MARINE TURTLE CULTURE - AN OVERVIEW

J. R. Hendrickson
Department of Biological Sciences
University of Arizona
Tucson, Arizona 85721

ABSTRACT

The general background and present status of this new branch of maricultural science are briefly surveyed, with a description of the only large industrial complex now in existence. Progress in turtle mariculture to the present is summarized and some outstanding scientific problems requiring solution are delineated. The new industry's interface with problems of conservation of wild stocks is discussed.

INTRODUCTION

As the entire field of marine turtle culture is likely to be a new one to many mariculturists, a background review seems appropriate. I wish to deal briefly with the principal culture species, the single major turtle farm now in existence, the state of the art at present, and the special relationship of this new culture field to wild stocks and conservation problems.[1]

THE GREEN SEA TURTLE, Chelonia mydas

The only species considered here is the green sea turtle, the only primarily herbivorous one of the seven described marine turtle species belonging to five genera. The plant diet presumably accounts

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[1] Ehrenfeld (1974) presents the conservationist case in an article published after this paper was prepared and presented. The present paper was intended to provide basic, background information bearing on the matter, but is in no sense intended to represent an opposing view--counter-arguments to Ehrenfeld are, I understand, in preparation by other parties.

for C. mydas being considered the most flavorsome of the marine turtles. It certainly makes it the most promising candidate, in energy terms, for large-scale commercial culture. One might consider it a reptilian "steer of the sea"--a red meat animal grazing on submarine pastures of turtle grass and algae, and reaching weights above 70 kg. As in all reptiles, growth continues at decreasing rates throughout life, and weights of 350 kg have been reached (Ingle and Smith, 1949); the lower weight ranges are likely to be important ones in commercial farming.

The green turtle reaches sexual maturity in the wild in something over 6 years, probably dependent upon the nutritional state of the individual. Maximum, or even average, life span in the wild is unknown; individuals have lived 20 years in captivity (Ernst and Barbour, 1972). Except for occasional basking above water line on a few remote beaches, and for the females' ascent of sea beaches to nest, the animals are totally aquatic. The females reproduce on a multi-annual cycle in the wild, making multiple nests of 100+ eggs each at intervals of from 10 to 15 days. Bi-annual, tri-annual and longer periodicities for nesting have been recorded, probably varying according to nutritional state and the length of migration route between feeding and nesting areas. The most remarkable migration known at present is that between the Brazilian coast and Ascension Island--some 2,000 km across the Atlantic Ocean (Carr, 1964, 1965). Each population tends to have a breeding season with a demonstrable peak in the mid-summer months of the appropriate hemisphere, although nesting may occur virtually the year around in some equatorial localities. The eggs develop unattended in the sand of the nesting beach and the young make their way to the sea upon emergence from the nest. For the first few days in the water, the young turtles apparently swim almost continually, thereby achieving wide dispersal at sea. So little is known of their life from this point until they reappear on the feeding grounds as "yearlings" from 20 to 25 cm in carapace length, that the term "lost year" is common currency among students of sea turtles. All available evidence points to their being obligate carnivores during this first year at sea, dependent upon the larger elements of the plankton and nekton for food. When they reappear in shallow waters, they apparently convert rapidly to an herbivorous diet of aquatic grasses and algae. Carr (1967), Hirth (1971), Bustard (1972), and Ernst and Barbour (1972) review the state of present knowledge of sea turtle biology, the latter three references providing good bibliographies of recent literature.

THE MARICULTURE, LTD. TURTLE FARM

Although captive rearing of stock obtained from the wild has been practiced for centuries, and in a few cases (Le Poulain, 1941) has developed into a traditional local industry, true captive culture over generations has not yet been developed. Full culture is now being attempted in a number of places, the best known of which are the Torres Straits, Australia program (Anon., 1970; Bustard, 1972), a pilot farm operated by the Caribbean Conservation Corporation on Great Inagua Island in the Bahamas (Carr, 1967), and the

major, capital-intensive operation established by Mariculture, Ltd. on Grand Cayman Island in the British West Indies. The latter is by far the largest and most advanced in its operations. So far as I know, it is the only one presently engaged in commercial marketing of its product.

