What might be "unknowable" about marine life in the North Pacific Ocean? In fact, "unknowable" is a moving concept, with what might be unknowable today perhaps being unknown tomorrow, but known the day after if the right scientific discoveries and technological developments occur. For example, the human genome was unknowable until methods of gene mapping were developed and resources applied to this problem. Today, the human genome has been mapped, although relating gene sequences to specific traits or actions still lags far behind.

the unknowable

Fundamentally unknowable

Identification of all species

It is unlikely that all species living in the North Pacific Ocean will ever be identified and described. New species are still being discovered, even in terrestrial environments where observations are far easier to make than in the ocean. The area of the globe covered by the North Pacific Ocean, its volume, its three-dimensional environment, and the difficulties of conducting direct observations lead to the conclusion that all species will never be discovered. Nevertheless, there is a hierarchy of discovery: larger species, in particular, those that live near the air-water interface, are more likely to be discovered. All organisms at the lower trophic levels, the smaller benthos (meiobenthos), zooplankton, phytoplankton, and bacterioplankton which are likely to be very speciose, but very difficult to discover, especially in the deep ocean, are those most likely to be unknowable. "Absence of evidence is not evidence of absence" is the appropriate advice here; if we believe we have discovered all species, it will take only one new find to prove us wrong. As for marine life in the North Pacific Ocean in the past, we may never know about all small marine organisms that may now be extinct.

Abundance of all species

For those species that are known to exist, it will be impossible to know the abundance of each. Sampling and time-scale problems are again the issue, since generation times range from less than a day, for bacteria and phytoplankton to decades for seabirds, marine mammals, turtles, and some fish and invertebrates (life spans of some rockfish and clam species in the North Pacific Ocean are known to exceed 100 years). Therefore, it is impossible to know the abundance of all marine organisms at any instant in time. Even "relative" abundances may be unknowable for all species, considering the difficulties of direct sampling and the errors that occur if proxy measures (fishery catches) are used. The difficulties and experiences of estimating the abundances of commercial fish stocks, despite the enormous world-wide resources expended, demonstrate the point.

Applied unknowables

Species dominance

The dominant species of phytoplankton blooms can be predicted in a statistical sense for some locations and seasons. For example, the species of diatoms that will dominate the composition of plankton blooms on the continental shelves of the North Pacific Ocean can be predicted using probabilities developed from observations of past blooms. However, the composition of localized blooms, such as red tides, are much more difficult to predict in space and time; this is particularly true for blooms which produce human neurotoxins such as domoic acid. The unexpected occurrences of coccolithophore and gelatinous zooplankton blooms in the Bering Sea and Gulf of Alaska further illustrate the problem. Computer simulations may be able to model and predict bloom dynamics for the most common phytoplankton, but they are unlikely to predict blooms of previously rare species. Even if the computing power were available to include all rare species, it is unlikely that information on their physiologies and responses to subtle differences in environmental conditions would be available to correctly parameterize the model to simulate the real bloom dynamics.

Response to change

When the complexity of marine ecosystems is considered (Figure 1), the responses of individual species to climatic and anthropogenic change may be unknowable. The response of any species will depend on how the change affects that species directly (*e.g.*, a change in current patterns or water temperature) or indirectly as its predators and prey also respond to change. It will also depend on whether the species has a narrow or wide tolerance to environmental change and the rate of change, whether it has a narrow or wide spectrum of prey to capture and ingest, and whether its predators are selective or generalists. In addition, many marine organisms occupy different trophic niches during their life span and may even prey on their ultimate predators during their early life stages. Many models are available, and more are being developed that simulate marine ecosystem responses to climatic and anthropogenic change. Unfortunately, these models often aggregate many species into single "boxes" (usually species at lower trophic levels such as macrozooplankton) that eliminate differences which may be crucial to understanding the real responses of the ecosystem. This leads to the question of whether or not there are emergent properties of marine ecosystems that are more than the sum of the characteristics of individual species. There are hints that such properties may occur, *e.g.*, biomass-size spectra, but there is an urgent need for the development of macro-ecological theories of marine ecosystem structure and function.

Policy implications of "unknowables"

Each of these unknowables of marine life in the North Pacific Ocean is critically important. The search for new species must continue, both for the excitement and wonder of discovering new organisms, and for the knowledge gained by studying another solution to the struggle for life. The search is also crucial for understanding how ecosystems function and are stabilized against perturbations (*i.e.*, the role of biodiversity in providing ecosystem "goods and services"). Knowing abundances, or at least estimating relative abundances, is therefore essential to understanding the roles of species in a marine ecosystem, and critically important for understanding how humans affect these ecosystems through activities, such as fishing. Knowing species' roles in bloom dynamics and ecosystem responses to changes would also lead to understanding why these systems change in response to both natural and human forcing; these problems are too important to ignore. Nevertheless, we must recognize how much we are likely to know and, most importantly, what we will never know. Analytical methods, predictions, and policy responses to these predictions must consider this uncertainty, and the limits to our knowledge. At the very least, acknowledging the extent of our ignorance and the uncertainties about what can never be known may reduce the occurrences of "surprises", which, all too frequently, seem to be unpleasant.