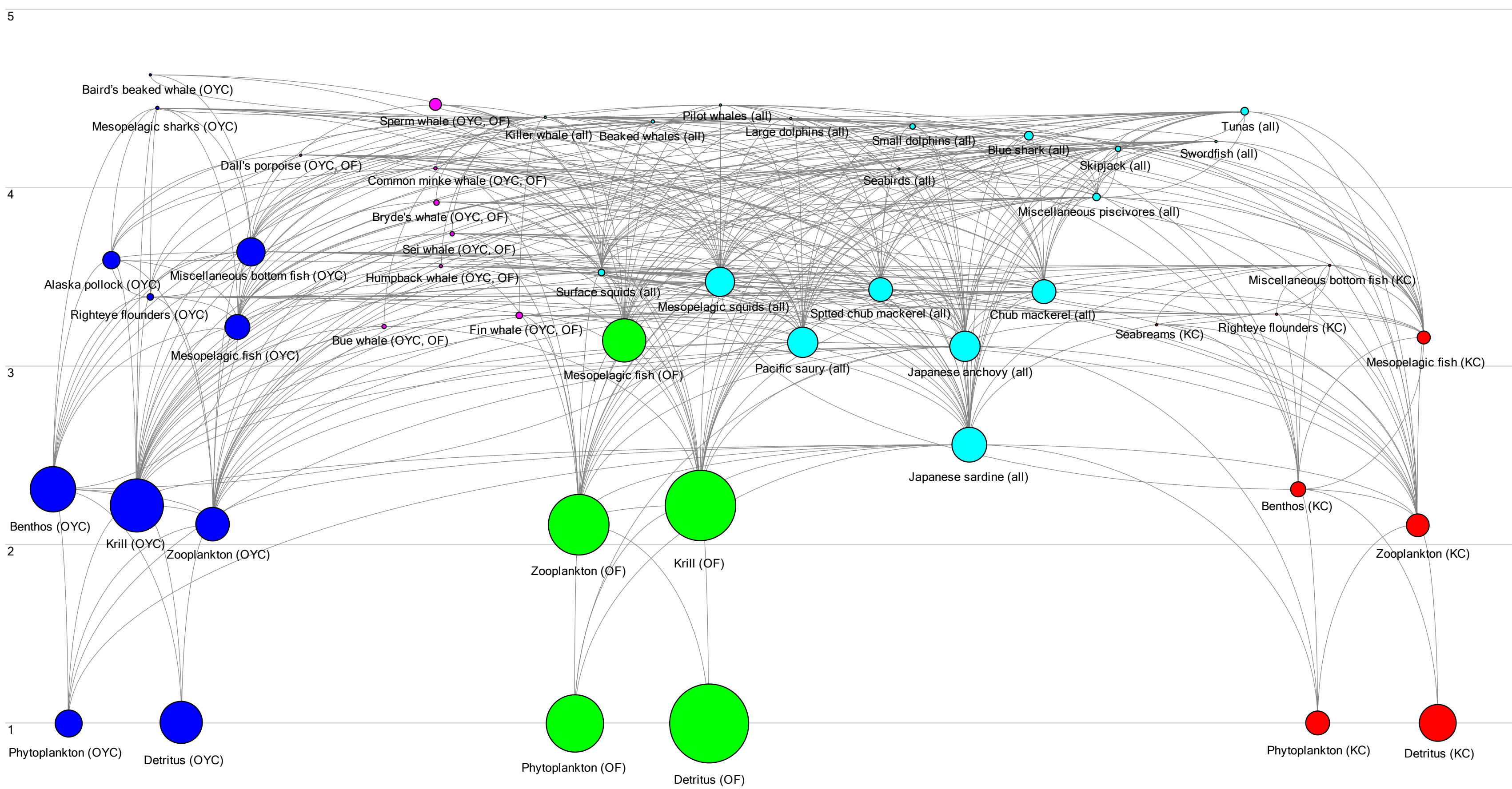

Fig. 5. Food web of the western North Pacific in 1994 estimated by Ecopath. Numbers (1-5) in the left indicate trophic levels. Size of bubbles represents biomass of each species/group. Colours of bubble indicate allocation of spatial blocks for species/groups. Blue: coastal Oyashio block, red: coastal Kuroshio block, light green: offshore block (OF), purple: OYC and OF blocks and sky blue: all blocks.

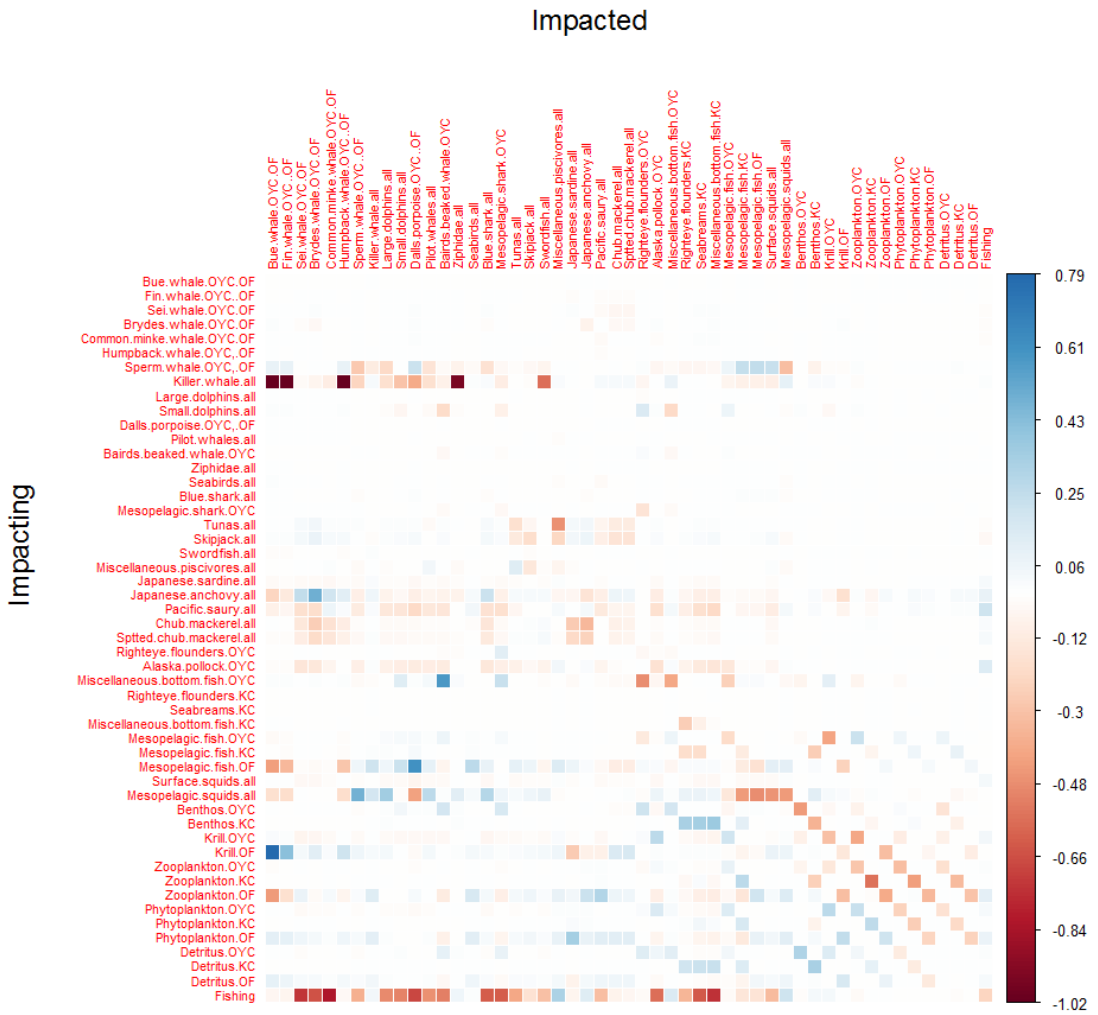

Fig. 6. Mixed trophic impact (MTI) relationships between species/groups in the western North Pacific in 2013. Values represents by colours indicated positive or negative impact by impacting species/groups on impacted species/groups.

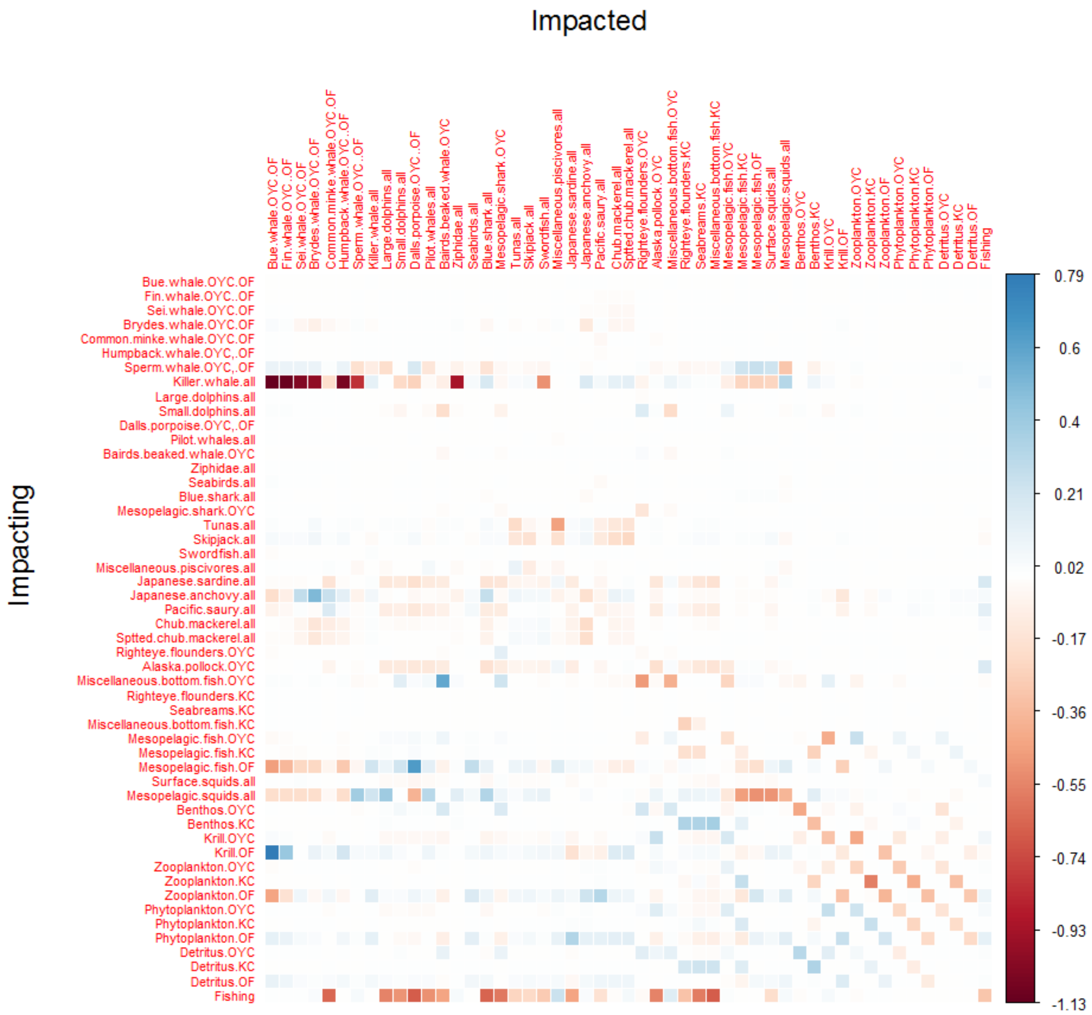

Fig. 7. Mixed trophic impact (MTI) relationships between species/groups in the western North Pacific in 1994. Values represents by colours indicated positive or negative impact by impacting species/groups on impacted species/groups.