Incorporated in 1968, Mariculture Ltd. began sales operations in 1972 and started a regular slaughtering program for 3 and 4 year-old, farm-reared stock (30 to 35 kg) in 1973. The farm (Figure 1) occupies about 4 ha with coastal exposure; 158 tanks ranging from 546 liters to 409,500 liters capacity house upward of 100,000 animals of all ages. A large breeding pond of approximately 4.5 million liters capacity has been excavated out of the coral rock and provided with a sand nesting beach. Total water circulation rates range above 9 million liters of natural sea water per hour.

All phases of the operation, from hatching of eggs to processing of market-sized stock, are systematized and automated as far as possible. Young hatchlings are converted as rapidly as possible from multiple daily feedings of minced natural food (squid, fish, etc.) to twice-daily feedings of prepared high-protein food. Thereafter, ordinary farm stock is fed mainly prepared pelleted food, with only occasional offerings of turtle grass to provide variety and bulk to the diet. Water circulation systems in the pools are devised to be self-cleaning; handling for purposes of medication and growth measurement is kept to a minimum to reduce stress on the animals. The turtles are kept under crowded conditions throughout their lives, as compared with normal densities in nature (Figures 2 and 3). The animals presumably accommodate to the stresses produced by crowding through the simple circumstance of never experiencing anything else--indeed, one gets the impression that they show less agonistic behavior in the crowded farm stock tanks than in experimental tanks where each animal has more individual space. The stock tanks are too crowded for coherent one-to-one encounters and there is no real opportunity for meaningful dominance hierarchies to develop; as a result, food is probably more equally distributed and less total energy is expended in non-growth activity.

Slaughtering is handled on a rigidly-controlled basis, with humane killing and scrupulous hygiene (Figure 4). Flesh is cut and packaged for freezing in several styles; fat is separated for extraction of turtle oil; livers are being experimentally used for pate; whole shells are cleaned and polished for sale as curios, and plates from imperfect carapaces support a small tortoise-shell jewelry industry on the premises. It is noteworthy that, while the scutes from wild green sea turtles are ordinarily too thin for use in jewelry-making, the scutes from these farm-reared animals fed high protein diets are abnormally thick and provide good quality material for jewelry.

TURTLE CULTURE PROBLEMS AND THE PRESENT STATE OF THE ART

Various aquaria and research establishments have for years maintained small numbers of green sea turtles successfully in captivity, and a considerable literature on this exists (see especially

the references cited in Hirth, 1971, and Ernst and Barbour, 1972). The problems of commercial sea turtle culture at present revolve largely around two central themes: economics of mass culture, and controlled breeding in captivity. Wood (1974), Rebell et al. (1974), and Haines et al. (1974) have addressed the first theme; Owens (1974), and Ulrich and Owens (1974) the second.

Throughout this discussion, certain essential differences from most other maricultural activities, and similarities to terrestrial meat-producing industries such as hog farming, will be noted. The individual animal unit in turtle culture is reared to large size over a relatively long time, and therefore has a high unit value. It is not marketed entire, but in parts. The pre-reproductive life history and the breeding cyclicity after maturation involve extended periods of time in nature; whether these time elements can be shortened in culture is probable but yet to be documented. Fecundity, however, is very much higher than for hogs and might be expected to rise as culture techniques reduce reproductive time parameters, increasing the similarity to most maricultural activities.

ECONOMICS OF MASS CULTURE

Mariculture, Ltd. has demonstrated success in developing techniques for mass rearing of green sea turtles on a paying, commercial level. The problems in this area, therefore, are less in the realm of qualitative "break-throughs" and more in the realm of quantitative refinements resulting in increased efficiency, improved quality, and in risk reduction. Non-biological problems of distribution, marketing, plant size, etc. will not be discussed here.

