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THE VALUE OF THE TIDAL MARSH

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the tendency for the value of the fish resource to be driven to zero in a market context is an example of market *failure* arising from common property problems in the fishery. That is, the zero market value on the fish resource is not condoned by conventional economics as GOP imply, but is cited as a classic example of market failure (Haveman, 1973).

13. One can see the possible fallacy of this assumption by reference to an example. Assume that an acre of wetland can produce a ton of marine worms per year. Furthermore, assume that a ton of marine worms could be artificially propagated in a laboratory at a cost of $100,000. Could we then conclude that wetland services that produce a ton of marine worms are worth $100,000 to society? The answer is an unequivocal no, unless we can convincingly demonstrate that society would be willing to pay $100,000 per ton for marine worms.
14. One particular waste assimilation benefit of marshland ignored by GOP, and by this discussion, is the assimilation of waste from nonpoint discharges. The cost of control of these wastes may be quite high, and the alternative of natural wetlands as a treatment source may be quite valuable.
15. The discussion in this article has not exhausted the various methodological issues that cast doubt on the validity of the GOP estimates. Other issues include their (1) failure to properly distinguish among marginal, average, and total values of wetlands, (2) choice of the appropriate discount rate for calculating present values, and (3) neglect of tradeoff possibilities between wetland services.

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THE VALUE OF THE TIDAL MARSH

by

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The objective evaluation of different land use strategies has been severely hampered by the difficulty of stating the value of different objectives in a common currency. Cost accounting techniques for industrial, commercial and residential development are well developed and these interests can bring strong pressures to bear because of the nearly universal acceptance of evaluation techniques which show the cash value of a particular management alternative. Against these evaluation techniques conservationists and natural resources economists have been at a disadvantage because of the difficulty of translating the value of natural or undeveloped areas into monetary terms. Frequently, therefore, the alternative management decision of leaving land in its natural state is not adequately defended or seriously considered. Although recreation, for instance, is recognized as a legitimate land use it is difficult to place a cash value on the esthetic pleasure derived from an unspoiled forest or a natural lake (for a discussion of this problem, see Pope, 1972). As a result, hearings on proposed land use developments are usually charged with a great deal of emotion and frustration for all parties involved. In this paper we develop a step-wise means of assessing

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the true value of natural tidal marshes to society as a whole - a v based, not only on commercial usage, but on social usage and the mo value of natural (i.e. "undeveloped") estuarine environment.

Tidal marshes are lands which are particularly vulnerable to capricious development (W. E. Odum, 1970), because many of the real values of marshes are not recognized, or accrue some distance from t marsh itself. Teal (1962) estimated that 45% of the net primary pro tion of a Georgia <u>Spartina alterniflora</u> marsh was flushed into the adjacent bay by tidal action. Odum and de la Cruz (1967) estimated the net export of organic matter (which includes many mineral nutrie from 25 hectares of such marsh was 40 kgms and 140 kgms on a neap an spring tidal cycle respectively. Stowe <u>et al</u>., (1971) have estimate that well over one-half of the total production of organic matter in Gulf Coast estuary originates from the surrounding marshes. In this coastal marshes and other shallow water production areas (reefs, sea and sea grass beds, etc.) all over the world export mineral and orga nutrients that support much of the production of the adjacent estuar and coastal waters (see E. P. Odum, 1971). Furthermore, as is well documented, estuaries serve as a nursery ground for commercially imp coastal fish and shellfish. McHugh (1966) estimates that two-thirds the cash value of species harvested on the Atlantic and Gulf Coasts "estuarine dependent". Thus, productive marshes are an integral par the estuarine system, which not only exports nutrients but also grow sea food that may be harvested in adjacent waters. Nursery ground i the only valuable function of an undisturbed marsh, but it is an imp and now generally recognized one. Even though the marsh may be privately owned the production of that marsh does not, at present, accrue directly to the owner, but to a commercial fishery, perhaps many miles away. Thus, the true value of a flowing-water, exporting system must be based on a much broader cost-accounting than is usually employed in real estate evaluation.