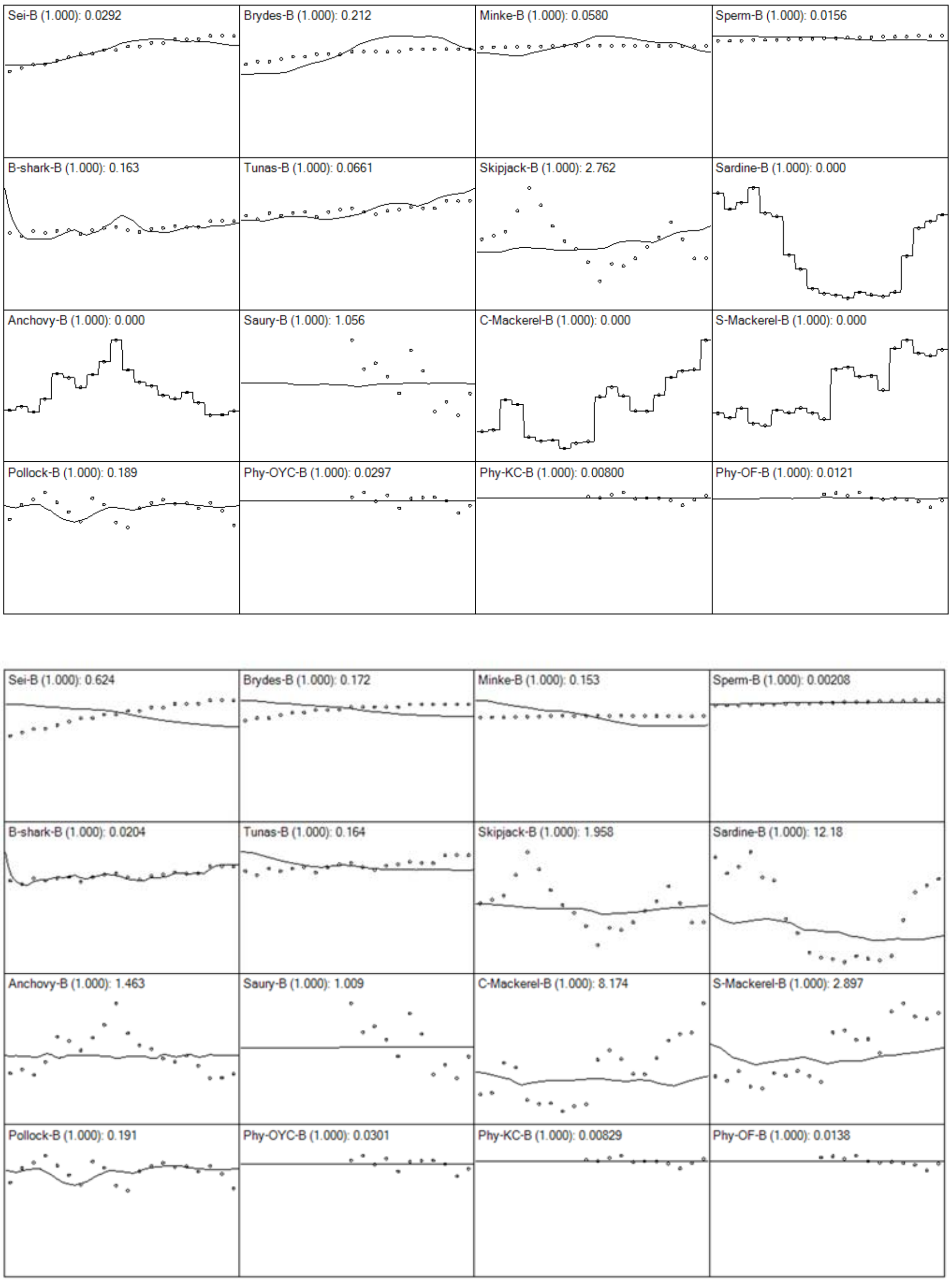

Fig. 8. Input time series data (circles) and estimated time series (lines) for biomass (B) by Ecosim in the western North Pacific from 1994 to 2013. Results of models with (model number 19 in Table 10; top) or without (model number 7 in Table 10; bottom) forcing on biomass time series of forage fish are shown.

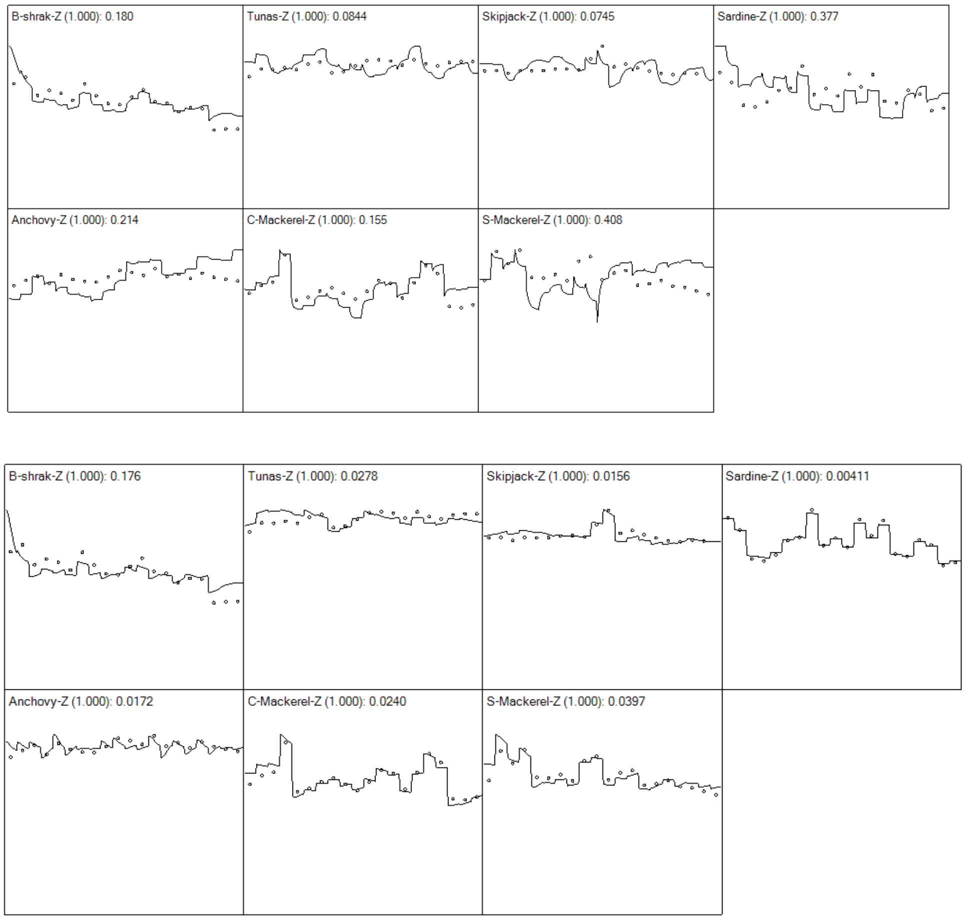

Fig. 9. Input time series data (circles) and estimated time series (lines) for total mortality (Z) by Ecosim in the western North Pacific from 1994 to 2013. Results of models with (model number 19 in Table 10; top) or without (model number 7 in Table 10; bottom) forcing on biomass time series of forage fish are shown.

Fig. 10.

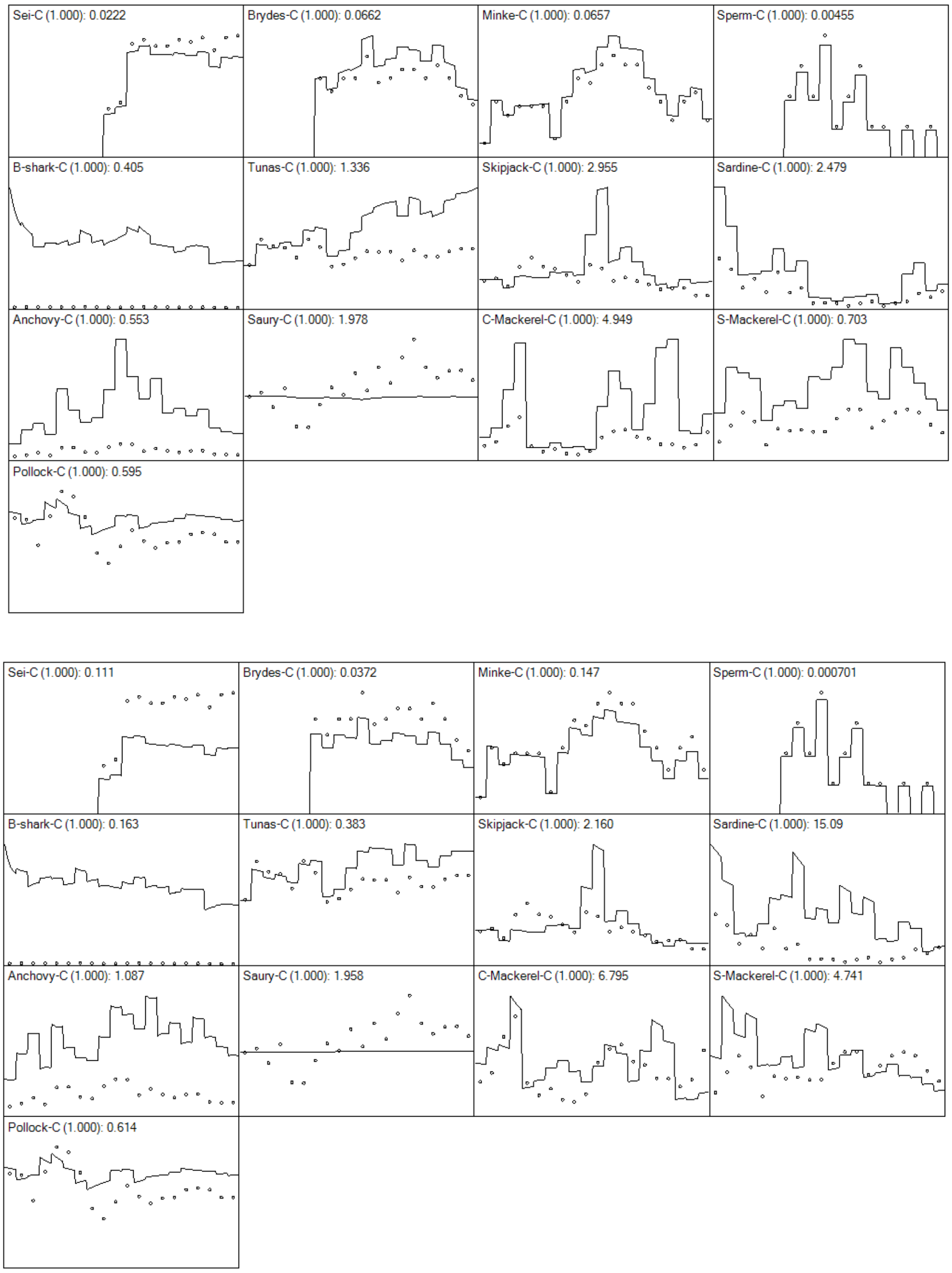

Fig. 10. Input time series data (circles) and estimated time series (lines) of catch (C) by Ecosim in the western North Pacific from 1994 to 2013. Results of models with (model number 19 in Table 10; top) or without (model number 7 in Table 10; bottom) forcing on biomass time series of forage fish are shown.

