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ABSTRACT

This manual was prepared for a teacher workshop in marine science. It includes information on when, where, and how to collect marine mollusks, and how to prepare a shell collection; a partial key to the classes, subclasses, and orders of the mollusca; notes on the ecology and physiology of marine bivalves and snails, and recipes for solutions useful for relaxing, killing and preserving marine organisms. An annotated bibliography of readings in marine sciences is keyed to student level (lower elementary, intermediate elementary, upper elementary, and secondary). (EB)

Conservation and Environmental Science Center

FOR SOUTHERN NEW JERSEY

MARINE SCIENCE SOURCEBOOK

FIRST EDITION

Written By: ROGER J. RAIMIST

Edited By: V. EUGENE VIVIAN
NORMA T. VIVIAN

Dear Workshop Participant:

Professor Raimist's materials have been edited and reproduced for these exploratory workshops to assist in the initiation of the teacher training and curriculum development phase of Marine Science for New Jersey's elementary and secondary schools.

One purpose of the exploratory workshops in Marine Science is to provide teachers with some idea of the scope of the curriculum materials now being utilized. Further, the workshops present some examples of curriculum materials now being employed at the elementary or secondary level. The Conservation and Environmental Science Center seeks teachers who will evaluate the potential utility of these existing materials.

We would like to identify teachers who are interested in helping to develop and evaluate materials produced by the Conservation and Environmental Science Center for particular use in New Jersey's marine waters.

V. Eugene Vivian

V. Eugene Vivian, Ph. D.
CESC Director

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CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
FOR SOUTHERN NEW JERSEY

HOW TO COLLECT MARINE MOLLUSKS

by Roger J. Raimist

Marine Mollusks - How To Collect Them

Collecting mollusks, particularly marine forms, is exciting not only for the natural beauty of the animals themselves but because this activity leads to further investigations of the marine environment.

There are hundreds of publications concerning the collection of marine mollusks that describe collection methods, many of which are detailed and extensive. Although useful as references, these publications are no substitute for actual experience. For a would-be collector, it is necessary to go to the beaches and salt marshes to actually collect specimens.

There is a number of basic rules people should follow in collecting mollusks. Never go collecting alone. You must know where the animals are and where they live. There is no substitute for this knowledge. There are no short cuts to finding out except by going to where the specimens may be found. You should know not only what specimens are available in which particular habitat, but also something about their biology. It is helpful to know whether they are carnivorous forms or whether they are kelp eaters. You should know something about their breeding seasons and their temperature ranges and other ecological requirements of their environment.

An experienced collector will also know the area in which he is collecting. A good source of information about collecting locations would be local marine oriented clubs, colleges or universities or local fishermen.

When collecting, you should not be hampered by great quantities of equipment. The rule is to use simple and reliable collecting equipment. An important criterion is to become a regular beachcomber. Often a leisurely walk along a beach may provide unusual or exciting specimens.

How to Collect Marine Mollusks

When to Look

Most people begin to look for shells during the afternoon while they are at a bathing beach. Sometimes this haphazard method is productive. Preferably, some preparation and reading about the habits of marine life will increase the probability of locating specimens.

Many marine forms are inactive during the day, and become active after dark or just before dawn. Shortly after the tide begins to rise, or after a severe storm many forms are exposed that would normally be hidden from view. Peaks of mollusk activity are also achieved during the various breeding seasons of many marine mollusks. A local college or university is often a good source of information about breeding seasons, times, types of mollusks.

Certainly during low tide much of the intertidal region is exposed and readily accessible to the collector. A very simple and effective procedure is to consult the calendar. The appearance of new and full moons can aid in your collection. During these time periods, spring tides, which are both higher and lower than usual, are produced which tend to expose more of the submerged and generally inaccessible habitats. The time of low water may be determined from local newspapers or tide tables published for coastal areas.

Where to Collect

There is a number of obvious places where most amateur collectors look for specimens. Specimens may be found along the beach, among the pilings and jetties, as well as in sandy or muddy bottoms. These areas, generally yield little of genuine interest to the serious collector. One should generally avoid bathing beaches as they offer practically nothing to the serious collector. Another site to avoid would be rocky cliffs with heavy pounding surf. These sites are often dangerous and only a very few mollusks have adapted themselves to such a rigorous environment.

A good collecting area would be a gently sloping shore that is protected by outer sand bars, kelp beds or other such structures. The often overlooked places such as salt marshes and submerged eel grasses offer a greater variety of unusual specimens. Many mollusks can be found among mangrove roots or other trees rooted in swamps or on the underside of boats that are about to be removed from

Where to Collect - cont'd

the water. Over-turning rocks in these habitats often reveal numerous animals hiding beneath them. Looking inside of rotting logs and probing among the kelps, can be suprisingly productive. A rubble-strewn bottom is ideal although sometime dangerous to the inexperienced collector. The sifting of mud bottoms and sandy bottoms can provide numerous small forms that are generally overlooked.

