# ON THE METHODOLOGY OF MARINE PLANKTON COLLECTION, WITH A SUGGESTED CLASSIFICATION

by

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The difficulties encountered in making quantitative plankton surveys, and the numerous controversies which arose in regard thereto at the end of the 19th and the beginning of the 20th centuries, have been described (*inter alios*) by Johnstone (1908), while Herdman (1923) has suggested that the only way of overcoming these difficulties is " more frequent sampling and more accurate and detailed determination of the characters, both physical and biological, of the various areas, currents and zones of waters making up our seas—and all that is being done, and must be done in still greater detail, by oceanographers all over the world."

Because of the remarkable morphological and ecological differences encountered in plankton, and because of the great range of population densities from time to time and from place to place, it has not been found practicable to devise any single method of sampling which will give uniformly acceptable results and which would be applicable to every area and to every occasion. However convenient it might be to have such a uniform, all-purpose system available, we are nevertheless confronted with the fact that not always is the same degree of precision essential for every purpose for which plankton is collected, and many factors, of which financial considerations are not the least important, may have to be taken into account when deciding the methodology to be adopted for a particular type of survey.

Certain over-all aspects are of course, axiomatic for some specific classes of investigation; for instance, water sampling for determining nanno-plankton, fine nets for micro-plankton, coarser nets for macro-plankton etc.; but if a broader view is taken, it will be seen that many other diagnostic features must be considered besides this conventional grading by size, depending on the particular aims pursued, especially where ecological conditions, population density and the relationships of plankton to the fisheries are the chief considerations.

## PRE-REQUISITES FOR STANDARDIZATION

With these views in mind, I believe that a series of pre-requisites should be considered before any international standards can be established in regard to the physical properties of sampling apparatus or the methodology to be employed. This is especially true in the Indo-Pacific Region, where there is a small number of plankton workers separated by vast distances. These pre-requisite steps are :—

(1) Determination of the general purposes for which sampling is to be undertaken according to the requirements of different regions or different fisheries, and of the degree of precision required for those purposes. This may be influenced by the information already available on morphology, distribution and other ecological factors;

(2) The sorting of these essential conditions (purpose, precision, biological information) into different types of collection according to the requirements of and the data supplied by the interested countries;

(3) On the basis of (1) and (2), determination, after discussion, for which of the essential types of collection it is feasible and advisable to lay down international standards, taking into account the practical and economic possibilities as regards research vessels, instruments, man-power etc.

(4) Finally, the specification for each of the above categories of the types of apparatus to be employed (pump, water bottle, net etc.) together with the physical specifications (quality of materials and, in the case of nets, size of mesh with special consideration of clogging effects and selectivity for size; flowmeters to evaluate water straining coefficient; towing methods (horizontal, vertical, oblique etc.), speed

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and duration of tow ; depth of operation ; closing devices if any, etc.

One important consideration which must always be kept in mind is that any standard technique which might be adopted should never obstruct the possible future introduction of new and improved methods or devices. Such changes in standards should however, only be considered after a careful comparison of their respective merits ; adequate precautions must always be taken so as to avoid confusion and to establish comparability between the old and the new standards.

## SUGGESTED CLASSIFICATION SYSTEM

As a guide in determining the purpose for which sampling is to be undertaken, and as an alternative to grading according to morphological considerations, the writer has in a previous paper (1948) attempted to classify plankton into several categories each having a specific relation to the commercial fisheries. It will be easily appreciated that this survey is still most incomplete in scope and detail and its submission here is, therefore, of an entirely interim nature.

The biological problems involved in any basic study of the fisheries are at least as complex as the industries themselves and this is particularly true in the world of plankton, which is one of the principal links in the chain of food organisms. Plankton may be classified according to morphology, ecology, physiology, bio-geography and many other attributes. When attempting a classification according to the relationships existing between the plankton and the commercial fisheries, it often becomes necessary to place a particular organism in more than one category, as will be seen from the following list. Each category is subsequently discussed in detail, while Table 1 gives a brief analysis of type locality and seasons of occurrence in Japanese waters, utility and relation to the fisheries, in respect of one species chosen to represent each of the proposed categories. The key letters refer to Table 1.