Appendix 1

Details of basic input parameters for Ecopath with Ecosim (EwE) in the western North Pacific in 2013 and 1994

This is Appendix 1 of "SC/F16/JR28. Murase, H., Tamura, T., Hakamada, T., Watari, S., Okazaki, M., Kiyofuji, H, Yonezaki, S and Kitakado, T. 2015 Ecosystem modelling in the western North Pacific from 1994 to 2013 using Ecopath with Ecosim (EwE): some preliminary results. Paper SC/F16/JR28 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished)".

1. BLUE WHALE

Species
One species, blue whale (*Balaenoptera musculus*), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC and OF.

Biomass (B)
Biomass is calculated using the latest abundance estimate (615 individuals) in JARPNII area (Hakamada and Matsuoka, 2016a: SC/F16/JR13) and mean body weight (102,737 kg) from Trites and Pauly (1998). Weighted mean (by number of month) of abundance estimates in early season (May-June) in 2011 and 2012, and late season (July-September) in 2008 is used. The same value is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.040) in the North Pacific in Table 2 of Ohsumi (1979) is used. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016:SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
It is assumed that this species feeds exclusively on krill. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

2. FIN WHALE

Species
One species, fin whale (*Balaenoptera physalus*), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC and OF.

Biomass (B)
Biomass is calculated using the latest abundance estimate (2,731 individuals) in JARPNII area (Hakamada and Matsuoka, 2016a: SC/F16/JR13) and mean body weight (55,590 kg) from Trites and Pauly (1998). Weighted mean (by number of month) of abundance estimates in early season (May-June) in 2011 and 2012, and late season (July-September) in 2008 is used. The same value is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.052) in the Northern Hemisphere in Table 2 of Ohsumi (1979) is used. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

3. SEI WHALE

Species
One species, sei whale (*Balaenoptera borealis*), is considered.

Distribution blocks

It is assumed that this species is distributed in OYC and OF.

Biomass (B)
Biomass in 2013 is calculated using the latest abundance estimate (5,185 individuals) in JARPNII area (Hakamada and Matsuoka, 2016c: SC/F16/JR12) and mean body weight (18,715 kg) in JARPNII area (Tamura *et al.*, 2016). Weighted mean (by number of month) of abundance estimates in early season (May-June), and late season (July-September) from 2008 to 2014 is used. Time series of abundance in JARPNII area from 1994 to 2013 is estimated applying Hitter-Fitter model using abundance estimates from JARPNII and POWER (Hakamada, unpublished data). One stock scenario is assumed. Biological parameters used in the model are as followed: age of maturity = 6.0 years old, natural mortality = 0.08/year, MSY level = 60% (of K). MSYR (mature) = 4% is assumed in the model. The time series estimated by Hitter-Fitter model is then scaled to size of JARPNII area. Above mentioned mean body weight is used to calculate biomass in the time series

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M = 0.08 is used assuming that the value is same as Bryde's whale (IWC, 2008). F in 2013 is calculated using JARPNII data. The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The diet compositions described in Tamura *et al.* (2016) are used but the species is allowed to feed on Japanese sardine in proportion of 0.01. The same compositions are assumed in 2013 and 1994.

Catch
There are no catch from 1994 to 2001. Catch data from JARPNII are used onward. Above mentioned mean body weight is used to calculate the catch biomass.

4. BRYDE'S WHALE

Species
One species, Bryde's whale (*Balaenoptera edeni* in the sense of IWC), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC and OF.

Biomass (B)
Biomass in 2013 is calculated using the latest abundance estimate (7,644 individuals) in JARPNII area (Hakamada and Matsuoka, 2016c: SC/F16/JR12) and mean body weight (13,078 kg) in JARPNII area (Tamura *et al.*, 2016). Weighted mean (by number of month) of abundance estimates in early season (May-June), and late season (July-September) from 2008 to 2014 is used. Time series of abundance in JARPNII area in from 1994 to 2013 is estimated applying Hitter-Fitter model using abundance estimates by Kitakado *et al.* (2008) (Hakamada, unpublished data). One stock in sub-area 1 is assumed. Biological parameters used in the model are as followed: age of maturity = 6.0 years old, natural mortality = 0.08/year, MSY level = 60% (of K). MSYR (mature) = 4% is assumed in the model. The time series estimated by Hitter-Fitter model is then scaled to size of JARPNII area. Above mentioned mean body weight is used to calculate biomass in the time series.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M = 0.08 is used (IWC, 2008). F in 2013 is calculated using JARPNII data. The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The diet compositions described in Tamura *et al.* (2016) are used but the species is allowed to feed on Japanese sardine in proportion of 0.01. The same compositions are assumed in 2013 and 1994.

Catch
There are no catch from 1994 to 1999. Catch data from JARPNII are used onward. Above mentioned mean body weight is used to calculate the catch biomass.

5. COMMON MINKE WHALE

Species
One species, common minke whale (*Balaenoptera acutorostrata*), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC and OF.

Biomass (B)

Biomass in 2013 is calculated using the latest abundance estimate (3,435 individuals) in JARPNII area (Hakamada and Matsuoka, 2016c: SC/F16/JR12) and mean body weight (4,766 kg) in JARPNII area (Tamura *et al.*, 2016). Weighted mean (by number of month) of abundance estimates in early season (May-June), and late season (July-September) from 2008 to 2014 is used. Time series of abundance in JARPNII area from 1994 to 2013 based on Hitter-Fitter model is used. The methods described in Hakamada (2009) is used. The time series of O-stock and J-stock are combined in this paper. The time series is then scalded to JARPNII area. Above mentioned mean body weight is used to calculate biomass in the time series.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)

M = 0.1 is used taking mean of M for 4 years old and 20+ years old (IWC, 2014). F in 2013 is calculated using JARPNII data. The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)

The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions

The diet compositions described in Tamura *et al.* (2016) are used but the species is allowed to feed on Japanese sardine in proportion of 0.01. The same compositions are assumed in 2013 and 1994.

Catch

Catch data from JARPN and JARPNII (1994 to 2013) are used. Above mentioned mean body weight is used to calculate the catch biomass.

6. HUMPBACK WHALE

Species

One species, humpback whale (*Megaptera novaeangliae*), is considered.

Distribution blocks

It is assumed that this species is distributed in OYC and OF.

Biomass (B)

Biomass is calculated using the latest abundance estimate (847 individuals) in JARPNII area (Hakamada and Matsuoka, 2016a: SC/F16/JR13) and mean body weight (30,408 kg) from Trites and Pauly (1998). Weighted mean (by number of month) of abundance estimates in early season (May-June) in 2011 and 2012, and late season (July-September) in 2008 is used. The same value is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)

Mean of M1 and M2 (0.072) in the Northern Pacific in Table 2 of Ohsumi (1979) is used. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)

The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions

The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

7. SPERM WHALE

Species
One species, sperm whale (*Physeter macrocephalus*), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC and OF.

Biomass (B)
Biomass is calculated using the latest abundance estimate (14,088 individuals) in JARPNII area (Hakamada and Matsuoka, 2016b: SC/F16/JR14) and mean body weight (30,408 kg) from Trites and Pauly (1998). Weighted mean (by number of month) of abundance estimates in early season (May-June) in 2011 and 2012, and late season (July-September) in 2008 is used. Time series of abundance from 1994 to 2013 is estimated using a method described in Whitehead (2002). Abundance estimate described in Kato and Miyashita (1998) and catch data within the estimated area are used in the method. In contrast to the original method, data from other regions (e.g. Atlantic) are not considered in this paper. The time series is then scaled to JARPNII area. Above mentioned mean body weight is used to calculate the biomass in the time series.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M=0.061 is used taking mean of female and male (IWC, 1983). F in 2013 is calculated based on JARPNII data. The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The methods described in Tamura *et al.* (2016: SC/F16/JR15) are adopted. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There are no catch from 1994 to 1999. Catch data from JARPNII are used onward. Above mentioned mean body weight is used to calculate the biomass

8. KILLER WHALE

Species
One species, killer whale (*Orcinus orca*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight (2,280 kg) from Trites and Pauly (1998) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M=0.1 is assumed for this species as no information is available. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994. It is assumed that this species

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this species stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. However, diet compositions for "high vertebrates" are reduced accordingly to balance Ecopath. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

9. LARGE DOLPHINS

Species
Bottlenose (*Tursiops truncates*) and Risso's (*Grampus griseus*) dolphins are included in the group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight from Trites and Pauly (1998) weighted by biomass of each species (216 kg) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.133) for bottlenose dolphin in the North Pacific in Table 2 of Ohsumi (1979) is used for this group as natural mortality for Risso's dolphin has not been documented. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this group stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions described in Pauly *et al.* (1998) are used as the basic information. The mean of compositions is calculated taking biomass as weight. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a) while Catch in 1994 is derived from Kasuya (2011).

10. SMALL DOLPHINS

Species
Rough-toothed (*Steno bredanensis),* spinner (*Stenella longirostris*), spotted (*Stenella attenuata*), striped (*Stenella coeruleoalba)*, *Delphinus* spp. and Pacific white-sided (*Lagenorhynchus obliquidens*) dolphins are included in this group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight from Trites and Pauly (1998) weighted by biomass of each species (94 kg) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of M1 and M2 (0.137) for spinner, spotted and striped dolphins in the North Pacific in Table 2 of Ohsumi (1979) is used for this group. Natural mortality for other species has not been documented. Mean F (weighted by biomass) is estimated using biomass and catch data. Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a). The same value is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this group stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
Mean standardized diet compositions (weighted by biomass) for this group is calculated using data in Pauly *et al.* (1998). It is used as the basic information. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a) while Catch in 1994 is derived from Kasuya (2011).

11. DALL'S PORPOISE

Species
One species, Dall's porpoise (*Phocoenoides dalli*), is considered. Types (Dalli- and Truei- types) are treated collectively.

Distribution blocks
It is assumed that this species is distributed in OYC and OF blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight (61 kg) from Trites and Pauly (1998) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.138) for Dall's porpoise in the North Pacific in Table 2 of Ohsumi (1979) is used. F in 2013 is calculated using biomass and catch data. Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a). The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this species stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a) while Catch in 1994 is derived from Kasuya (2011).

12. PILOT WHALES

Species
False killer (*Pseudorca crassidens)*, short-finned pilot (*Globicephala macrorhynchus)* and melon-headed (*Peponocephala electra)* whales are included in this group.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight from Trites and Pauly (1998) weighted by biomass of each species (616 kg) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.111) for pilot whale in the North Atlantic in Table 2 of Ohsumi (1979) is used. F in 2013 is calculated using biomass and catch data. Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a). The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this species stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same compositions are assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. The mean of compositions is calculated taking biomass as weight. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a) while Catch in 1994 is derived from Kasuya (2011).