At the other end of the spectrum of interested parties is the land developer. Since the coasts are often the most densely populated parts of the country, there is strong pressure to fill marshland for commercial, industrial and residential use. California has lost 67% of its marshland in this way; New York and New Jersey 10-25% (Sweet, 1971). Additionally, due to alterations in natural processes brought about by land management decisions, Louisiana is currently losing 16.5 square miles of marshland per year (Gagliano, Kwon and van Beek, 1970). Indeed, with high marsh in prime commercial areas of New Jersey selling for as much as $80,000 per acre the economic incentive to develop is extremely strong.

In the paragraphs below we present first the value of a natural tidal marsh-estuary based on identifiable present commercial and recreational uses for which monetary values can rather well be determined. Since this omits a number of other values the marsh has, which are identifiable but more difficult to quantify, we discuss next potential additional values and attempt to equate these with dollars. Thirdly, we calculate the total "life support" value of the tidal marsh according to the procedure suggested by Odum and Odum (1972). Finally, a summary table is presented as a method of integrating and summing values as a basis for land use planning in the coastal zone.

Fishery Production Based on Harvest of Naturally Produced Animals (Natural Secondary Production)

Since, as already acknowledged, fishery production in estuarin coastal waters is linked to shallow water production zones such as marshes, reefs and sea grass beds, one can estimate the present val of an acre of marsh and its associated tidal creeks by evaluating t dependent commercial fishery. For instance, on the Georgia coast t dockside value of fish and shellfish (including shrimp) in 1965 was million dollars (Carley, 1968). Value added in processing amounted 5.23 million dollars raising the total value to 8.9 million (Table Georgia has 393,000 acres of coastal marshland (Spinner, 1969). Dir proportioned this works out to about $23 per acre per year. Sport f along the Georgia coast is estimated to involve 280,000 fishermen wh spend an average of $80 each per year (E. P. Odum, 1968). Other rec tional uses such as hunting and boating are arbitrarily valued at on half the sport fishing so that a total "sports" value comes to $108 p acre per year value (Table 1). Comparable statistics for Louisiana a Florida marshes are shown in Table 2. They vary somewhat from the Ge figure but yield similar estimates suggesting a minimal value of abou $100 per year per acre of marsh just from the standpoint of fishery a recreational values.

These figures place a value upon a piece of real estate which is easily comprehended in terms of present evaluation techniques. Using income-capitalization approach (see Barlowe, 1965, page 180) and the formula, V = R/i where V represents the value of a parcel of land, R represents the annual return from it, and i represents the appropriate interest rate, it may be easily seen that the minimum value of an acre of marshland, due to fishery and recreational returns is \$2000, if R = \$100 and we assume an interest rate of 5%.

Admittedly the estimate of \$2000 can be questioned since one cannot prove that all the fishery would be destroyed if the marshes were; nor can one say exactly how many acres of marsh are necessary to support the present level of fishery activity in estuarine and offshore waters. The low *Spartina alterniflora* marshes, because they are subjected to vigorous tidal flushing that acts an an "energy subsidy", are certainly more valuable per unit area for estuarine productivity than the higher, dwarf *Spartina* or *Juncus* marshes (Odum and Fanning, 1973). Of course, if the latter cover large areas, the total contribution can be considerable. As we aim to show even an inflated value based only on the harvest of naturally produced by-products falls far short of the value obtained by a more complete cost accounting that includes other, and in the long run, more important considerations.

Aquaculture Based on the Utilization of Natural Primary Production

Another approach to evaluation of land is to consider its potential for development, and this is usually the major factor in conventional real estate dealings. In estuaries, development could range anywhere from intensive aquaculture to draining and filling for industrial or other use. Since this paper is concerned with evaluation of natural marshes we will consider only practices which would use the marsh as a renewable resource but retain it in it's more or less self-maintaining natural state. Oyster aquaculture provides a promising possibility since less modification of the estuary is required than for intensive shrimp or fish cult Coastal estuaries can certainly support oyster production on a intensive scale than is found at present. Estimates for incom might be obtained from this kind of development are shown in T Annual yields of 1800 pounds of oyster meat per acre worth $10 value added) were obtained by the late Dr. Robert Lunz, with m intensive culture in the marsh-bordered estuaries at Bear Bluff (E. P. Odum, 1968). Very intensive raft culture, as developed with rafts covering 1/10 the water surface, could theoretically high as 4500 pounds of oyster meat per acre with a value of $26 year (Table 3, column 1). This kind of intensive aquaculture i only in flowing water systems where the organic production of a passes across the oyster rafts, and the feces produced by the c oyster population are also carried away from the rafts.

