

AN ABSTRACT OF THE THESIS OF

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Title: TAXONOMY AND SOME ASPECTS OF THE BIOLOGY OF  
THE SEA PEN PTILOSARCUS GURNEYI (CNIDARIA,  
PENNATULACEA)

Abstract approved: Redacted for Privacy  
John E. Morris

At present there is much confusion regarding the correct genus and species name for the shallow water, West coast sea pen. Originally described in 1860 as Sarcoptilus (Ptilosarcus) gurneyi Gray, this sea pen has subsequently been placed in three different genera, one of which has had three spelling variations, and in three different species groups under three spelling variations. Not only is there extensive synonymy, but also homonymy exists between the generic names of a sea pen and a moth.

The purpose of this investigation was to determine the valid taxonomic name and to supply more information about the sea pen with respect to its anatomy and biology.

Sea pens were collected from Puget Sound, Washington, and from Monterey Bay, California. Their internal and external morphologies were compared; no detectable differences were found between the

two populations, except in coloration. Coloration was not considered to be a stable enough character upon which to base species differences.

The taxonomic history of the West coast sea pen was presented and reasons given for the subordination of the genus Leioptilus to the genus Ptilosarcus. Ptilosarcus gurneyi was recommended as the proper and valid binomen for the shallow water sea pen with all other names being subordinated.

Taxonomy and Some Aspects of the Biology of the  
Sea Pen Ptilosarcus gurneyi (Cnidaria, Pennatulacea)

by

Robert Edward Batie

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TAXONOMY AND SOME ASPECTS OF THE BIOLOGY OF THE  
SEA PEN PTILOSARCUS GURNEYI (CNIDARIA, PENNATULACEA)

INTRODUCTION

The shallow water sea pen from the West coast of North America has been described by several authors (Gray, 1860; Gabb, 1862; Moroff, 1902; Flora, 1966). Variations in color, among other features, have led to the assignment of different generic and specific names without clear evidence that different taxa were actually being described. The purpose of this investigation was to make a detailed examination of specimens from several northeastern Pacific Ocean sea pen populations in order to determine the validity of existing taxonomic designations. This examination included measurements and descriptions of several anatomical characteristics to determine population and species differences.

Distribution

Sea pens are found in shall waters from Prince William Sound, Alaska to La Jolla, California, usually in a muddy or sand substrate (Verrill, 1922; Deichmann, 1936). In Prince William Sound, the sea pens are found "a little below a very low tide" (Verrill, 1922, p. 11). In Puget Sound, Washington, I have found the sea pens at about three meters below mean lower low water. On the outer coast, they have been reported from 27 meters off Cape Flattery, Washington (Gabb, 1862) and from 13 meters off Monterey, California

(Dr. Donald Abbott, personal communication).

The upper limit of the range of the sea pens thus seems to be the shallow subtidal area. The actual limiting factors of the animals' upper range are probably physical in nature (Connell, 1961). The most important of these factors in the subtidal community is probably physical abrasion due to bottom turbulence caused by large winter waves. This is suggested by the few shallow specimens obtained or observed in the unprotected, outer coast area where winter waves reach to depths of 30 meters. In the quiet, protected waters of Puget Sound, however, there is no deep wave action, and the animals can be found a few meters below lower low water.

The lower limit of their range may be more influenced by biological factors than by physical factors. Near the lower limit of their range there are several major predators which are not as abundant higher up within their range. These predators include three nudibranchs: Tritonia festiva, Armina californica, and Hermisenda crassicornis; and four sea stars: Mediaster aequalis, Crossaster papposus, Hippasteria spinosa, and Dermasterias imbricata (Birkeland, 1968; Mauzey, et. al., 1968).

In Puget Sound, the sea pens form a nearly continuous population from Olympia, southern Puget Sound, to Everett, northern Puget Sound, with the densest population being from 10 to 25 meters deep (Birkeland, 1968). However, Shapeero (personal communication) has

dredged them from 70 meters.

Seasonal sampling by the Oregon State University Department of Oceanography over the past six years has yielded only four specimens, two from 50 meters and two from 86 meters. The range of depth of the bottom trawls varied from 50 meters to over 3,000 meters (Dr. Andrew Carey, personal communication). Off the central California coast, the sea pens have been reported from 66 meters to 134 meters (Nutting, 1909) and are apparently found only rarely above 40 meters (personal observation). Thus they seem to be limited to a narrow band from about three meters to 135 meters in depth from Alaska to southern California.

### Taxonomy

#### Sea pen nomenclature

The following is a list of taxonomic names all of which at one time or another have been used to describe what is apparently a single species. A history of these nomenclatural changes is presented immediately following the list.

#### Sarcoptilus Gray, 1848

Sarcoptilus (Ptilosarcus) gurneyi Gray, 1860

#### Ptilosarcus Verrill, 1865

P. gurneyi (Gray, 1860)

P. quadrangularis Moroff, 1902

P. quadrangulare Flora, 1966

P. guerneyi Deichmann, 1941

P. verrilli Boone, 1933

Leioptilus Gray, 1860

L. guerneyi Flora, 1966

L. quadrangulare Flora, 1966

Leioptilum Verrill, 1865

L. quadrangulare Kükenthal, 1913

Leioptillum Verrill, 1868

Lioptilum Kölliker, 1872

Pennatula Linnaeus, 1758

P. tenua Gabb, 1862

P. tenuis Gray, 1870

Gray (1848) described the genus Sarcoptilus which he later (1860) divided into two subgenera, Sarcoptilus and Ptilosarcus. He named two new species, Sarcoptilus (Ptilosarcus) sinuosus from New Guinea and Sarcoptilus (Ptilosarcus) gurneyi from Monterey Bay, California. He also (1860) named a new genus from Japan, Leioptilus. This animal was previously called Pennatula fimbriata Herklots, 1858, but was removed from Pennatula by Gray and the new genus established with Leioptilus fimbriata (Herklots, 1858) as the type species.

Subsequent spelling variations of Leioptilum (Verrill, 1865), Leioptillum (Verrill, 1868), and Lioptilum (Kölliker, 1872) were applied to this genus, but the first spelling of Leioptilus by Gray (1860) is the correct spelling of this genus (International Code of Zoological Nomenclature, 1964, art. 23).

In 1865 A. E. Verrill described a new species of sea pen he called Leioptilum undulatum, giving Gray credit for the generic name

but using the neuter ending. Verrill stated that the subgenera Ptilosarcus and Sarcoptilus were actually separate genera and listed the Monterey Bay specimen as Ptilosarcus gurneyi.

Gray (1870) listed Gabb's (1862) Pennatula tenuis (sic) as a synonym of Ptilosarcus gurneyi. The situation was further confused when Moroff (1902) described Ptilosarcus quadrangularis from Monterey Bay, California. He also suggested that Ptilosarcus and Leioptilum are not distinct enough to be separate genera. Later, Kükenthal (1913) suggested that the name Leioptilum quadrangulare be used for the California species and indicated that the name Ptilosarcus should be subordinated to the name Leioptilum. Conversely, Deichmann (1936) stated that Leioptilus is equivalent to Ptilosarcus but Ptilosarcus is preferred.

More currently, Flora (1966) listed, without discussion, the animal as Leioptilus gurneyi = Leioptilus quadrangulare = Ptilosarcus quadrangulare = Ptilosarcus quadrangularis.

A question of priority, however, exists concerning the generic name Leioptilus. This name was published simultaneously by Gray (1860) for the sea pen and by Wallengren (1860) for a European plume moth (Lepidoptera, Pterophoridae) as cited by Neave (1939). However, Wallengren's article was actually published in October of 1859; Gray's article was not published until 1860. This gives Wallengren's genus Leioptilus priority and, therefore, the name cannot be applied to the sea pen.

Since later authors (Kölliker, 1872; Moroff, 1902; Kükenthal, 1911; Kükenthal and Broch, 1913; Kükenthal, 1915; Hickson, 1916) felt that the sea pen names Leioptilus and Ptilosarcus are synonyms, it is apparent that Ptilosarcus is the earliest valid generic name for the sea pen.

#### Moth Nomenclature

Zeller (1867) changed the spelling of Wallengren's genus of moth from Leioptilus to Lioptilus. However, Neave (1939) has indicated that the genus Lioptilus was already occupied by 1867, having been used by Cabanis in 1850 to describe a genus of bird. Thus Cabanis' (1850) Lioptilus is a senior homonym of Zeller's (1867) Lioptilus, which is therefore invalid. As a consequence, Lioptilus cannot be applied to the moth genus, emphasizing that Leioptilus is the correct spelling for the moth genus.

Forbes (1923), Essig (1926), Leonard (1928), and McDunnough (1939) all concurred in transferring the species of Leioptilus into the genus Oidaematophorus Wallengren, 1860, thus freeing Leioptilus for use as a generic name.

The type species for the sea pen Leioptilus was originally called Pennatula fimbriata Herklots, 1858, but was renamed Leioptilus fimbriata by Gray (1860) (= L. fimbriatus Gray [1870]). However, Pennatula fimbriata was later restored as the correct name by

Deichmann in 1936, thus abolishing the sea pen genus Leioptilus. By 1939 the use of Leioptilus as a genus of moth had been abandoned, making this name available for occupancy. If the sea pen genera Ptilosarcus Verrill, 1865, and Leioptilus Gray, 1860 are synonyms, Ptilosarcus must be used as the correct generic name up to 1939 because of prior occupancy of Leioptilus by the moth. Although the name Leioptilus was available after 1939, Ptilosarcus Verrill, 1865 must still be used since Ptilosarcus was described prior to the date at which Leioptilus became available for occupancy.

This research demonstrated that all the West coast sea pens previously included in Ptilosarcus and Leioptilus are members of the same genus and that the correct name for the shallow water West coast sea pen is Ptilosarcus gurneyi (Gray, 1860).