13. BAIRD'S BEAKED WHALE

Species
One species, Baird's beaked whale (*Berardius bairdii*), is considered.

Distribution blocks
It is assumed that this species is distributed in OYC block.

Biomass (B)
Abundance estimated by Okamura *et al.* (2012) is used. Mean body weight (3136 kg) from Trites and Pauly (1998) is multiplied by abundance to calculate biomass. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean of M1 and M2 (0.083) for Baird's beaked whale in the North Pacific in Table 2 of Ohsumi (1979) is used. F in 2013 is calculated using biomass and catch data. Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a). The same P/B is assumed in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this species stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions for this species described in Pauly *et al.* (1998) are used as the basic information. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 is derived from Fisheries Agency and Fisheries Research Agency of Japan (2015a) while Catch in 1994 is derived from Kasuya (2011).

14. BEAKED WHALES

Species
Species belonging to Ziphiidae (beaked whales, apart from Baird's beaked whale) are included in the group.

Distribution blocks

It is assumed that this group is distributed in all blocks.

Biomass (B)
Abundance within the EwE modelling area is estimated by using a generalized additive model (GAM) based density surface model (Kanaji, unpublished data). Sighting data from 1983 and 2006 collected by National Research Institute of Far Seas Fisheries are used in the analysis. Mean body weight (216 kg) of

following species from Trites and Pauly (1998) is multiplied by abundance to calculate biomass: Longman's (*Indopacetus pacificus*), Blainville's (*Mesoplodon densirostris*), Stejneger's (*Mesoplodon stejnegeri*), Ginkgo-toothed (*Mesoplodon gingkodens*), . Hubb's (*Mesoplodon carlhubbsi*) and Cuvier's (*Ziphius cavirostris*) beaked whales. The same biomass is assumed in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M=0.1 is assumed for this species as no information is available. There is no fishing mortality between 1994 and 2013. The same value is assumed in 2013 and 1994. It is assumed that this species.

Consumption/biomass ratio (Q/B)
The calculation method described in Tamura *et al.* (2016: SC/F16/JR15) are adopted but it is assumed that this species stays in the modelled area for 180 days. For this paper, mean of standard metabolic rate (SMRs) calculated by using 3 equations (Boyd, 2002; Perez *et al.*, 1990; Sigurjonsson and Vikingsson, 1997) is calculated. The same value is assumed in 2013 and 1994.

Diet compositions
The standardized diet compositions described in Pauly *et al.* (1998) are used as the basic information. The mean of compositions of above mentioned species is calculated. Specific diet compositions based on the information are then assigned based on published qualitative information (Ohizumi, 2008) and the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

15. SEABIRDS

Species
Black-footed (*Phoebastria nigripes*) and Lysan (*Phoebastria immutabilis*) Albatross, sooty (*Puffinus griseus*), short-tailed (*Puffinus tenuirostris*) and Buller's (*Bulweria bulwerii*) and flesh-footed (*Puffinus carneipes*) shearwaters are included in this species.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Biomass of these species in Hunt *et al.* (2000) is used.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value in the Central Gulf of Alaska Ecopath model described in Ruzicka *et al.* (2013) is used as no such a value is available in our modelled area.

Consumption/biomass ratio (Q/B)
Consumption of these species in Hunt *et al.* (2000) is divided by the biomass.

Diet compositions
Mean (weighted by biomass) of standardized diet compositions of these species in Hunt *et al.* (2000) is used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
There is no catch from 1994 to 2013.

16. BLUE SHARK

Species
One species, blue shark (*Prionace glauca*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1994 to 2012 reported in ISC (2014c) is scaled to our modelled area.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Natural mortality rate and fishing mortality rate reported in ISC (2014c) are used.

Consumption/biomass ratio (Q/B)
The ratio reported in Cox *et al.* (2002) is used but it is assumed that this species stays in the modelled area for 180 days.

Diet compositions
Unpublished diet compositions (Ohshimo, unpublished data) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data used in ISC (2014c) is scaled to our modelled area.

17. MESOPELAGIC SHARKS

Species
Mesopelagic sharks distributed in OYC block such as spiny dogfish (*Squalus suckleyi*) are assumed in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of spiny dogfish in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

18. TUNAS

Species
Bigeye (*Thunnus obesus*), yellowfin (*Thunnus albacares*) and bluefin (*Thunnus orientalis*) tunas and albacore (*Thunnus alalunga*) are included in the group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Biomass of bigeye, yellowfin and bluefin tunas and albacore from 1994 to 2012 reported in the references are scaled to our modelling area (Davies *et al.*, 2014; Harley *et al.*, 2014; ISC, 2014b; d).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values from 1994 to 2013 reported in the references is used (Davies *et al.*, 2014; Harley *et al.*, 2014; ISC, 2014b; d)

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values in the references (Cox *et al.*, 2002; Essington, 2003; Olson and Watters, 2003) is used but it is assumed that these species stay in the modelled area for 180 days.

Diet compositions
Mean (weighted by biomass) diet compositions in Olson and Watters (2003) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data used in the references (Davies *et al.*, 2014; Harley *et al.*, 2014; ISC, 2014b; d) are scaled to our modelled area.

19. SKIPJACK

Species
One species, skipjack (*Katsuwonus pelamis*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1994 to 2012 reported in Rice *et al.* (2014) is scaled to our modelling area.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Rice *et al.* (2014) is used.

Consumption/biomass ratio (Q/B)
The value reported in Essington (2003) is used but it is assumed that this species stays in the modelled area for 180 days.

Diet compositions
Diet compositions in Olson and Watters (2003) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catches used in Rice *et al.* (2014) are scaled to our modelled area.

20. SWORDFISH

Species
One species, swordfish (*Xiphias gladius*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 2013 reported in ISC (2014a) is scaled to our modelled area. The same value is used in 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value in 2013 reported in ISC (2014a) is used. The same value is used in 1994.

Consumption/biomass ratio (Q/B)
The value reported in Cox *et al.* (2002) is used but it is assumed that this species stays in the modelled area for 180 days.

Diet compositions
Diet compositions in Olson and Watters (2003) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch in 2013 used in ISC (2014a) are scaled to our modelled area. The same value is used in 1994.

21. MISCELLANEOUS PISCIVORES

Species
Though no specific target species is considered, various piscivores such as dolphinfish (*Coryphaena hippurus*) and Pacific pomfret (*Brama japonica*) are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) for this group in Olson and Watters (2003) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Olson and Watters (2003) is used. The same value is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Olson and Watters (2003) is used. The same value is used in 2013 and 1994.

Diet compositions
Diet compositions are assigned based on the authors' expert guess. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

22. JAPANESE SARDINE

Species
One species, Japanese sardine (*Sardinops melanostictus*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1994 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is increased as the same factor applied to Japanese anchovy (See below).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used but F is scaled down based on the factor mentioned above..

Consumption/biomass ratio (Q/B)
It is assumed that production and consumption ratio (P/Q) for this species is 0.2. Q/B is calculated in Ecopath based on other basic input parameters.

Diet compositions
Based on qualitative information in Garrido and Van der Lingen (2014), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used.

23. JAPANESE ANCHOVY

Species
One species, Japanese anchovy (*Engraulis japonicus*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1994 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is estimated by cohort analysis using commercial catch data and an egg production method using a systematic net sampling data set. The estimates of abundance and biomass are only available in the coastal waters because the cohort analysis and egg production data are restricted to those obtained near coastal waters. However, biomass estimates in offshore using echosounder data reveal that considerable number of Japanese anchovy is distributed offshore (Murase *et al.*, 2012). The biomass reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is increased as the factor of biomass reported in Murase *et al.* (2012) considering size of the modelling area. The same factor is applied to Japanese sardine and chub and spotted mackerels.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used but F is scaled down based on the factor mentioned above.

Consumption/biomass ratio (Q/B)
It is assumed that production and consumption ratio (P/Q) for this species is 0.2. Q/B is calculated in Ecopath based on other basic input parameters.

Diet compositions
Based on qualitative information in Garrido and Van der Lingen (2014), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used.

24. PACIFIC SAURY

Species
One species, Pacific saury (*Cololabis saira*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 2003 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used.

Consumption/biomass ratio (Q/B)
It is assumed that production and consumption ratio (P/Q) for this species is 0.2. Q/B is calculated in Ecopath based on other basic input parameters.

Diet compositions
Based on qualitative information in references (Hotta and Odate, 1956; Odate, 1977), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catches from 1994 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used.

25. CHUB MACKEREL

Species
One species, chub mackerel (*Scomber japonicus*), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1994 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is increased as the same factor applied to Japanese anchovy (see above).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used but F is scaled down based on the factor mentioned above..

Consumption/biomass ratio (Q/B)
It is assumed that production and consumption ratio (P/Q) for this species is 0.2. Q/B is calculated in Ecopath based on other basic input parameters.

Diet compositions
Based on information in Nakatsuka *et al.* (2010), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used.

26. SPOTTED MACKEREL

Species
One species, spotted (blue) mackerel (*Scomber australasicus*; also known as blue mackerel), is considered.

Distribution blocks
It is assumed that this species is distributed in all blocks.

Biomass (B)
Biomass from 1995 to 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is increased as the same factor applied to Japanese anchovy (See abobe).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used but F is scaled down based on the factor mentioned above..

Consumption/biomass ratio (Q/B)
It is assumed that production and consumption ratio (P/Q) for this species is 0.2. Q/B is calculated in Ecopath based on other basic input parameters.

Diet compositions
Based on information in Nakatsuka *et al.* (2010), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch data reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used.

27. RIGHTEYE FLOUNDERS IN OYC BLOCK

Species
Species belonging to Pleuronectidae (righteye flounders) distributed in OYC block are included in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
The values reported in Yonezaki *et al.* (2015) is used in 2013 and 1994. The biomass is doubled to balance Ecopath.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values reported in Yonezaki *et al.* (2015) is used in 2013 and 1994 .

Diet compositions
Mean Diet compositions (weighted by biomass) in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of righteye flounders in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

28. ALASKA POLLOCK IN OYC BLOCK

Species
One species, Alaska pollock (*Theragra chalcogramma*; also known as walleye pollock), is considered.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
The values in 2013 and 1994 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catches reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) from 1994 to 2013 are used.

29. MISCELLANEOUS BOTTOM FISH IN OYC BLOCK

Species
Bottom fish in OYC block described in Yonezaki *et al.* (2015) other than righteye flounders and Alaska pollock are included in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
The values reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Mean Diet compositions (weighted by biomass) in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of miscellaneous bottom fish in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

30. RIGHTEYE FLOUNDERS IN KC BLOCK

Species
Species belonging to Pleuronectidae (righteye flounders) distributed in KC block are included in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is calculated based on catch statistics of offshore bottom trawl fisheries in 2013 assuming harvest rate = 0.2. The same value is used in 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The same values for righteye flounders in OYC block is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The same values for righteye flounders in OYC block is used in 2013 and 1994.

Diet compositions
Mean Diet compositions (weighted by biomass) for righteye flounders in OYC block in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of righteye flounders in KC block in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

31. SEABREAMS

Species
Seabreams and seabream-like species (e.g. *Pagrus major*, red seabream) are included in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is calculated based on catch statistics of offshore bottom trawl fisheries in 2013 assuming harvest rate = 0.2. The same value is used in 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
M and F of red seabream for 2012 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) are used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Consumption/biomass ratio (Q/B) is assumed as 0.2 of P/B.