Equipment

Often times collectors who have a serious interest begin to accumulate great quantities of collecting equipment. They try to take all this equipment with them at one time. Too much heavy equipment can hamper a collection trip. Much of this gear is generally unnecessary. Unless you are going to do some specific collecting for a given purpose, items like crowbars and picks and heavy nets should be avoided.

A boat is helpful if one is doing some dredging, but not absolutely necessary. Sneakers or boots should be used as protection against injury. Heavy cotton or canvas gloves are also essential to avoid cuts and scratches while collecting specimens. Never go collecting barefooted under any circumstances. A laundry bag or a bucket is useful in holding and protecting specimens. A hat should be worn to protect the collector against the sun.

If you are collecting at night an ordinary kerosene or battery operated lantern is useful. A few plastic medicine vials to hold small specimens can easily be placed in your pocket and will prevent damage to any delicate forms. A clam rake and a pen knife are useful in prying specimens loose or sifting through the bottom.

For the serious collector who plans to collect specimens in deeper water, a diving mask or water bucket are essential. Snorkeling for specimens in deeper waters is useful but should never be done alone. Seines and dredges are essential for collecting deeper froms and can be used from a row boat. A general rule of thumb would be to use three times as much line on the dredge as the water is deep. All marine and navigation maps provide information on water depths.

Equipment - cont'd

Baiting traps for some carnivorous forms can be productive. A field notebook and field labels are essential for recording information on-site.

Preparing A Collection

Proper preparations and storage of any serious collection are essectial if one is to utilize the collection for any purpose. Often times an amateur's collection is of little value because it is either not cared for properly or does not contain information as to how, when and where it was collected.

The removal of soft or fleshy portions from mollusks is a rather simple matter. If you start with a pot of cold water, gently place the organism(s) in the water, bring to a boil and boil for ten minutes, and allow the water to cool slowly, you will find that a fork, pin or some such instrument can easily remove the organism from its shell.

Specimens whose shells have a glassy appearance or shine should never be subjected to extremes in temperature. Such treatment will tend to crack the shell and ruin the specimen. Many snails have a horny operculum at the base of the animal and this should be removed, glued to a piece of cotton and replaced in the shell. It is part of the animal and can be used for identification purposes.

There is a number of things that you can do to eliminate organic material that remains in the shell and produces bad odors. You can add some water and allow the material to rot for two or three days and then wash very vigorously with running water. Repeat this procedure if necessary. Sometimes, the addition of two or three drops of formalin to the shell will dry the organic material which can later be removed. This should eliminate any odors.

After the removal of the animal, the shells should be cleaned by scrubbing them with some soap and water using a fingernail brush or toothbrush. Some people prefer to remove the periostracum from the outer covering of the shell in order to reveal the shell's intricate and beautiful patterns. A serious collection should contain not only a shell without the periostracum but also a specimen with the periostracum.

Preparing A Collection - cont'd

Agal growth or the periostracum can be removed by soaking the specimen in clorox or vinegar. This procedure should be used with caution as both of these substances are corrosive to the shell.

In addition to the clean and natural shells in the collection, one should preserve the animals within the shell for later study. In order to do this, it is necessary to relax the animal first so that it will not withdraw within the shell and be inaccessible for study.

A number of procedures can be used for the relaxation of the soft parts. One that has been used with some success is to heat gently the container in which the animal is placed thus removing the oxygen and gently killing the animal without causing muscular contraction. Another method is to add rubbing alcohol to the water in small drops over several hours or days until the animal dies in a relaxed condition. Epsom salts can also be added in a similar manner with like results.

The specimen should then be fixed by placing it in a 10 percent formalin solution (which can be purchased in a drugstore), for at least 24 hours and then stored in a glass container with a plastic lined lid in 50 percent isopropyl alcohol (rubbing alcohol).

The shell collection may be stored in cigar boxes or in more elaborate display cases, in a systematic and organized fashion. Label all specimens with a number in an inconspicuous portion of the shell. Preferably, using a fine tipped rapidograph pen and india ink. A coating of clear nail polish over the number will protect it.

Record in a file or in a log book the following information:

Catalog Number -
Scientific Name -
Common Name -
Where Collected -
When Collected -
By Whom Collected -

Preparing A Collection - cont'd

It might appear as follows:

Catalog Number	1256
Scientific Name	Spisula solidissima, Dill
Common Name	Atlantic surf clam
Where Collected	Cape May Point, Cape, May, N.J.
When Collected	August 12, 1968
By Whom Collected	R.J. Raimist

Live study of marine mollusks is essential for serious understanding of the animals. This knowledge can be gained by returning one or two specimens to a seawater tank at home kept out of direct sunlight. The tank should not contain any metal and should not be overcrowded with animals. Observe all activities - feeding, movement, reproduction, excretion, fighting, etc. Specimens may be studied for a day or two and then released.

CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
FOR SOUTHERN NEW JERSEY

Biological Solutions Helpful in Preserving Marine Specimens

by Roger J. Raimist

RELAXING AGENTS - prevent muscular contractions in the soft parts of marine animals.

A relaxing agent should be used first for most specimens that are to be preserved for later study or display. This preparation enables the entire animal to appear in a natural condition and thus be easily studied.

1. Magnesium Chloride ($MgCl_2$ 6 H_2O)

- a crystalline form that is readily accessible and excellent for use with many marine invertebrates - worms, starfish, snails, etc. Dissolve 80 grams of magnesium chloride in a liter of tap water. Place the animals in this solution. In approximately one to four hours, they will have been sufficiently relaxed to be preserved. Add some formalin, a little at a time, until the animals are quiet and have died. They may be transferred then to any desired preservative.

2. Magnesium Sulphate ($MgSO4 \cdot 7\ H_2O$)

- is readily available in drug stores as Epsom Salts. This solution works very well on sea anemones, worms, fish and other marine animals. Place the animal into a solution made from equal parts of sea water and a 20% solution of Epsom Salts in tap water.

One could also allow the animal(s) to expand naturally in a small amount of sea water. Then add the Epsom Salts a little at a time over several hours until the animal(s) are relaxed and quiet. After the specimen is relaxed, kill the animal and preserve it.

Biological Solutions Helpful in Preserving Marine Specimens

KILLING AGENTS - these kill the specimen and prepare them for preserving.

1. Ether - very commonly used, but must be handled with extreme caution as the fumes are highly explosive. Add some to the water; 3 parts water, 1 part ether.

2. Carbon Tetrachloride - available at most drug stores and also sold as a cleaning fluid under the name "Carbona". Add some to the water, 3 parts water, 1 part carbon tetrachloride.

3. Chloroform - must also be used with caution because of its dangerous fumes, but is frequently available and works well on larger animals. Add some to the water, 3 parts water, 1 part chloroform.

4. Nitric Acid - 1% solution is the best agent for killing flat worms. Nitric acid must be handled very carefully when the solution is prepared. The animals should not be left in it for more than 2 minutes. Do not allow concentrated nitric acid to touch skin or clothing.

5. Alcohol & Formaldehyde - animals can be dropped in these solutions.

PRESERVATIVES - a preservative should always be used after killing, to preserve the specimen for study and display.

1. Formalin - (Formaldehyde) 37-40% formaldehyde solution. A 5 - 10% solution of formalin is one of the most commonly used preservatives. Formalin has a disagreeable odor and in stronger solutions it causes eyes to smart. Some persons are allergic to it. It is well to avoid placing hands directly in it. This is an excellent perservative that hardens tissues.

2. Alcohol - Any alcohol which can be diluted with water can be used. Rubbing alcohol is usually sold as a 70% solution. Isopropyl alcohol is obtainable in strengths of 95-99% and can be diluted to any strength.

reservatives - cont'd

3. FAAG - (Formo-acetic-alcohol-glycerine). Good for worms, sponges, or other animals with a calcified exoskeleton.

95% Alcohol	240 ml.
Formalin	150 ml.
Acetic acid, glacial	50 ml.
Glycerine	100 ml.
Tap water	460 ml.

to make - 1000 ml. or 1 liter

4. FAA Plant Preservative - 1 liter

Part I.

Formalin	100 ml.
Glacial acetic acid	50 ml.
70% Iso-alcohol	850 ml.

Saturate the above solution with copper sulfate.

Immerse the plants in FAA Part I for 1 day to retain the chlorophyll. Then transfer the plant to FAA - Part II for a permanent mount.

Part II.

Formalin	100 ml.
Glacial acetic acid	50 ml.
70% Iso-alcohol	850 ml. to make 1 liter

CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
FOR SOUTHERN NEW JERSEY

A Partial Artificial Key to the Classes, Subclasses and Orders of Molluska

by Roger J. Raimist

Note: It is important when using this key that you have a complete specimen - shell and animal. When you have reached the indicated name for the specimen, check its full description in a good reference book. If the description in the book does not match your specimen satisfactorily:

(a) it may not be a common animal in this vicinity
(b) you may need to follow the clues again.

When selecting a reference manual for identification, it is important that you know the anatomical terms used in the descriptions. A reference book with a good glossary will help you over this difficulty. Reference books with photographs and/or explanatory sketches are most helpful for beginners.