In still another approach Stowe _et al._, (1970) estimated t annual primary production of estuarine waters in Louisiana to b 18,000 pounds dry weight per acre. Half of this originates in t and is flushed into estuarine waters by tides. Using these figu assuming a conversion efficiency of 10% from the primary photosy product to oyster meat, it would appear that intensive raft cult oysters would require about three acres of marsh and three acres estuary per acre of oyster raft. On the basis of an acre of mar then, the potential value from oyster culture, including value a during processing, would be about $350 per year for a moderate c level, and nearly $900 per year with intensive raft culture (Tab Column 1).

Waste Treatment Work as a Basis for Economic Evaluation

The shortcomings of evaluating environment only in terms of direct uses or products is that such cost-accounting ignores the extremely valuable life-support work natural areas carry out without any development or direct use by man. It is this "free work of nature" that is grossly undervalued, simply because it has always been taken for granted, or assumed to be unlimited in capacity. Since development by man may adversely affect this work, it is important to evaluate it before deciding on what kind of development, if any, is in the long term best interest of both the environment and the economy.

One very important contribution estuaries make to the growth and economic wealth of highly urbanized regions is the waste treatment that active ecosystems can accomplish without appreciable reduction in water quality. Sweet's (1971) estimate of the waste assimilated by five mid-Atlantic estuaries, in terms of BOD load received, is shown in Table 4. In general, the sewage discharge in these estuaries does not stop at the "secondary" stage but continues through the "tertiary" stage of nutrient removal and assimilation. Since artificial tertiary treatment of sewage is very much more expensive than secondary, then an acre of marsh-estuary is doing about $14,000 worth of work per year at a daily loading of 19.4 lb. BOD, assuming the cost of artificial tertiary treatment is at least $2/lb BOD (Table 5). In other words, this is what it would cost man to deal directly with his wastes if the acre was not available to do this work. Resorting, again, to the income-capitalization calculation an acre of estuary that is able to handle the mean waste loading shown in Table 4 is worth a whopping $280,000 (Table 5, Column 2). It is no wonder that large cities and industrial complexes tend to be located wher bodies of water are available for "free" treatment plants!

Of course, it is apparent that mid-Atlantic estuaries ar overloaded (see especially Hudson and James estuaries, Table 4 extent that oxygen and other water quality aspects are reduced undesirable level, especially in terms of fisheries and recrea value of $280,000/acre thus represents a large "overload" of w has serious pollution side-effects, and if continued or increa result in system breakdown. If the BOD load can be reduced, th estuaries would function better as tertiary treatment plants an valuable overall.

In a detailed study of the Delaware estuary the Federal Wa tion Control Administration estimated the cost of water treatme increase the minimum dissolved oxygen level to 4.5 mg/litre (a imum water quality level) at $460 million (amortized capital an costs for 25 years). This works out to $264 per acre per year. resulting improvement in water quality would yield recreational and, more important, reduce stress on the system's ability to d tertiary treatment. $264/acre seems a small price to pay to ins the acre can safely do thousands of dollars of work free!

It is clear, then, that estuaries are not really effective secondary treatment since large amounts of organic matter introd into systems naturally high in organic detritus reduces the diss oxygen levels to an undesirable extent. And, as we have seen, th omic value of estuaries as secondary treatment plants is relativ since the energy* and money necessary for artificial secondary treatment is not large per unit volume of waste. The most important contribution marshes and estuaries can make in waste treatment is in tertiary treatment to remove and recycle inorganic nutrients, a very expensive process if carried out by man in artificial systems as we have seen. When nutrient rich effluents enter a marsh-estuarine system the nutrients are effectively trapped by the tidal circulation pattern (Bowden, 1967), and assimilated in the productive biological system. Estuarine ecosystems have evolved adaptations to high nutrient levels, and have a large capacity to buffer nutrient changes. Pomeroy, *et al.*, (1972) have shown that the phosphate recycle system is so large and homeostatic in Georgia estuarine and marsh sediments that the level of phosphate in those waters varies little throughout the year, despite variations in input. Studies in Louisiana (Ho *et al.*, 1970) confirm this. The sediments act as both source and sink, effectively buffering the effects of large additions of phosphate to the estuarine system.