**1. Exploitable Plankton (EX Plankton)**[1]

A. Immediately Exploitable Plankton IE
- (*a*) Human Consumption Plankton HC
- (*b*) Bait-Use Plankton BU
- (*c*) Farm-Use Plankton FU

B. Exploitable-in-Future Plankton EF
- (*a*) Fish-Egg Plankton FE
- (*b*) Fish-Larval Plankton FL

**2. Fish-Related Plankton** FR

A. Direct-Food Plankton DF
- (*a*) Zooplankton DFZ
- (*b*) Phytoplankton DFP

B. Indirect-Food Plankton IDF

C. Injurious Plankton INJ
- (*a*) Water-Polluting Plankton WP
- (*b*) Spawn-Predatory Plankton SP

D. Symbiotic Plankton SB

**3. Fishing-Related Plankton** FGR

A. Fish-Indicator Plankton FIND
- (*a*) Direct-Food Plankton DF
- (*b*) Indirect-Food Plankton IDF
- (*c*) Coinciding-with-Fish Plankton CF
- (*d*) Adverse Indicator Plankton AD
- (*e*) Luminous Indicator Plankton LI

B. Fisherman-Disabling Plankton FD
- (*a*) Gear-Impairing Plankton GI
- (*b*) Echo-Sounder-Deceiving Plankton ESD
- (*c*) Physically Injurious Plankton PHI
- (*d*) Water-Darkening Plankton WD
- (*e*) Catch-Affecting-Luminous Plankton CAL
- (*f*) Catch-Plundering Plankton CP

### 1. Exploitable Plankton

Included in this category are those plankters which may be regarded as direct objectives of fishing either in their existing form or after future transformation. They fall into a few subdivisions according to their utility and developmental stages, as follows.

### A. Immediately Exploitable Plankton

(a) *Human Consumption Plankton* : This type of plankton includes relatively important organisms utilized for immediate human consumption. There are for instance in Japan numerous fishing villages the economy of which is supported by the commercial fishing of the post-larvae of the anchovy, *Engraulis japonicus*, although the capture of the fish at this early stage of life has long been a controversial topic in relation to the conservation of the fishery resource.

It has been observed that some plankton organisms seem to have occasional toxic effects ; however,

[1] The recent hypothesis that the phytoplankton might in the future be directly exploited for human food is not discussed here.

no specific category has been set up for them at this time, pending further scientific information.

(b) *Bait-Use Plankton*: Included under this subdivision are the forms which are used for bait in angling or long-line fishing, and for the chum of seiners. In some types of fishing they are used for luring fish within the operational range of the gear.

(c) *Farm-Use Plankton*: Among the plankton forms which grow profusely inshore, some are readily caught by simple fishing gear for use as food in fish culture and animal husbandry. Once in a while they may be utilized as organic manure on farm lands.

### B. **Exploitable-in-Future Plankton**

Most aquatic animals in their early stages of development lead a planktonic life as pelagic eggs or larvae. The greater part of them belong to the meroplankton and the survivors are subject to capture sooner or later as adults. As was pointed out by Hjort (1926) and others, the mortality of every organism is critically high during its early life stages, so that the magnitude of the marine resources depends on the survival rate. The plankton falling into this category is, therefore, very important from the viewpoint of commercial fisheries and may be divided into two sub-groups: (a) Fish-Egg Plankton and (b) Fish-Larval Plankton.

## 2. Fish-Related Plankton

This group includes not only those forms which serve directly or indirectly as the food of economically important fishes, but also those which have a favourable influence other than as food, or an unfavourable one through preying on them or dispersing their aggregations.

Quantitative, qualitative, seasonal, and geographical distribution of the plankton referred to here is intimately related with various biological phases of the economic fishes such as growth, nutrition, propagation, migration, distribution, and magnitude of stocks. Information on these organisms is essential to research on resource conservation and in forecasting fishing conditions.

### A. **Direct-Food Plankton**

Many species of whales, fishes and mollusks take plankton directly as their food. This direct food plankton is classified into two well-established types: (a) Zooplankton (DFZ Plankton) and (b) Phytoplankton (DFP Plankton).