Any artificial key is designed to guide the uninitiated student to the appropriate section of an adequate reference book. The key is never to be used as the sole means of identification.

IF		TURN TO
1A	Animal contains a shell	2
1B	Animal does not contain a shell	6
2A	Shell is composed of a single piece	3
2B	Shell is composed of more than one piece	5
3A	Shell is symmetrical	4
3B	Shell is asymmetrical or coiled and animal has less than 8 or no tentacles...class Gastropoda (snails)	10
3C	Shell is asymmetrical or coiled and animal has 8 tentacles about head	7

A Partial Artificial Key

IF		TURN TO
4A	Shell is oval	class Monoplacophora
4B	Shell is tube-like and open at both ends	class Scaphopoda (tusk shells)
5A	Shell has 8 pieces	class Amphineura (chitons), Sub-class Polyplacophora
5B	Shell has 2 hinged valves	class Bivalva (clams and oysters) 8
6A	Animal does not contain a well developed head, mouth and anus terminal	class Amphineura (chitons), Sub-class Aplacophora
6B	Animal contains a well developed head	7
7A	Circle of at least 8 tentacles around head	class Cephalopoda (squids and octapods) 14
7B	1 or 2 pairs of tentacles	class Gastropoda 12
7C	No tentacles	class Gastropoda 10
8A	Gills filamentous	9
8B	Gills non-filamentous, forming a muscular septum	Sub-class Septibranchia
9A	Gills flat and non-reflected filaments	Sub-class Protobranchia
9B	Gills large and elongated and reflected forming two-sided lamellae	Sub-class Lamellibranchia 16
10A	Sexes separate and one pair of tentacles and an operculum	Sub-class Prosobranchia 28
10B	Hermaphroditic	11
11A	No tentacles	Sub-class Opisthobranchia 21
11B	Tentacles	12
12A	1 pair of tentacles	13
12B	2 pairs of tentacles	Sub-class Pulmonata, order Stytommatophora
13A	Mantle cavity vascularized as lung	Sub-class Pulmonata, order Basommatophora
13B	Mantle cavity not vascularized as lung	Sub-class Protobranchia
14A	8 sucking arms, no shell	order Octopoda
14B	8 sucking arms and 2 retractile arms	15

A Partial Artificial Key

IF		TURN TO
15A	Horny rings on suckers, no webbing	order Decapoda
15B	No horny rings on suckers and webbing between arms	order Vampyromorpha
16A	Gills eulamellibranch	18
16B	Bills not eulamellibranch	17
17A	Gills filamentous and free	order Taxodonta
17B	Gills usually filibranch and adductor muscles dissimilar and a small foot	order Anisomyaria
18A	Hinge teeth present	19
18B	Hinge teeth absent	order Anomalodesmata
19A	Siphon long and united	order Adapedonta
19B	Siphon not long and united	20
20A	Heterodont dentition on hinge	order Heterodonta
20B	Schizodont dentition on hinge	order Schizondonta
21A	Animal contains parapodia	22
21B	Animal does not contain parapodia	25
22A	Head forms a shield for burrowing	order Cephalaspidea
22B	Head does not form a shield	23
23A	Animal contains a shell	24
23B	Animal does not contain a shell	order Gymnasomata
24A	Shell reduced and internal	order Anaspidea
24B	Shell is spirally coiled or not spirally coiled	order Thecosomata
25A	Animal has a shell	26
25B	Animal has no shell	27
26A	Shell reduced and internal	order Notaspidea
26B	Shell spirally coiled	order Sacoglossa
27A	Spicules	order Acochlidiacea
27B	Outgrowth (fleshy) on dorsal integument	order Acoela

A Partial Artificial Key

IF		TURN TO
28A	Gills monopectinate	order Mesogastropoda
28B	Gills bipectinate	29
29A	Two renal organs	order Archaeogastropoda
29B	Left renal organ only	order Neritacea
29C	Shell siphonate	order Neogastropoda

CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
FOR SOUTHERN NEW JERSEY

Some Notes on Marine Bivalves

by Roger J. Raimist

HABITAT

Marine bivalves can be found in a variety of habitats. These environments may include open oceans, brackish waters, estuaries and bays. Bivalves are to be found in a variety of places, within these habitats.

In the open oceans and bays, scallop shells swim by clacking the valves together and squirting water out between the valves.

In a slightly different habitat along warm, sandy shores, one may expect to find clams washing up on the beach with each wave and then burrowing quickly beneath the sand. Many forms can burrow through the sand by extending the muscular foot into it and then expanding the bulbous portion. Then the animal pulls itself forward by withdrawing the foot into its shell.

When looking through a mangrove swamp along a beach in southern waters, the roots of the mangrove trees will contain certain bivalve varieties. During the larval stages the young forms become attached to the mangrove roots.

