ASPECTS OF THE NATURAL HISTORY OF <u>OCTOPUS</u> <u>DOFLEINI</u>,

THE GIANT PACIFIC OCTOPUS

by

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ABSTRACT

A two part project spanning four and one half years was designed to investigate a number of aspects of the natural history of Octopus dofleini in the Northeast Pacific.

The tag-release-recapture (Part I) involved weekly SCUBA dives, during daylight hours, at three sites on Southern Vancouver Island, British Columbia, Canada. A total of 320 octopuses were sighted during 616 dives (Part I) and 151 of those octopuses were tagged or recaptured.

The ratio of dives per octopus sighted was 1.93:1 and the ratio of dives per octopus tagged or recaptured was 4.08:1.

A total of 98 octopuses were tagged (Part I) and 30 of those octopuses were recaptured two or more times for a recapture rate of 30.61%.

Statistical analysis of data weighted to provide uniform effort showed Site 1 (Tanner Rock) to have a significantly greater number of large octopuses while Site 2 (Tozier Rock) had a significantly greater number of very small octopuses.

An analysis of the data on octopus sex ratios found no significant difference between the number of males and females at each site even though there had been a significant difference in the ratio within Site 2.

Analysis of data on annual distribution of octopus body weight combined with the results from the recapture of individual octopuses led to the proposal of a four year lifespan for female *Octopus dofleini* and an undetermined, but longer, lifespan for males of the species.

An examination of the data on octopus movement showed that a peak number of small octopuses (approximately 250 g) appeared at the sites in February. The evidence showed that over the next 19 to 22 months the octopuses grew from approximately 250 grams to a preadult body weight of 13.8 kg for males (in September) and 14.7 kg for females (in December). No octopuses between 16 and 19.5 kg were captured suggesting a movement of octopuses of that body weight away from the sites. Small numbers of octopuses weighing between 19.5 kg and 28 kg were captured mainly during the first half of the year.

An analysis of octopus position data showed that *Octopus dofleini* does not maintain a constant distance from its nearest neighbour. Nearest neighbour distance was not significantly influenced by the size or sex of the neighbour nor by changes in water temperature.

A highly significant correlation was found between estimated den volume and octopus body weight. There were no significant relationships between den surroundings, number of exits, den type and den depth when compared to den usage suggesting that *Octopus dofleini* is an opportunistic animal using whatever shelter of appropriate volume it discovers.

The major food item at all sites as determined by midden heap contents was the Red Rock Crab, *Cancer productus*.

An examination of the physical condition of each octopus captured revealed 21.2% of the animals had either scars or amputated arms or both.

Correlations examining the relationships between water temperature and growth rate, body weight, sex and nearest neighbour distance were nonsignificant.

Part II of the project was the physical measuring and describing of each den at each site. During the 126 SCUBA dives done another 127 octopuses were sighted. As octopuses were captured only when it was necessary to examine the inside of the den there were only 11 octopuses captured during the second part of the project.

In total, 447 octopuses were sighted during 742 dives. This results in an effort per octopus sighted of 1.66 dives per octopus.

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INTRODUCTION

Since the original description of *Octopus dofleini* (Wülker, 1910) by Gerard Wülker in 1910 and its amendment by Madokia Sasaki in 1920 this cephalopod has been investigated by many workers.

The 1965 collapse of the herring fishery in Japan led to greater interest in the exploitation of octopus as a food source. The Japanese examined fishing methods (Satō, 1959; Fukuda *et al*., 1960; Kanamaru, 1965) as well as ways of culturing and raising octopuses (Tauchi and Matsumoto, 1954; Tanaka, 1963; Itami *et al*., 1963; Yamashita, 1974). Tag-release-recapture studies (Kanamaru and Yamashita, 1966, 1969; Yamashita and Toshida, 1973) revealed that *Octopus dofleini* was a highly mobile animal with a biannual pattern of onshore-offshore movement. These studies also suggested that *Octopus dofleini* grows rapidly reaching a reproductive size of 15-20 kg in two years (Kanamaru and Yamashita, 1966).

From 1956-1962 the fishermen of Hokkaidō caught an average of 23,000 tons of octopus per year (Mottet, 1975) and the majority of this was *Octopus dofleini*. "By 1967, however, the Japanese themselves had become major importers of octopus (mainly *Octopus vulgaris* from Africa) and were importing more than they were catching" (Mottet, 1975).

The presence of a Japanese market for octopus plus declining traditional fish stocks on the west coast of North America led to an increased interest in *Octopus dofleini* as a potential resource to be harvested by North American fishermen.

