Productivity Measurements in Texas Turtle Grass and the Effects of Dredging an Intracoastal Channel

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Productivity Measurements in Texas Turtle Grass and the Effects of Dredging an Intracoastal Channel

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Abstract

Measurements of benthic chlorophyll "A" and diurnal oxygen productivity were made in turtle grass beds containing *Thalassia testudinum* and *Diplanthera wrightii* in Redfish Bay, Texas, before and after the dredging of an intracoastal canal. Moderate values of photosynthesis 2 to 8 g O_2/m^2 per day were observed in the spring of 1959 following a period of shading by turbid dredge-waters, but exceptionally high values 12 to 38 g/m^2 per day were recorded the following spring in those areas not smothered with silt. Chlorophyll "A" in 1959 averaged 0.0338 g/m^2 but increased to 0.68 g/m^2 the following summer.

Introduction

The high productivity of turtle grass ecosystems in Texas, Florida, and Puerto Rico has already been established by previous measurements of diurnal properties. Oxygen production values, for example, have been found up to 40 g/m^2 per day (Odum, 1957; Odum and Hoskin, 1958; Odum, Burkholder, and Rivero, 1959; Odum and Wilson, 1962). Bottle studies compared with free water measurements (Odum and Hoskin, 1958) indicated the minor role of plankton production as compared with benthic production in these flats. High densities of juvenile animal populations in these shallow systems have been established in an annual study in Texas flats with the drop net by Hoese and Jones (1963), and by studies of Springer and Woodburn (1960). High values of Chlorophyll "A" in the benthic plants were given by Odum, McConnell, and Abbott (1958). These indices support the concept that is widely held in the Gulf Coastal region that the grassy shallows are food production nurseries, at least during the warmer seasons. Schultz (1961) discusses the distribution of juvenile fish and shrimp in the study area.

In 1959 an intracoastal channel 12 ft deep and 125 ft wide was dredged through Redfish Bay, Aransas Pass, Texas, an area of fertile grass previously studied as cited above. Data on this bay were obtained relative to the dredging operation by several persons. Kornicker, Oppenheimer, and Conover (1959) described some mud-balls resultings from the dredging. Hellier and Kornicker (1962) described the stations and the sedimentological effects in which there was heavy sediment accumulation associated with a spoil island extending about 0.2 mile. Ronald Schultz (personal communication) reported some variable animal collections from push net and shovel-sieve sampling at the same stations. *Lucina pectinata* and *Chione cancellata* were predominant. This report

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concerns two indices of productivity, diurnal oxygen curves and chlorophyll "A" during this period.

Area and Sequence of Events

Redfish Bay is pictured in the map in Fig. 1. Fig. 2 has aerial photographs of the study area facing east from the spoil bank along the transect line of 5 stations set up at about 0.25 mile intervals. Prior to dredging the water was deepest at station 1 where *Thalassia* beds were maximal (about 0.5 m at ordinary tide levels), shoaling gradually to 0.30 m at station 5 with increasing percentages of *Diplanthera*. Station distances given in Hellier and Kornicker (1962) were apparently too large.

Some measurements of productivity were made in similar grass in the area of Ransom Island south of the Port Aransas Causeway in 1957. The transect of station poles was set up north of the causeway in November 1958. The dredge began to affect the area in the last of February 1959 with clouds of drifting silt obscuring the grass on many days