Although research results are not as clear for nitrogen, flooded marshes appear to be uniquely adapted for denitrification and, therefore, may be extremely valuable for treatment of inorganic nitrogen wastes also. Studies in flooded swamp and marsh soils (Patrick *et al.*, 1971) have shown substantial loss of inorganic nitrogen by denitrification in the anaerobic zone.

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*A Rand report (R-1098-NSF; 1972) just seen lists the amount of electrical energy needed for secondary treatment of 10^6 gallons municipal wastes as 660 kWhr (about 56.8 x 10^4 Kcal) which on a per capital basis works out to be less than 1% of the electricity now consumed in an urban area.

Experimental confirmation of these important water quality of marsh-estuarine systems is slowly evolving. Valiela and Tea treated salt marsh plots with sludge from a secondary sewage tr plant, and measured the inorganic nitrogen and phosphorous loss first tide following each application. From late May through m November they applied 25.2 g sludge $m^{-2}wk^{-1}$ for a total of about pounds N and 400 pounds P were removed per acre of marsh in thes

Grant and Patrick (1970) give a second example in Tinicum m Pennsylvania. Water flowing out of this marsh showed an average reduction per acre of 6.4 pounds of phosphorous (as phosphate) a pounds of nitrogen (nitrate and ammonia), as compared with pollu flowing into the marsh.

Using Culp's <u>et al</u>., (1966) estimates of tertiary treatment $100 per million gallons and Seibel's (1969) estimate of 10 ppm phorous in sewage water, 83 pounds phosphorous could be removed a of $100. At this rate, the work done by the marsh in phosphorou is worth $480 per year (Valiela and Teal's data) to $1420 per ye and Patrick's data, assuming effective biological activity 185 d year). Income-capitalization of these data yield a per acre val of $9,600 and $28,400, respectively, for removal of only one maj

In summary, it is clear that man should pay for secondary tr of wastes since such treatment is relatively inexpensive and untr organic materials greatly stress any natural aquatic system, but ially marsh-estuaries. However, man will and should depend on pr natural ecosystems for tertiary treatment of hugh volumes of low wastes which would be extremely expensive to treat artificially.

the economic value of estuaries as tertiary treatment plants can be valued in tens of thousands of dollars per acre as compared to mere hundreds that accrue from by-product uses. The shallow-water zones occupied by marshes play a major role in this very valuable life support work since their contribution to the overall metabolism of the estuary is proportionally high.

Other Marsh Functions

Other functions of the natural marsh are more difficult to quantify, but no less real. Perhaps the most important of these is the role of the marsh in global cycles of nitrogen and sulfur. The continuing normal function of the biosphere depends on the chemical reduction of carbon, nitrogen and sulfur, which are incorporated into all living tissues. While carbon reduction occurs through photosynthesis in oxidizing atmosphere, completion of the cycle of the other two elements depends on microbial action in a reducing environment (Deevey, 1971). Nitrogen fixation in the world has been nearly doubled by industrial fertilizer production (Delwiche, 1970). Some of this reduced nitrogen is accumulating in the slowly increasing biomass on the earth's surface, as shown by entrophied water bodies, but apparently the global biosphere has compensated for increased nitrogen inputs to some extent by increased denitrification. This microbial process requires the close proximity of oxidized and reduced zones. Nitrogen of biological origin is oxidized to nitrate in the oxidized layer, diffuses into the reduced zone and is reduced to nitrogen gas, escaping to the atmosphere. Tidal marshes are ideally suited for this function. Tidal waters carry nutrients to the marsh surface where they diffuse through a thin layer of oxidized iment to the anaerobic zone below. The sulfur cycle, in the same depends on reduction of sulfates in anaerobic muds to sulfur and s fides. Oxygen is a by-product of the reaction. In Linsley Pond, sulfate reduction may be as much as 10% of carbon reduction (Deevey 1971), so its magnitude is of some significance. The industrial cor bution to atmospheric sulfur has increased to about one-third of th total atmospheric sulfur burden (Kellogg *et al.*, 1972). This sulfu washed from the atmosphere by rain, primarily as sulfate. The lack widespread accumulation of sulfuric acid is evidence of the efficien of the sulfate reduction system in anaerobic muds.