Bivalves are not only found in clean sand but in some rather thick, viscous and often foul-smelling mud. In this type of mud can be found the angel wing Barnea. The angel wing form can burrow 2 to 3 feet down into the mud. This burrowing habit is not unusual. Many forms can burrow into coral, rocks and wood by mechanically scraping the shell against the host surface.

Bivalves are to be found in shallow as well as deep water. Many specimens have been dredged from depths below 5,000 meters, or about 3 miles down.

Some Notes on Marine Bivalves

GROWTH

Bivalves, as the term implies, consist of two shells or valves hinged at the back. These shells grow by the secretion of calcium carbonate, (which is called calcite or aragonite), by the mantle tissue of the animal. On those shells that are found along the shore a thin layer has usually been worn away. This is not composed of calcium carbonate, is usually brown or black in color and is called the periostricum.

The actual structure of the shell varies. There may be a prismatic layer composed of tightly packed prisms which one can see under the microscope. A foliated portion of overlapping layers may be present. A nacreous, or Mother-of-Pearl layer is often found, as is a sandstone-like granular layer. The shell may be crossed lamellar in long layers or it may be homogeneous, (no apparent changes in shell composition or texture.)

Most growth occurs within the first two years of the bivalve's life. However, growth is continuous throughout the life of the bivalves. The growth rates are controlled by a variety of factors other than genetic ones. The most critical growth factor is the environmental temperature.

FEEDING

Bivalves are remarkably efficient feeders ard they ingest a wide variety of materials. For the most part, they are filter feeders. This is accomplished by drawing in a constant stream of water through the bivalve's incurrent siphon. The water is passed over the gills before it is eliminated through the bivalve's excurrent siphon. The bivalve's gills are laden with mucous and contain active cilia. The Protozoans, Diatoms, Dinoflagellates and other materials suspended in the water are trapped by the mucous and are subsequently transported by the cilia to the mouth of the animals.

This pumping action of the water through the mantle cavity in order to obtain the free-swimming or suspended organisms is utilized by oysters, mussels and the like. This method is called suspension feeding.

Some Notes on Marine Bivalves

Feeding - cont'd

There are also animals called deposit feeders. Animals like Macoma and Tellina use long siphons to suck up mud from the bottom and extract food in this fashion. A few bivalves live on worms and crustaceans but this is a rare occurrence.

RESPIRATION

The main function of the gills of a bivalve is not respiration but feeding. True, the cilia on the gills do create a water current and the oxygen carbon dioxide exchange is facilitated by this current, but for the most part respiration is accomplished by the bivalve's mantle cells.

Clams that have been taken out of the water and have closed tightly may obtain oxygen from a different source other than extraction from water. Oxygen is probably obtained from the breakdown of glycogen-like substances in the tissues.

There are four basic gill types, the most primitive of which is a single simple plate as exhibited by Nuclea. This gill type is called a protobranch. The filibranch is a long, double folded gill-like structure found in arks and mussels. The eulamellibranch is a long, double-folded gill that is connected internally by cross channels. This is found in the Venus clam. A degenerate gill that has been reduced to a small slit instead of gill filaments is to be found in Cuspidaria. This is called the septibranch.

REPRODUCTION

Some species deposit eggs directly into the water to allow for external development while others retain eggs for internal development. The sexes are usually separate (dioecious), however, in some cases one animal possesses both sexes (monoecious). Sex reversal may also occur in bivalves. In some cases the early forms are female and by the time adulthood is reached they have become males. For example, the quohog Mercenaria, start out as male, some remain such, while others later develop into females. It is also known that some oysters can change their sex many times.

CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
FOR SOUTHERN NEW JERSEY

Some Notes on Marine Snails

by Roger J. Raimist

HABITAT

The usual habitat of marine gastropods (snails) is the intertidal zone, the region between high and low tides. There is also a large number of marine snails found along mud flats and rocky coasts. Nerites and Periwinkles can be found on marine plants near the shore line.

It is not unusual to find some species of snails occupying a pelagic or open-ocean habitat. For example, in southern waters one can find a beautiful blue snail that lives its entire life as a free floater - Janthina. It secretes a raft of bubbles to keep itself afloat.

It is also interesting to note that some marine snails have evolved a shell-less condition and have elaborately structured gills. These animals, classified as Nudibranchs, are found in pelagic (open-ocean) habitats as well.

Many snails are to be found in areas where there is an abundance of food. Snails exhibit two basic feeding habits - they are either carnivorous or herbivarous. For example, Polinices, the Moon Snail, is found in the sand where clam beds are located. Polinices is a clam feeder.

Limpets are often found grazing along rocks and jettyies. These animals scrape the algae from the rocks and are typical of the herbivores.

