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THE UTILIZATION OF ECHINODERMS AND OF GASTEROPOD MOLLUSKS

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The Puget Sound region, in the State of Washington, is noted for the wonderful abundance and diversity of its fauna. The region is also noted for its several groups of archipelagoes, of which the San Juan Archipelago is an especially beautiful one.

Around the shores of these islands, echinoderms are found in great profusion. Particularly noticeable are the common forms of starfish, sea urchins, and sea cucumbers. The most common starfish are Piaster ochraceus and Evasterias troschelli, which show, respectively, considerable substantive and merestic variation. In the environs of Bremerton, the latter finds more congenial conditions than any of the other common species, and there it occurs in a ratio of 25 to 4 of the former, while in the San Juan island group, P. ochraceus is by far the most numerous. Besides these two species, P. paucispinus and many others are also found, but in smaller numbers. The twenty-rayed starfish, Pycnopodia helianthoides, occurs quite plentifully at various places, e.g., Bremerton, Griffin Bay, East Sound, etc. Sea urchins, Strongylocentrotus drobachiensis, S. purpuratus, (S. franciscanus are very numerous, especially the former. At low-water, S. drobachiensis may be seen in the bays of the northern part of the sound in large patches, and at a depth of only four meters. S. franciscanus, which becomes very large - 7 to 13 centimeters in diameter - is found just below low-water mark; I have seen it in large numbers in the vicinity of the Biological Station at Friday Harbor. The most noticeable species of sea cucumbers are Cucumaria japonica (Semper), C. chrondjelmi (Theil), and Stichopus californicus (Stimpson) Edwards. C. chrondjelmi is exceedingly abundant near the Sucia Islands. All these species may be obtained by dredging, and C. japonica may be picked by hand at low-tide.

Of all the echinoderms, common starfish, Piaster, Evasterias, etc., are most easily obtained. They occur within the lower limit of the average ebb-tide and sometimes in such profusion that, especially when the stars are brightly colored, they may be seen at half a mile's distance. Their occurrence is independent of town sites, being determined by the nature of food

NOTE.--Supersedes Memorandum S-170, issued by the former Bureau of Fisheries.

available. Shores well supplied with barnacles usually have a large number of starfish. And the fact that they are abundant at a distance from towns adds to the desirability of their use as a food product. The parts of the starfish and sea urchins utilizable as food are the gonads. During the breeding season, these grow enormously, so that in the starfish the body becomes twice its normal size, the gonads completely filling the gastric cavity. The part of the sea cucumber utilizable as food is the muscles.

Echinoderm gonads as a food commodity would be the object of an industry of annual periodicity like the salmon industry. As the spawning season of starfish and sea urchins comes in the spring, the canning of the roe could be well completed before the salmon season begins; or the making of echinoderm gonads into caviar might well be done along with the canning of fish, whether salmon or otherwise. The gonads of the various species of the larger starfish are ripe in April; those of the sea urchin, in June, as regards species of the north Pacific coast.

There can be no question about the advisability of using the spawn and muscles of echinoderms as food, even in a country where all kinds of food are as plentiful as in the United States. The question is rather how to utilize this part of nature's storehouse to the best advantage for mankind.

Barbier (1908) states that the native of Madagascar have developed a considerable industry in the utilization of starfish, sea urchins, and sea cucumbers as food. In 1902, the marketable quantity of sea cucumbers represented a value of 175,000 francs. The province of Tulear produced alone 30 tons, but the lack of necessary labor prevented further production that year.

Taylor (1908) reports an interesting fact, namely, that the Arctic Fox of the Aleutian Islands, so highly valued for its beautiful fur, feeds, in winter, on echinoderms, e.g., sea urchins.

Reagan (1907) claims that the sea urchin (Strongylocentrotus drobachiensis) is used by the Pacific coast Indians as food.

In conversation with the United States Commissioner of Fisheries (1916) I learned that the roe of starfish is being used in France as food and also as bait in the sardine fisheries; and through Professor Kincaid, I am informed that certain species of sea urchins, which in the market of Naples are called "Frutta di mare," and in the West Indies "Sea eggs," are sold as food, but I have not had the opportunity to consult literature on these points.

Brunchorst (1898) shows that a number of excellent food fish common to the coast of Norway feed on echinoderms, and mentions especially: Anarrhichas lupus, and A. minor; Lycodes esmarckii; Pleuronectes microcephalus, and P. platessa; others not used as food fish but which feed on echinoderms are A. latifrons, P. cynoglossus, and Galeus vulgarus. Perhaps other food fish such as Gadus callarias and G. pollachius also feed on echinoderms, as I have at least found at times small starfish in their stomachs.