## METHODS AND MATERIALS

### Collection of Animals

The sea pens collected from Puget Sound were obtained from two stations: Golden Gardens and Dash Point (Figures 1-a, 1-b).

A preliminary collection of the animals, obtained with the aid of S. C. U. B. A. , from Golden Gardens Beach in Seattle, Washington in about eight meters of water was made in June of 1966. A stake with an attached rope was randomly placed in the bed of sea pens and a circle of 4.7 meters in diameter was scribed out on the bottom. All of the sea pens inside the circle were removed and preserved.

The second collection site was near Tacoma, Washington, at Dash Point City Park, Dash Point, Washington. The animals were collected on July 4, 1970, one half of a meter on either side of a line extending from 18.5 meters to 25 meters in depth along the vertical fall line.

The substrate at each of the Puget Sound sites was a fine muddy-sand.

Three specimens were obtained from the Hopkins Marine Station at Monterey, California on August 1, 1970 (Figures 1-a, 1-c, 2). These specimens were collected in 14.5 meters of water directly off the laboratories. Later searching of the vast sand beds off shore from the labs to a depth of 42 meters yielded no sightings of any sea pens.

Figure 1-a. The coast of western North America from Puget Sound to Monterey Bay, California.

Figure 1-b. Collection sites in Puget Sound, Washington:

1. Golden Gardens Beach, Seattle, Washington
2. Dash Point, Washington (near Tacoma, Washington).

Figure 1-c. Monterey Bay, California (see figure 2).

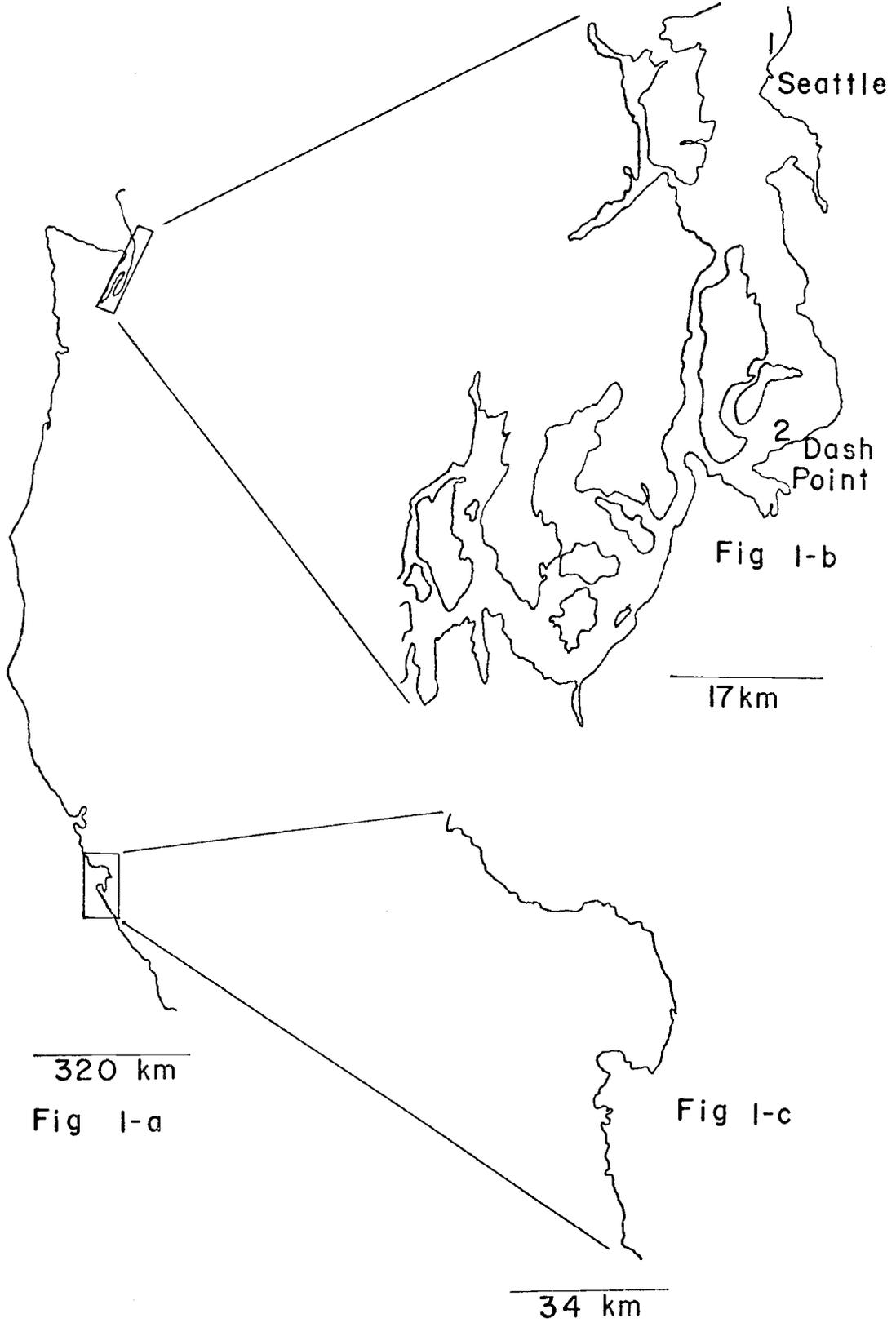


Figure 2. Collection sites in Monterey Bay, California:

1. Del Monte Beach
2. Cannery Row
3. Hopkins Marine Laboratories
4. Lover's Point

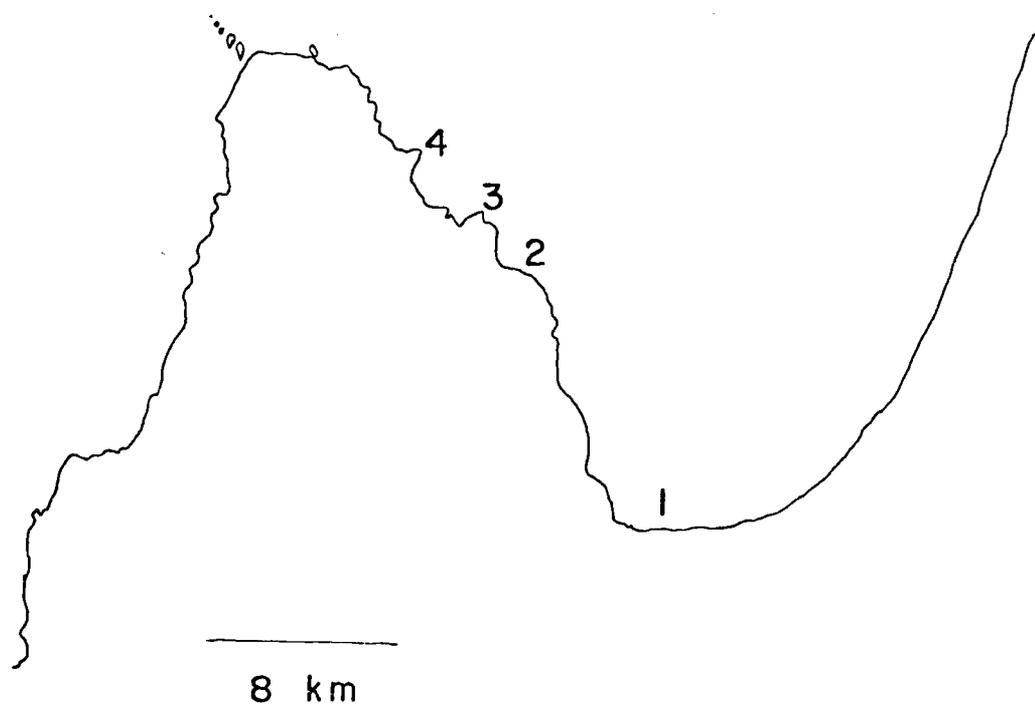


Fig 2

Several reconnaissance dives off of Del Monte Beach, Cannery Row, the marine labs, and Lover's Point (Figure 2) failed to locate any additional animals.

### Measurements

Sea pens are capable of a great degree of expansion and contraction. A fully expanded colony may measure 60-75 cm and upon contraction measure only 15-20 cm. Because of this ability to undergo great extensions of length, meaningful measurements of length must be taken on either fully contracted or fully expanded animals. Measurements on fully contracted animals were chosen for several reasons: (i) most of the animals contracted upon handling during collection, (ii) the animals are more easily handled in the contracted state, and (iii) the state of "complete contraction" is more easily standardized than the state of "complete expansion". One cannot tell when expansion is complete because water is present in all parts of the leaves, rachis, and peduncle in animals that are either semi-expanded or totally expanded. Since the animals also undergo slow rhythmic contractions, measurements at any one time may lead to large errors. However, in completely contracted animals, all of the water has been forced out of the mesenteric channels, leaves and tissue; the peduncle then takes on the hard consistency of dense tissue. Since complete contraction was induced in living sea pens by handling or by exposure

to preservatives, all measurements were made on alcohol-formalin-acetic acid (A. F. A.) preserved specimens to increase standardization and to facilitate comparison with museum specimens.

Measurements of total length were made from the tip of the rachis down the dorsal<sup>1</sup> surface between the two siphonozoid bands to the junction of the peduncle and the rachis as marked by the area where the leaf buds appear. The peduncle length was taken as the length from the rachis-peduncle junction to the lower tip of the peduncle. The length of the internal supporting rod was measured as the length from the curved portion in the tip of the rachis to the curved portion in the tip of the peduncle.

The total dry weight of each colony was determined by placing the alcohol-formalin-acetic acid preserved sea pens in an enameled pan in a drying oven at 85°C until a constant weight was obtained.

The plate number was determined by counting those only on the right side of the colony. Rows of autozooids at the rachis-peduncle junction were considered to be plates even if the underlying plate was not yet formed. Such leaf plates where the autozooids are in direct contact with the main colony axis are called pre-plate buds.