Investigations into various fishing methods (Mottet, 1975; High, 1976; Adkins, 1980; Pennington, 1979; Hartwick, 1982) have provided much information but have also raised many questions and have pointed out many serious gaps in our knowledge of the natural history of *Octopus dofleini*.

Green (1973) in her thesis *Planktonic Octopods in the Northeast Pacific* described what was known of the embryology and larval development of *Octopus dofleini*. Chance matings and egg-layings in aquaria (Gabe, 1975; Marliave, 1981) as well as rare *in situ* observations (High, 1976) have increased our knowledge of the early life of *Octopus dofleini* but still leave questions. We do not know much about the time between a planktonic total length of 35 mm (Mottet, 1975) and an epibenthic total length of approximately 150 mm (125 grams).

The use of SCUBA has allowed investigators such as E.B. Hartwick, P.A. Breen, L. Tulloch, G. Thorarinsson, R.F. Ambrose, S.M.C. Robinson, W.L. High, M.A. Kyte, G.W. Courteney, J. Mather, S. Resler and J. Cosgrove to examine many aspects of the natural history of *Octopus dofleini* and to interact with the animals in ways which were not previously possible.

Hartwick *et al*. (1978) investigated the rate at which dens would repopulate after the original animals were removed. Hartwick and Thorarinsson (1978) described the animals associated with *Octopus dofleini* dens. Kyte and Courtney (1977) were able to observe and describe an aggressive encounter between two octopuses. Snow (1970) described two cases where SCUBA divers were bitten by *Octopus dofleini*.

The use of tags to identify individuals was first documented in 1958 (High, 1963; pers. comm.). A version of the spaghetti tag used by High was also used by Kanamaru and Yamashita (1966).

Sonic tags were employed in a short term study of Octopus dofleini den use and daily movement patterns (Mather et al., 1985) but for long term studies of growth (Hartwick et al., 1981; Robinson and Hartwick, 1986), population dynamics (Hartwick et al., 1984a) and den utilization (Hartwick et al., 1984b) the Petersen disc has proved more effective.

The present project was designed to obtain long term data on octopus movement into, within, and out of specific research sites. In addition, data on weight, recaptures, growth rate, sex, den type, den surroundings, midden heap contents, den depth, water temperature and nearest neighbour distance were obtained.

This project differed from those of other investigators (e.g. Hartwick, Thorarinsson, Robinson and Ambrose) in several ways. Data collection was done on a weekly basis at each site and was continuous for three years rather than biweekly or monthly and intermittent. The research sites chosen included 2 areas of isolated rock which were protected from heavy wave action and subject to small tidal currents and small tidal ranges. The third site chosen was exposed to heavier wave action and was subject to faster tidal currents although not as strong or as fast as the waves and currents at Hartwick's open coast sites.

This project was undertaken in order to provide information on the following questions:

1. Is there any evidence to indicate that a biannual migration of Octopus dofleini exists in the waters of the Northeast Pacific as cited for the waters of the Northwest Pacific (Kanamaru and Yamashita, 1966, 1969)?

2. What is the lifespan of *Octopus dofleini* in the Northeast Pacific and is the lifespan the same for both sexes?

3. What growth rates are typical of each year of the animals' life and how do they differ between sexes and in different seasons of the year?

4. Does *Octopus dofleini* maintain a uniform distance from its nearest neighbours and if so, how does that distance vary as the octopus grows larger?

5. What environmental cues does *Octopus dofleini* use in selecting a den?

6. What, if any, is the relationship between water temperature and migration, water temperature and growth rate, and water temperature and nearest neighbour distance?

It is realized that there is considerable literature regarding these questions for species of octopuses other than *Octopus dofleini*. I have chosen, however, to use only literature on *Octopus dofleini* in this thesis.

MATERIALS AND METHODS

(a) Sites

Three study sites were selected on the southern part of Vancouver Island, British Columbia, Canada (Fig. 1).

Site 1 was Tanner Rock (lat. 48° 37' 7"N; long. 123° 31' 4"W) in Saanich Inlet (Fig. 2). This site had been used in previous studies (Cosgrove, 1974; unpublished data; Mather *et al.*, 1985) and was known to be a source of octopuses. Tanner Rock is a small rock which is completely submerged at high tide leaving only a navigation marker exposed. The site has an area of approximately 4,000 square meters. The west side of the rock shallows out to a sand flat at a depth of 10 meters. The sand flat is continuous around the rock with the deepest areas being in the south-east to east regions where a cliff face meets the sand bottom in 16 meters of water.

During the three years of the project 13 dens containing *Octopus dofleini* were located on the Tanner Rock site.