Carr (1907) found that out of 150 starry rays (Raia radiata) ten contained echinoderms (Asterias, Echinus, and Ophiocoma), and out of 12 haddock (Gadus aeglefinus) two contained echinoderms (Ophiocoma). Three out of 13 wolf-fish (Anarrhichas lupus) contained echinoderms. In 1908, the same author

tabulated observations on 370 common dab (Pleuronectes limanda) and showed that out of this number, 56 contained echinoderms, e.g., Ophiuroids and Echinoids; 5 long rough dab (Hippoglossus limandioides) out of 60 fish contained Ophiuroids; 10 out of 25 G. aeglefinus, contained echinoderms (Ophiuroids and Echincoyamus), and one gray gurnard (Trigla gurnades) out of 150 fish also contained echinoderms.

From the findings of Brunchorst and Carr, it is seen that various kinds of fish feed on echinoderms, whence the suggestion that echinoderms be used as bait. However, it may be that for a number of forms echinoderms are resorted to only when other food is out of reach, though the common dab, according to Carr, appears to eat them during the greater part of the year. The long rough dab feeds less on echinoderms than the common dab, perhaps owing to a difference in migration habits of the two.

A large part of an echinoderm industry would be bi-products, since the main bulk of the starfish consists of material best suited for guano. No absolute waste material need remain; all of the animal may be utilized. Indirectly, the shellfish industries would be benefited by reducing the number of starfish in regions where shellfish live, as various forms of starfish feed on marketable shellfish. Lebour (1916) makes an interesting statement:

> The mussels on this coast have not many enemies, but by far the most important of these is the starfish, Asterias rubens, which constantly preys upon them. A formerly flourishing bed near the Tyne has lately been exterminated by this starfish and it is a bad enemy everywhere. Purpura lapillus (a small gasteropod) devours the mussels on the soaup, Holy Island, and here in parts the devastation caused by this small and very destructive mollusk is great. It does not, however, appear to be a scourge elsewhere. The only possible way of dealing with such foes would be to destroy all starfish whenever found, and to collect the Purpura lapillus systematically, and also its spawn, and destroy both.

Kellogg (1910) records nothing favorable about the starfish. To him it is a pest.

> The removal of these pests has always been a very difficult matter, and no entirely satisfactory method has been devised for accomplishing it.

When the economic value of starfish is realized, depletion of starfish may result from overfishing, and "to destroy all starfish whenever found" will be out of the question. If it proves necessary to protect starfish, where only the gonads are to be used, these may be removed on the grounds, while fishing, and the starfish at once put back into the water below low-tide level to avoid unnecessary exposure. The operation of removing the gonads could be carried out successfully without killing the animal, since echinoderms possess great regenerative powers. As male gonads may not be unfit for caviar, it is worth noting that they can be easily distinguished from the female since the latter are of pinkish color while the former are of ligh yellowish hue. The reproductive power, and growth of starfish, are very great. According to Kellogg, "A female starfish may, if large enough (depending on the amount of food) begin to extrude eggs during its second summer, and many by that time attain the required size."

As echinoderms, on the north Pacific coast, can be more easily caught than any other kind of sea food, the starfish and some of the sea cucumbers may simply be picked up at low-tide, and sea urchins and certain sea cucumbers may be obtained by dredging, the expenses connected with their utilization as a whole should be comparatively low, making it possible to sell the products at a reasonable price.

In quoting Lebour, I mentioned Purpura lapillus as a destructive enemy of bivalve mollusks. I now wish to point out the possibility of utilizing destructive gasteropods:

Polynices lewisii, a very large gasterpod, is a great destroyer of mollusks of commercial value. Its foot may reach the length of 21 centimeters and a width of 13 centimeters, and a depth of the body about 10 1/2 centimeters. It destroys oyster beds by its burrowing in them in search of clams, but it is not known whether it attacks oysters directly. On account of its burrowing habits, the oystermen, at the head waters of Puget Sound, destroy large numbers of them.

Keep (1888), speaking of Lunatia Lewisii Gld., now merged in Polynices, claims that it possesses a flint drill which it carries in its mouth, and by use of which it drills into the clam or whatever mollusk it may encounter, killing the same. This, it is claimed, is a common habit of members of the family Naticidae of which the genera Natica and Lunatica are best known. Daughtery (1912) says:

> Natica is another drilling sea-snail common to our coast. It burrows in the sand for clams and bores a hole with its radula, rotating its own body in the action.