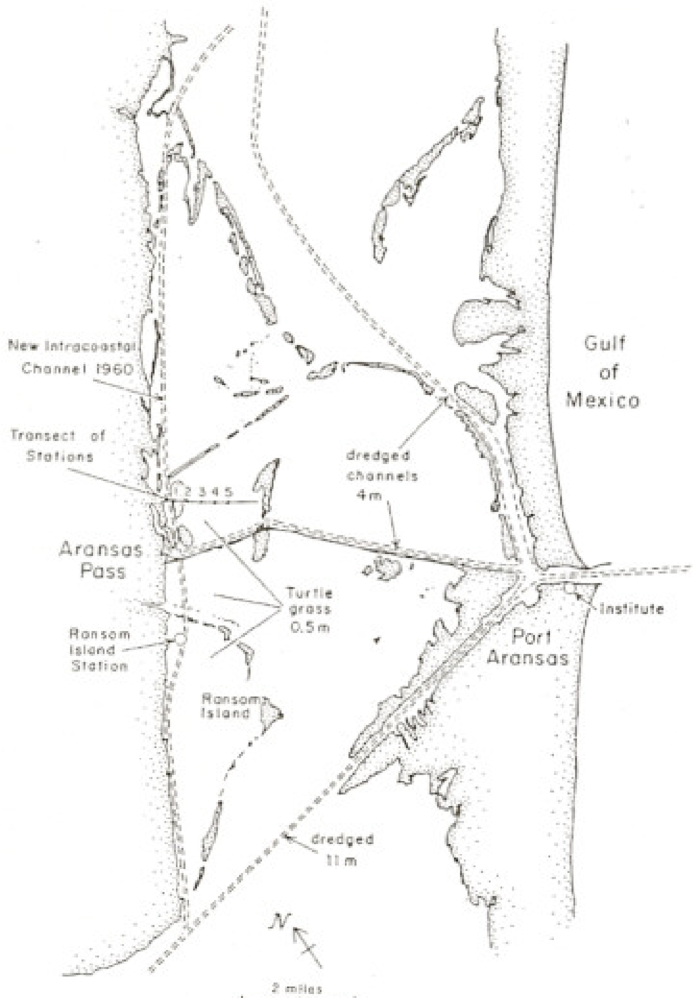

FIG. 1. Map of Redfish Bay near Aransas Pass, Texas, indicating the study area, the 5 stations, the intracoastal channel, and the Ransom Island Station.

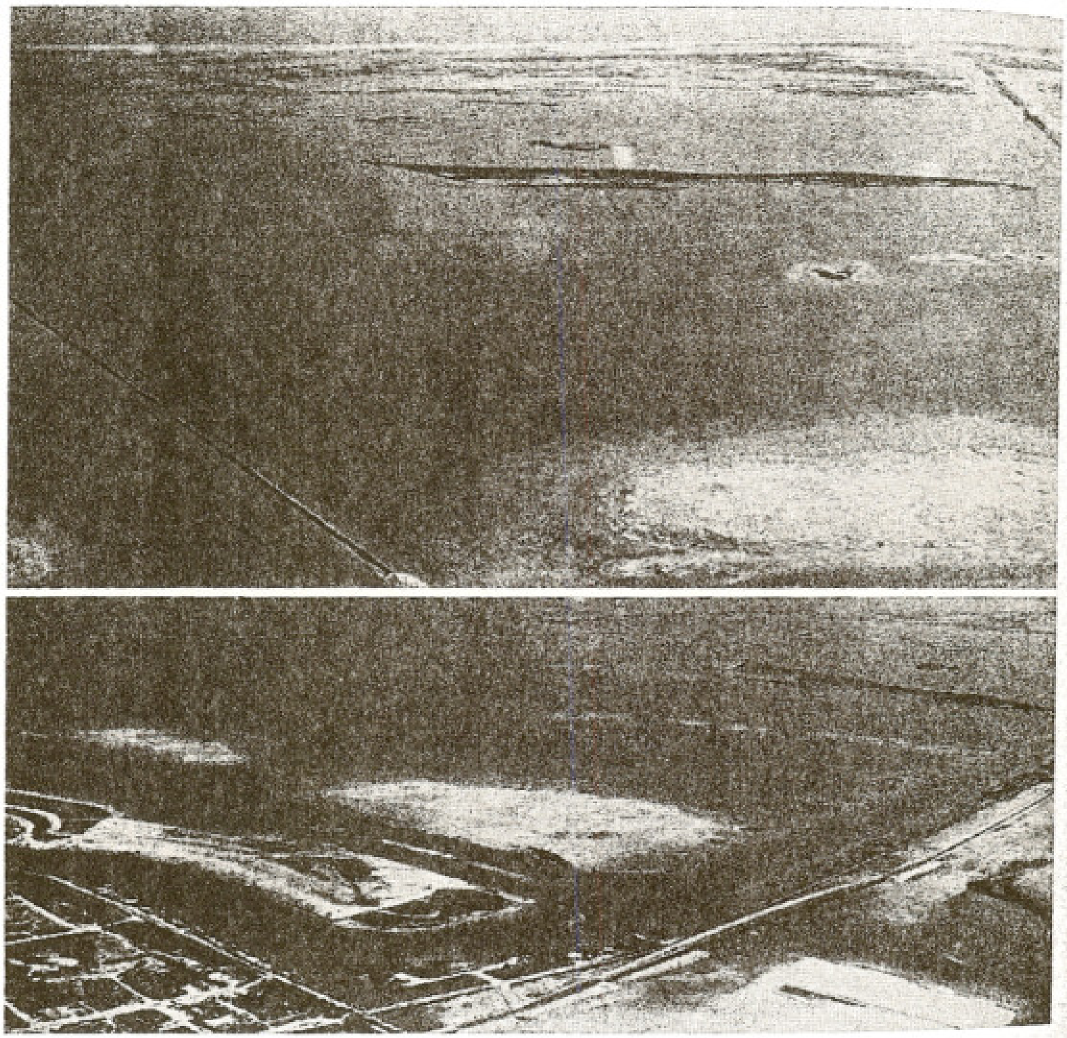

FIG. 2A. Aerial photographs: above, March 21, 1961, with a view facing east across the new spoil island along the transect of 5 stations. Note the outline of the uncovered grass between stations 2 and 3. Below, new channel and spoil islands.