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<sup>1</sup>The term dorsal is used here to help clarify the adult position of the siphonozoids relative to the leaf plates. The terms dorsal and ventral are actually not applicable to a bi-radial animal; however, the use of these terms will be employed throughout this discussion, as they are in the literature, to avoid the introduction of new and confusing terminology.

### Preparation for Microscopy

Slides of the autozooids, siphonozooids, and leaves were made in order to compare internal structures between the Puget Sound and the Monterey Bay sea pens.

The appropriate structures from A.F.A. fixed specimens were dissected out, run through an alcohol-toluene dehydration procedure, and embedded in blocks of Paraplast.<sup>2</sup> Sections of the specimens were then made at a 12 $\mu$  thickness and attached to slides with Haupt's gelatin. After two days of drying, the Paraplast was dissolved away and the sections were stained with Harris's hematoxylin stain and counter stained with alcoholic eosin.

### Spicule Analysis

Various tests were performed on the autozoid spicules to determine if they were organic or inorganic.

### Calcium carbonate

Spicules were immersed in 2 to 10% HCl; evolution of bubbles was taken as a positive test for the presence of carbonate.

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<sup>2</sup>Paraplast is a registered trade name for a compound of paraffin and plastic polymers of regulated molecular weight which is used as an embedding medium. It is manufactured by Sherwood Medical Industries Inc., St. Louis, Missouri.

### Protein

The spicules were subjected to an organic digest in an alkaline solution of pancreatin (50 mg/ml) at 37°C for 24 hours. Loss of dense material, as determined by microscopic examination, was taken as evidence for readily hydrolyzable proteins.

### Chitin

The spicules were tested for the presence of chitin as described by Campbell (cited by Richards, 1951). The chitin was converted to chitosan in KOH heated in a glycerine bath to 130°C for 45 minutes. The treated spicules were then divided into two 1/4 ml samples. To the first sample, 3% acetic acid was added followed by one drop of 1% H<sub>2</sub>SO<sub>4</sub>, chitosan being soluble in 3% acetic acid and giving a white precipitate in 1% or less H<sub>2</sub>SO<sub>4</sub>. To the second sample of spicules, 2% I<sub>2</sub> in KI was added and the color reaction noted, a brown color indicating the presence of chitosan. The excess KI solution was then removed and replaced with 1% H<sub>2</sub>SO<sub>4</sub> and the color again noted. A red to violet color indicates the presence of chitosan. Seventy-five percent H<sub>2</sub>SO<sub>4</sub> was then added to the spicules for the final test, chitosan being soluble in 75% but not in 1% H<sub>2</sub>SO<sub>4</sub>.

### Pigment Analysis

The colored pigments from the Puget Sound and the Monterey Bay sea pens were isolated following the extraction procedure of Machlis and Torrey (1956). Several grams of peduncle tissue were ground with a mortar and pestle and then stirred with 40 ml of 80% acetone. After the pigments were leached into the acetone solution, the resulting solution was filtered twice on a Buchner funnel and the residue discarded. The pigments were extracted from the acetone-pigment solution by adding 50 ml of petroleum ether, mixing, and then adding 70 ml of distilled water. The water acetone layer was then discarded and the pigment-ether solution was washed three times, each with 50 ml of distilled water, to remove any trace of acetone. Fifty ml of 92% methyl alcohol were then added to the pigment-ether solution and gently stirred. Chlorophyll-a, if present, and any carotenes would be in the petroleum ether layer, and chlorophyll-b and any xanthophylls would be in the methyl alcohol layer.

The two separate solutions were then each subjected to spectrophotometric analysis on a Coleman Model 6/20 Junior II Spectrophotometer, at 25 m $\mu$  intervals from 325 m $\mu$  to 825 m $\mu$ .

## RESULTS

Physical Measurements

Several variables were analyzed with respect to the dependent variable of total dry weight of the colony (TDW). The independent variables were plate number (P), style length (SL), dry weight of the style (SW), and total length of the colony (CL).

It was hoped that two large samples of animals could be obtained, one from Puget Sound and one from Monterey Bay, and their physical affinities statistically compared. However, a statistically sufficient number of animals was collected from only the Puget Sound area. Therefore, it was not possible to compare their measurements with the Monterey Bay population for taxonomic purposes, but a predictive equation was formulated for future use in estimating the biomass of sea pens in a given population.

The independent variables raised to their first, second, and third powers were compared with the dependent variable using a step-wise least squares multiple regression. The variable of best fit, based on an high F level (6940) and an high  $R^2$  (0.968), was style length squared ( $X^2$ ) when regressed with total dry weight of the colony (Y) (Figure 3). The resulting equation was:

Figure 3. Graph showing relationship between total colony weight and style length.

Abscissa: style length squared in centimeters

Ordinate: total colony dry weight in milligrams

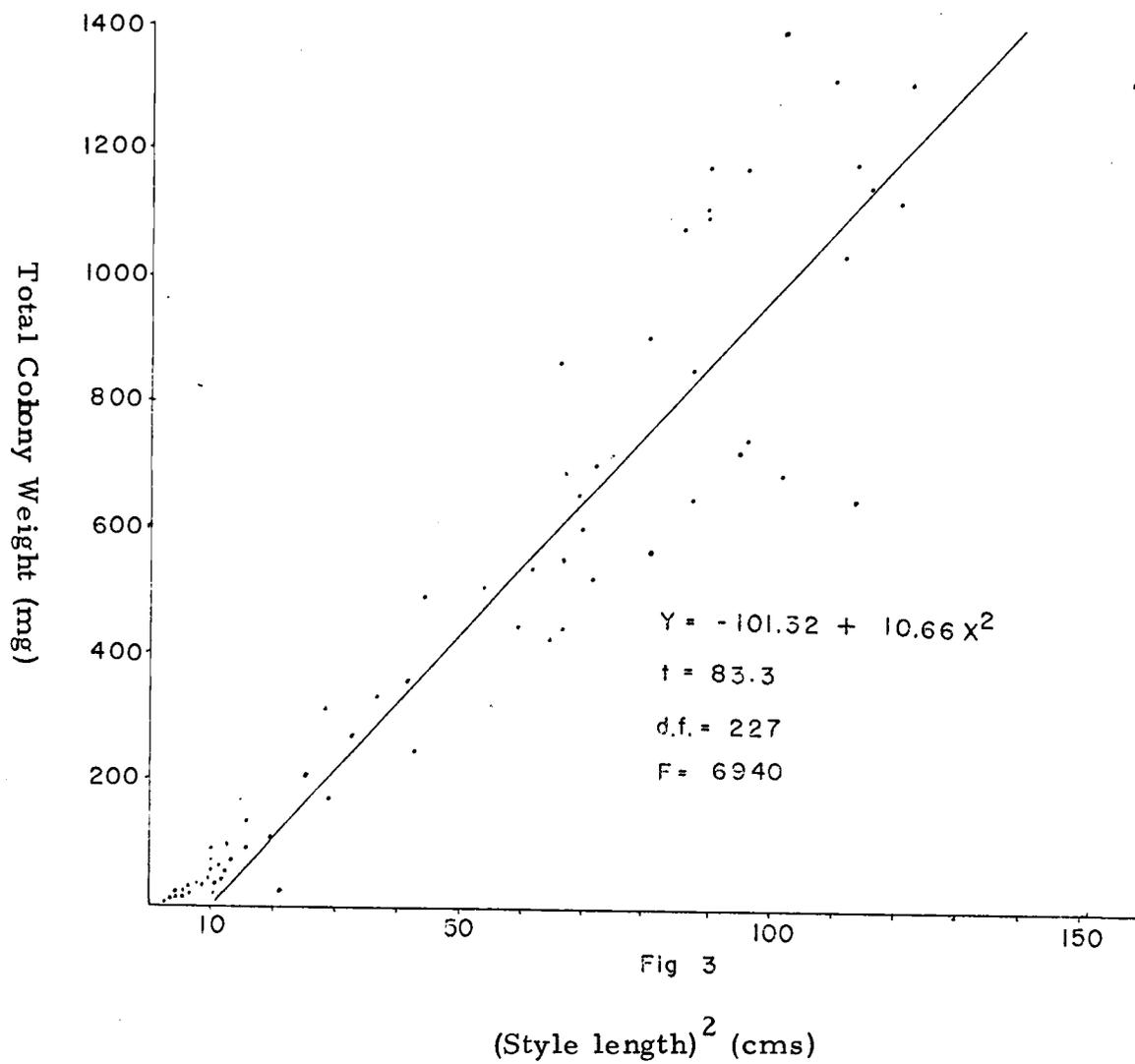


Fig 3

$$Y = -101.32 + 10.66 X^{2**} + e$$

(t=83.3)

\*\* Significantly different from zero at the 1% test level.

Thus from directly measuring the style length, and squaring it, one can estimate the total dry weight of the colony. This is an extremely useful and relatively easy measurement of biomass since the style length does not depend on the state of contraction of the animal, but remains rigid and fixed in length.

The estimation of biomass of a species per unit area in the benthic community is valuable in helping to determine the stability of the standing stock of that species. Sea pens, for instance, are very abundant in Puget Sound, supporting several major predators without apparently suffering heavy standing stock reduction. Hence, from knowing the interaction between predator and prey species, and from having the means to estimate standing stock by a biomass determination, one can observe the relative stability of the community and more clearly evaluate the potential impact of additional pressures at the community and eco-system levels.

### Anatomy

The primary polyp is composed of the peduncle and the rachis (Figure 4). At the peduncle-rachis junction, the leaf plates bearing the autozooids are budded off. Along the dorsal surface of the rachis,

Figure 4. Figure showing external anatomical features of the sea pen colony Ptilosarcus gurneyi.