### B. **Indirect-Food Plankton**

Practically every type of plankton may be considered to fall under this category, provided that feeders of them are in turn preyed on by other economic species. There are, of course, many marine organisms, e.g., some species of benthos and large sized migratory fishes, which do not directly feed on the plankton, although they are dependent for their life on the supply of other forms which in turn feed either on living plankton or on the carcasses of plankton, in which case plankton becomes the indirect source of nutrition. In particular, phytoplankton is an indirect nutrient of all the higher animals, which, being themselves unable to synthesize organic matter from inorganic substances, are ultimately dependent on plant life.

### C. **Injurious Plankton**

(a) *Water-Polluting Plankton*: Occurring in abnormal concentrations, the water-polluting plankton often inflicts chemical or physical harm on economic aquatic organisms. This type of plankton sometimes drives other organisms away or obliges them to evade the area where it grows. This type of outburst appears to exclude all other forms of life and certain of these phenomena are known in English as "red tides" or "brown tides" and among Japanese fishermen by various names such as "akashio" (red water), "yakumizu" (evil water), "yodo" (stagnant water), "nigashio" (bitter water), and "kusare mizu" (spoiled water). Fishing and the culture of shellfish and seaweeds along coastal areas and in sheltered bays frequently suffer heavy damage from these invasions.

(b) *Spawn-Predatory Plankton*: Those organisms which prey on eggs and larvae of economic fishes or are harmful to their development are included in this category. Since the growth and distribution of plankton fluctuate to a considerable extent depending on the environment, the relationship between SP Plankton and its potential victims cannot be neglected when considering the economic marine resources. Plankton which consumes the larger, adult forms, is discussed under Catch-plundering Plankton (CP Plankton).

### D. **Symbiotic Plankton**

Little attention has been paid to that type of plankton which appears to be in a state of symbiosis with economic fishes. Nevertheless, young fish of some species are from time to time reported to associate with jellyfish. The author was able to observe "kita yurei kurage" (north ghost medusa), *Cyanea capillata* Eschscholtz, being followed by a host of the young of "komai" or wachna cod, *Eleginus novaga* (Kolreuter). The observation led me to the assumption that the latter fish would escape from its enemies' attack under the shelter of the former, while the medusa could easily feed on the latter's enemies approaching them. However, the question as to whether or not animals in these cases are really in symbiosis with each other, still remains to be proved. They are not, therefore, at present considered important to the commercial fisheries.

3. Fishing-Related Plankton

Information on standing crops of plankton in an area often facilitates the detection of fish shoals and hence the location of profitable fishing grounds. Little attention has, however, been given to the relationships existing between plankton and various other factors involved in fishing such as gear, methods, efficiency of operation and size of catch. We will deal with these problems under separate categories.

### A. Fish-Indicator Plankton

As is mentioned in a previous paragraph, the majority of plankton serves directly or indirectly as food for economic marine life. Although some of the species are harmful and repellent to fishes, it is probable that the occurrence of plankton is almost always associated in some way with the presence of economic fishes. For this reason, the distribution of plankton and its quantitative, qualitative, seasonal, diurnal, and geographical occurrence, has much to do with the distribution, migration and the detection of the existence of marine animals.

(a) *Direct-Food Plankton* : The relationship between the distribution of aquatic animals and the food on which they depend can be made use of in selecting a fishing ground. Certain types of commercial fisheries are making use of this technique.

(b) *Indirect-Food Plankton* : An animal in a higher order may depend indirectly on the presence of other, lower organisms even though they do not enter directly into its food. Plankton in such an association with economic fish may be used as an indirect indicator of fishable waters.

(c) *Coinciding-with-Fish Plankton*: There are some plankton and economic fishes which occur in a common environment, although there is apparently not a food relationship. In such cases, proper judgement on the periodical occurrence, amount and geographical distribution of fish may sometimes be determined from the presence of this type of plankton.