Diet compositions
Based on qualitative information in Fisheries Agency and Fisheries Research Agency of Japan (2015b), specific diet compositions are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of seabreams in KC block in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

32. MISCELLANEOUS BOTTOM FISH IN KC BLOCK

Species
Bottom fish other than righteye flounders and seabreams in KC block recorded in catch statistics of offshore bottom trawl fisheries are included in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is calculated based on catch statistics of offshore bottom trawl fisheries in 2013 assuming harvest rate = 0.2. The same value is used in 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The same value for miscellaneous bottom fish in OYC block is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The same value for miscellaneous bottom fish in OYC block is used in 2013 and 1994.

Diet compositions
The same diet compositions of miscellaneous bottom fish in OYC block are used but they are adjusted based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of miscellaneous bottom fish in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

33. MESOPELAGIC FISH IN OYC BLOCK

Species
Though no specific target species is considered, various myctophids are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) for this group in Yonezaki *et al.* (2015) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

34. MESOPELAGIC FISH IN KC BLOCK

Species
Though no specific target species is considered, various myctophids are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) for this group in Yonezaki *et al.* (2015) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

35. MESOPELAGIC FISH IN OF BLOCK

Species
Though no specific target species is considered, various myctophids are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OF block.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) for this group in Yonezaki *et al.* (2015) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

36. SURFACE CEPHALOPODS

Species
Though no specific target species is considered, surface squids, such as Japanese flying squid (*Todarodes pacificus*) and spear squid (*Heterololigo bleekeri*) are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) for the two species in Yonezaki *et al.* (2015) is used. Mean (weighted by biomass) of the values is calculated. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values of the two species reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values of the two species reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Mean (weighted by biomass) diet compositions of the two species in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of Japanese flying squid in 2013 reported in Fisheries Agency and Fisheries Research Agency of Japan (2015b) is used. Same value is used in 1994.

37. MESOPELAGIC CEPHALOPODS

Species
Various mesopelagic cephalopods are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in all blocks.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, ecotrophic efficiency (EE) fromesopelagic cephalopods in Yonezaki *et al.* (2015) is used. Mean (weighted by biomass) of the values is calculated. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values of the mesopelagic cephalopods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values of mesopelagic cephalopods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Mean (weighted by biomass) diet compositions of the mesopelagic cephalopods in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

38. BENTHOS IN OYC BLOCK

Species
Though no specific target species is considered, crabs, shrimps and macrobenthos are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Biomass of benthos in Yonezaki *et al.* (2015) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values of the benthos reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values of benthos reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Mean (weighted by biomass) diet compositions of the benthos in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of crabs in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

39. BENTHOS IN KC BLOCK

Species
Though no specific target species is considered, shrimps and macrobenthos are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is estimated by Ecopath. To estimate the biomass, mean (weighted by biomass) of ecotrophic efficiency (EE) for benthos in Yonezaki *et al.* (2015) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Mean (weighted by biomass) of the values of the benthos reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
Mean (weighted by biomass) of the values of benthos reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Mean (weighted by biomass) diet compositions of the benthos in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of shrimps in 2013 is extracted from catch statistics of offshore bottom trawl fisheries. The same catch is assumed in 1994.

40. KRILL IN OYC BLOCK

Species
Species belonging to Euphausiidae (krill) are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Mean biomass around OYC block estimated by Murase *et al.* (2007) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
Catch of *Euphausia pacifica* in 2013 is extracted from catch statistics. The same catch is assumed in 1994.

41. KRILL IN OF BLOCK

Species
Species belonging to Euphausiidae (krill) are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OF block.

Biomass (B)
Minimum biomass in OF block estimated by Murase *et al.* (2007) is used. The same value is used in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

42. ZOOPLANKTON IN OYC BLOCK

Species
Though no specific target species is considered, various planktons such as copepods and chaetognaths are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Mean biomass from 1994 to 2013 is calculated using NORPAC (North Pacific standard net) data (Takasuka, unpublished data). The biomass is doubled to balance Ecopath in 2013 and 1994.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions of copepods in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

43. ZOOPLANKTON IN KC BLOCK

Species
Though no specific target species is considered, various planktons such as copepods and chaetognaths are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Mean biomass from 1994 to 2013 is calculated using NORPAC (North Pacific standard net) data (Takasuka, unpublished data).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions of copepods in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

44. ZOOPLANKTON IN OF BLOCK

Species
Though no specific target species is considered, various planktons such as copepods and chaetognaths are assumed to be categorized in the group.

Distribution blocks
It is assumed that this group is distributed in OF block.

Biomass (B)
A mean biomass in the block is calculated using all NORPAC (North Pacific standard net) data from 1978 to 2013 as sampling coverage is not sufficient (Takasuka, unpublished data).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Consumption/biomass ratio (Q/B)
The value of copepods reported in Yonezaki *et al.* (2015) is used in 2013 and 1994.

Diet compositions
Diet compositions of copepods in Yonezaki *et al.* (2015) are used as the basic information. Specific diet compositions based on the information are then assigned based on the authors' expert knowledge. The same compositions are assumed in 2013 and 1994.

Catch
No catch is assumed for this group.

45. PHYTOPLANKTON IN OYC BLOCK

Species
No s species is assumed.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Annual means of chlorophyll-a volume concentrations (mg/m^3) from 2003 to 2013 obtained by Moderate Resolution Imaging Spectroradiometer aboard the Aqua satellite (Aqua MODIS) are firstly converted to surface concentrations (mg/m^2) based on Morel and Berthon (1989). The surface chlorophyll-a concentrations are multiplied by a conversation factor, 400, described in Link *et al.* (2006) to convert to wet weight (mg/ m^2).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Annual means of primary production around OYC block (Kameda, unpublished data) are used as P.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

46. PHYTOPLANKTON IN KC BLOCK

Species
No species is assumed.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Annual means of chlorophyll-a volume concentrations (mg/m^3) from 2003 to 2013 obtained by Moderate Resolution Imaging Spectroradiometer aboard the Aqua satellite (Aqua MODIS) are firstly converted to surface concentrations (mg/m^2) based on Morel and Berthon (1989). The surface chlorophyll-a concentrations are multiplied by a conversation factor, 400, described in Link *et al.* (2006) to convert to wet weight (mg/ m^2).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Annual means of primary production around KC block (Kameda, unpublished data) are used as P.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

47. PHYTOPLANKTON IN OF BLOCK

Species
No species is assumed.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Annual means of chlorophyll-a volume concentrations (mg/m^3) from 2003 to 2013 obtained by Moderate Resolution Imaging Spectroradiometer aboard the Aqua satellite (Aqua MODIS) are firstly converted to surface concentrations (mg/m^2) based on Morel and Berthon (1989). The surface chlorophyll-a concentrations are multiplied by a conversation factor, 400, described in Link *et al.* (2006) to convert to wet weight (mg/ m^2).

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
The same Annual means of primary production in OYC block are used as P.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

48. DETRITUS IN OYC BLCOK

Species
Not applicable.

Distribution blocks
It is assumed that this group is distributed in OYC block.

Biomass (B)
Biomass is calculated based on Pauly *et al.* (1993) using phytoplankton data in the block.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Not applicable.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

49. DETRITUS IN KC BLOCK

Species
Not applicable.

Distribution blocks
It is assumed that this group is distributed in KC block.

Biomass (B)
Biomass is calculated based on Pauly *et al.* (1993) using phytoplankton data in the block.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Not applicable.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

50. DETRITUS IN OF BLOCK

Species
Not applicable.

Distribution blocks
It is assumed that this group is distributed in OF block.

Biomass (B)
Biomass is calculated based on Pauly *et al.* (1993) using phytoplankton data in the block.

Production/biomass ratio (P/B) or total mortality (Z; natural mortality rate, M, plus fishing mortality rate, F)
Not applicable.

Consumption/biomass ratio (Q/B)
Not applicable.

Diet compositions
Not applicable.

Catch
No catch is assumed for this group.

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Appendix 2

Results of pre-balance diagnostics for Ecopath in 2013 based on Link (2010)

This is Appendix 2 of "SC/F16/JR28. Murase, H., Tamura, T., Hakamada, T., Watari, S., Okazaki, M., Kiyofuji, H, Yonezaki, S and Kitakado, T. 2015 Ecosystem modelling in the western North Pacific from 1994 to 2013 using Ecopath with Ecosim (EwE): some preliminary results. Paper SC/F16/JR28 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished)".

Table A2-1. Summary of results of pre-balance diagnostics for Ecopath in in the western North Pacific in 2013 based on Link (2010).The diagnostics are based on the authors' judgment.

	Diagnostic criterion	Results	Diagnostics		
			Good	Acceptable	Caution
Class of diagnostic: Biomasses across taxa/TLs					
1	Biomass should span 5–7 orders of magnitude		x		
2	Slope (on log scale) should be ~5–10% decline	Fig.A2-1	x		
3	Taxa notably above or below slope-line may need more attention				x
Class of diagnostic: Biomass ratios					
4	Compared across taxa, predators biomass should be less than that of (1 relative to) their prey		x		
5	Number of zeroes indicates potential trophic difference between predators and prey	TableA2-2		x	
6	Compared across taxa, ratios indicate major pathways of trophic flows (e.g. benthic vs pelagic)			x	
Class of diagnostic: Vital rates across taxa/TLs					
7	Normal biomass decomposition of C/B, P/B and R/B (exception for homeotherms at upper TLs)	Fig.A2-2		x	
8	Taxa notably above or below trend merit further attention			x	
Class of diagnostic: Vital rate ratios					
9	Compared across taxa, predators' C/B, P/B and R/B should be less than 1 relative to their prey	TableA2-3			x
10	Number of zeroes indicates potential trophic difference between predators and prey				x
11	P and B relative to PP approximate TL	Fig.A2-3		x	
12	Compared across vital rates; P/Cs or P/Rs near 1 merit reevaluating	Fig.A2-4		x	
Class of diagnostic: Total production and removals					
13	Total, scaled values of P, C and R should again follow a decomposition with increasing TL			x	
14	Consumption of a taxa should be less than production by that taxa	Fig.A2-5	x		
15	Consumption by a taxa should be more than production by that taxa		x		
16	Total human removals should be less than total production of a taxa	Fig.A2-6		x	
17	Total human removals should be compared to consumption of a taxa		x		

Table A2-2. Biomass ratio which are corresponding to the diagnostic criterions 4-5 in Table A2-1. PP: primary producers, ZP: zooplankton and HMF: highly migratory fish.

Prey/Predator	Biomass ratio
Pelagic/mesopelagics:PP	0.901
ZP:PP	4.204
Pelagic/mesopelagics:ZP	0.214
Baleen whales:ZP	0.005
Demersal:Pelagic/mesopelagics	0.082
HMF:Pelagic/mesopelagics	0.127
Toothed whales:Pelagic/mesopelagics	0.019
Pelagic fish:all fish	0.368
Mesopelagic gish:all fish	0.426
Demersal fish:all fish	0.081
HMF: all fish	0.124
TL4:<TL3	0.02425

Table A2-3. Vital rate ratio which are corresponding to the diagnostic criterions 9-10 in Table A2-1. PP: primary producers, ZP: zooplankton and HMF: highly migratory fish.