- a. Rachis
- b. peduncle
- c. leaf plates with autozooids
- d. dorsal bands of siphonozooids

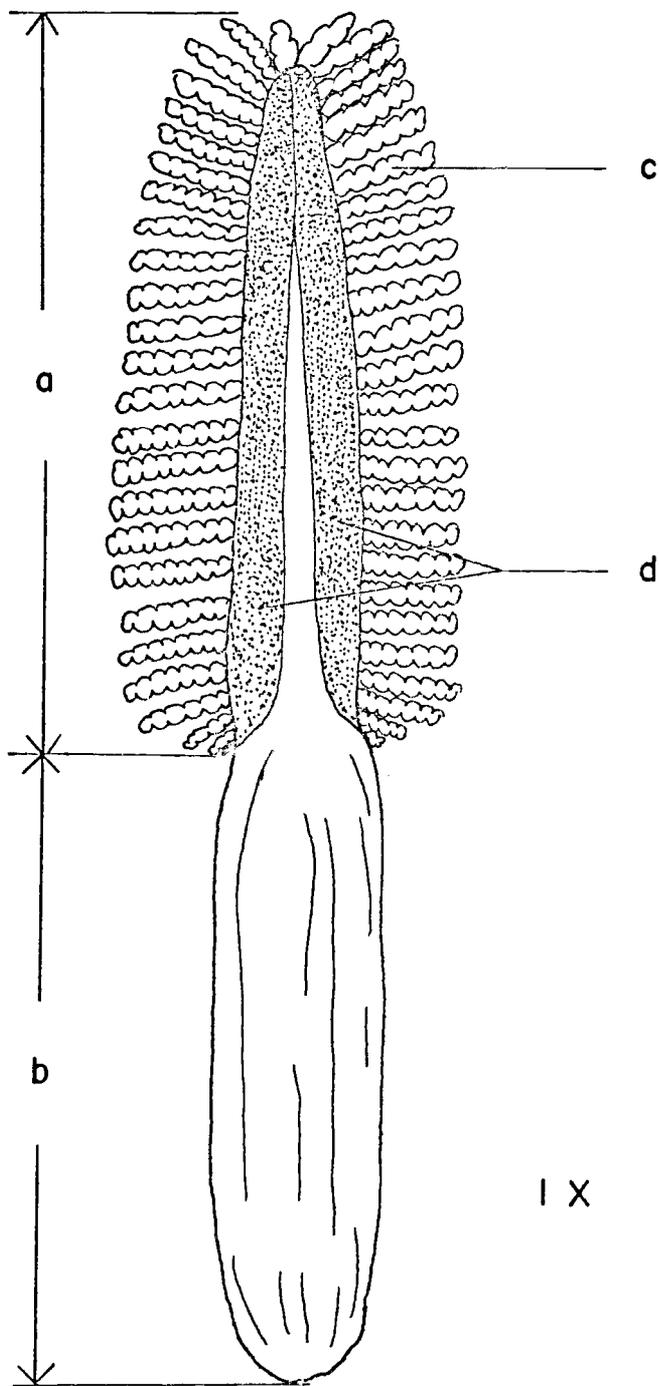


Fig 4

two longitudinal rows of individuals lacking tentacles, the siphonozoids, are also budded off. Thus, the autozooids and the siphonozoids are secondarily derived from the primary polyp.

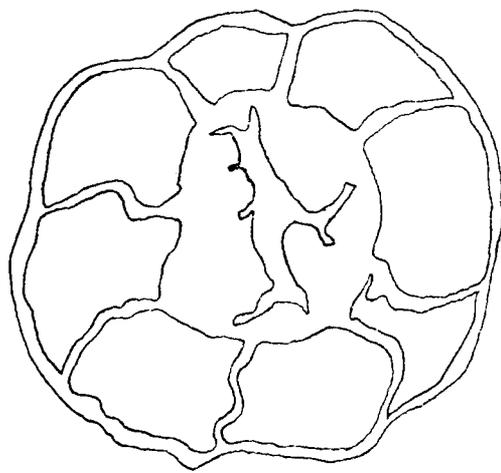
Each autozoid is capable of retracting into the calyx. The calyx is composed of two teeth, which have taxonomic value, or projecting spines composed of numerous large tri-flanged spicules. The spicules are embedded deeply into the calyx and lie very close to the polyp wall, but are not a part of it.

The autozooids have eight fimbriated, hollow tentacles which are characteristic of the order Pennatulacea. The outer edge of the tentacle has up to twenty fimbriations, each being hollow and continuous with the cavity of the tentacle proper. The hollow portion of the tentacle is in direct communication with the mesentery channels, formed by the eight mesenteries in the body of the autozoid (Figures 5 and 6). The mesenteries continue down into the polyp and connect the esophageal wall with the polyp wall. The mesenteries disappear towards the base of the polyp; the esophageal wall and polyp wall thus merge. Hence, the hollow tentacular and mesenterial channels are not continuous with the esophageal opening.

The esophageal opening, at the center of the tentacular ring, continues down to the base of the polyp and is continuous with the channels in the leaf plates. These leaf plate channels are rectangular in shape, the long axis being across the leaf plate. Thus, each

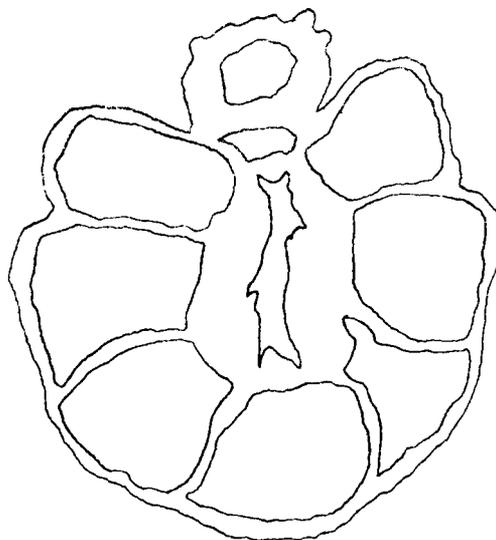
Figure 5-a. Cross section through isolated autozoid showing eight mesenteries, eight mesenterial channels, and esophageal opening.

Figure 5-b. Cross section higher up on autozoid showing hollow tentacle emerging from mesenterial channel.



150 u

Fig 5-a



150 u

Fig 5-b

Figure 6. Cross section through tentacles of autozoid showing eight hollow tentacles, tentacular channel running length of tentacle, and fimbriated edge of tentacle.

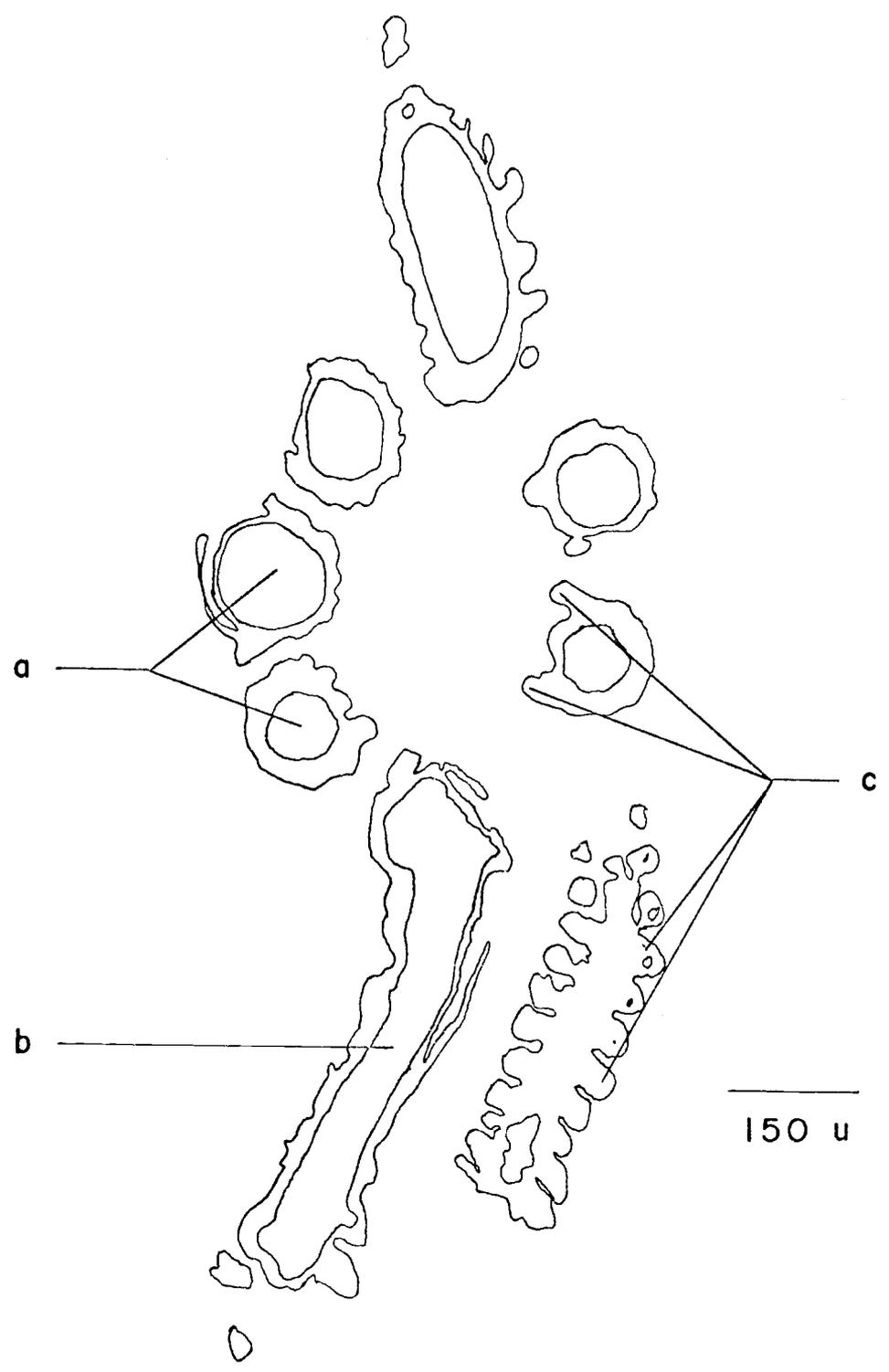


Fig 6

autozoid communicates with one leaf plate channel through the esophageal opening. Each leaf plate channel then merges into the spongy layer of the rachis wall and eventually communicates with the ventral canal in the inner canal system.