around March 1, 1959. Then dredging was stopped when rock was reached so that by March 13 the dredge had been removed and the water again was clear. No spoil island had been deposited at this time in the transect area. Final dredging began again in November 1959 with the deposition of the spoil island and silt on top of the grass as far as station 2 as seen in Fig. 2. Thereafter measurements of productivity were made in the vicinity of station 3, which received a few centimeters of silt only.

Methods, Replications Within the Bay System

Measurements of productivity with the diurnal method were made as described in detail in a previous paper (Odum and Hoskin, 1958). Fig. 3 is a representative diurnal graph with computations as used for estimating gross production and total community respiration. Following the earlier studies on this and other similar shallow bays in which the aeration coefficient on a volume basis was observed to be relatively conservative

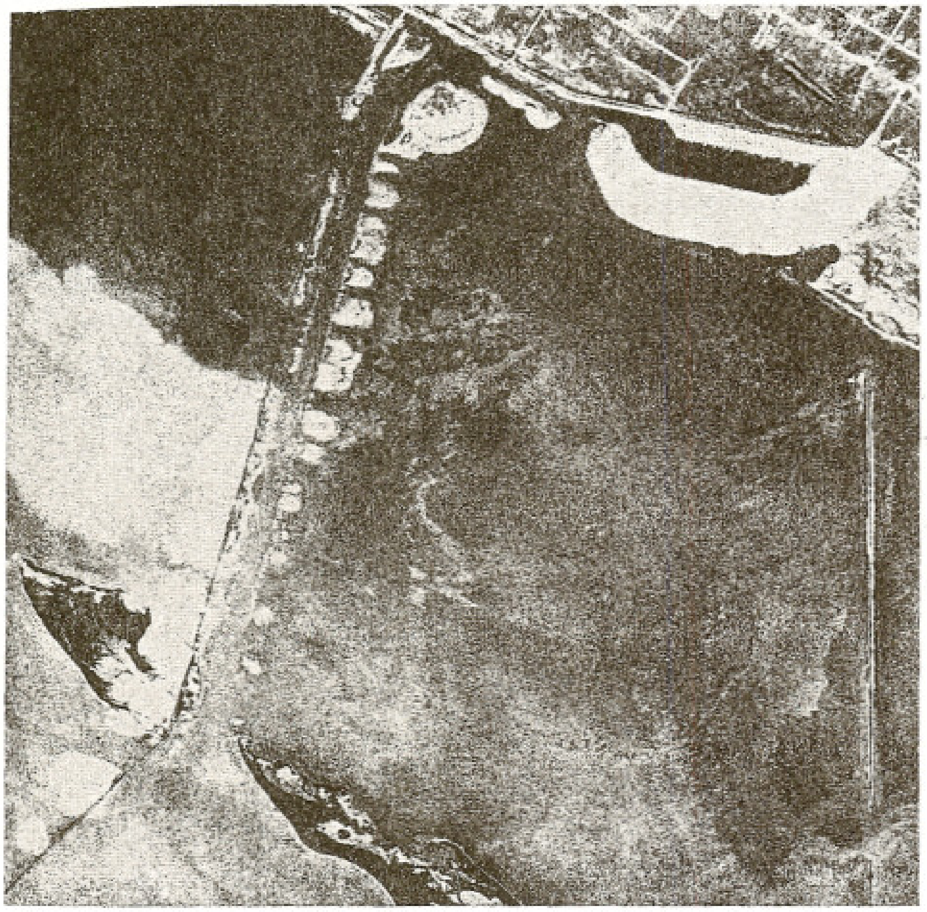

FIG. 2B. Aerial view of turtle grass beds (dark areas) prior to dredging of the intracoastal channel. Photograph was taken March 20, 1950 by the U.S. Production and Marketing Administration (DIX-6G-49).

(Odum and Wilson, 1962), a constant reaeration constant (k) was used in this paper as 1 g O_2/m^3 per hr for 100% deficit gradient across the water-air interface.

