Gulf of Alaska Salmon Production

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Abstract

The following is a brief account of how phytoplankton production and the size of primary producers may affect to production of salmon in the Gulf of Alaska.

Introduction

It is well known (e.g. Iverson, 1990 and others) that the amount of fish in different parts of the ocean is related to differences in primary production. While the correlation is strong, there is considerable variance in the relationship such that it can not be used by itself in any predictive sense. A missing factor in this relationship is that the primary producers vary by nine orders of magnitude in size – this is analogous to terrestrial plants which range in size from a blade of grass to a giant tree, and while their primary production may be similar, the ecology of grasslands and forests are very different. In the oceans the size difference of the phytoplankton which may come to dominate in different environments is seldom taken into account and data on such differences are generally lacking. Never-the-less from only a cursory view of the ocean one finds that large phytoplankton cells (e.g. diatoms) dominate in areas of abundant fisheries (e.g. upwelling) while small phytoplankton cells (e.g. flagellates) dominate in areas where there are practically no fisheries (e.g. convergent waters inhabited by coral reefs) . The following discussion is an attempt to show that within a large ocean areas, fish production may be limited by changes not only in the primary production but also in the size of the primary producers (see Parsons, 1972 for general discussion). Hence variations in the abundance of salmon in the Gulf of Alaska may be dependent on inter-annual changes in the structure of the phytoplankton community.

Discussion

In this presentation I have used a simplistic equation to illustrate the kind of difference that one could expect in salmon production in the Gulf of Alaska based both on the total amount of primary production and a change in the size spectrum of primary producers. The possible size difference in primary producers could vary by several orders of magnitude but there are no long term data sets on which to make actual comparisons. However, Figure 1 is a conceptual illustration of an ocean food chain from primary producers to fish based on a logarithmic size scale and the amount of annual primary production. This concept might help in understanding how changes in the parameters of this figure could explain why the amount of salmon produced in the Gulf of Alaska could change quite dramatically.
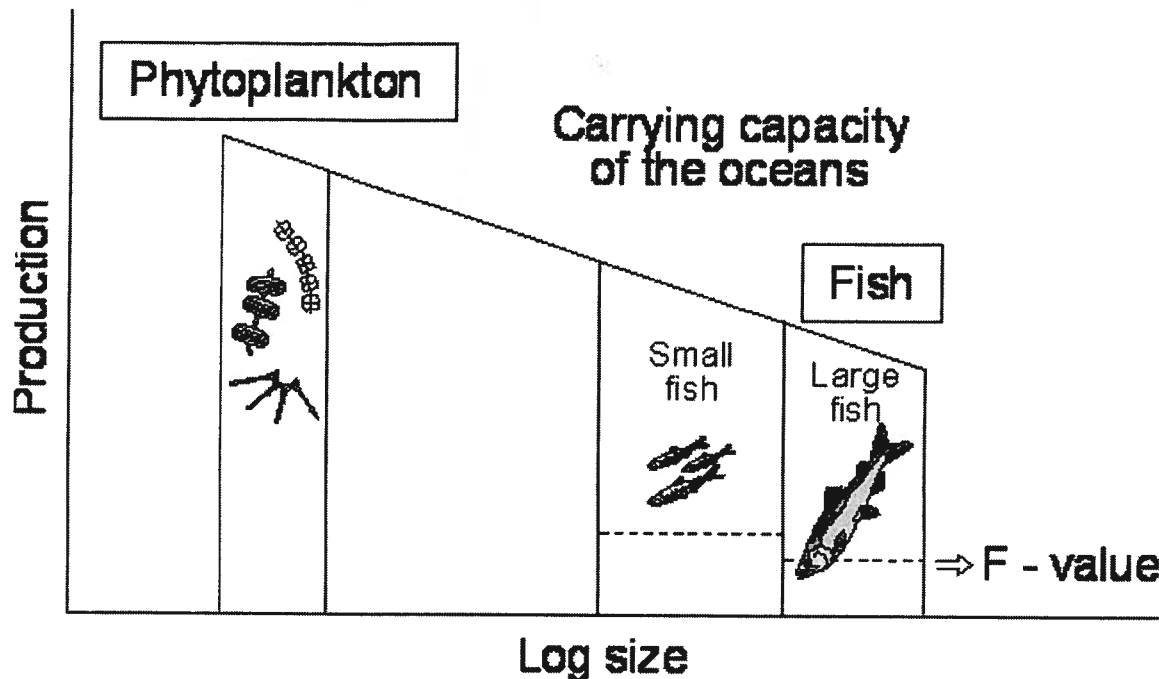
Protein from the Oceans

Figure 1 An example of macroecology in the sea. The size spectrum of organisms from phytoplankton to fish is used to calculate the carrying capacity of different ocean areas, based on Sheldon et al (1982). The figure allows for the following calculation:

$$\text{Total fish production (tonnes/yr)} = P \cdot 10 \cdot (f_c/f_p) \cdot (D_c/D_p)^{-x} \cdot A$$

where,

P = primary production ($mgC/m^2/yr$)

(f_c/f_p) = number of size classes of predator and prey

(D_c/D_p) = ratio of mean size of predator and prey

A = area of the fishery in km^2

x = empirically derived constant relating growth rate of different sized organisms (usually x = 0.72 giving a ca. 0.15 transfer efficiency for each step in the food chain) and 10 is a scaling factor.

F = the ratio of new to recycled nitrogen. The multiplication of total fish production by F, gives the amount of harvestable fish production of either small, or large fish.

Using the above equation, one can make an approximation of the salmon production in the Gulf of Alaska assuming some value for the primary production, together with median sizes for the salmon and the primary producers, which are largely small flagellates.

A low figure for the annual primary production of the Gulf is 80 (see all units in the attached figure), the Gulf has an area of 3.96×10^6, the size classes of fish to phytoplankton is 3/11 and the

mid-sized value for phytoplankton size is 7.12 um[1] while for salmon (excluding Chinook) it is 18 cm[2]. This gives an annual salmon production for the Gulf of 589,000 (applying a f=0.5 gives a maximum harvest of less than 300,000 tonnes for the whole Gulf which is not an unreasonable estimate for "normal" conditions).

If one applies the same calculation for the Gulf in which the primary production is doubled (160) and the size of the phytoplankton (diatoms now, not flagellates) is also doubled (linear dimensions) then the production of salmon is 1,963,000 tonnes or about 3 times the "normal" production.

Applying different F ratios to these figures could further change the availability of fish depending on the nutrient regime in any one year.

Conclusions

        The above discussion is purely illustrative of how the amount of primary production and the size of primary producers could influence the amount of food for salmon in the Gulf of Alaska, in either coastal or oceanic waters. By further variations of the size and total primary production, it is not difficult to produce as much as a ten-fold change in the supply of salmon – a change that could be realized by differences in interannual weather patterns..

Footnotes
1.   phytoplankton size and distribution are taken from Parsons, T.R.(1972) Size fractionation of primary produces in the Subarctic Pacific Ocean. In: Biological Ocanography of the Northern North Pacific. Publ. Idemitsu Shoten, Tokyo, Japan 275-278.
2.   for salmon size and distribution the equivalent spherical diameter of a 3 kg salmon in 3 size classes is assumed

References

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Sheldon, R.W., W.H.Sutcliffe and K.Drinkwater (1982) Fish production in multispecies fisheries. Can. Spec. Publ. Fish. Aquatic Sci. 59: 28-34