Methods developed at the farm for hatching sea turtle eggs include incubation in styrofoam containers (Figure 5) and mechanical opening of all eggs, once normal hatching has begun. These methods produce significantly higher percentages of living young than are observed emerging to the beach surface from wild nests, but include unknown proportions of weak, non-viable individuals (see next paragraph) which in the wild are eliminated by their inability to escape from the shell or to make their way successfully to the surface of the beach. At the least, the farm methods appear to yield the equivalent of the wild production rate.

Mortality during the first few months of life is high on the turtle farm and the reduction of this rate, which has exceeded 50% on occasion, is presently one of the priority concerns of the industry; it is, however, miniscule when compared with that in wild populations subject to predation. Hendrickson (1958) attempted an armchair speculation of wild hatchling losses based on several years of field observation in southeast Asia and estimated that, for a completely undisturbed beach under natural conditions, 40% of the hatchlings emerging from nests might be killed before reaching the sea and 50% of the remainder might be eaten during their first hour at sea. It would not be surprising to learn that the normal wastage rate in the wild comes close to 50% per day for the first week of

life out of the nest.

Culture problems with marine turtles during the main 3 to 4 year period of flesh production seem remarkably similar to those of other modern, meat-growing industries on land. Continual effort must be directed to studies on essential dietary ingredients, palatability, digestive efficiency, and feeding behavior. An effort must be made to produce diets, from cheap and dependable sources, which will result in the greatest amount of marketable flesh and fat of desired qualities in the least amount of time, from the smallest amount of food consumed. At present, costs of pelleted food are undesirably high and tolerable only because the sale price of turtle products is so high. Prices must be lowered as the market expands and volume increases, and a large portion of the reduced production costs must come from the food bill. Mariculture, Ltd. has developed an efficient, mechanized harvester of turtle grass, and abundant "hay" is available from nearby submarine pastures, but the pelleted food is presently preferred for the main feeding pens because of assured constancy of supply. The farm turtles tend to become strongly habituated to the form of their food, adapting to new foods only with some resistance.

As with most new culture animals, one of the most serious problems in the mass culture of sea turtles is disease: its prevention, diagnosis, and treatment. A whole, confusing array of pathological conditions have been identified, and new ones continue to appear. Some can be related to conditions found in wild sea turtles, exacerbated under the crowding and special stresses of culture; most are new to our experience, and coping with them is a pioneering task of first magnitude. It may be that lifting the larger, heavier animals by their front flippers (a convenient technique) produces internal strains with resultant bad effects. Even repeated strandings of the larger stock for weighing, medication, etc. may be injurious. Inspiration of excessive amounts of water during frenzied action (feeding time in a crowded tank, release to the water after treatment under restraint, etc.) may produce serious pneumonic problems. A generally-observed fatty liver condition will continue to cause concern until its cause and, if necessary, its cure have been determined. This may well be a simple nutritional disorder linked with the high-energy diet fed to produce the desired rapid growth rates in culture, and it has merit for the production of liver pate, but its etiology and relation to other aspects of culture must be known as thoroughly as possible.

The greatest problems have been encountered in the area of infectious bacterial and viral diseases. Many and varied conditions appear, some relatively constant, others sporadic and epidemic in proportions. It is of the greatest urgency that progress be made in identifying causal microbial agents of serious disease, and in distinguishing these from a host of other forms which may be more or less normal symbionts or secondary agents infecting bite lesions produced by other turtles, etc. Development of efficient, specific treatments can then be attempted. When, in time, full culture has

been developed (see below), planned breeding programs can include selection for disease resistance.

Parasitism has yet to be identified as a major problem in sea turtle culture, but a host of available agents exists, and it would seem likely that problems of massive parasite infestation will occur sooner or later.

Without waiting for the specific and serial developments mentioned above, attention must be given to study of the entire physical plant of the farm from an epidemiological point of view. All elements of siting, process, and general functional communication must be studied with a view to providing minimal disease transmission risk and optimal quarantine capability for containment of contagious infections.