Prey/predator	C/B	P/B	R/B
Pelagic/mesopelagics:ZP	0.287	0.158	0.214
ZP:PP	-	0.059	-
Pelagic/mesopelagics:PP	-	0.009	-
Demersal:Pelagic/mesopelagics	0.453	0.352	4.134
HMF:Pelagic/mesopelagics	0.797	0.298	0.559
Toothed whales:Pelagic/mesopelagics	1.380	0.053	0.930
Baleen whales:ZP	0.226	0.008	0.102

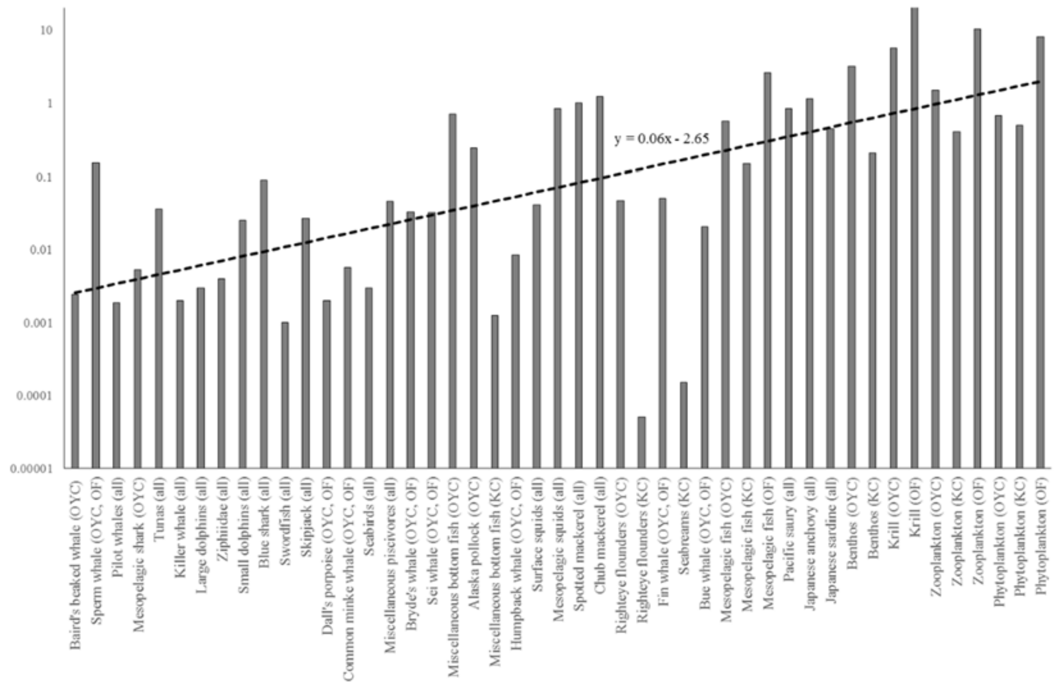

Fig. A2-1. Trophic decomposition (trend line), showing variously declining levels of biomass with increasing trophic level (log scale). Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 1-3 in Table A2-1.

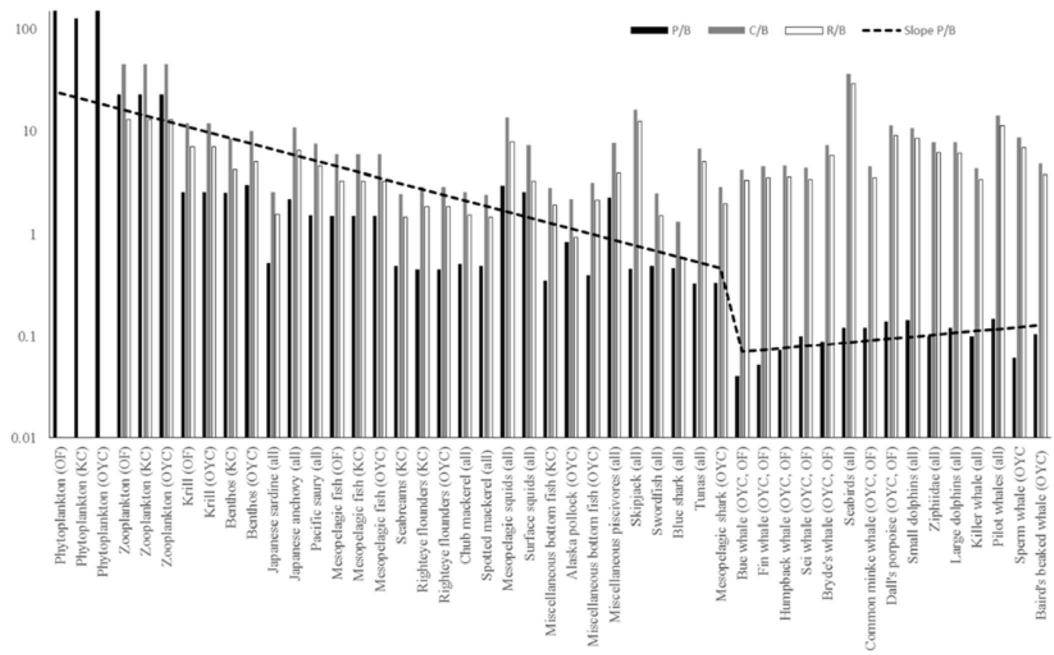

Fig. A2-2. Vital rates (log scale) that expresses trophic decomposition (trend line) with the exception of consumption and respiration for homeotherms. Trophic level increases from left to right. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 7-8 in Table A2-1.

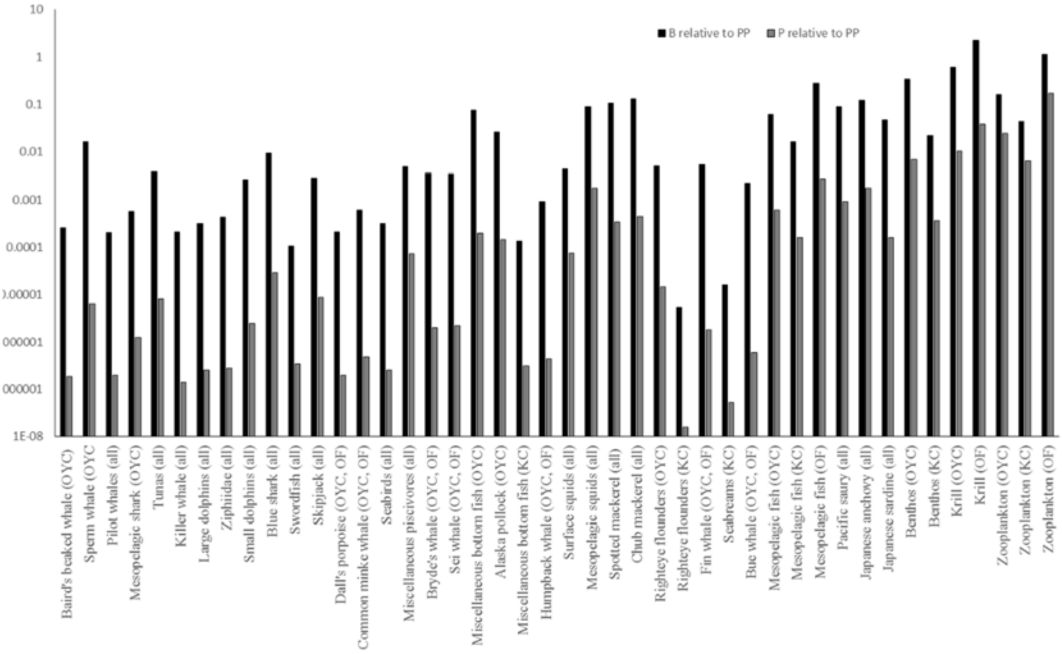

Fig. A2-3. Vital rate ratios (log scale), as compared to the primary producers. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterion 11 in Table A2-1.

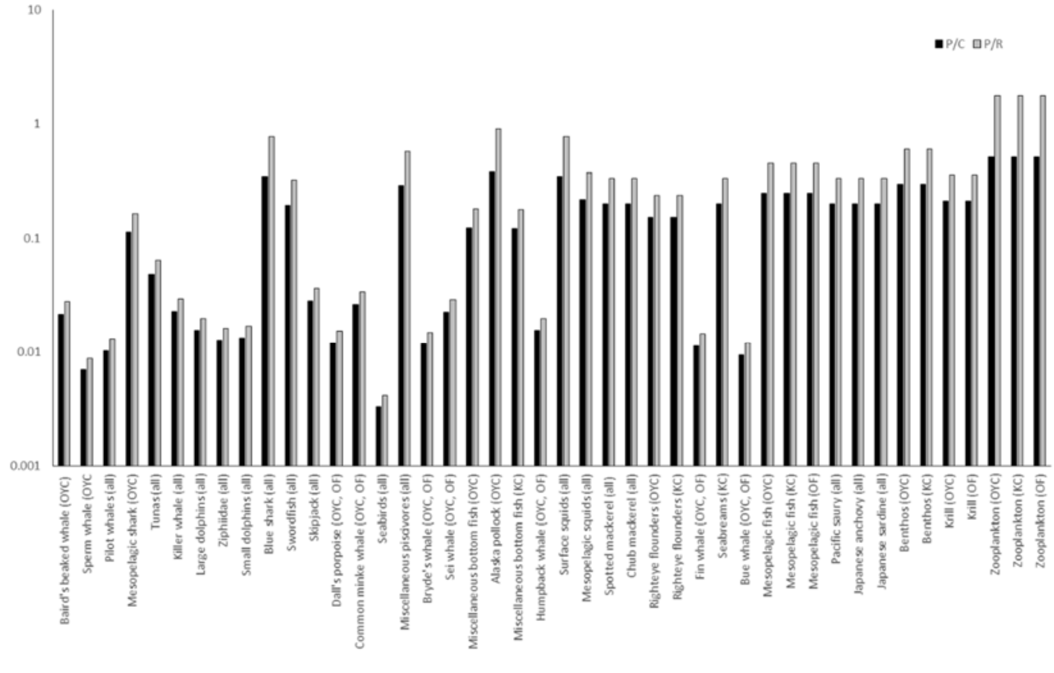

Fig. A2-4. Vital rate ratios, as compared across rates for each taxa. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterion 12 in Table A2-1.