In the preceding paper some duplicate stations were studied in Redfish Bay along with some measurements within a fiber glass enclosure. Similarly, in the data taken in 1961, 2 to 5 duplicate stations were measured in order to indicate homogeneity and heterogeneity of the circulating waters. Some representative curves reproduced in Fig. 4 indicated a general similarity in metabolic patterns at the main stations in the waters over the grass flats of Redfish Bay. Each curve was based on sample pairs taken at each time of measurement. The moving water averaged the production over sizeable areas. Thus, samples taken at different stations as shown in Fig. 4 were sub-samples. When the productivity for each curve was computed separately, station differences were greater (Fig. 5) because the station depths were different. The general similarity of the graphs in Fig. 4 may justify computations which were made when data from only one of these stations was obtained.

The approximation of constant daytime and nighttime respiration often used in productivity studies for lack of better information was continued in this paper throughout for purposes of uniformity although it was recognized that this approximation may be far from accurate. In considering the ratio of P (gross photosynthesis) to R (total system

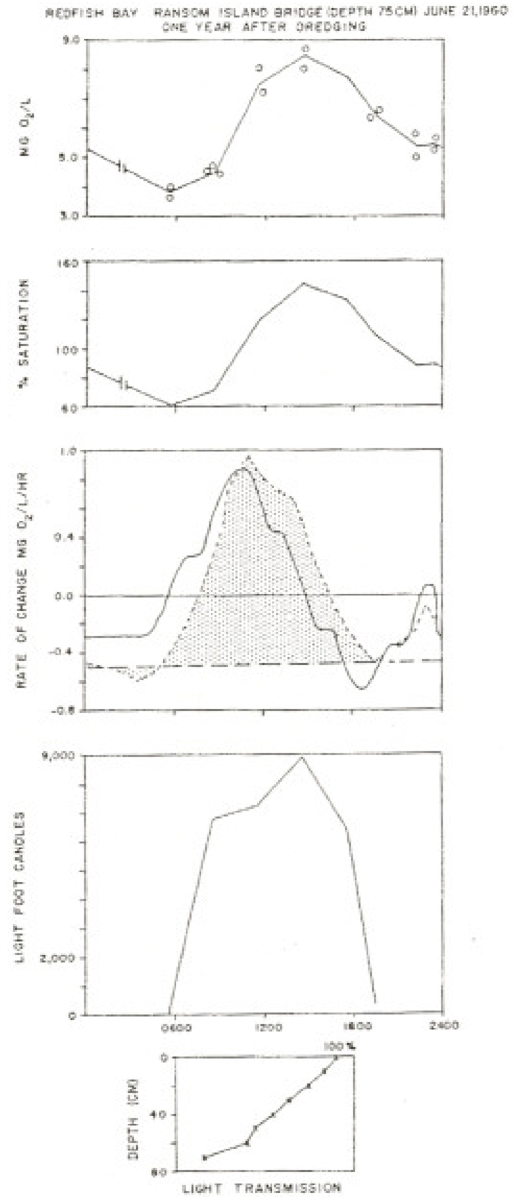

FIG. 3. Diurnal curve from a station near Ransom Island, June 21, 1960, the summer following the dredging. Vertical transmission of white light with a selenium photometer and frosted glass is provided in the lower graph. Summer graphs like this one show a post-sunset bulge and artifact due to the strong evening sea breeze providing increased aeration not allowed for in the diffussion correction.