Agersborg (1918), during the summer of 1916, observed a number of specimens of Polynices in the actual act of killing and eating clams. At low-tide, when rowing along the shores of Dyes Inlet near Chico, Washington, a large number of Polynices was found. As the tide was very low it was possible to pick them up by using a dip-net. Some of them, however, were not so easily removed from the bottom as others, holding to the same by means of the enormous foot, or having sucked down into the sand to the depth of about ten centimeters, leaving only part of the shell uncovered in the middle of a pit. It was soon found that there was a definite cause for their holding on to the bottom so firmly; these individuals of Polynices were feeding. The process of feeding was found to be somewhat different from that described by Keep and Daugherty.

As Polynices crawls along the bottom it kills any clam it encounters by suffocation. The soft-shelled clam, Mya arenaria, which is quite numerous in the bays of Puget Sound, is a common victim. Hard-shelled clams, Paphia staminea, Cardium corbis, are also an easy prey for this ravener. In the case of Mya, the gasteropod sucks itself over the syphon down into the sand until its victim is dead from suffocation, and then when the clam has opened, Polynices simply sends its proboscis between the valves and devours the content. As for the hard-shelled clams, the process of feeding is similar to that used when eating a Mya but the method of killing is different. In this case the prey is held in the "sole" of the foot until the adductor muscles are relaxed or the victim is dead, when the feeding begins. Several dead

clams, of these species mentioned, were found in possession of Polynices, but none of them were drilled. It is thus seen that this gasteropod is very decidedly an enemy of the bivalved mollusks, but its method of killing clams is different from that described by Keep and Daugherty.

Several specimens of Polynices lewisii were obtained and brought to Bremerton, where experimentation on the possibility of utilizing them as food was carried out. Two methods of preparing the animals for the table were used; first, steaming in the moisture contained within its swollen foot, and second, breaking the shell and frying the animal alive in butter. Either of these methods gave good results. By the former a delicious broth was the principal result; by the latter, a large piece of variant meat. The foot, however, by either method, becomes rather tough when cooked. As some one has held that the meat of Polynices is poisonous, not so very much was eaten; no ill effects, however, were felt from that consumed. The idea that Polynices is unfit for food is of course baseless, as I am informed by Professor Kincaid that thousands of Polynices shells may be found in the Indian kitchen-middies, which indicates that the Indians used this mollusk as food, and as the Polynices' shells are found in these remains in much greater proportion than any other shells, this gasteropod must have been widely sought by the Aborigines; or it may be that Polynices was formerly more abundant than any other mollusk on our western coast. At any rate, this gasteropod seems to have been a common diet of the Indians who lived along Puget Sound. The tastes of Indian and white man are not unlike in these matters, for white people eat various species of clams, also an Indian diet, and seem to delight in such food, as is well demonstrated by the establishment of shellfish canneries on our coasts.

It does not seem unreasonable, therefore, that Polynices as well will find a ready market. In fact, it might well be prepared as an extra delicacy and sold as such, and in that way made to make up partly for injuries that it inflicts on the bivalve-mollusks.

Barbier (1908) enumerates a large number of gasteropod mollusks used by the natives of Madagascar in various ways. Not only is the animal matter used as food, but the shells are commercialized as well. Having enumerated ten species of the genus Murex, and 139 species from different genera including Littorina, Nerita, Cypraea, Pterocera, Strombus, Neritina, Turbo, Conus, Terebra, Natica, Cassis, Harpa, Mitra, Voluta, Vasum, Oliva, Fasciolaria, Purpura, Rapana, Eburna, Nassa, Ranella, Triton, Fusus, Naptuna, Busycon, and Pyrula, all of which are marine forms, he adds the following terrestrial and freshwater gasteropods: Helix haemastoma L., Bulimus perversus L., Mulimulus multilineatus Say, Pupa uva L., Clausilia cana Gld., Auriculus auris Midae L., Tudora versicolor Pfr., and Helicina Miltochila Cross, and says:

Tous ces coquilla es servent a la nourriture des indigenes qui mangent leur chair cuite dans la coquille sur un feu ardent sans acun assaisonnement.