(d) *Adverse Indicator Plankton* : In contrast with direct and indirect food planktons, there is another type of plankton which is either detrimental or unrelated to fish life. Some of these may be actually harmful to fishes and often drive them away. Others may live in an environment altogether different from that suitable for fishes. It may therefore not be profitable for fishermen to operate in an area where these types of plankton are found. In other words, the plankton provides fishermen with a negative indicator.

(e) *Luminous Indicator Plankton*: As is known among fishermen in Japan and elsewhere, movements of fish through the water sometimes stimulate a phosphorescent glow caused by certain luminous plankton. In consequence, fishermen operating at night are able to judge as to the size and location of a shoal of fish and decide whether to cast their nets in that particular water. These phenomena are known by Japanese fishermen as 'hiki' or 'shirami' (phosphorescent glow).

### B. Fishermen-Disabling Plankton

All the plankton which affects fishing operations, either by physical injury to the fishermen or by affecting the fishing gear, is included here. This type of plankton may seriously hinder fishermen and affect the size of their catch.

(a) *Gear-Impairing Plankton* : Fishing gear such as drift nets, round hauls, boat seines and fixed nets, will decompose faster than usual if certain kinds of plankton adhere to them while immersed. It frequently happens that purse seines and boat seines are damaged as a result of hauling up unexpectedly large numbers of unwelcome visitors such as jellyfish, and on such occasions fishermen may even have to allow their catch to escape from the net. Concentrations of the plankton may even represent too great a risk to costly nets to justify fishing, and operations may have to be abandoned for days until the plankton disappears from the water.

(b) *Echo-Sounder-Deceiving Plankton* : Needless to say, the recent development of echo-sounders has made a remarkable contribution to fishing techniques. As yet, difficulty in distinguishing a host of medusas or similar plankton from fish shoals by this device may deceive fishermen into hauling up the useless plankton instead of the fish sought after.

(c) *Physically Injurious Plankton* : Not infrequently it happens that fishing divers are attacked by a poisonous medusa whose nematocyst causes severe pain and even dangerous illness. Fishermen on board a boat are also liable to injury through mishandling medusas which are often mixed with the catch.

(d) *Water-Darkening Plankton* : Phytoplankton in general is apt to decrease the transparency of the water to some extent, occasionally disturbing the migration and distribution of fish by an excessive concentration. Another effect of this decrease in transparency may be to inhibit photosynthesis and therefore reduce the productivity of the deeper water. Here we refer, however, only to those phenomena which hamper fishing efficiency. There are fishermen in this country who harvest fish and seaweeds with the help of a glass frame or goggles. In the case of a spring burst of phytoplankton, visibility through the water may be so much reduced as to involve serious loss of fishing time.

In other cases, the light of lamps used to attract fishes may not penetrate through the water under such adverse conditions, and this again will seriously affect the catch. This is cited as one of the reasons why most of the fishing boats in the northernmost part of Japan have not been equipped with fishing lamps, which are of little use in the presence of dense planktonic concentrations.

(e) *Catch-Affecting-Luminous Plankton*: The luminous plankton will on the one hand assist fishermen in locating fishing grounds as described in a foregoing paragraph. On the other hand, when several boats gather together in an area, this plankton may have an adverse effect on fishing operations, on account of the phosphorescent glow stimulated by the manoeuvering of the boats and nets, which tends to frighten the fish.

(f) *Catch-Plundering Plankton*: It is sometimes the case that long-line fishermen operating for cod and similar species find that their catch has been eaten up by a swarm of plankton before the hooked fish can be hauled in, and the same, of course, may happen to the bait. Such plankton may be called catch plunderers.

## CONCLUSIONS

The useful classification of plankton for fisheries purposes does not depend upon the conventional grading by size, and standard methods will be determined according to (1) purpose of survey, precision required and biological circumstances, (2) the consequent establishment of different methods of collection and (3) economic considerations. An attempt is made to classify plankton into numerous categories each having relation to the fisheries.