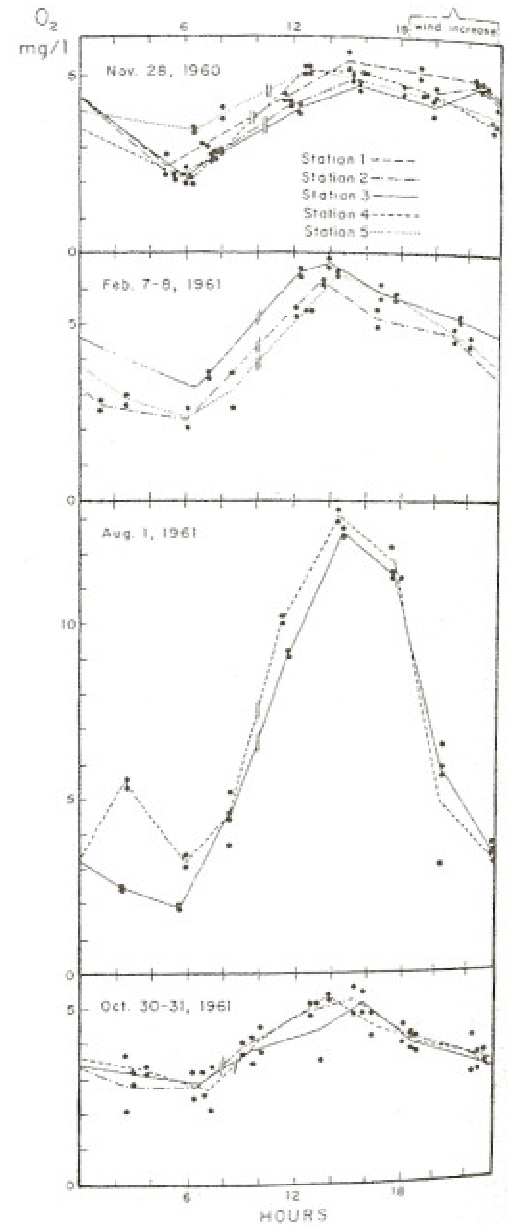

FIG. 4. Oxygen curves taken at more than one station at the same time. Metabolic figures based on these curves were computed separately and included as points in Fig. 6.

respiration) any error in drawing the base line for daytime respiration affects both P and R.

In Fig. 6 is reported one graph in which the diurnal oxygen and diurnal carbon metabolic rates are both plotted. The carbon-dioxide metabolism was computed with the pH-CO_2 titration method (Beyers and Odum, 1959). pH was taken with a Beckman

Model W industrial meter operating in the field from a generator. The quotient of carbon to oxygen metabolism was 1.3 for gross photosynthesis and 1.25 for respiration. Since the carbon-metabolism data do not involve a diffusion correction and since the quotients are not greatly off from the range expected in ordinary metabolism of single organisms in aerobic processes, some additional confidence may be derived concerning the interpretation of the figures for P and R. The kind of abnormal respiratory quotients found in some polluted systems, anaerobic marine bays, and bottle studies, were apparently not involved in the aerobic grass flats. Three other examples were studied in grass flats of the Lower Laguna Madre (Table 2).

Chlorophyll "A" was measured in the benthic plants as described in Odum, McConnell, and Abbott (1958). Conover's stove pipe sampling procedure was used to collect the plants which were washed, ground, aliquoted, and extracted in acetone. Whereas the freewater diurnal values represented larger expanses of the bay averaged, chlorophyll measurements of benthic plants served as an index of localized fertility.

Results

Fig. 3 is a typical diurnal record of oxygen with graphic computations for estimating gross photosynthesis and total community respiration. Fig. 6 is a record of the diurnal curve measurements in Redfish Bay grass flats from 1957 through 1961, each pair of points representing one diurnal record like that in Fig. 3. A record of salinities, the times of dredging, and other events, are also noted. The strongly seasonal pulse of productivity like that previously found in the Laguna Madre in a 4 year series is recognizable with winter minimum.

Chlorophyll "A" contents of the benthic plants in 1959 and 1960 are reported in Table 1 with very large differences observed. The relatively sparse grass during 1959 was followed by thick growths in 1960 as indicated in the chlorophyll "A" figures. The dry weights of benthic plants per m^2 for July 26 samples (stations 3, 4, and 5) were 470, 322, 464, 427; 634, 409, 418, 516; 232, 192, 181, 217. The weights per area were less than turtle grass weights in Puerto Rico measured by Burkholder (1959) reflecting in part the smaller proportionate weight of the rhizome systems in the Texas beds.

The Redfish Bay beds during the sparse condition of summer 1959 were apparently similar in density to those of Boca Ciega Bay, as reported by Pomeroy (1960) with 0.054 g/m^2 of benthic chlorophyll and 81 g/m^2 dry plant matter.

The productivity and chlorophyll "A" data indicate diminished fertility during the year 1959 when there was some disturbance and shading in the spring. Values of photosynthesis and chlorophyll were less than in previous years. In contrast, 1960, the year immediately after dredging, had unusually heavy growths and higher values of photosynthesis and chlorophyll than observed previously, except in stations 1 and 2 where the benthic communities had been smothered with soft silt. On February 7, 1961, after the annual winter decline, chlorophyll "A" values were as high as those in the summer of the dredging. Winter values in winter of 1958 before dredging ranged 0.04–0.48 g/m^2. Station 2 was examined further during the fall of 1962 and still had no growths other than microscopic algae and a few diminutive blades of *Ruppia*. There was an algal crust but the silt below was little consolidated.

