POTENTIAL RESEARCH BENEFITS TO BE DERIVED FROM ESTUARINE HETEROGENEITY

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INTRODUCTION

Estuaries are notoriously rigorous habitats. Chemical and physical variables present shocking and formidable conditions for those organisms that enter, by predilection or obligation, the forbidding confines of river mouths. For many species the rewards of life in these turbulent areas transcend the dangers. As a result, we find a rich and valuable fauna—capable of coping with the rigors and receiving the benefits.

Because of their economic importance and relatively easy accessability, the faunal and floral species of estuaries have received abundant attention from shore based biologists. Most of this interest has been in recent years, during the time that most biological and physical sciences were expanding.

But the work has been piecemeal. Almost all of the projects were directed toward a very narrow aspect of the total habitat, most of them centering about one species or one group of organisms. In a few cases, studies were carried out on one or two hydrographic features, but these were rarely correlated in detail with the animals and plants of the area.

Consequently, we now have a vast accumulation of miscellaneous information about estuaries and the animals and plants that live in them, very little of which provides broad ecological interpretations or makes possible any correlations with other naturally occurring phenomena. This is wasteful research because the same studies carried out under a different system could, for the same effort, provide a much greater understanding.

We are all familiar with the limitations of experimental studies, usually conducted upon an isolated mechanism or function under laboratory conditions. The complexity of organisms and their surroundings are difficult to synthesize under artificial conditions. This problem has recently been discussed (Redfield, 1958).

Estuaries, with their easily available transient conditions, can provide experimental situations on a grand scale. These facilities will not have the deficiencies inherent in laboratory procedures.

THE PLAN

A type of program is now suggested that might be called *Selective Concentration.* (The idea is not entirely original. It was suggested by Dr. George Rounsefell and his group, from Galveston, Texas, in March, 1961, at the meeting of the Gulf States Marine Fisheries Commission in Biloxi, Mississippi. The present paper is an expansion and prospectus of this plan of action.)

Under this plan, several prominent estuaries would be selected for comprehensive use of all the myriad scientific disciplines that are available. Chemistry, physics, zoology, botany, fisheries biology, geology, parasitology, meteorology and the many derived specialties would find a place. All data obtained would be stored on IBM cards or other records suitable for later analysis by machines and computers.

It seems unlikely that all of the studies of potential value could be pursued simultaneously. There would doubtless be a continuous procession of various projects and investigators through the institution established at each estuary.

But many of the undertakings would proceed with no planned termination. These would include:

water temperature
salinity
weather
fishery landings
turbidity
plankton

All would be studied over a wide geographical area about each river mouth.

Such other short term investigations as might seem desirable or for which personnel might be available would be laced into the over-all program. The results of these would be interpreted in the forms and with the

[1] Contribution No. 63.

background of the long term studies listed above.

All plankton samples would be kept. Any investigator wishing to study a particular animal or group would have a long series of samples instantly available. There would be no need to wait several years for the acquisition of suitable material.

Present Status

Although the institutions recommended are, at this time, hypothetical, certain existing laboratories and groups along our coasts are in some respects carrying out the functions outlined.

Small laboratories have been established along the shore for various reasons. Some were founded to begin investigations on valuable indigenous fisheries; some were established because of a prevailing local manifestation such as red tide; others were adjuncts to university training programs; a few were organized to serve a particular industrial concern or branch of the armed forces.

Whatever their origin, these installations became loci toward which gravitated many different types of investigators, each one providing a new facet of information. Because of the agglutination over the years, these already existing facilities represent the best opportunity for the *Selected Concentration* being proposed.

In some areas, multiple installations exist in reasonable proximity. Here, the program will be accordingly more easily instigated.

Very few of the existing stations have long range sampling programs. Even where such data is available, there are usually long gaps during which no samples were taken or observations made. The methods, sampling stations and conditions are not standardized.

In summary, there exist laboratories and organizations near estuaries with suitable equipment for long term sampling. It only remains for the leadership of these institutions to establish the necessary policies.

Discussion and Recommendations

No attempt will be made here to anticipate all of the possible benefits likely to be derived from the suggested plan of action. But a few examples will illustrate the type of knowledge that can be developed.

Multiple estuaries.—Because of their amenability to cultivation, oysters have been the subject of long and serious study over the world. In our own country, and Canada, more effort has probably been expended on this animal than any other in salt water.

Although most of the studies were directed towards local habitats and growing conditions, the printed reports give information on a wide spectrum of environmental conditions from Newfoundland to Texas.