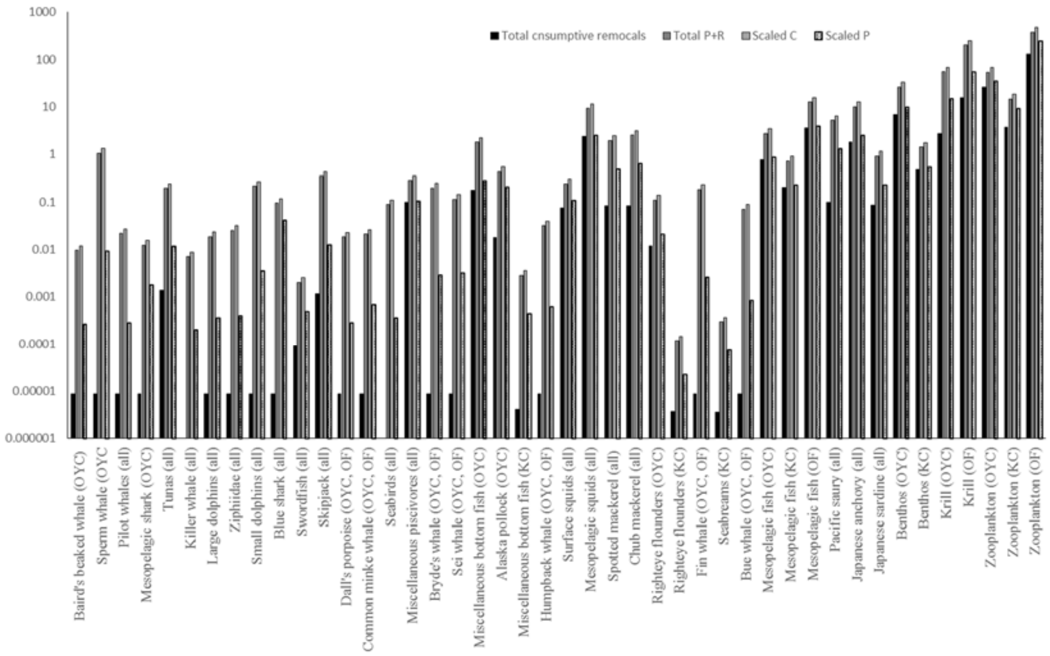

Fig. A2-5. Total production and removals, scaled to the full ecosystem, comparing internal flows. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 13-15 in Table A2-1.

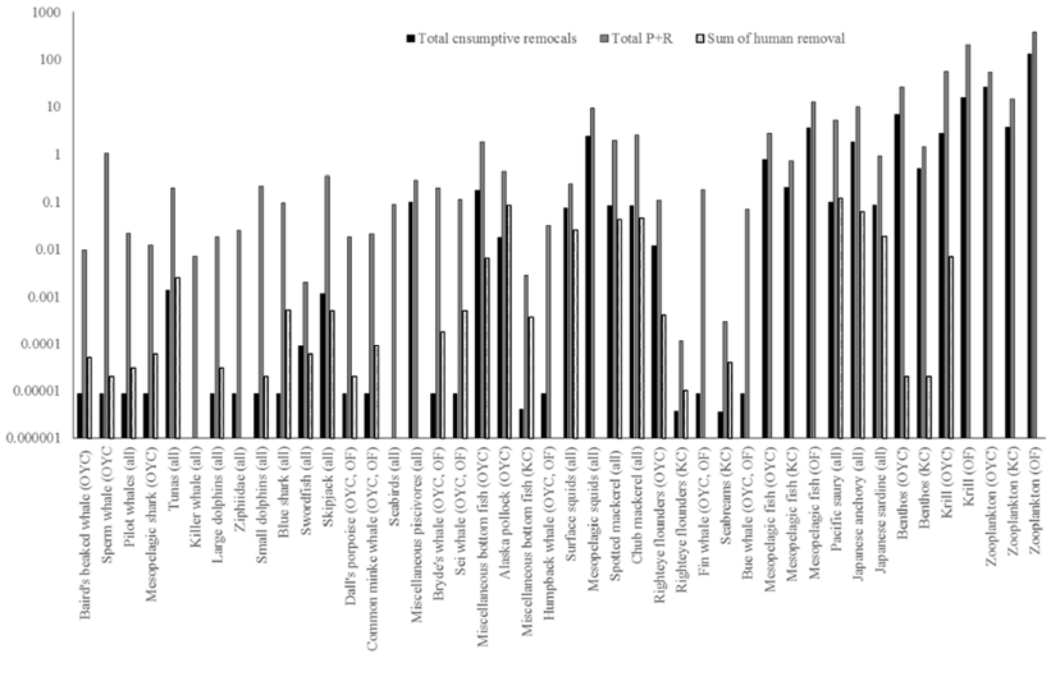

Fig. A2-6. Flows relative to external removals. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 16-17 in Table A2-1.

REFERENCES

Link, J.S. 2010. Adding rigor to ecological network models by evaluating a set of pre-balance diagnostics: A plea for PREBAL. Ecol. Model. 221: 1580-91.

Appendix 3

Results of pre-balance diagnostics for Ecopath in 1994 based on Link (2010)

This is Appendix 3 of "SC/F16/JR28. Murase, H., Tamura, T., Hakamada, T., Watari, S., Okazaki, M., Kiyofuji, H, Yonezaki, S and Kitakado, T. 2015 Ecosystem modelling in the western North Pacific from 1994 to 2013 using Ecopath with Ecosim (EwE): some preliminary results. Paper SC/F16/JR28 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished)".

Table A3-1. Summary of results of pre-balance diagnostics for Ecopath in in the western North Pacific in 2013 based on Link (2010). The diagnostics are based on the authors' judgment.

	Diagnostic criterion	Results	Diagnostics		
			Good	Acceptable	Caution
Class of diagnostic: Biomasses across taxa/TLs					
1	Biomass should span 5–7 orders of magnitude		x		
2	Slope (on log scale) should be ~5–10% decline	Fig.A3-1	x		
3	Taxa notably above or below slope-line may need more attention				x
Class of diagnostic: Biomass ratios					
4	Compared across taxa, predators biomass should be less than that of (1 relative to) their prey		x		
5	Number of zeroes indicates potential trophic difference between predators and prey	TableA3-2		x	
6	Compared across taxa, ratios indicate major pathways of trophic flows (e.g. benthic vs pelagic)			x	
Class of diagnostic: Vital rates across taxa/TLs					
7	Normal biomass decomposition of C/B, P/B and R/B (exception for homeotherms at upper TLs)	Fig.A3-2		x	
8	Taxa notably above or below trend merit further attention			x	
Class of diagnostic: Vital rate ratios					
9	Compared across taxa, predators' C/B, P/B and R/B should be less than 1 relative to their prey	TableA3-3			x
10	Number of zeroes indicates potential trophic difference between predators and prey				x
11	P and B relative to PP approximate TL	Fig.A3-3		x	
12	Compared across vital rates; P/Cs or P/Rs near 1 merit reevaluating	Fig.A3-4		x	
Class of diagnostic: Total production and removals					
13	Total, scaled values of P, C and R should again follow a decomposition with increasing TL			x	
14	Consumption of a taxa should be less than production by that taxa	Fig.A3-5	x		
15	Consumption by a taxa should be more than production by that taxa		x		
16	Total human removals should be less than total production of a taxa	Fig.A3-6		x	
17	Total human removals should be compared to consumption of a taxa		x		

Table A3-2. Biomass ratio which are corresponding to the diagnostic criterions 4-5 in Table A3-1. PP: primary producers, ZP: zooplankton and HMF: highly migratory fish.

Prey/Predator	Biomass ratio
Pelagic/mesopelagics:PP	0.872
ZP:PP	4.173
Pelagic/mesopelagics:ZP	0.209
Baleen whales:ZP	0.004
Demersal:Pelagic/mesopelagics	0.125
HMF:Pelagic/mesopelagics	0.021
Toothed whales:Pelagic/mesopelagics	0.021
Pelagic fish:all fish	0.472
Mesopelagic gish:all fish	0.381
Demersal fish:all fish	0.119
HMF: all fish	0.02
TL4:<TL3	0.007

Table A3-3. Vital rate ratio which are corresponding to the diagnostic criterions 9-10 in Table A3-1. PP: primary producers, ZP: zooplankton and HMF: highly migratory fish.

Prey/predator	C/B	P/B	R/B
Pelagic/mesopelagics:ZP	0.290	0.162	0.418
ZP:PP		0.059	
Pelagic/mesopelagics:PP		0.010	
Demersal:Pelagic/mesopelagics	1.540	2.071	1.335
HMF:Pelagic/mesopelagics	0.956	0.366	1.184
Toothed whales:Pelagic/mesopelagics	1.379	0.054	1.892
Baleen whales:ZP	0.232	0.008	0.455

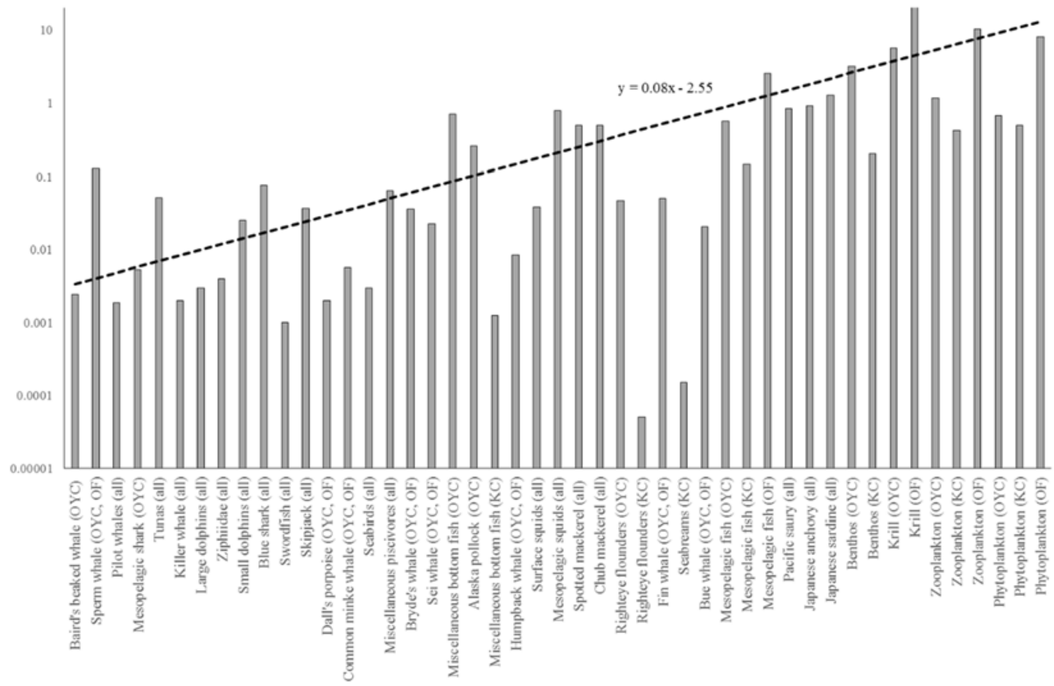

Fig. A3-1. Trophic decomposition (trend line), showing variously declining levels of biomass with increasing trophic level (log scale). Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 1-3 in Table A3-1.