In previous studies an excess of respiration over photosynthesis was noted when salinity was falling in Texas bays associated with river-borne organic matter, but photo-

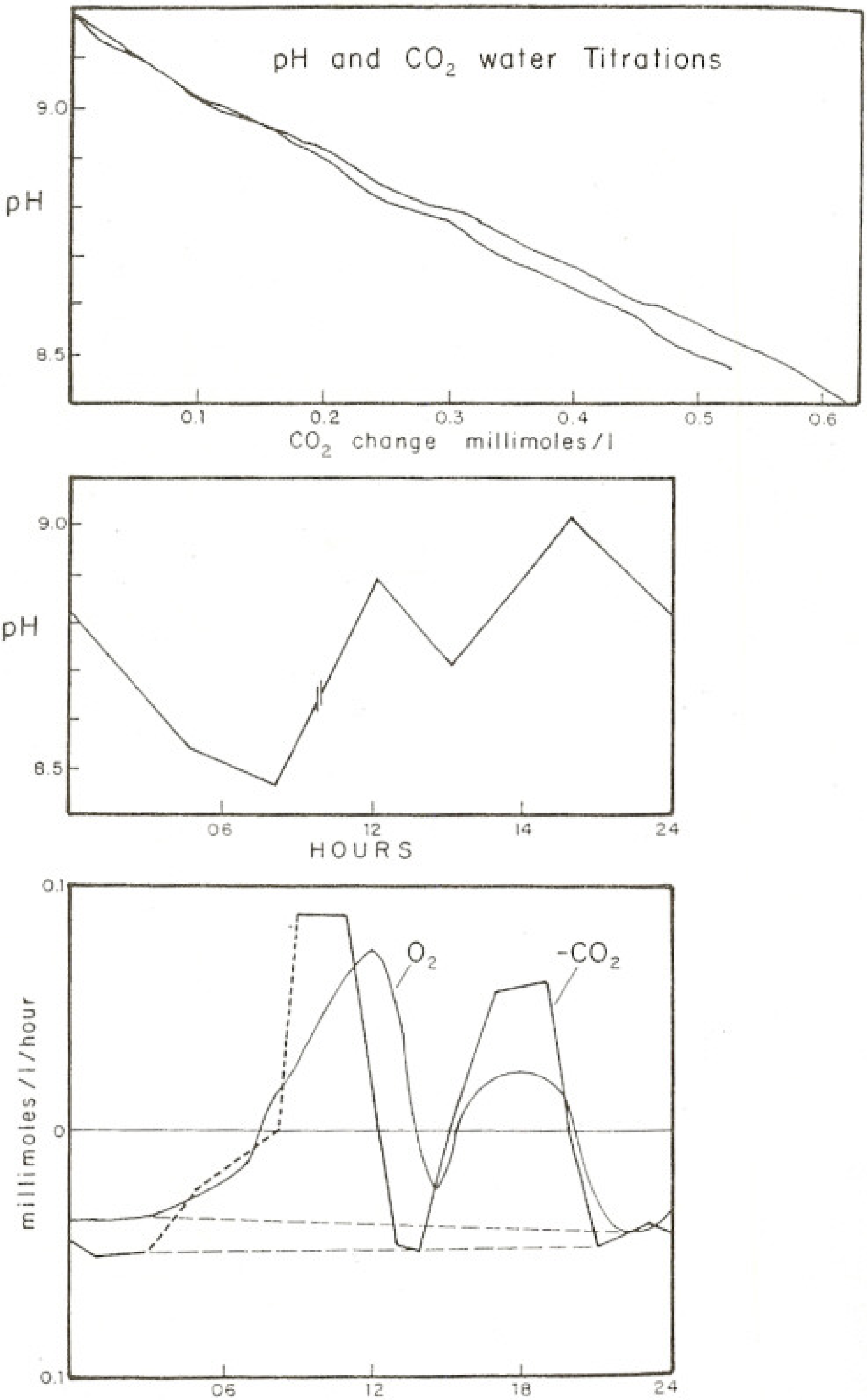

FIG. 5. Diurnal oxygen and pH curves for Redfish Bay, station 2, Aug. 15–16, 1961. The rate of change graphs for both oxygen and carbon are plotted together below on a millimole per hour basis. The carbon curve is reversed with increasing values plotted downward.