A synthesis of this material provides insights into the basic physiology of oysters that would not be possible from any one of the individual areas. Where previously it was thought that one species of oyster occupied the entire range, we now know that physiological subspecies or species occur in various localities. Temperature requirements for Florida oysters are so high that they do not reproduce in the colder waters of Long Island Sound. Characteristic hibernation of northern populations does not occur in the Gulf of Mexico. Southern oysters cannot endure the cold winter temperature of Connecticut waters. Growth rates are more rapid and are continuous throughout the year in the South. Spawning proceeds for most of the year in Florida but is limited to a few weeks in New England. In many cases, quantitative values have been established for these functions.

Practical implications from all of this are at once apparent. For any area, oyster spawning, growth and vigor may vary predictably from one year to the next because of a variation in temperature regime.

Actually, a system of prognostication exists now in Long Island Sound which takes into account (in addition to temperature) the presence of microscopical plankters suspected as being inimical to oyster larvae. This forecasting also involves the estimation of spawning success of known predators.

As the many chemicals, physical and biological differences between estuaries are further identified and measured, and these are correlated with differences in oyster activities in each place, more detailed understanding will be available.

Several years ago, Albert Collier, Sammy Ray and their groups worked on organic compounds in the waters around Pensacola that showed a possible influence on oyster pumping. References pertinent to this are included in two of Colliers later papers (Collier, 158; Collier, 1959).

It may be that valuable experiments are presently being performed fortuitously, and

naturally, in the various estuaries of this country that will help to further resolve the importance of the compounds Collier found (as well as others). Chemical investigations correlated with oyster survival and well-being should demonstrate identifiable differences in individuals subjected to various concentrations of the presumptively important compounds in separate river mouths.

The critical values of various ecological factors for a particular organism can be established in many cases where an animal or plant is living under marginal conditions. This has been discussed earlier for temperature (Hutchins, 1947).

In some areas the temperature required for spawning is present for a very short period of the year. In colder years, only a very minor or negligible reproduction may take place. The needed temperature can, in most cases, be confirmed by a study of spawning and temperature in the regions having longer periods of high temperatures. By using the critical temperatures so established it may be possible to predict spawning success and the year class abundance in quite distant habitats by the simple expedient of taking water temperatures.

A few examples of the use of this method will suffice. It has been shown in a recent work (Phillips, 1960) that *Thalassia* reproduces sexually in Tampa Bay but such flowerings are not aboudant. Other observers (Hilary Moore, pers. comm.; Gilbert Voss, pers. comm.) indicated a much more abundant florescence in the Florida Keys. Phillips concluded that "Possibly the Tarpon Springs area represents the northern limit of the flowering condition in *Thalassia*."

There may be other factors which are more important than temperature. Phillips mentions photoperiodicity, a factor whose potency is well established in plant physiology. A careful study of these elements in several widely separated estuaries would help to define the relative importance of any particular parameter. The particular problem of *Thalassia* reproduction would be greatliy improved by studies in the northern Gulf if such studies were correlated with the monitoring of basic hydrographic and meteorological regimes.

Although a substantial amount of research has been done on shrimp, and abundance appears to be related to rainfall in two of the common species (see below), the effects of temperature have received but little attention.

Using scattered temperature data, landings statistics and a few providential studies in various parts of the range of *Penaeus duoarum,* it has been possible recently to make a few speculations concerning the role of temperature in spawning and resulting year class abundance (Eldred *et al,* 1961). These authors theorize a spawning temperature of 75° F. which may help to explain the diminished abundance of this species in the northern Gulf. The length of time each year that water temperature might be expected to rise above 75° F. would be presumably less in Texas than in Tortugas, for instance. It is also suggested that the relative and absolute abundance of the other two species may, to some extent, be dependent upon temperature.

Population density, distribution and fishing success have already been shown to be dependent upon temperature in the case of certain Mediterranean shrimp species (Ghidalia and Bourgois, 1961). Similar observations have been made on penaeids of southeastern United States. (Mr. Harvey Bullis, personal communication).

The *selective concentration* studies I suggest will be an invaluable aid in establishing the roles of temperature, salinity and other factors in success of year classes. Detailed temperature studies should throw light on the importance of winter minima, rate of warming, length of time above the critical spawning temperature, rate of cooling not only on spawning but on growth and survival as well.

Due to intensive gathering of shrimp production figures since 1956, a broad picture of abundance is available for each locality of southeastern U. S. from North Carolina to Texas. These data comprehend sizes of shrimp, species, and depth of water in which they are found.

Recently, using this information, a summary of shrimp landings was prepared for the first half of 1961 (Gunn 1961a).