These two processes have not been quantified on an area basis i estuarine systems but impressive evidence points to the importance o the coastal anaerobic muds to continued normal functioning of global cycles of nitrogen and sulfur.

There are still other marsh functions worthy of mention for whi cost accounting is yet to be accomplished. A salt marsh is an import buffer against storms. In particular, it absorbs the enormous energy storm waves and acts as a water reservoir for coastal storm waters, t reducing damage further inland. Some idea of the protective value of wide band of energy-absorbing marshes and barrier islands is seen in increasing national cost for "disaster relief" in coastal areas which either lack these natural protective "breakwaters" or where they have been filled in or "bulkheaded" for housing or other development; marsh and island protected coasts suffer comparatively little damage even in fierce hurricanes. Rising costs of coastal development is very often the result of ill-planned modification of natural protective systems, not the result of increased storm intensity.

It is also becoming apparent that marshes are important in the protection of the beautiful white sand beaches of the outer barrier islands and "banks" (see Hoyt, 1967; Dolan, Godfrey, and W. E. Odum, 1973). Where the energy and muddy sediments of storm tides can be absorbed by large areas of marsh-estuary the natural erosion of beaches is at least balanced by formation of new beaches. Beaches are degraded or lost where they receive the full brunt of storm tides unless man resorts to very expensive artificial breakwaters. Therefore, one is justified in adding some of the enormous economic value of outer beaches to the value of the inner marsh-estuaries. The powerful flow of water in and out of large tidal basins also tend to keep harbors and inlets "dredged" - another example of useful "free work of nature". Recently reprinted in "Benchmark Papers in Geology" (Coates, ed. 1972) is an article by M. Burrows (Page 350), published in 1888 that describes how all of the early harbors on the southeastern coast of England were silted in when the great marshes were first diked and filled in; constant dredging and "a vast expenditure of national funds" then became necessary to keep harbors operational.

One value of coastal marshes that is generally recognized is their importance as habitats for migratory birds which have esthetic and hunting values, not only locally, but elsewhere in the continent. Tidal marshes that receive large inputs of freshwater are especially valuable in this regard. For example, almost the entire North American population of snow and blue geese (millions of birds) are dependent on the marshes of the Texas and Louisiana coasts, which are their sole wint grounds. Some of these same low salinity marshes are also h for their production of muskrat fur, but again the monetary such by-products on an acre basis is not large.

Life Support Value as a Function of Productive Energy Flow

So far in this article we have resorted to the "compone that is, identifying and separately evaluating products, use functions that are judged to have a value, or potential valu The shortcomings of this approach lies in the difficulty of i or summing the component values, because many of the uses co one another. Thus, intensive aquaculture would reduce sport recreational boating values, or heavy use for secondary trea sewage would greatly reduce many other values - and so on. T it is difficult to obtain an overall value by the component Also, most of the component values so far discussed relate t estuarine system and not to the marshes per se; yet it is th that need to be valued in monetary terms since they are the system most vulnerable to modification and development by man

H. T. Odum (1971) has suggested an "ecosystem" approach lating the total work of nature into monetary terms, so that value of a delimited natural area can be determined without h specify how the work flow might be divided into different use functions. Odum and Odum (1972) have extended this approach of land-use planning in which natural areas are considered as part of man's total environment. Since the exchange of energ is the basis for economic transactions it is suggested that the ratio of Gross National Product to National Energy Consumption can be used to equate energy with money. In round figures for the United States 10^{16} Kilocalories are consumed yearly to produce a Gross National Product of 10^{12} dollars, so that approximately 10^{4} Kilocalories is equal to one dollar. Since the rate of primary production is a measure of energy flow of a natural community and an index of the useful work that might be accomplished, the ratio can be used to place a dollar value on any part of the natural environment where primary production can be measured or estimated.