The siphonozooids (Figure 4) are found in two bands along the dorsal tract of the rachis; they have no tentacles, no protective calyces, and are not retractable. The siphonoglyph, however, is heavily ciliated, indicating this may be the primary site of water movement into the colony (Hyman, 1940). The enteric tract of the siphonozooids communicates directly with the spongy layer of the rachis and then through the various channels into the dorsal canal.

The peduncle wall is highly porous, allowing for great distention. Two series of channels make up the spongy layer of the peduncle wall. The outer layer of channels runs longitudinally or parallel with the peduncle. Just medial to this spongy layer is a second porous layer which, being circular, surrounds the inner mesenteries and the style.

The style, centrally located in the primary polyp, runs the length of the peduncle and into the rachis, depending on the state of contraction of the colony. In fully expanded colonies, it may barely extend into the rachis area and not reach to the bottom of the peduncle. In fully contracted specimens, it may reach the entire length of the colony. The style is circular in the rachis region, hooks over at its tip, rapidly becomes slender, and merges imperceptibly with the

mesenteries. In the peduncle region, the style is round and thickens to an area about one-half the way down the style length. Here the circular rod becomes quadrangular in shape. The base of the style hooks over, becoming much smaller and circular again, and merges with the mesenteries.

The style lies in a sheath of mesenteries for its whole length. Four mesentery sheets come off of the inner peduncle wall next to the spongy circular layer that encloses the style. The four sheets divide the central cavity of the primary polyp into five canals: a ventral canal, two lateral canals, a dorsal canal, and the small blind ended canal into which the style fits.

In the peduncle, four flat bands of muscles run obliquely from the inner wall to the quadrangular portion of the style (Figure 7). Each muscle attaches to one of the flat sides of the style and runs along one of the four mesenterial septa which makes the four channels around the style. In the bulb of the peduncle, however, there is a circular flap of tissue which divides the space between the two lower muscles into two spaces or channels. The original channel between the muscles continues down and forms a blind pouch, into which the style rests. The second channel diverts over the mesenterial flap towards the peduncle wall and its continuous with the space in the peduncle bulb. Thus, the peduncle bulb is in direct communication with the ventral canal.

Figure 7. Dissection of Ptilosarcus gurneyi. Incision down dorsal tract of peduncle showing muscles from peduncle wall attaching to flattened portion of style. Tip of style is seen in blind ended pouch of mesentery tissue. Note quadrangular portion of removed style.

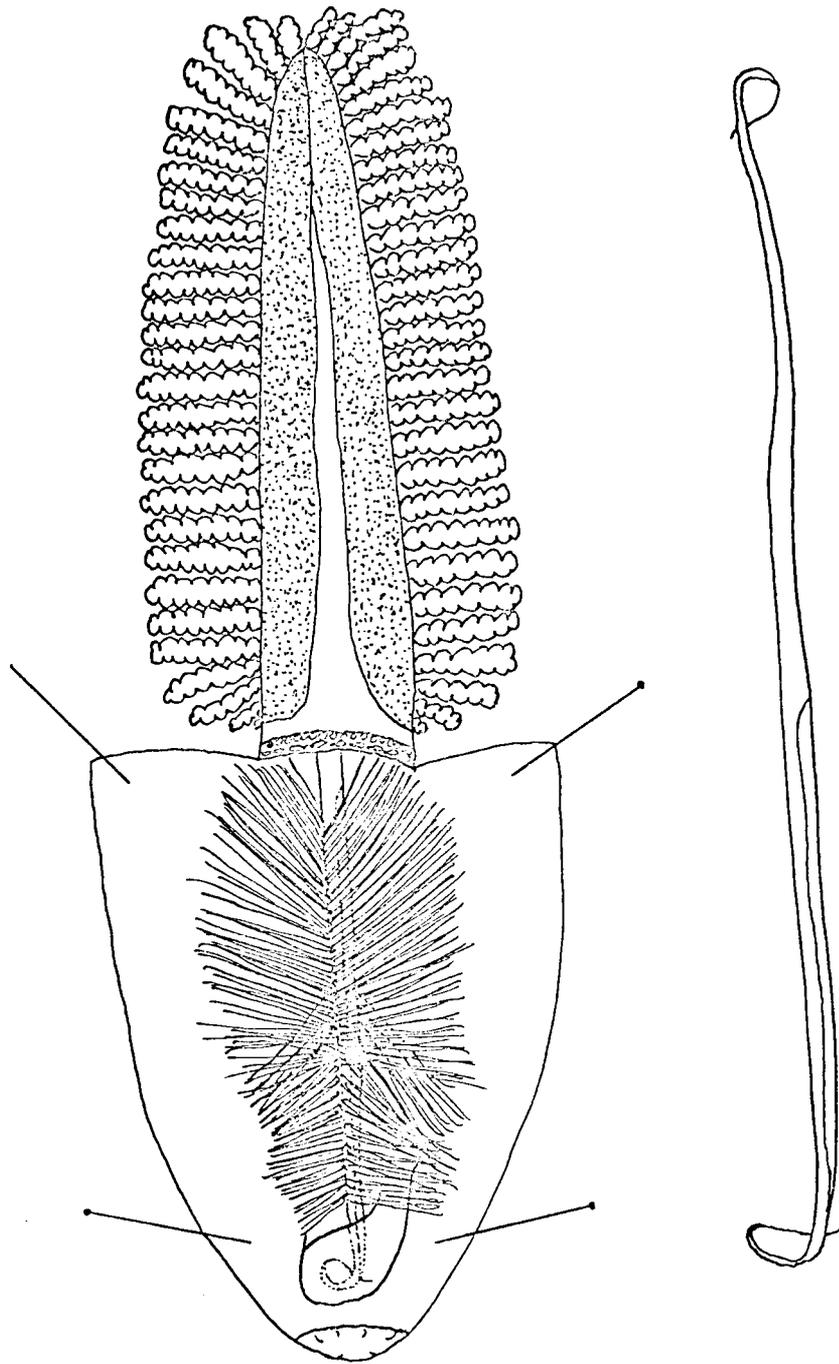


Fig 7

The canals vary in size at different locations along the colony. The right and left axial canals are usually quite small; the dorsal canal, however, is quite large near the tip of the rachis while the ventral canal is largest near the peduncle tip.

Comparisons were made of the siphonozooids, autozooids, and also of the style with its internal mesentery and muscle attachments. No differences of the internal anatomy were found between the Puget Sound and the Monterey Bay sea pens.

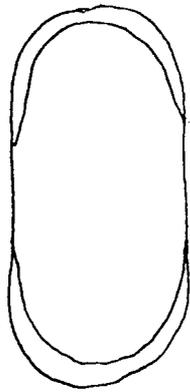
#### Spicule Composition

The spicules of the sea pen were of two shapes: tri-flanged, elongated spicules from 500 $\mu$  to 600 $\mu$  which lie among the autozooids and the siphonozooids (Figure 8-a) and shorter, 70 $\mu$  to 80 $\mu$ , rice grain shaped spicules in the peduncle wall region (Figure 8-b). The spicules seem to harbor some of the colored pigments of the colony as the orange colonies have orange spicules and the reddish colonies have reddish spicules. The spicules have been reported as being lime, or calcium carbonate (Kölliker, 1872; Moroff, 1902; Kükenthal and Broch, 1911), or as containing chitin (Shapeero, 1969). Several tests were performed on isolated masses of spicules (Table 1) and it was found that although the spicules gave a conclusive test for carbonate, they did not for chitin. It appeared that the spicules were composed of two compounds: an inner core of calcium carbonate and an outer capsule

Figure 8-a. Isolated tri-flanged spicule from autozoid region.

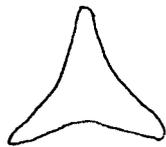
Figure 8-b. Same spicule as figure 8-a but in cross section.

Figure 8-c. Isolated spicule from the peduncle region. The spicule is flattened and appears to have an outer shell and an inner core of calcium carbonate.



$\overline{20u}$

Fig 8 - c



$\overline{20u}$

Fig 8 - b

$\overline{20u}$

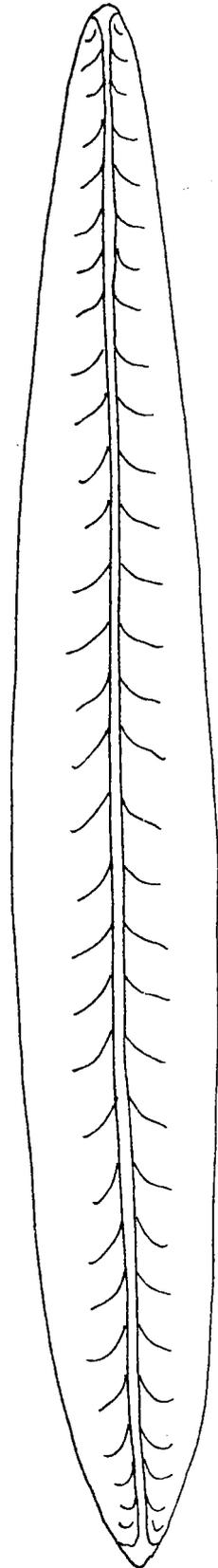


Fig 8 - a

Table 1. Results of various tests on spicules from autozooid and peduncle region from Ptilosarcus gurneyi.

