

## **ECOPATH model of the Western North Pacific (Oyashio–Transition–Kuroshio Region)**

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Our objective of building an Ecopath with Ecosim (EwE) model in the western North Pacific region is to evaluate the potential impact of whales migrating to the western North Pacific off Japan on Japan's fisheries resources. From 1994 to 1999, a survey called JARPN (Japanese whale research program under special permit in the western North Pacific) has been carried out mainly in this region, and from 2000 to 2007, the second phase of this survey (called JARPN II) has been carried out. The survey has collected information on whale abundance, prey preferences, diet composition, rates of consumption for predator and prey, and oceanography. Based mainly on these collected data, we are currently building an EwE model. Here, we focus on briefly introducing physical and biological backgrounds of such Ecopath model.

The modeled area is east of northern Honshu Island, north of 35°N, and west of 170°E, south of Hokkaido (excluding Russia's EEZ), which corresponds to sub-areas 7,8 and 9 for the North Pacific IWC minke whale management area. The area covers part of the Oyashio and Kuroshio region and the transition zone between the two currents. Several environmental factors are thought to affect the distribution and dynamics of the species in the modeled area. One is the southern limit of the Oyashio current. The southern limit of Oyashio varies by season and year. When the southern limit is towards the north side, suitable fishing area of Pacific saury becomes near shore, and when the southern limit is towards the southern side, suitable fishing area of Pacific saury becomes offshore, and often when it is too south, poor harvesting of fisheries is expected. Another important factor to consider is the pattern of the pathway of the Kuroshio Current. The pathway of Kuroshio varies by year and there are mainly three pathways.

There are some other environmental factors that are thought to affect the dynamics of the species considered in the model. In the western North Pacific, 'fish species alteration' has been observed. The abundant species has altered from sardine to anchovy to mackerel then again to sardine then anchovy. Both biomass and catch of sardine drastically declined in the end of 1980s. Possible environmental factors that affect this phenomenon are thought to be, for example, strength of the ALPI (Aleutian Low Pressure Index) and the PDO (Pacific Decadal Oscillation). When the strength of ALPI is weak, it is thought that the condition is not suitable for sardine, and when the strength of ALPI is strong, it is thought

that it brings good condition for sardine. Also, surface water temperature of the Kuroshio Extension area may be affecting the dynamics of the species in this area. When the surface water temperature of the Kuroshio Extension is low, it is thought to bring good condition for sardine, and when the surface water temperature of the Kuroshio Extension is high, it is thought to bring poor condition for sardines. However, the detail mechanism of fish species alteration in the western North Pacific is not yet well known, and is currently under investigation.

The Ecopath model consists of 31 species (or groups) and the modeled year is around 2006-2007. As for primary producers, phytoplankton is considered. As for zooplankton, we considered three groups; one is euphausiids, another is 'copepods eaten by whales' and the other is 'other copepods'. Major euphausiid species in the area are *Euphausia pacifica*, *Thysanoessa inspinata*, and *Nyctiphanes difficillis*. As for 'copepods eaten by whales', we considered mainly three species which are *Neocalanus cristatus*, *N. plumchrus*, and *N. flemingeri*. Biomass of these species is estimated from net-sampling and echo-sounder data obtained from JARPNII. As for fish and squids, we considered 11 fish species and four squid species or groups, totaling 15 species/groups. Among the 15 species/groups considered, six species are at high biomass level (which are albacore, skipjack tuna, blue shark, spotted chub mackerel, anchovy and Pacific saury), two species are at middle biomass level (which are sword fish, large surface squid), and three species are at low level (which are neon-flying squid, chub mackerel and sardine). As for the trend of biomass, most of the species are stable in recent years, except that biomass of blue shark and chub mackerel is increasing currently, and biomass of spotted chub-mackerel and anchovy is slightly decreasing. Among these species, lanternfish has the largest biomass. Neon-flying squid, mackerel, sardine, anchovy and pacific saucy are important Japanese fish resources. Among these five fish/squid species, catch and biomass of sardine drastically decreased from the end of 1980s to the 1990s and currently is at very low level. Also, catch and biomass of mackerel also decreased at the end of 1970s. For other species such as pacific saucy, neon-flying squid and anchovy, no obvious trend in catch and biomass can be seen for the past 40 years. Total catch of Pacific saury is the highest among these five species resulting in approximately 2 million tons/year, followed by that of anchovy of 1.5 million tons then mackerel of about 1.2 million tons. Total catch of sardine and neon-flying squid is about 450 thousand tons/year.

As for marine mammals, since we are focusing on these species and its interactions, groups are classified in quite details and we considered nine whale species or groups, and one fur seals. Whale species considered included: minke; Bryde's; sei; sperm; Baird's beaked; and short-finned pilot whale. We also considered other baleen whales, ziphiidae, and other toothed whales. Among the marine mammals, sperm whale has the largest biomass. Biomass estimates, Q/B and diet composition data are mainly obtained from JARPNII.

As for trophic interactions, from JARPNII, we found that minke whales mainly feed on Pacific saury and anchovy, Bryde's whales and sei whales also mainly feed on anchovy. Diet of sperm whales was different from other species and they feed mainly on mid-deep water sea squid. When relative consumption on Pacific saury and anchovy by predators is compared, consumption by mackerel and whales is relatively high; the largest predation on anchovy (mature component) is by whales; followed by skipjack tuna, mackerel, and neon-flying squid. Thus, whales seems to be important predators for Pacific saury and anchovy, and this is the reason why we are focusing our research on this point which is the impact of whale's consumption on Japan's fisheries resources.

As for fisheries and management systems, catch of mackerel, sardine and Pacific saury are controlled by TAC system in Japan. Current stock assessment indicates that  $F$  of chub-mackerel and sardine, especially  $F$  on the immature component, needs to be reduced than the current level. For other species, no major limit on catch is set. For baleen whales, management procedure was agreed by IWC. But it has not been implemented yet in this area.

Finally, as for major natural drives or critical factors that cause ecosystem change in a several decadal scale, possible environmental factors are strength of ALPI, PDO, surface water temperature of the Kuroshio Extension area, and for yearly or monthly change, southern limit of Oyashio or pattern of the pathway of Kuroshio affects distribution of fishes, and also to some extent, we believe that predator-prey interactions and fisheries are affecting the dynamics of the species.