Several recent estimates of the annual net primary production of coastal salt marshes are listed in Table 6. Several of these estimates, and most of those published prior to 1968, are underestimates because they are based on "standing crops" uncorrected for dry matter exported by the tides during the annual cycle. We judge the Louisiana and Georgia figures, as shown in Table 6, to be most representative of the highly productive marshes of the Gulf and south Atlantic coasts. Since, as already indicated, productivity is to a certain extent a function of water flow separate estimates are given for the higher or inner marshes (that receive less water flow subsidy) and the outer or low marshes (Table 6, Columns 1 and 2, respectively). Conservative estimates in round figures, then, are: 1000 gm/M^2 for high marshes; 3000 gm/M^2 for well-irrigated low marshes; and 2000 gm/M^2 for large areas of total marsh with an approximate 50-50 distribution of high and low types. Satisfactory measurements of total, or gross, primary production have not yet been accomplished for salt marshes. Since Spartina grasses utilize

the recently discovered C_4 photosynthetic pathway, the amount
photosynthate dissipated in respiration is certainly not as la
earlier estimated by Teal (1962). Based on the efficiency of
plants adding 25% to the net production would give a reasonabl
of gross production. Thus, annual gross primary production is
of the order of 2500 gm dry matter/M^2 overall, 1250 gm/M^2 for h
marshes and 3750 gm/M^2 for the more productive low marsh stands

To estimate the dollar value of an acre of marsh based on
energy/money conversion outlined in the second paragraph of this
we need only to multiply the round figure productivity estimates
to get Kcal/M^2 (see Odum and Fanning, 1973), and by 4046 to get
and divide by 10^4 to get dollars/acre. Such a calculation gives
of $4,147/year for the marsh as a whole (range: $2,703 for high
and $6,2207 for low marsh). The income-capitalized value would b
$82,940 per acre overall. This is a larger value than obtained b
of the component estimates, except for the "overloaded" tertiary
ment value (Table 5), which as already discussed is unreasonably
and also one that involves very large volumes of river and bay wat
with the marshes. The advantage of cost accounting based on produ
(i.e. capacity for life support work) is that it can be applied to
particular acre, or acres, of marshland itself as it functions as
of the whole estuary.

Discussion

Round figure values based on by-products, waste treatment and
productivity are summarized in Table 7. The values of estuaries fo

waste assimilation and general life support is greater than that accruing from by-products, even intensive aquaculture which if carried out on a large scale would eliminate most recreational and other uses. Summing values for components that could conceivably be non-competitive gives a "multiple-use" value approaching that based on productivity. As already emphasized the latter value (Table 7, No. 5) pertains directly to the marshlands, whereas all the other values summarized in Table 7 are based on the estuarine system as it functions as a whole.

Demonstrating that marshlands and estuaries have a substantial dollar value in their natural state certainly provides a big boost to preservation of such areas that are in public ownership. If large values such as those in Table 7 (items 4 and 5) are generally recognized and accepted, then state or federal agencies or commissions which have jurisdiction over the property or resource will be less likely to lease, give away, or sell valuable marshlands for capricious development. Also, planners will have a greater incentive and public support for zoning such areas into permanent protective categories. However, if the marshlands is in private ownership, the owner will stand to gain by selling for development no matter how high the appraisal, since leaving the area in its natural state would earn the owner little or no return. The dichotomy of interests between the value to the owner and the value to society becomes an increasing serious problem as population grwoth and industrial development accelerates. The pricing system, which one school of economics holds will solve all economic problems if left to operate unhampered, offers no solution to this problem since development becomes essentially an irreversible action. Thus, even though the va marshland increases as it becomes scarcer to an eventual poin life support value could "outbid" other land uses there is no convert the previous development back to its former (and now uable) state. The irony of dependence on the price system is can make a reasonable sounding argument for developing marshla can even offer an argument that a point will be reached when t should be converted back to marsh, but it cannot effectively r marshland, a very expensive process, even if technically possi

Evaluation of marshland as a renewable resource - e.g. as stream stretching into the future and increasing continually - one way to alleviate the destructive tendency inherent in the p system as it now operates. The time has come to seek ways to l owners of natural resources with value to society receive a ret Direct purchase by Government is one solution, of course; scenic space easement and tax relief are other approaches. Setting up "banks" where the owner is paid not to develop (as in "soil bank perhaps a feasible "delayed option" procedure in cases where ou purchase can not be made at a particular time.