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**Table 1.—Some examples of Marine Plankton in Japanese Waters**

Classified by Utility and Relation to Fisheries

| Classification* | Example of Plankton** | Type Locality in Japan | Occurring Season in Japan | Utility and Relation to Fisheries | Reported by *** |
|---|---|---|---|---|---|
| EX/HC | Post-larva of anchovy, *Engraulis japonicus* T. & S. | All the coastal waters except the northern region | Nearly throughout the year | Man's food | Nishikawa, T. (1901) |
| BU | Medusa, *Stomolopus nomurai* (Kishinouye) | Off Iki and Tsushima Islands, Nagasaki Prefecture | May to June | Bait of long-line fishing for sea bream, *Pagrosomus major* (T. & S.) | Nakai, Z. (1948) |
| FU | Mysis, *Acanthomysis sagamiensis* (Nakazawa) | Off Kanagawa Prefecture | Throughout the year | Food for fish culture, live-stock; occasionally used as manure | Nakazawa, K. (1910) |
| FE | Egg of sardine, *Sardinia melanosticta* (T. & S.) | Coastal areas of Kyushu, coastal areas of Japan Sea | February to March, March to June | To be caught in adult form | Nishikawa, T. (1903) |
| FL | Larva of sardine, *I. melanosticta.* | do. | do. | do. | |
| FR/DFZ | Copepod, *Euphausia pacifica* Hansen | Japan Sea | February to June | Food of mackerels | Nakai, Z. (1942) |
| DFP | Diatom, *Rhizosolenia setigera* Brightwell | Coastal areas of Kyushu | February to March | Food of sardines | Nakai, Z. (1938) |
| IDF | All the marine plankton | | | Indirect food of fish | |
| WP | *Gonyaulax porigramma* Stein | Ago Bay, Mie Prefecture | Autumn | A cause of 'akashio' (red water) which kills pearl oyster *Pinctada martensii* (Dunker) | Nishikawa, T. (1901) |
| SP | Medusa, *Porpita umbella* O. F. Muller | Tsushima Strait | Spring to Summer | Preys on young of mackerels and horse mackerels | Nakai, Z. (1948) |
| SB | Medusa, *Cyanea capillata* Eschscholtz | Hokkaido | May to June | Followed by numbers of young cod, *Eleginus novaga* (Kolreuter) | Nakai, Z. (1948) |

| | | | | | |
|---|---|---|---|---|---|
| FGR/DF | (Same as FR/DFZ and DFP) | | | Reveals fishing grounds | |
| IDF | All the marine plankton | | | Reveals fishing grounds | |
| CF | Copepod, *Sapphirina* spp. | North Pacific area | February to August | Indicates fishing grounds of skipjack, *Katsuwonus vagans* (Lesson) by co-occurrence with the fish. | Marukawa, H. (1925) |
| AD | *Noctiluca scintillans* Macartrey | Suruga Bay, Shizuoka Prefecture | May to June | Negative indication for anchovy as the fish do not occur in presence of the plankton | |
| LI | *Noctiluca scintillans* M. | All the coastal areas | Spring to Summer | Reveals fishing grounds of sardine through phosphorescence at night | |
| GI | Medusa, *Aurelia aurita* Lamark | Sheltered Bay | Nearly throughout the year | Damage to gear such as boat seine and beach seine when caught *en masse* | Nakai, Z. (1948) |
| ESD | Various medusae | Chiba Prefecture Coastal waters | Throughout the year | Affects echo-sounders of purse seiners operating for sardine and anchovy | |
| PHI | Medusa, *Datylometra pacifica* Gette | Coastal areas of Japan Sea | Summer to Autumn | Severe stings upon contact by fishermen | |
| WD | Various diatoms | Coastal areas of Japan Sea | April to June | Darkens inshore waters and interrupts fishing operations | Nakai, Z. (1948) |
| CAL | *Noctiluca scintillans* M. | All the coastal waters | Spring to Summer | Fish evades nets through luminosity | |
| CP | Various amphipods | Coastal areas of Hokkaido | Spring to Summer | Preys on fish such as cod, *Gadus macrocephalus*, and pollack, *Theragra chalcoggramma*, caught on long-line ; also destroys bait. | |

* See abbreviations on p. 72.
** An example is cited for each category.
*** Cited as one biologist of many who first made a scientific report on the case. The examples tabulated without names of reporters include those cases which are either popularly known among fishermen or are referred to here on the basis of unpublished data.