CAPTIVE BREEDING PROGRAM

It is in this area that there is the most serious lack of basic information and experience, and that the most crucial problems for the survival and development of the industry lie. Not only is full control of breeding in captivity the sine qua non for true culture of marine turtles, and essential to development of improved strains to meet industrial requirements but, as is discussed in the last section of this review, it is related to unusually pressing circumstances from a conservation point of view. A "break-through" in this area is not only highly desirable, but is virtually mandatory within the very near future if the industry is to survive.

There has been a great deal of speculation regarding possible barriers to the systematic reproduction of sea turtles in captivity, largely based on what is known about wild turtles. Certain phenomena have been postulated as potentially important for normal reproduction as, for example, a long migration prior to breeding and relative isolation of sexes (and individuals) for long periods followed by aggregation off nesting sites as physiological or behavioral substrate necessities. The work of Ulrich and Owens (personal communication) largely removed these doubts and provides grounds for cautious optimism.

INTERFACE WITH CONSERVATION PROBLEMS

So far as I know, the green sea turtle is the only existing maricultural subject of clear commercial promise which is classified as potentially threatened with extinction. In the Red Data Book of the International Union for the Conservation of Nature and Natural Resources (Honnegger, 1970), Chelonia mydas is placed in Category 3: "Continuing to decline at a rate which gives cause for serious concern." The Convention on International Trade in Endangered Species signed by representatives at a plenipotentiary conference this year places it in Category 2: "...species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to

avoid utilization incompatible with their survival...."

The late development of culture methods for the green sea turtle, then, combined with its continually depleting stocks in the wild state, provide a two-fold problem for any sea turtle farm proposing to develop this species as a new domestic animal. Mariculturists must inevitably depend upon wild-laid eggs as seed stock during the initial developmental years while operating under increasing pressure to develop total independence from such wild resources in the shortest possible time (and it takes from 6 to 8 years to mature a farm-reared turtle to the point where serious breeding attempts may be made!). Mariculture, Ltd. expresses recognition of a special obligation to support active turtle conservation work in every way possible, as they concurrently pursue a crash program to develop total self-sufficiency in producing fresh stock. This obligation is presently being discharged through financing of conservation censuses and studies in selected areas (e.g., Aves Island in the Caribbean), through provision of facilities at the Grand Cayman farm for pure scientific studies as well as goal-directed, applied studies, and through a variety of self-imposed controls on their own collections of hatching eggs from the wild. The latter include attempts to define and restrict activities to a category of wild nests termed "doomed" (those without significant promise of contributing to the wild populations, even if left undisturbed).

In some localities the intense site-fixation of experienced nesting females produces heavy concentrations of nests on small areas of beach where later-nesting females destroy already-incubating clutches in the process of excavating their own nest cavities (Hendrickson, 1958; Bustard and Tognetti, 1969). This density-dependent phenomenon can in some instances permit collection of early nests for farm hatching without effect on the natural recruitment rate. The difficulty lies in accurate prediction of nesting densities over future time, and statistical justification for the exact harvest taken.

In other areas the eroding action of changing marine current systems and cyclical storms may destroy incubating nests before development can be completed (Schulz, 1968, 1969; Pritchard, 1971). Certain sea beaches of volcanic origin where nests allegedly have exceedingly low rates of success, presumably due to sulfur content of the sand or other adverse chemical or physical factors, are reported on Ascension Island. In several tropical countries where numbers of sea turtles nest on very remote beaches, patrol and enforcement of protective laws is virtually impossible; recruitment from such beaches is alleged to be near zero. It has been suggested that farm personnel stationed on such beaches by agreement with the parent Government could "earn" a complement of eggs by providing free patrol and simultaneously operating "transplant hatcheries" to guarantee an annual return to the sea, under natural conditions, of a sizable number of young.