	Autozooid spicules			Peduncle spicules			Control (beetle elytrum)			Control (human skin)
	Group 1	2	3	1	2	3	1	2	3	1
2-10 % HCL	Bubbles but "shell" remains			Bubbles but "shell" remains			-			
Hot KOH		-			-			-		
2% I <sub>2</sub> in KI		N. R.			N. R.			turned brown		turned brown *
1% H <sub>2</sub> SO <sub>4</sub>		slowly into solution			slowly into solution			N. R.		
3 % Acetic acid			became twisted, slowly into soln.			slowly into solution			slowly into solution	
1 drop 1% H <sub>2</sub> SO <sub>4</sub>			N. R.			N. R.			white precipitate	
75% H <sub>2</sub> SO <sub>4</sub>			into soln.			into soln.				

\* Positive colorimetric test for chitosan.

of some other material which did not yield a definitive test for chitin. Therefore, Shapeero's (1969) claim of chitin in the spicules of this species was not confirmed. It is of interest to note that the above test is not specific for chitin, also being positive for certain other carbohydrates and proteins (Strickland and Parsons, 1965). Controls of beetle elytra and human skin gave positive colorimetric results with the chitosan test.

### Coloration

Coloration has been used as a taxonomic characteristic of sea pens (Gray, 1860; Moroff, 1902). It was considered important, therefore, to demonstrate whether the pigment was stable and whether the pigment occurred in the sea pens or their natural food.

All of the Puget Sound sea pens collected or observed appeared orange in color. The orange pigment was removed by a petroleum ether extraction procedure (Machlis and Torrey, 1956) and found to have a single absorption peak at  $465\text{m}\mu$  in a petroleum ether solution (Figure 9). The Monterey Bay sea pens were one of two colors: orange or brick red. An analysis of the pigments of the red sea pen, extracted in the same manner as were the pigments of the Puget Sound sea pens, yielded two peaks with absorption maxima at  $465\text{m}\mu$  and  $490\text{m}\mu$  (Figure 10). Since the red sea pen had some orange coloring in it, the orange pigments of the Puget Sound and Monterey sea pens

Figure 9. Absorption spectrum of petroleum-ether extracted pigment from orange colony from Puget Sound population. Abscissa:  $m\mu$ , ordinate: Absorbancy.

Figure 10. Absorption spectrum of petroleum-ether extracted pigment from red colony from Monterey Bay population. Abscissa:  $m\mu$ , ordinate: % transmission.

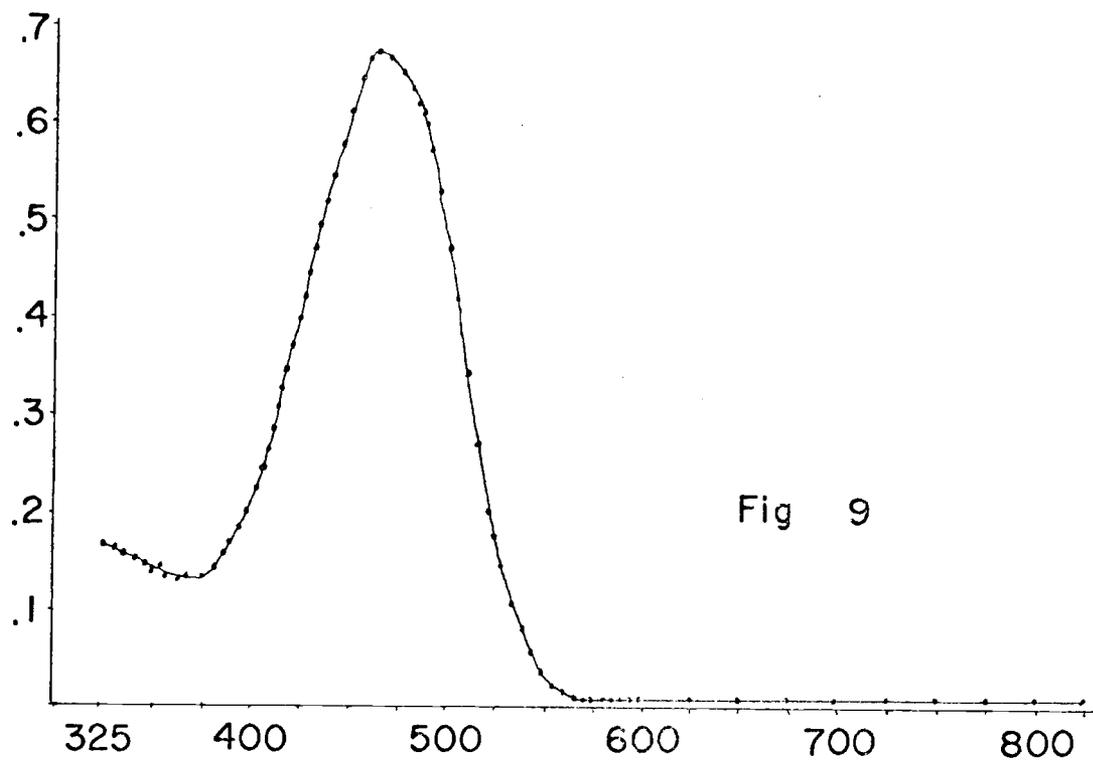


Fig 9

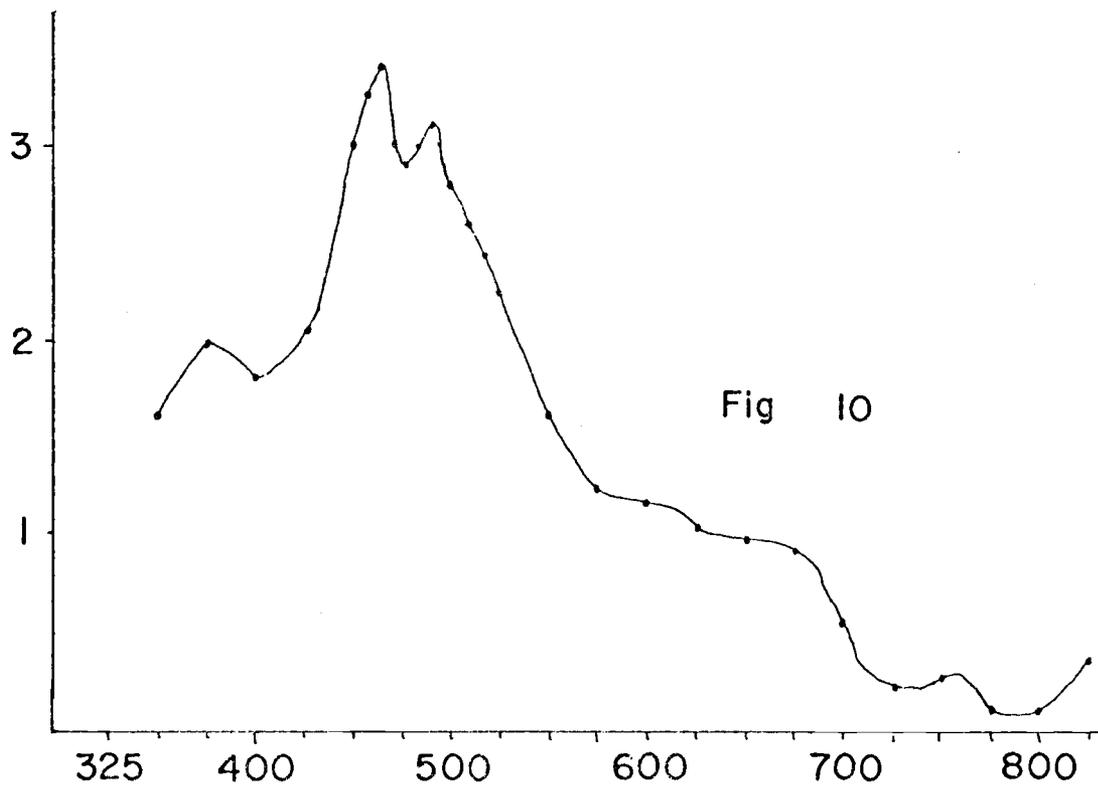


Fig 10

were probably identical. The absorption maximum at 490m $\mu$  was totally lacking in both the solid orange Puget Sound sea pens and in the solid orange Monterey Bay animals. Thus, the red coloration of the Monterey Bay sea pen was due to the pigment with the absorption maximum at 490m $\mu$ . Although the pigments were not further analyzed, it is of interest to note that the red pigment has an absorption spectrum which resembles  $\gamma$ - carotene (Strain, 1951), a pigment found in diatoms. Since this sea pen feeds as a mucoid suspension feeder, it is not unreasonable to assume that it could ingest a  $\gamma$ - carotene rich food source. The incorporation of the ingested carotenes into cellular pigments within the sea pen, however, has not been demonstrated.

#### Commensalism

Reports of commensalism between sea pens and other animals are infrequent in the literature. A gymnoblastic hydroid has been reported on the autozooids of a sea pen from the Malayan sea, a barnacle on the stalk of Virgularia, an ophiuroid on a sea pen, and a polychaete worm on a Malayan and Japanese sea pen (Hickman, 1916). Jones (1960) reported a porcellanid crab associated with Pteroeides and Humes (1957) observed a parasitic copepod of the genus Lamippe in the gastrovascular cavity of Virgularia from West Africa. More recently, Johnstone (1969) reported two species of Lamippe, a caprellid, an amphipod, and also a shrimp as being commensals with

Ptilosarcus gurneyi from Puget Sound.

From the collection in Puget Sound for this study, no epiphytes or epizooites were observed, although easily dislodged organisms could have been lost during collection. However, it was noted that 141 (73.5%) of the 192 animals collected at Dash Point (July) had copepod infections (Lamippe sp.) in one or more leaves. Johnstone (1969) reported that the summer infection rate was higher than the winter rate, suggesting that the observed infection rate was approaching a maximum value.

A symbiotic alga was observed in the mesentery tissue at the upper end of the style. An infection rate of 13.5% was noted for these Puget Sound specimens. Although the alga was not identified with any degree of certainty, it was tentatively identified as Desmarestia (Dr. Harry Phinney, personal communication).