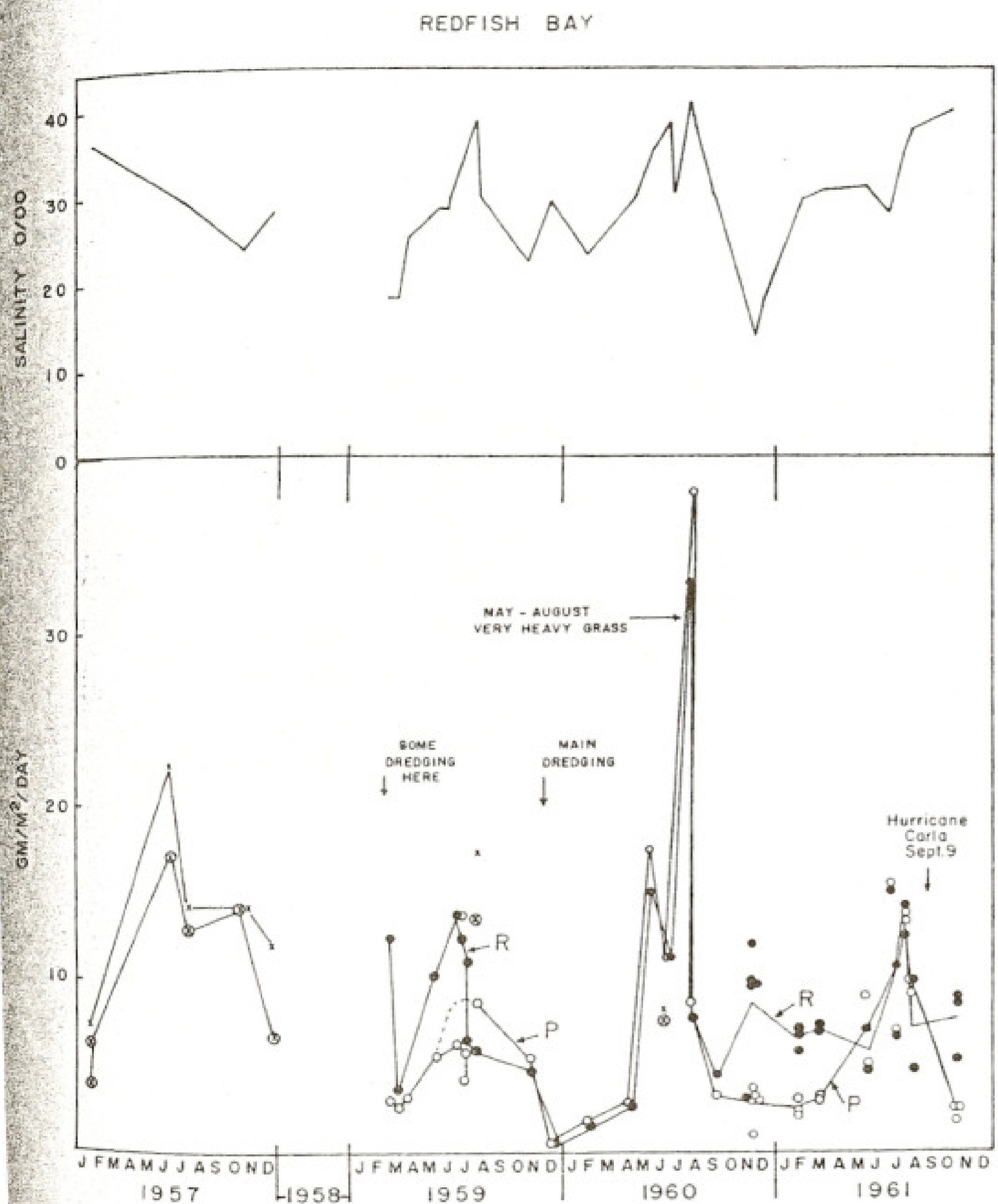

FIG. 6. Record of salinity, gross photosynthesis, and total respiration 1957–1961. Data represented by crosses (x) were taken near Ransom Island (Fig. 1) whereas the other data were taken between stations 2 and 3 in the transect.

synthesis and respiration in high salinity waters of Redfish Bay were usually similar. The 1959 data were distinctive with a greater imbalance with excess respiration over photosynthesis. Much higher R than P was found in the fall of 1960 at a time when excessive benthic growths of the previous year were decaying and salinities were diminishing.

Diurnal productivity data from the grass beds near Port Isabel, Texas are included in Table 2. The values were comparable with those in the Redfish Bay area.