The best solution is a "look ahead" land-use plan which deli the amount and location of life-support natural areas that will b necessary to support a future desirable level of development. Su can then be acquired or zoned into the public domain before the s of land speculation raises the market price. Odum and Odum (1971 present an overall model to show how the ratio of undeveloped to compartments could be objectively determined. Since many coastal are more productive than adjacent areas, they would generally receive high priority for inclusion into the undeveloped compartment.

Summary

Four levels were selected for monetary evaluation of marshlands and estuaries of the South Atlantic and Gulf Coasts: (1) by-product production (fisheries, etc.); (2) potential for aquacultural development; (3) waste assimilation; and (4) total "life support" value in terms of the "work of nature" as a function of primary production. Money values of marsh-estuaries in their natural state were calculated in terms of (a) annual return and (b) an income-capitalized value. Round figure values per acre at the four levels were: (1) a, $100; b, $2,000; (2) a, $350; b, $7,000; (3) a, $2,500; b, $50,000; (4) a, $4,150; b, $83,000.

The value of waste assimilation and total life support work (levels 3 and 4) are at least an order of magnitude higher than that which can be obtained from by-products, even under intensive aquacultural development which in itself would eliminate recreational and most other uses. These high values (levels 3 and 4) represent estimates of what man would have to pay (i.e. "internalize") in terms of the value of the useful work of an acre of estuary should it not be available to do this work. Summing values for specific functions judged to be non-competitive results in a value approaching that obtained by a total life support calculation (level 4), but the weakness of such a "component approach" is that most "multiple uses" do, in fact, compete at high levels of use. The advantage of level 4 cost accounting is that it can be applied to a particular acre, or acres, of marshland without having to specify how the work flow might

be divided into different uses and functions (which will
time to time and place to place).

Detailed analysis of waste assimilation shows that m
estuaries are not very effective (and, therefore, not ver
for secondary treatment of municipal wastes, but that the
tremendous capacity for tertiary treatment of nutrients, e
phosphorous. Since secondary treatment is relatively inex
tertiary treatment very expensive if done by man in artifi
it is clear that the large BOD loading now borne by many e
should be greatly reduced by organic matter digestion in
plants in order that the natural systems can effectively c
tiary treatment and maintain a water quality that preserve
increases sea food production, recreation and other by-pro

Demonstrating that marshlands have a substantial doll
their natural state provides an incentive for preservation
that are in public ownership, but not for preservation of
private ownership since the owner may receive little or no
no matter how high is the appraised value to society. The
as it now operates, does not work in this case since real e
opment of marshlands becomes essentially an irreversible ac
clear that marshlands must be evaluated as a renewable reso
value that increases with urban-industrial development.

The time has come to seek means of letting owners of n
resources with high value to society receive a return. The
term solution is a land-use plan which delimits the amount

of natural areas that will be necessary to support a future optimum level of urban-industrial development. Then such natural areas can be acquired, or zoned, before the spiral of land speculation raises the market price. The technology of systems ecology is now being developed to the point that an objective compartmentalization between developed and undeveloped environment can be made. Since many coastal wetlands are more productive than adjacent areas, they would generally receive high priority for inclusion into the undeveloped compartment.

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Table 7. Marsh-estuary values as determined by various methods of evaluation.

Basis for evaluation	Annual Return per acre	Income-Capitalization Value per acre (at interest rate 5%)
(1) Commercial & Sports Fisheries	$ 100	$2,000
(2) Aquaculture potential (Table 3)		
(a) Moderate oyster culture level	350	7,000
(b) Intensive oyster culture level	900	18,000
(3) Waste treatment (Table 5)		
(a) Secondary	280	5,600
(b) Phosphorous removal[1]	950	19,000
(c) Adjusted tertiary[2]	2,500	50,000
(4) Maximum non-competitive summation of values		
(a) 1 + 3c	2,600	52,000
(b) 2b + 3c	3,400	68,000
(5) Total life support value[3]	4,150	83,000

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[1] Mean of two values shown in Table 5.

[2] BOD loading (as shown in Table 4) reduced to 3.5 lb/day, a level that reduces O_2 levels about 1 ppm.

[3] See text for calculation based on gross primary production.