DISCUSSION OF THE TAXONOMIC STATUS OF  
PTILOSARCUS GURNEYI

Gray's removal of Leioptilus from Pennatula was considered to be incorrect, based on two characters which he used to separate the two genera: (i) the leaf shape and (ii) the position of the siphonozoids. The leaf shape of Pennatula varies from a triangular shape to a sickle shape. The leaf shape of Gray's Leioptilus fimbriata is also sickle shaped. The siphonozoids of Pennatula extend from the dorsal tract out between the leaf plates. Gray's Leioptilus fimbriata has the same characteristic. Therefore Gray's Leioptilus can not be shown to be different from Pennatula and should be abolished according to current taxonomic procedure (ICZN, art. 23, 1964). Species which were later placed in Leioptilus clearly belong to Ptilosarcus. Leioptilus fimbriata should therefore be replaced by Pennatula fimbriata Herklots, 1858, and the remaining species of Leioptilus (L. undulatum Verrill, 1865) should be moved into Ptilosarcus (ICZN arts. 23, 79, 1964).

Gray's genus Leioptilus has been shown to be invalid based on two different criteria: (i) homonymy (see introduction) and (ii) taxonomic synonymy.

The genus Ptilosarcus is the correct and valid generic name for the West coast sea pen, for which two species have been described from the Monterey Bay region of California. The first is Sarcoptilus (Ptilosarcus) gurneyi Gray, 1860, now validly called Ptilosarcus

gurneyi since Verrill raised the subgenus Ptilosarcus to full generic status. The second is Ptilosarcus quadrangularis Moroff, 1902. However, from the description of the two type specimens, no significant taxonomic differences could be found to justify retention of P. quadrangularis as a separate species.

Gray (1860 p. 23) described the new subgenus Ptilosarcus as having

Pinnules with a flattened, rather broad edge, spinulose on the margin; cells large, on the flattened edge surrounded with spicula. Stem 1/2 the entire length.

He continued with a description of the new species Sarcoptilus (Ptilosarcus) gurneyi:

Orange. Pinnules smooth, very much crowded, closely imbricated, with a rather broad, distinctly spinulose edge. Cells crowded. Stem elongate, thick, half the entire length, much swollen above. California, Monterey. J. H. Gurney, Esq., M. P. Brit. Mus.

Moroff (1902 p. 385) in describing the new species Ptilosarcus quadrangularis states that the:

Plant is slim, strong, dorsoventrally enclosed; stem comprises almost half of the plant, is very thick, and above the middle has a strong swelling; feather is 2 1/2 times as long as it is wide; 54 leaves in all, semicircular, widely attached, close together, with many small lime needles under the skin; polyp area is 3-4 rowed, covered with strong needles; polyp calyces with two teeth; polyps without lime needles in the tentacles; ventral zooids are of a kind found on low warts; no lateral zooids; axis has four edges, is orange in color; chalk grains appear overall, orange in color.

Because of the ambiguous descriptions, it was therefore necessary to obtain the two type specimens, P. gurneyi from the British Museum, and P. quadrangularis from the Munich Museum. Upon receipt of the animals from the British Museum, it was discovered that the animal from which the new subgenus and species were erected by Gray (1860) was mislabeled. The collection site, collection date, and collector were all correct but the specimen inside the jar was obviously not the specimen described by Gray. The mislabeled animal was identified as Pteroeides griseum, an Atlantic species. Thus the type specimen of Ptilosarcus gurneyi has been lost, with no syntypes existing.

The specimens from Munich were labeled as Ptilosarcus quadrangularis Moroff, 1902 and consisted of three syntypes in the same container, no one animal having been declared the type specimen. From the description of P. quadrangularis given by Moroff and from the comparison of other specimens of P. gurneyi from both museums (Table 2), it is apparent that Ptilosarcus gurneyi and Ptilosarcus quadrangularis are complete synonyms.

A comparison of the spicules from the peduncle, siphonozoids, and autozoids of Ptilosarcus gurneyi and Ptilosarcus quadrangularis indicated there are no taxonomic differences between the two. Both have rice grain-shaped, flat spicules in the peduncle ( $39\mu \times 78\mu$ ) and large tri-flanged spicules from the autozoids and the siphonozoids

Table 2. Comparison of taxonomic characters of Ptilosarcus gurneyi and Ptilosarcus quadrangularis.

British Museum Specimens	Color	Plate Number	Total length	Ped./Rachis ratio
<u>Leioptilum quadrangularis</u>	red	30	12.5 cms.	5.3/7.2
<u>Leioptilum gurneyi</u>	brown	-	-	10.2/-
<u>Leioptilum gurneyi</u>	orange	52	25.6	12.9/12.7
Munich Museum Specimens				
<u>Ptilosarcus quadrangularis</u>				
Typus I	red to orange	48	23.2	10.2/13.0
Typus II	red to orange	33	13.9	7.0/6.9
Typus III	red to orange	22	6.5	3.4/3.1
<u>Ptilosarcus gurneyi</u>	brown	53	15.6	6.5/9.1
<u>Ptilosarcus</u> sp.	orange	54	25.6	13.4/12.2
				Rachis
British Museum Specimens	Ped./Rachis fraction	Calyx #	Thickness	Width
<u>Leioptilum quadrangularis</u>	.736	2	2.5	1.4
<u>Leioptilum gurneyi</u>	-	2	2.7	1.8
<u>Leioptilum gurneyi</u>	1.015	2	2.6	4.0
Munich Museum Specimens				
<u>Ptilosarcus quadrangularis</u>				
Typus I	.785	2	3.2	2.5
Typus II	1.013	2	1.7	1.2
Typus III	1.095	2	1.0	.6
<u>Ptilosarcus gurneyi</u> *	.715	-	1.6	2.2
<u>Ptilosarcus</u> sp.	1.098	2	2.9	5.0

\* = Specimen appears to have been very old when collected as the calyses are worn off.

(47 - 78 $\mu$  x 500-600 $\mu$ ). Both specimens had two well formed calyx teeth arching over the autozooids, produced by the larger spicules coming together to a pointed projection. The only apparent distinction between the two species was that of color. All of the animals labeled Ptilosarcus quadrangularis TYPUS were reddish in color. This red color, however, does not seem to be a stable enough character on which to base species differences, as it is not always found uniformly throughout a colony. The edges of the leaves may be red without the peduncle being red, or the entire colony may be red. I have observed some colonies off of the Oregon coast that had partially red colored leaves, although the peduncle and the majority of the leaves were orange. It is not known whether this red coloration is seasonal, but it can be highly variable.

The similarity of anatomy, spicule shapes and arrangements, and the variability of color suggests that Ptilosarcus gurneyi and Ptilosarcus quadrangularis are complete synonyms. Since P. gurneyi was described in 1860 and P. quadrangularis in 1902, the name P. gurneyi priority. The syntypes of P. quadrangularis should thus be stricken as syntypes and should be considered as P. gurneyi topotypes. Therefore, based on earlier findings, it is apparent that Ptilosarcus and Leioptilus are complete synonyms, with Ptilosarcus the preferred name. It is also apparent that Ptilosarcus gurneyi (Gray, 1860) and Ptilosarcus quadrangularis Moroff, 1902 are complete synonyms. It

is therefore suggested that all of the species formerly allied with Leioptilus (except L. fimbriata which is a Pennatula) be now allied with Ptilosarcus and that Ptilosarcus gurneyi be used instead of Ptilosarcus quadrangularis.

A complete synonymy of the valid species of Ptilosarcus is quite complicated although there apparently are only three species: P. gurneyi, P. sinuosus, and P. undulatus (the species name here being a respelling of Verrill's Leioptilum undulatum to agree in gender with Ptilosarcus). A detailed history of the names applied to this genus and a review of its synonymy are presented in graphic form in Appendix A. A suggested taxonomic key to the genera of Pennatulidae, including Ptilosarcus, is presented in Appendix B.

Because of the confusion regarding the correct generic and specific name for the West coast sea pen, and because the type specimen of P. gurneyi was lost, I recommend that a neotype be erected to replace the lost type specimen of Ptilosarcus gurneyi. I suggest that a topotype be used and further suggest that it be lodged with the British Museum (National History), Cromwell Road, London, S. W. 7, England. I recommend this location because it was here that the type specimen was first lodged, and it will minimize any future confusion as to the location of the proper type specimen.

### Summary

1. A model for the prediction of the total dry weight of a sea pen, based on style length, was presented. This model permits the rapid estimate of sea pen biomass to be made in the field.

2. The internal anatomy of the West coast sea pen was described. No detectable anatomical differences between specimens from Puget Sound and Monterey Bay populations were found.

3. The spicules of the sea pens were found to contain an inner core of calcium carbonate and an outer shell of an unidentified substance which gave inconclusive tests for chitin.

4. The color differences between the red and the orange sea pens were found to be due to a petroleum ether extractable pigment. The orange pigment had as absorption maximum at 465m $\mu$ . The red pigment had two peaks of absorption maxima, one at 465m $\mu$  and one at 490m $\mu$ .

5. Over 70% of the Puget Sound specimens collected in July were infected with a parasitic copepod of the genus Lamippe. The infection site was the enteric canal in the leaf plates. In those colonies infected, several infections could occur per colony. Although several infection blisters per leaf were noted, only one copepod per infection site was ever observed.

6. About 13% of the colonies harbored a symbiotic alga in the

mesentery tissue surrounding the upper portion of the style. It was tentatively identified as Desmarestia.

7. Taxonomic revisions and synonymies were given for related species of Ptilosarcus.

8. Ptilosarcus gurneyi was established as the correct and valid binomen for the West coast sea pen with all other synonyms being subordinated.

9. A key to the genera of Pennatulidae and to the species of Ptilosarcus found on the West coast was given.

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## APPENDICES

## Appendix A

The following is an historical account of the different names applied to this genus (Appendix A Table 1). Appendix A Table 2 gives a synonymy of the different genera and species involved in this intriguing problem.