Marine gastropods are basically nocturnal and most activity occurs after dark. These animals actively avoid light. During the day, one should look for these gastropods in crevices and difficult-to-get-at places; these are the dark spots where they hide. Occasionally, they are found among the kelps that they are feeding upon, as well as inside some sea squirts, sponges and other small animals.

Some Notes on Marine Snails

Habitat - cont'd

There are a few species that are parasitic in nature. Brachystoma is an ectoparasite commonly found on Mytilus, the Blue Mussel. Brachystoma, which are very small, (smaller than an eraser on end of a pencil), are not very common and are usually overlooked by the casual observer.

GROWTH

Gastropod shells grow by the secretion of calcium carbonate deposits laid down by the mantle tissue of the animal. (It may be helpful at this time to refer to a good general zoology text or field guide like the Seashores by Zim.) The outer layer of the shells generally contain a rather unattractive horny layer of materials called the periostricum, which is most often a brown or black color. On shells that are commonly washed up along the shore, the periostricum has usually been worn away. Some shells do not possess a periostricum because the animal has fleshy extensions of the mantle which can migrate out over the shell. Thus, the animal is constantly laying down a thin layer of new shell material, which gives the high sheen to some shells, i.e. any of the Cowries.

Shell consists of a number of specific layers. These layers are: periostricum, prismatic layer and pearly nacre commonly called Mother of Pearl. Beneath the Mother of Pearl layer is the mantle tissue that secretes the shell.

Some of the mollusks grow continuously during their entire lifetime, while others grow only to sexual maturity at which time all physical growth ceases. Specific cells in the mantle secrete minerals which account for the deposition of color patterns in the shell. If the cells are continuously active as the shell grows, stripes will be formed. If the cells are intermittently active, anything from a small splotch to a broken line may appear on the shell surface.

Occasionally, shells are found that contain a thick, regularly spaced rib. This rib is indicative of the animal's resting period. The lower or thinner portion of the shell denotes rapid growth, sometimes only a few days in duration. The period that accounts for the rib, or varix, may encompass several months or longer.

It is not unusual to find various stages of development in a single species that to the amateur might appear as separate species. One very vivid example of this is the developmental stages of the Keyhole Limpet, Fissurella.

Some Notes on Marine Snails

Growth - cont'd

In the early stage of development there is a slit or notch in the shell in the anterior part of the animal. This slit gradually migrates dorsally and eventually becomes the hole in the Keyhole Limpet. The spire of the animal gradually seems to uncoil and disappear as the animal goes from a very snail-like appearance to that of a typical Limpet.

FEEDING

Snails generally feed by using a rasp-like tougue apparatus, the radula, to scrape away bits of flesh or plant material which is then ingested. This is the typical pattern, other feeding habits are variations on that basic method. For example, the Oyster Drill, Urosalpinx, will drill a hole through the shell of the clam and then proceed to eat the animal using a long proboscus. Murex and Busicon pry open shells using the muscular foot on one valve, then proceed to eat the animal.

A vegetarian diet is considered, by most authorities, to be the most primitive type of diet for snails. For example, there are seaweed grazers like the Limpets, Nerites, Trochids and Turbans. There are mud swallowers which swallow mud as they pass through it and extract algal cells and diatoms. These are Ceriths and Periwinkles. It's interesting to note that a fairly common form Crepidula, the Atlantic Slipper, feeds like an oyster does. It generates its own water current to extract diatomaceous material.

RESPIRATION

Most snails draw water in through a siphon and pass it over the gills and out the other side. For the most part, snails breathe through a gill-like structure within the shell. Two pairs of gills are considered the more primitive condition in snails. Examples of this can be found in Limpets and Slit shells. In higher groups of snails only the left gill remains. In ceriths, the gills are so reduced that only small stumps remain and respiration is accomplished through the mantle by osmosis.

Some Notes on Marine Snails

REPRODUCTION

The sexes are mostly separate (dioecious) but in some cases one animal possesses organs of both sexes (monoecious). Sex reversal is not unusual. The snail may start out as a male and later becomes a female, as is exhibited by Crepidula, the Atlantic Slipper. Fertilization occurs both internally and externally in the snail group and some hatch as miniature adults while others hatch as a free-swimming minute ciliated larvae, known as veliger larvae. In most cases, female snails are larger than the males.

CONSERVATION AND ENVIRONMENTAL SCIENCE CENTER
For Southern New Jersey

Selected Readings in Marine Science

Prepared and Reviewed by Roger J. Raimist

Key: L, I, U, S

L - Lower Elementary
I - Intermediate Elementary
U - Upper Elementary
S - Secondary

GENERAL

S — Coker, R.E., This Great and Wide Sea, Harper & Row, N.Y., 1962.
$2.25 (paperback)
A dated but still excellent book on oceanography in general.