It is worth noting that genus Purpura which causes great destruction of the mussel beds on the English coast, and which was suggested by Lebour to be systematically collected and destroyed, serves the Indians of Madagascar as food. Murex, Natica, Nassa, Busycon, and others related to the gasteropod types on our coasts are being utilized as food by the natives

of Madagascar. Cycotypus canaliculatus, Verrill and Smith, 1873, (Busycon canaliculatus Say, or Fulgur canaliculata Gould, 1887, Dall, 1889), is a very pernicious enemy of oysters. According to Sumner, Osborn and Cole, 1908.

> It is abundant in shallower water generally . . . pretty generally distributed throught Buzzards Bay and Vineyard Sound. It preys upon mollusks and is said to be destructive to oysters (p. 707).

It is still of little commercial value save that of being used for dissecting purposes, and some Europeans, in New England, have ventured to use it as food, but this is by no means a common practice. The genus Urosalpinx is closely allied to Murex; several of its species are found on the east coast of the United States. Arnold (1916) says of Urosalpinx cinerea:

> This well-known species is regarded by Chesapeake and Long Island Sound oystermen much in the light of a plague. These active predaceous mollusks live upon bivalves, and preferably upon oysters. They bore a small hole through the shell of their helpless victims, and then proceed to extract the succulent, fleshy animal from within. The oystermen call them by the suggestive name of "drill," and wage incessant warfare upon them.

Daugherty claims: "It is a feeder upon oysters;" and Kellogg says in part:

> There are several species of the snails that are destructive to bivalves. Among these the large winkles or conchs of northern shores do very little damage; but some of the smaller forms, particularly the oyster drill, cause large losses here and there along the Atlantic coast . . . The drill, or Urosalpinx, is most destructive to young oysters. It seems to be unable to bore through the shell of large individuals . . . Like starfish, oyster drills were formerly not numerous on the New England oyster beds, but in recent years have increased greatly. In New York Bay, and in the Chesapeake, they are abundant . . . in Louisiana, a larger drill, Purpura floridana, is sometimes very destructive.

Opinions thus seem to vary as to the destructive habits of some of the gasteropods upon bivalve mollusks, but the findings of Dr. Copeland (1916) are very conclusive: Busycon reacts positively toward oyster juice, in fact, the oyster often forms a conspicuous part of its natural diet. All the investigators, however, seem to agree about the habits of Urosalpinx. In view of the fact that these gasteropods are esculent, injurious to other marketable mollusks, near large cities, and generally easily obtained, it seems rather strange that they are seldom found in the market. Polynices lewisii, which is still quite abundant in the upper part of Puget Sound, is generally destroyed by the oystermen whenever found in the vicinity of oyster fields. As a natural enemy, P. lewisii seems to have none more dangerous than the twenty-rayed starfish (Pycnopodia helianthoides). As a matter of fact, bays that have none or very few Pycnopodia may have a large number of Polynices, and bays that are well populated with this starfish have remarkably few Polynices present. When I later experimented on the sensitivity of Polynices to Pycnopodia (Agersborg, 1918) I found in all

instances, that when the slug came into contact with the star, it withdrew its foot at once. The monstrous foot, though it seemed impossible that it could be withdrawn within the shell, was very quickly covered thereby. Upon withdrawing the foot in a hurry, as it does when in contact with Pycnopodia, the periphery of the foot, which is perforated, throws a spray like a garden sprinkler with the holes in the spray-disk plugged except those around the periphery. No matter how much larger the animal is than its shell, when all the water is squeezed out of the foot, the former can be completely covered by the latter. In such a condition, however, Polynices cannot live very long. It is itself easily exhausted when completely shut up within its shell. If it is not allowed to take in fresh water supply when it comes out to breathe it soon relaxes, an easy prey to the gluttonous Pycnopodia. In fact, when leaving Polynices with Pycnopodia in an aquarium, two of the former were killed and eaten by the latter within three days, leaving the shells and opercula.

The absence of Polynices where Pycnopodia abounds, together with the facts observed when keeping the two in the same aquarium, seems to indicate definitely that Pycnopodia preys on Polynices. As mentioned above, Polynices is a nuisance to oyster growers, even if it does not feed on oysters, for it destroys the oyster beds by burrowing in them; primarily Pyncopodia is a gasteropod feeder, and though it is quite omnivorous and may feed on anything it happens to encounter, it is not known whether it feeds on oysters. The question then is: might not Pycnopodia be used as a check against Polynices in the oyster beds? This could easily be tested out experimentally; Pycnopodia could be placed on oyster beds to see whether it remains there or crawls away. If the latter was found to be the case then Pycnopodia is not adapted to feed on oysters and might then be kept on the outside of the oyster beds as a guard against the inroad of Polynices.