It is certain that Pennatula tenua, Pennatula tenuis, Ptilosarcus quadrangularis, and Ptilosarcus verrilli (Boone, not P. verrilli of Pfeffer) are junior synonyms of Ptilosarcus gurneyi. Similarly, Leioptilus fimbriata, Leioptilus fimbriatus, Ptilosarcus grayi, Ptilosarcus brevicaulis, Pennatula sulcata and possibly Ptilosarcus sinuosus are junior synonyms of Pennatula fimbriata.

Ptilosarcus gurneyi (= P. guernei) (Boone, 1933, not P. gurneyi of Gray), Leioptilum solidum, Ptilosarcus verrilli (not P. verrilli of Boone), and Ptilosarcus sinuosus (not P. sinuosus of Gray) are all junior synonyms of Ptilosarcus undulatus (emend.).

Thus there seems to be three main areas of distribution of the genus Ptilosarcus: from Alaska to southern California (P. gurneyi), from the Gulf of California to Peru (P. undulatus), and from Australia and New Zealand (P. sinuosus, if this is different from Pennatula fimbriata).

Appendix A Table 1

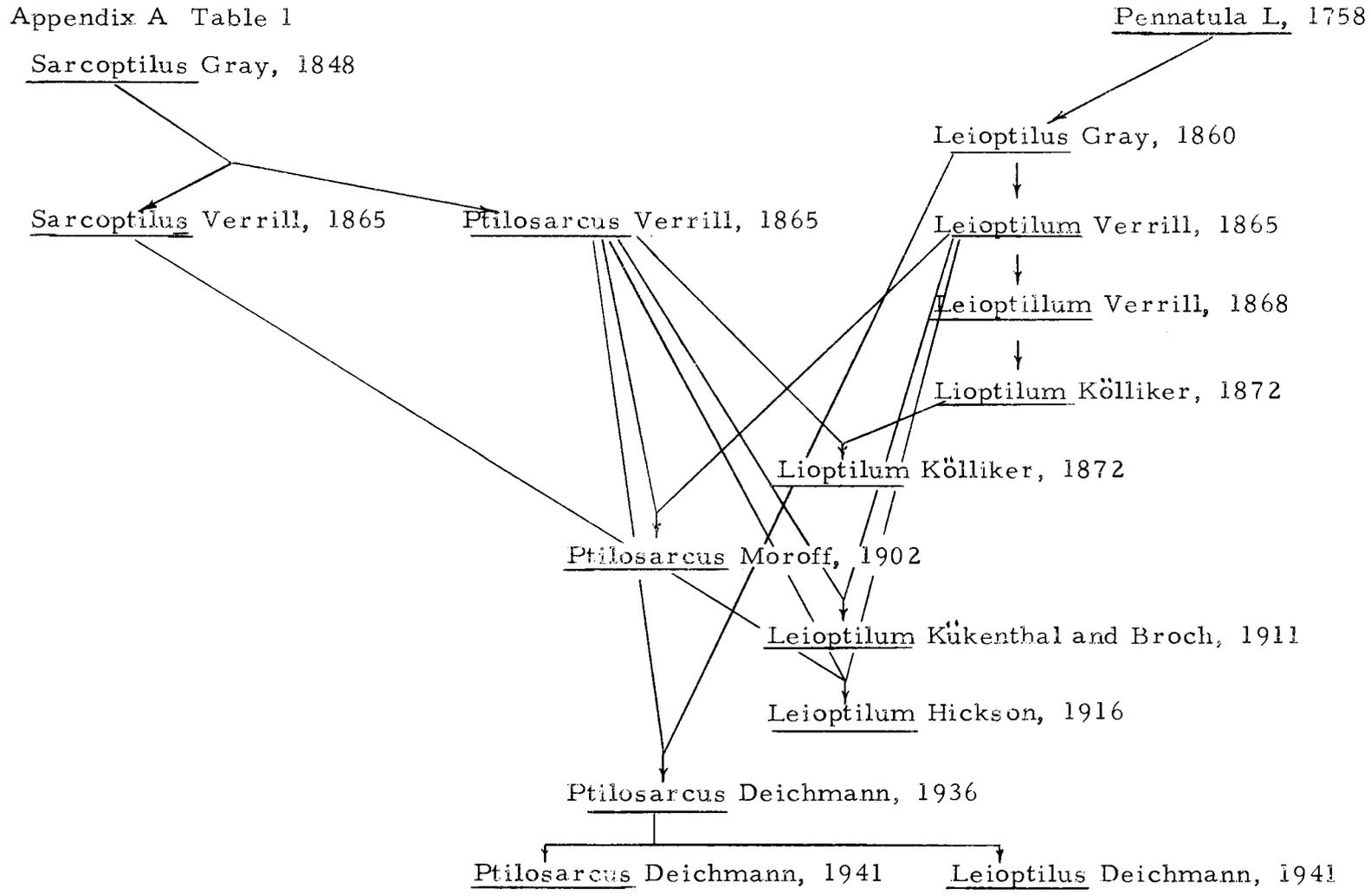
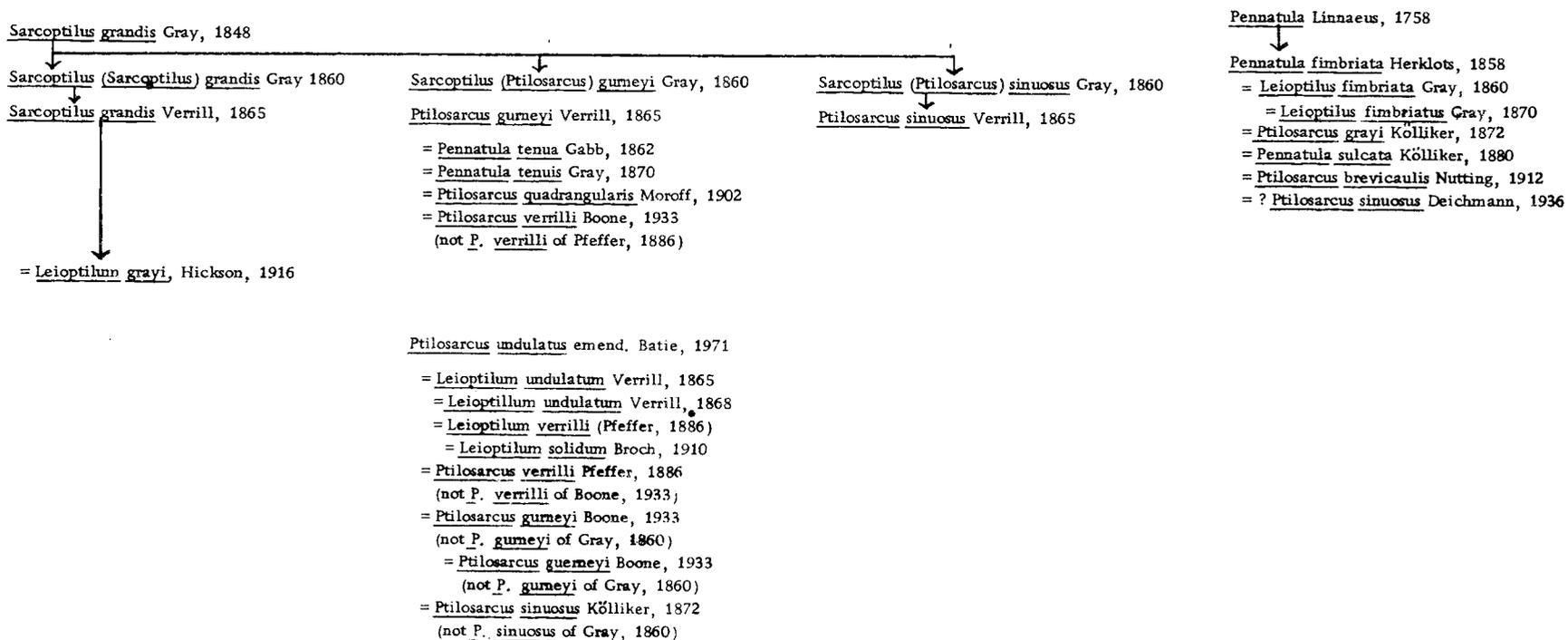


Table showing synonymies of Sarcoptilus, Ptilosarcus and Leioptilus. Arrows point from genera under consideration to combined genus with author and date following emended designation.

APPENDIX A

Table 2. Table showing synonymies at species level. Arrows show from which genus new genus or subgenus is derived. Synonymous names are placed under oldest described name for that genus.



## Appendix B

The following is a suggested key to the genera of Pennatulidae accompanied by a key to the species of Ptilosarcus found on the West coast.

(adapted from Hickson, 1916 and Deichmann, 1936)

- 1a. With large (300-600 $\mu$ ) tri-flanged spicules in the leaves. May be limited to edge or cover most of leaf surface. No spicules in tentacles of autozooids.  
 ..... 2
- 2a. Leaves triangular, fan-shaped or sickle-shaped with long, prominent calyx teeth. Siphonozooids never on leaves but may extend between leaves.  
 ..... Pennatula
- 2b. Leaves kidney-shaped, calyx teeth short and broad. Siphonozooids never extend between leaves but form two bands down dorsal tract of rachis, may be single or in clumps.  
 ..... Ptilosarcus 3
- 3a. With two distinct calyx teeth. Orange to red in color. Siphonozooids not clumped.  
 ..... P. gurneyi
- 3b. With one distinct calyx tooth. Siphonozooids and dorsal tract red. Siphonozooids clumped. Calyx tooth yellow tipped.  
 ..... P. undulatus
- 1b. With large tri-flanged spicules forming fan-shaped support at base of leaves. Small (30 $\mu$ ) flat spicules in the calices, rachis and tentacles.  
 ..... Acanthoptilum
- 1c. With small (50 $\mu$ ) flat spicules in the leaves.  
 ..... Scytalium