U, S — Cowen, R.C., Frontiers of the Sea, Bantam Books, N.Y., 1960.
$ .60 (paperback)
This book is a good general reference on oceanography.

I, U, S — Cromie, W.J., Exploring the Secrets of the Sea, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1962.
$5.95
An excellent book; this is a must on everybody's list. Concerning general oceanography, it is fascinating.

L, I — Dudley, R., Sea Shells, Thomas Crowell Company, N.Y., 1953.
$3.50
A well-done book on shore life: general.

I, U, S — Epstein, S. & B., The First Book of the Ocean, Franklin Watts, Inc., N.Y., 1961.
$2.75
A good book about general oceanography.

U, S — Hay, J. & Farb, P., The Atlantic Shore, "Human and Natural History from Long Island to Labrador," Harper & Row, N.Y., 1966.
$6.00
A must for all interested students - excellent.

U, S — Hull, S., The Bountiful Sea, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1964.
$6.95
An excellent book on general oceanography with many fine photos.

GENERAL - cont'd

U, S Kovalik, V. and N., The Ocean World, Holiday House, N.Y., 1966.
$4.50
This is a good book on general oceanography.

U, S Long, E.J., Ocean Sciences, George Banta Co., Inc., Menasha, Wisconsin, 1964.
$10.00
A good book on general oceanography.

I, U, S Reed, M.W. & Bronson, W.S., The Sea for Sam, Harcourt, Brace & World, Inc., N.Y., 1960.
$4.95
A general book about the oceans and ocean life.

L, I Scharff, R., The How and Why Wonder Book of Oceanography, Grosset & Dunlap, N.Y., 1967.
$1.25
A good, well-illustrated book on oceanography in general.

U, S Sherman, D., You and the Oceans, Children's Press, Chicago, Ill., 1965.
$2.50
A general book on oceanography.

S Turekian, K.K., Oceans, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1968.
$2.00 (paperback)
An excellent recent and up-to-date work on the physical aspects of the ocean.

L, I, U, S Waters, R. & J., Salt-Water Aquariums, Holiday House, N.Y., 1967.
$3.95
An excellent publication on techniques.

U, S Yasso, W.E., Oceanography, Holt, Rinehart & Winston, Inc., N.Y., 1965.
(paperback)
A good book on oceanography.

IDENTIFICATION

I, U, S Abbott, R.T., American Seashells, D. Van Nostrand Co., Inc., Princeton, N.J., 1954.
$12.50
This is a most useful and readable volume - a must.

U, S Abbott, R.T., How to Know the American Marine Shells, The New American Library, N.Y., 1961.
$ .75
An excellent guide to marine mollusks, with some pictures.

L, I, U, S Abbott, R.T., & Zim, H.S., Sea Shells of the World, Golden Press, N.Y., 1963.
(paperback)
An excellent field guide.

S Dawson, E.Y., How to Know the Seaweeds, Wm. C. Brown Co., Publishers, Dubugue Iowa, 1956.
$2.25 (paperback)
Useful, an excellent guide.

L, I, U, S Harris, C., Seashore Life, Great Outdoors Publishing, St. Petersburg, Florida, 1961.
$1.00 (paperback)
An excellent paperback on the identification of marine animals with illustrations.

I, U, S Low, D.F., Sea Shells, Grosset & Dunlap, N.Y., 1961.
$1.25
A well illustrated book on shells - their classification, collection and biology.

L, I, U, S Miner, R.W., Field Book of Seashore Life, G.P. Putnam's Sons, N.Y., 1950.
$8.00
This is a must as a general field guide.

I, U, S Morris, P.A., A Field Guide to the Shells, Houghton Mifflin Co., Boston, Mass., 1947.
$4.95
This is an excellent guide with many photos.

IDENTIFICATION - cont'd

I, U, S Morris, P.A., A Field Guide to Shells (of the Pacific Coast and Hawaii), Houghton Mifflin Co., Boston, Mass., 1966.
$4.95
This is quite good, with many photographs.

L, I, U, S Perlmutter, A., Guide to Marine Fishes, New York University Press, N.Y., 1961.
$6.50
This book is a must and an excellent guide.

I, U, S Perry, L.M. & Schwengel, J.S., Marine Shells of the Western Coast of Florida, Paleontological Research Institution, Ithaca, N.Y., 1955

Excellent book, it contains many photographs.

S Rogers, J.E., The Shell Book, Charles T. Branford Co., Boston, Mass., 1936.
$9.50
This is a good book on shells.

I, U, S Taylor, W.R., Marine Algae of the Northeastern Coast of North America, The University of Michigan Press, Ann Arbor, 1957.
$12.50
A classic volume on algae; this book is excellent.