A second major concern regarding green sea turtle farming is that poaching pressure on wild populations might increase due to development of new markets with high prices, before farms attain the volume production necessary to satisfy ~~demands~~ (Carr, 1969). The attendant recommendation is that the necessary maricultural work go ahead in small, pilot programs without a commercial interface until required techniques are available for efficient, high volume production at low prices. Doubts have been expressed as to the logic of expecting any technique with profit potential to develop to full flower without commercial interfaces, willy-nilly. It does seem unlikely that any business enterprise would be able to leap more or less instantaneously into high volume, low-priced production of the sort envisioned. The realities of modern economics would seem to demand that any such new industry must develop through a process of evolutionary growth in close association with the dynamics of national and international commerce.

Of greater import, to my mind, is the promise of the International Convention mentioned above and of local laws at national and state level which support the full conservation impact by prohibiting trade in turtles and turtle products from wild sources, while allowing openings for farm-reared products under carefully-designed rules for certification, inspections, and control of temporary wild egg collection from "doomed" nests along the lines outlined above.

I am motivated primarily by desires to conserve and build back the wild stocks of these magnificent creatures, and secondarily by interest in developing sources of self-renewing protein in a crowding world. The greatest barrier to fulfillment of the first is lack of knowledge of sea turtle biology; I would hope that commercial turtle farms would contribute significantly to our knowledge by direct aid and through their incomparable facilities for many types of study. Less immediate, but more pervasive, is my desire to make it cheaper to farm turtles than to poach them. I can most clearly see this as coming to pass when sea turtles are protected more by offering an attractive substitute in consonance whith man's baser instincts than by prohibitions which automatically run counter to his essentially adventurous, acquisitive nature.

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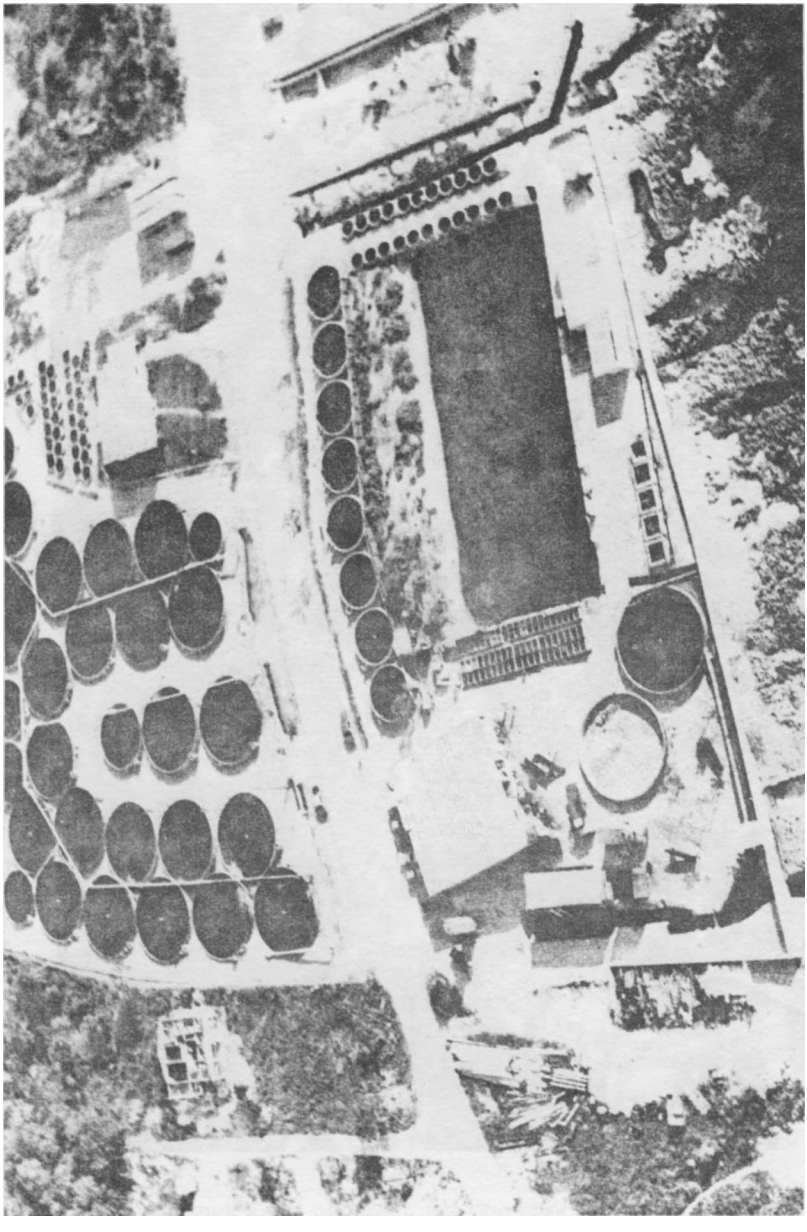