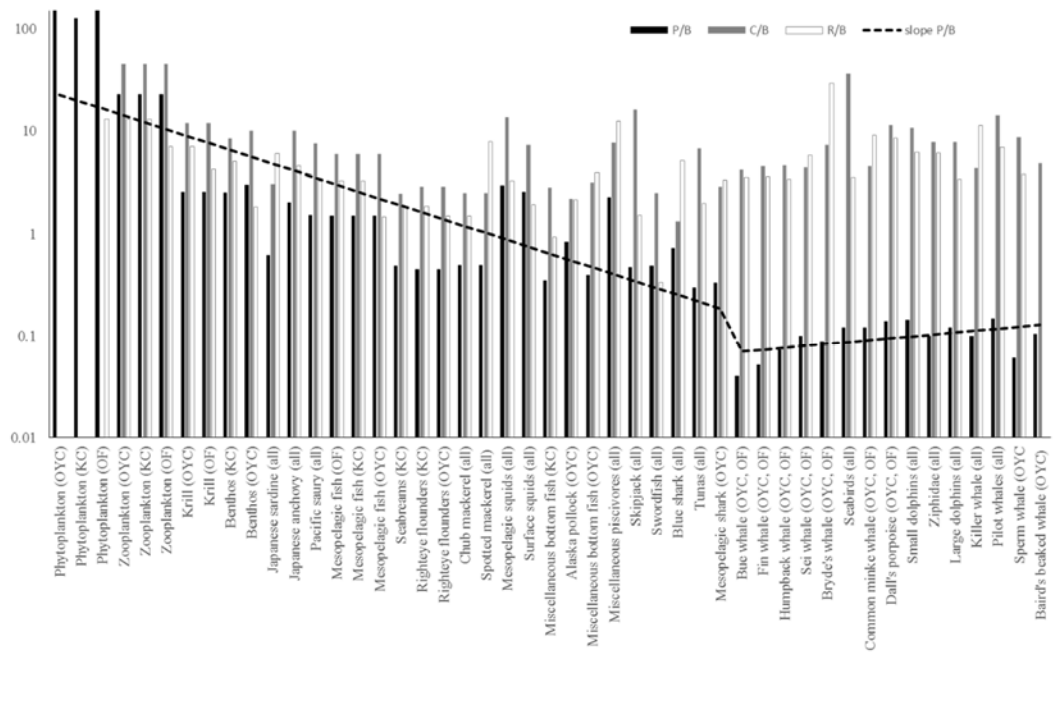

Fig. A3-2. Vital rates (log scale) that expresses trophic decomposition (trend line) with the exception of consumption and respiration for homeotherms. Trophic level increases from left to right. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 7-8 in Table A3-1.

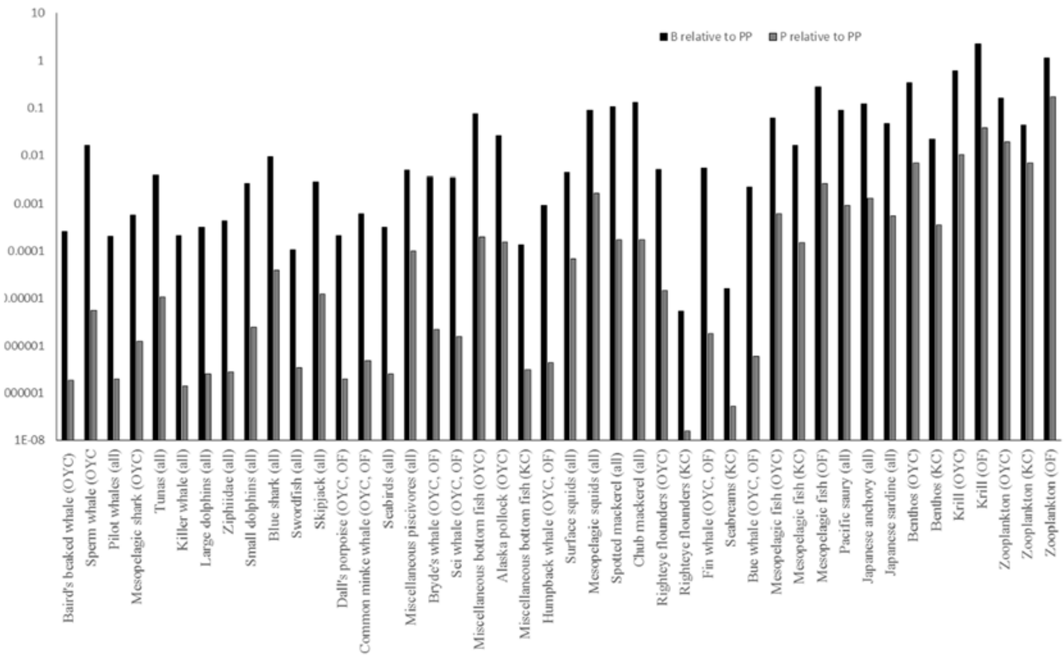

Fig. A3-3. Vital rate ratios (log scale), as compared to the primary producers. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterion 11 in Table A3-1.

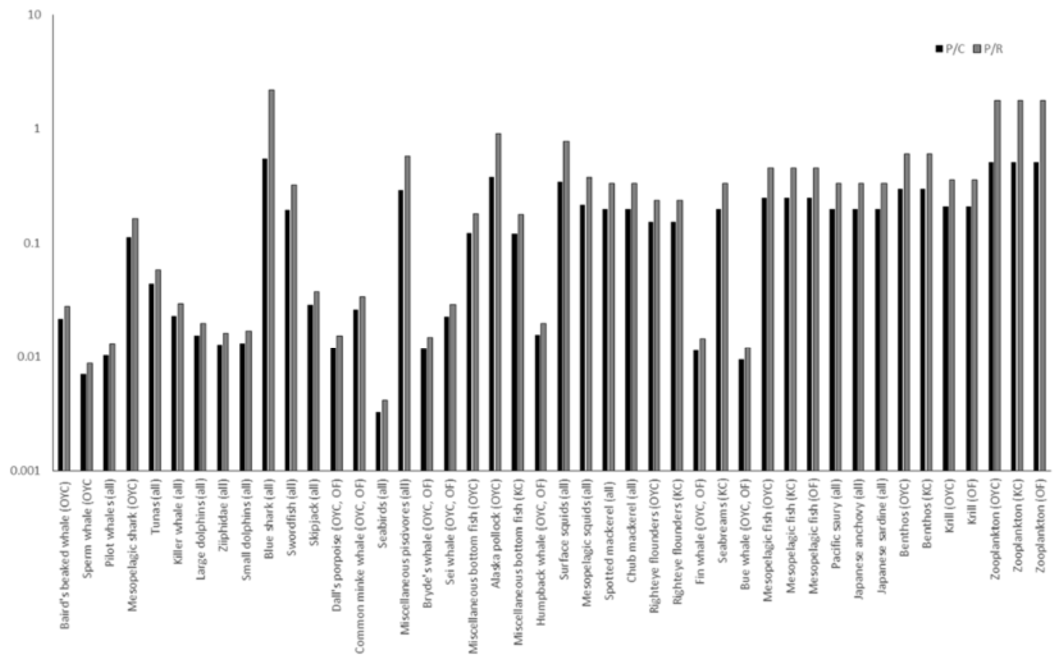

Fig. A3-4. Vital rate ratios, as compared across rates for each taxa. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterion 12 in Table A3-1.

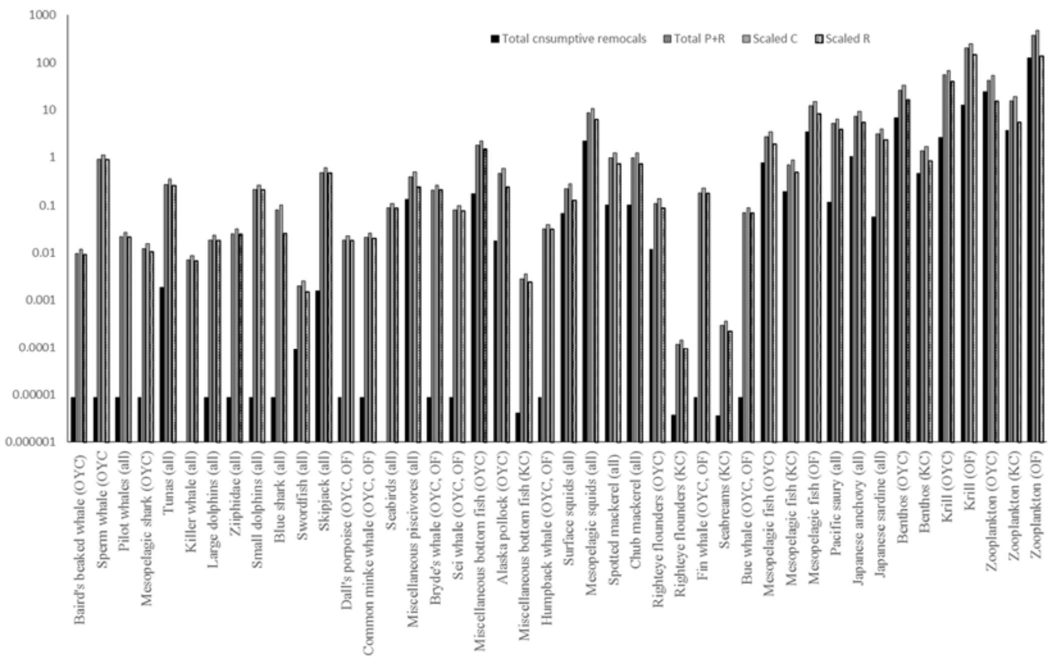

Fig. A3-5. Total production and removals, scaled to the full ecosystem, comparing internal flows. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 13-15 in Table A3-1.

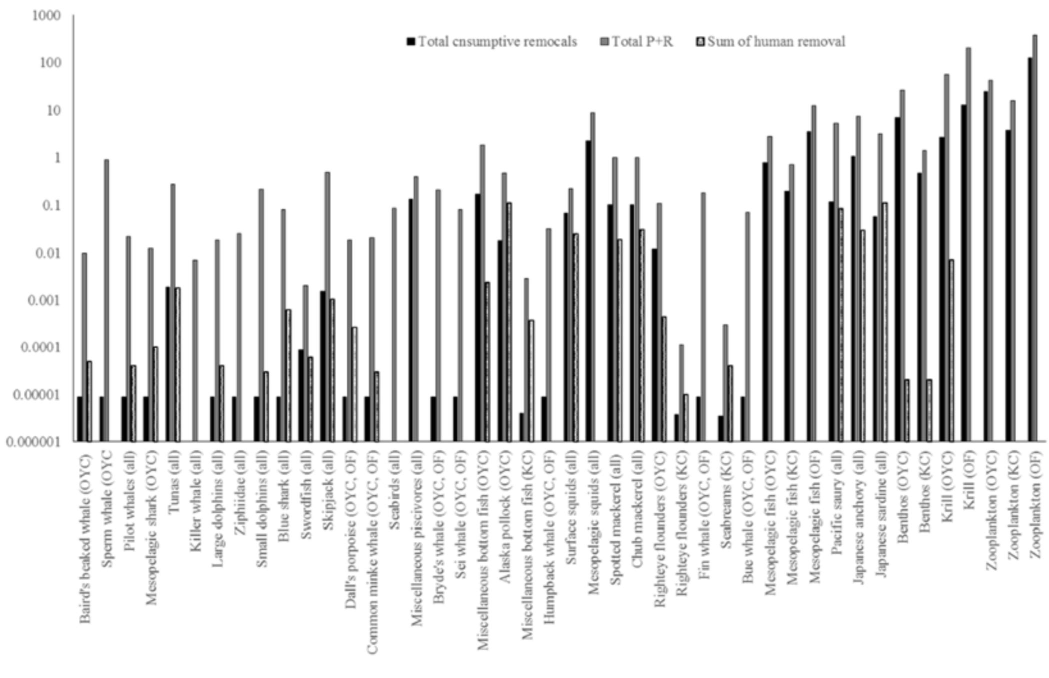

Fig. A3-6. Flows relative to external removals. Trophic level increases from right to left. OYC: coastal Oyashio block, KC: coastal Kuroshio block and OF: offshore block. This figure corresponds to the diagnostic criterions 16-17 in Table A3-1.

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