Since the period covered was that during which the brown shrimp, *P. aztecus,* production might be expected to predominate in the western Gulf, a relatively small abundance was evident for this species over a wide geographical area. One ecological parameter that might account for this wide-

spread phenomenon, and which would be general enough to account for the shortage is temperature.

It is remarkable, therefore, to know that with the small amount of temperature data extant from various incidental studies along the Gulf, and without the strong supporting data that could be available, there was an opinion on the part of several biologists concerned that temperature might well have been the critical factor (Gunn, 1961b).

Had temperature monitoring been pursued over the area, as presently recommended, these landings data might be subject to greater interpretation and understanding than they are now. For the present we can only hypothesize.

A similar situation existed in the case of the pink spotted shrimp, *P. duorarum,* in 1959. After the coldest winter of record in Florida in 1957-58, the catch of shrimp in the spring of 1959 was a complete failure along the west coast of that state and Tortugas landings were the poorest of record for the same species (Eldred, *et al, op. cit.*).

But here again, water temperatures sufficient to suport a detailed analysis were not available. It would appear, then, that one of the elements of the suggested monitoring is present now in the form of accurate landings, but that supporting hydrographic surveys must yet be added to complete the picture.

Single estuaries.—While conclusions can be drawn from estuarine differences of geographical origin (e.g., temperature averages due to latitude and chemical aberrances due to geologically different water sheds), other dissimilarities may be found in any one estuary temporally and locally. Thus, information on temperature and salinity tolerances can be obtained for many organisms by a careful recording of changes in abundance in parts of a river mouth; by a careful monitoring of selected habitats over a period of several years; and comparing abundance, growth and spawning with hydrographic conditions.

Here again, the easiest examples to mention are oysters and shrimp.

Those of us who have had the opportunity to observe oyster growing habitats over a considerable number of years are acquainted with the fact that cycles of wet years result in a high productivity of the reefs lying in peripheral regions. During a series of dry years these reefs are decimated by snails, disease and noxious associated organisms such as sponges. The average salinity values of such periods are much more meaningful in establishing ecological limits of the organisms concerned than those of a short term basis.

Similar findings exist for shrimp. During the great drouth of 1948-1956, brown shrimp, *Penaeus aztecus* largely replaced the white shrimp, *P. setiferus,* in the estuaries of the western Gulf of Mexico. When rainfal returned to normal, the white shrimp again achieved a greater abundance.

Abundance of shrimp as demonstrated by landings has also been shown to be correlated with rainfall (Hildebrand and Gunter, 1953; Gunter and Hildebrand, 1954).

In the present connection, the following quotation from the latter work is worth repeating:

> "In view of the general paucity of long term hydrographic work in estuarine areas over the world, it goes without saying that salinity data, adequate for relation to the shrimp catch, even in one bay let alone the whole Texas coast for the 26 year period, is completely absent. For that reason the writers have utilized rainfall, which is one step removed from the probably effective factor, salinity, in this analysis."

As implied above, definite salinity studies in selected nursery and growing areas should elucidate the salinity requirements of the white and brown shrimp more quantitatively and meaningfully.

Under the plan of investigation being here recommended, the same information can be developed for those animals and plants not now so well understood.

Another example of the use of single estuaries is in the oportunity afforded for the evaluation of osmoregulatory abilities of various animals. These can be established under definitely measurable chemical and physical parameters. Then, as in the case of the St. Johns River (Odum, 1953), and the Homosassa River (Herald and Strickland, 1949), both of Florida, a comparison is possible in which one or more of the chemical constituents is altered (Ferguson *et al,* 1947). Laboratory experimentation on such a scale would, of course, be unthinkable.

Summary and Recommendations

1. The heterogeneity of estuaries is discussed. Inasmuch as change and difference are useful qualities in experimentation, the diverse qualities of river mouths offer splendid experimental situations for research if properly utilized.

2. The need for *selective concentration* of estuarine studies is asserted. Those estuaries already possessing laboratories, especially where these installations have been in existence for a relatively long duration, offer the most favorable sites. In those cases, the suggested program could be effected by merely extending, expanding and standardizing activities that are presently underway in a more or less haphazard fashion and by integrating them with similar studies over a wide range of brackish water habitats.

3. Examples of the type of benefit to be derived from suggested studies are provided, using only a few common organisms of southeastern U. S. and the Gulf of Mexico that have already received extensive studies over a relatively wide range. Although others could be mentioned, only a small percentage of organisms has received attention. Proposed studies would bring out salient physiological and ecological factors not now comprehended.

4. Inasmuch as estuarine animals and those of the offshore waters intermingle and are not, in many cases, restricted to either habitat, the proposed studies should embrace, besides the river mouths, the waters nearby for a considerable distance offshore.

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