Figure 1. Goat Rock Turtle Farm of Mariculture, Ltd. on Grand Cayman Island, British West Indies.

Figure 2. Normally Crowded Stock Tank of Green Sea Turtles, Mariculture, Ltd.

Figure 3. Stock Tank of Green Sea Turtles, Drained for Spray Treatment of Skin Lesions, Mariculture Ltd.

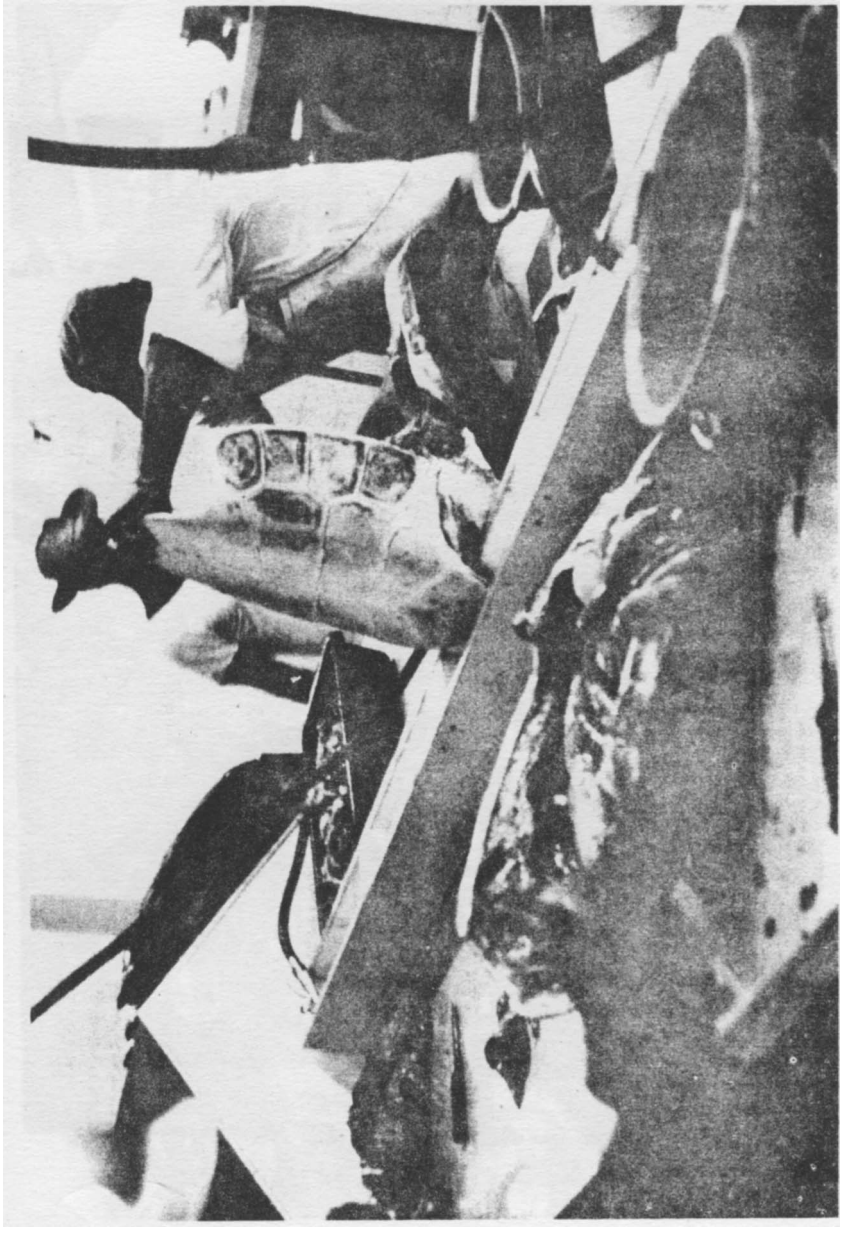

Figure 4. Slaughtering Operation at Mariculture, Ltd. Green Sea Turtle Farm.

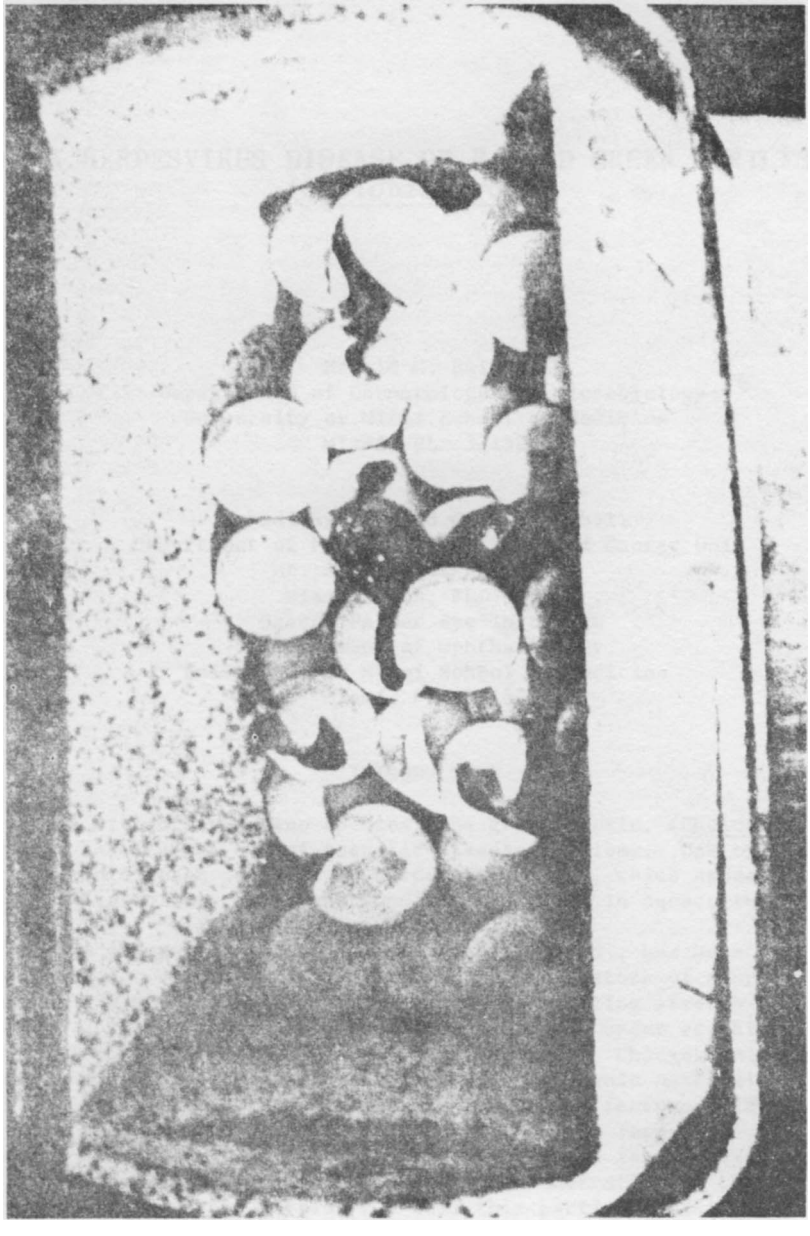

Figure 5. Hatching Green Sea Turtles, Mariculture, Ltd.