TABLE 1

Chlorophyll "A" in benthic plants along the Redfish Bay transect in 1959 and 1960. Data in g/m²

Station	Distance from new channel	Summer 1959	Summer 1960	Winter‖ 1961
1	0	0.0078* 0.0113* 0.0180* 0.0086* 0.029* 0.052* 0.0015* 0.115* 0.041†	Station now out of water as spoil island.	....
2	0.25 mile east	0.0208‡ 0.0106‡ 0.0074‡ 0.0052‡ 0.0105‡ 0.0110†	Beds covered with 30 cm of soft silt; no plants.	....
3	0.5 mile east	0.079§ 0.042§ 0.087§ 0.022§ 0.062†	1.14¶ 1.21¶ 1.32¶ 1.46¶	0.021 0.019 0.153 0.103 0.130 0.012 0.055 0.133
4	0.75 mile east	0.087§ 0.033§ 0.011§ 0.048†	0.26¶ 0.42¶ 0.49¶ 0.47¶	....
5	1.0 mile east	0.050§ 0.022§ 0.0195†	0.20¶ 0.26¶ 0.28¶	....
Mean		0.03379	0.6827	....

* May 30, 1959.
† July 15, 1959.
‡ April 27, 1959.
§ June 30, 1959.
¶ July 26, 1960.
‖ Feb. 7, 1961.

TABLE 2

Metabolism of Turtle Grass Bay Areas in the Lower Laguna Madre at Port Isabel, Texas

	Depth m	Salinity ‰	T	Oxygen g/m²/day P	Oxygen g/m²/day R	Carbon g/m²/day P	Carbon g/m²/day R	Quotient CO_2/O_2 AQ	Quotient CO_2/O_2 RQ
August 8–9, 1960	1.4	37	28–30	26.3	13.8	......	......	......	......
	1.4	37	28–30	30.0	19.7	......	......	......	......
	0.9	37	28–30	11.7	4.3	......	......	......	......
January 20–22, 1961	1.8	30	11–12	4.0	5.8	......	......	......	......
July 3–4, 1961									
Port Isabel	1.5	37	....	10.8	[illegible].3	3.6	3.0	0.9	1.0
Laguna Vista	1.0	40	....	11.2	10.3	11.2	6.8	1.7	1.8
Queen Isabel Causeway	1.0	36	....	7.4	9.6	6.7	7.4	2.4	1.5

Discussion

Data reported here indicate a marked seasonal cycle in productivity with considerable year to year variation possible. The values for the Redfish Bay Turtle Grass were not as high as some grass flat data in the lower Laguna Madre of Texas where higher values were recorded associated with clearer waters (Odum and Wilson, 1962).

The decreased productivity and imbalance of respiration over photosynthesis of the summer of 1959 may have been associated with the silts turned loose over the flats by the start of dredging that spring. Certainly, during the weeks of dredging nearby, light penetration was much reduced and the plant beds may have received a set-back at this time.

Whatever diminished productivity during that year was not permanent. Growths the following year were exceptional. The suggestion by Ingle (1952) that dredging may stimulate by adding nutrients may have merit.

Apparently, therefore, the channel dredging entirely removed from the available nursery grounds the 125 ft of channel and a quarter of a mile of beds under and adjacent to the spoil island, but did not permanently damage the productivity of the beds beyond. A geometric consideration may be important in comparing these results to those given by Ingle (1952) and Mackin (1962) for dredging in slightly deeper waters. Where the spoil from a channel of this dimension is discharged in only 0.5 m of water or less, it may shoal the water depth critically over a much wider zone than where the discharge is into a bay that is already 3 to 10 ft in depth.

In the fall and winter of 1960–1961, respiration remained higher than photosynthesis. Close similarity of P and R which was observed in Redfish Bay in 1957 and 1960 and in 4 years in the Laguna Madre was upset. The great mats of decaying grass observed in the fall of 1960 due to the exceptional growth that summer and the influx of low salinity river water may have raised respiration rates. P and R were again in balance during the growing season of 1961, but another excessive respiration period was found following Hurricane Carla, possibly reflecting the upset bottom conditions following an approximate 8 ft tide and storm waves over the flats. Photosynthesis Oct. 31, 6 weeks following the hurricane, was less than photosynthesis at this time in other years. Because the center of the storm went inland to the east, rains in the Redfish Bay area were not excessive and salinities in this bay did not fall excessively. Thomas, Moore, and Work (1960) found extensive windrows of turtle grass following a hurricane in the Miami area, but showed from weight calculations that the portions of the beds washed ashore were negligible.

The record of metabolism and chlorophyll "A" as reported over the period from 1957 through 1961 indicated some pattern of a regular seasonal pulse, but the changing patterns of precipitation, hurricanes, and man-made interferences such as dredging were apparently keeping the ecosystem metabolically upset so that the kind of steady state found in shallow aquarium ecosystem of benthic plant type (Beyers, 1963) did not become established. The imbalances of P and R were related to the type of disturbance such as organic storages and lags; bottom disturbances; organic river imports; and damage to plant beds.

Acknowledgments

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