I, U, S Warmke, G.L. & Abbott, R.T., Caribbean Seashells, Livingston Publishing Co., Narberth, Pa., 1961.
$8.95
An excellent and useful book with many photographs.

L, I, U, S Zim, H.S. & Shoemaker, H.H., Fishes "A Guide to Familiar American Species," Golden Press, N.Y., 1956.
$1.00 (paperback)
An excellent beginners' guide to fishes with excellent pictures.

Selected Readings in Marine Science

BIOLOGICAL

L, I, U — Andrews, C.R., All About Whales, Random House, N.Y., 1954.
$1.95
An interesting book about whales.

I, U, S — Blassingame, W., The First Book of the Seashore, Franklin Watts, Inc., N.Y., 1964.
$1.98
An excellent book which covers the complete life of the seashore environment.

I, U, S — Breder, C.M., Jr., Field Book of Marine Fishes of the Atlantic Coast, G.P. Putnam's Sons, N.Y., 1929.
$5.00
This is a fine book.

I, U, S — Coe, G., Fish, Grosset & Dunlap, N.Y., 1963.
$1.25
A well-illustrated, up-to-date book on fish, their origin and evolution.

I, U — Cooper, E.K., Science on the Shores and Banks, Harcourt, Brace and World, N.Y., 1960.
$3.50
An interesting book on shore life.

I, U, S — Hylander, C.J., Sea and Shore, The Macmillan Co., N.Y., 1950.
$3.00
Excellent book on the seashore plants and animals and how they live. It is well worth reading.

U, S — McCoy, C.J., Vertebrates, Reinhold Book Corporation, N.Y., 1968.
(paperback)
An excellent paperback on vertebrate biology and evaluation.

S — Morton, J.E., Mollusks, Harper & Brothers, N.Y., 1960.
(paperback)
It is comprehensive and rather sophisticated.

U, S — Nichols, D., Echinoderms, Hutchinson University Library, London, 1967.
(paperback)
Excellent on the biology and ecology of this group.

BIOLOGICAL - cont'd

S Prescott, G.W., The Algae: A Review, Houghton Mifflin Co., N.Y., 1968.
$7.95
A comprehensive review of the biology of algae.

L, I Ray, C., Wonders of the Living Sea, Parents' Magazine Press, N.Y., 1967.

A colorful, well-illustrated book on life in all parts of the ocean. Discusses all ecological aspects of marine life.

S Rounds, H.D., Invertebrates, Reinhold Book Corp., N.Y., 1968.

A good book on the biology and evaluation of invertebrates.

S Schmitt, W.L., Crustaceans, The University of Michigan Press, Ann Arbor, 1965.
$1.95 (paperback)
An excellent book on the biology and classification of the crustaceans.

I, U, S Schroeder, R.E., Something Rich and Strange, Harper & Row, N.Y., 1965.
$5.50
An interesting book about marine life and the day-night cycle.

I, U, S Silverberg, R., The World of Coral, Duell, Sloan and Pearce, N.Y. 1965.
$3.95
A fine book about life in the corals.

U, S Wheat, G.C., Whales and Dolphins, Golden Press, N.Y., 1963.
$1.69
An interesting book on the classification, biology, and evaluation of whales and dolphins.

L, I, U, S Zim, H.S. & Ingle, S., Seashores, Golden Press, N.Y., 1963. (paperback)
An excellent field guide.

PHYSICAL

S — Bascom, W., Waves and Beaches, Doubleday & Company, Inc., Garden City, N.Y., 1964.
$1.45 (paperback)
A classic on marine erosion and wave anatomy.

U, S — Brindze, R., The Rise and Fall of the Seas, Harcourt, Brace and World, Inc., N.Y., 1964.
$3.50
An excellent book on tides and how they work.

S — Carter, S. III, Kingdon of the Tides, Hawthorn Books, Inc., N.Y., 1966.
$3.95
An excellent and up-to-date book on tides and tidal phenomena.

I, U, S — Clark, D.L., Fossils, Paleontology and Evolution, Wm. C. Brown Co., Dubuque, Iowa, 1968.

This is quite a fine book, easily read and very useful.

S — Darwin, C., Coral Reefs, University of California Press, Berkeley and Los Angeles, 1962.
$1.95 (paperback)
A classic - dated but still excellent on corals and island development.

I, U — Kinney, J. & C., What Does The Tide Do?, Young Scott Books, N.Y., 1966.

An excellent book on how the tides work and how they affect the ecology of the beach. Excellent.

U, S — Spar, J., Earth, Sea, & Air "A Survey of the Geophysical Sciences" Wesley Publishing Co., Inc., Reading, Mass., 1965.
$1.95 (paperback)
A book on earth sciences containing good material on the sea.