The second site selected was also located in Saanich Inlet. Tozier Rock (lat. 48° 37' 1"N; long. 123° 30' 7"W) is 1.4 km south of Tanner Rock and has an area of approximately 28,000 square meters (Fig. 3). As with Tanner Rock, this site had also been used for previous work (Mather *et al.*, 1985) and was known to be a source of octopuses. Tozier Rock also has a sand flat off the west side of the reef which continues to the shore. Located on the sand flat, midway between the reef and shore, are several fingers of rock in which one den was located (Den 28). The sand flat on the west side meets the reef at a depth of 8 meters and continues to a depth of 16 meters before rising again to the shore. The

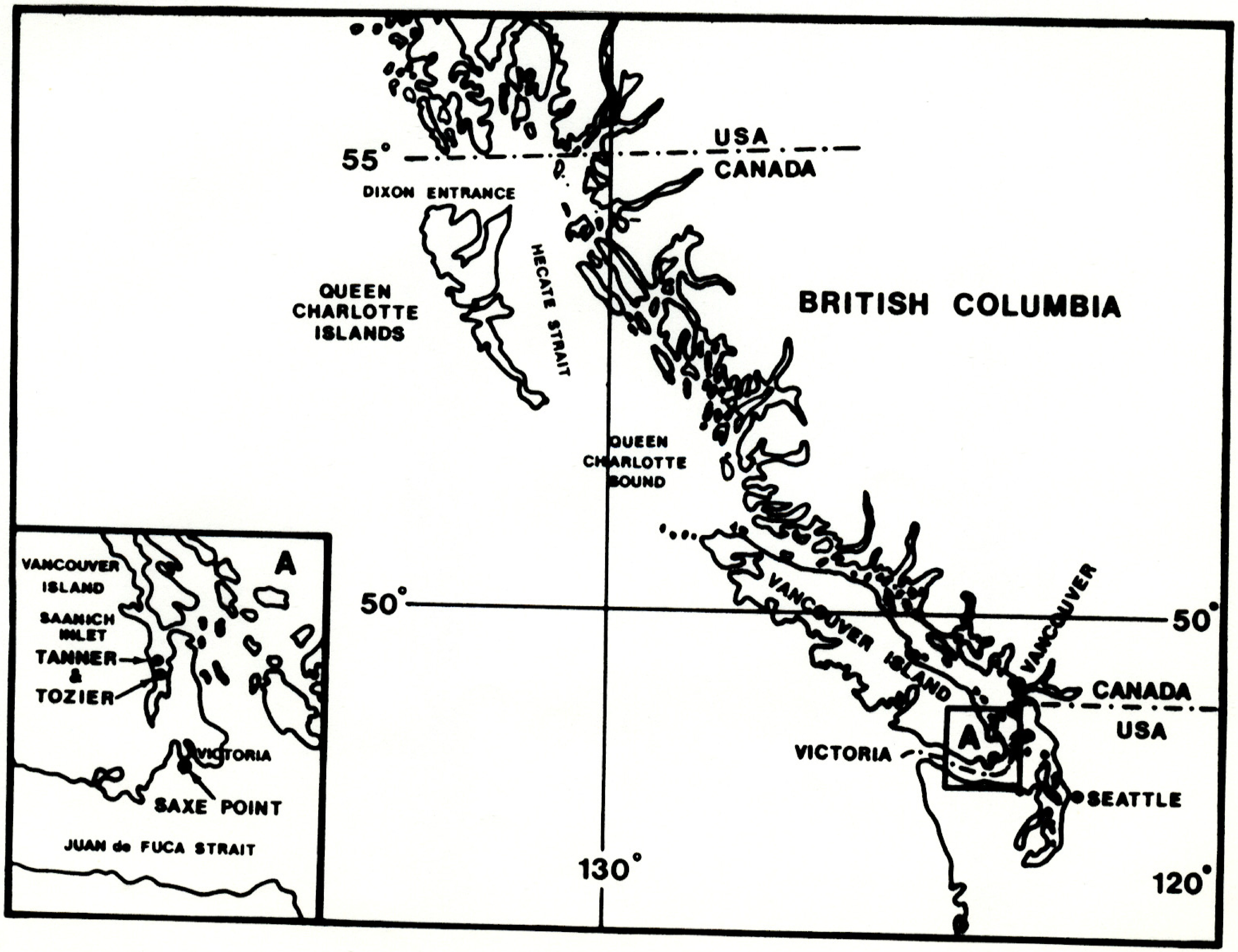

FIGURE 1. Study Sites

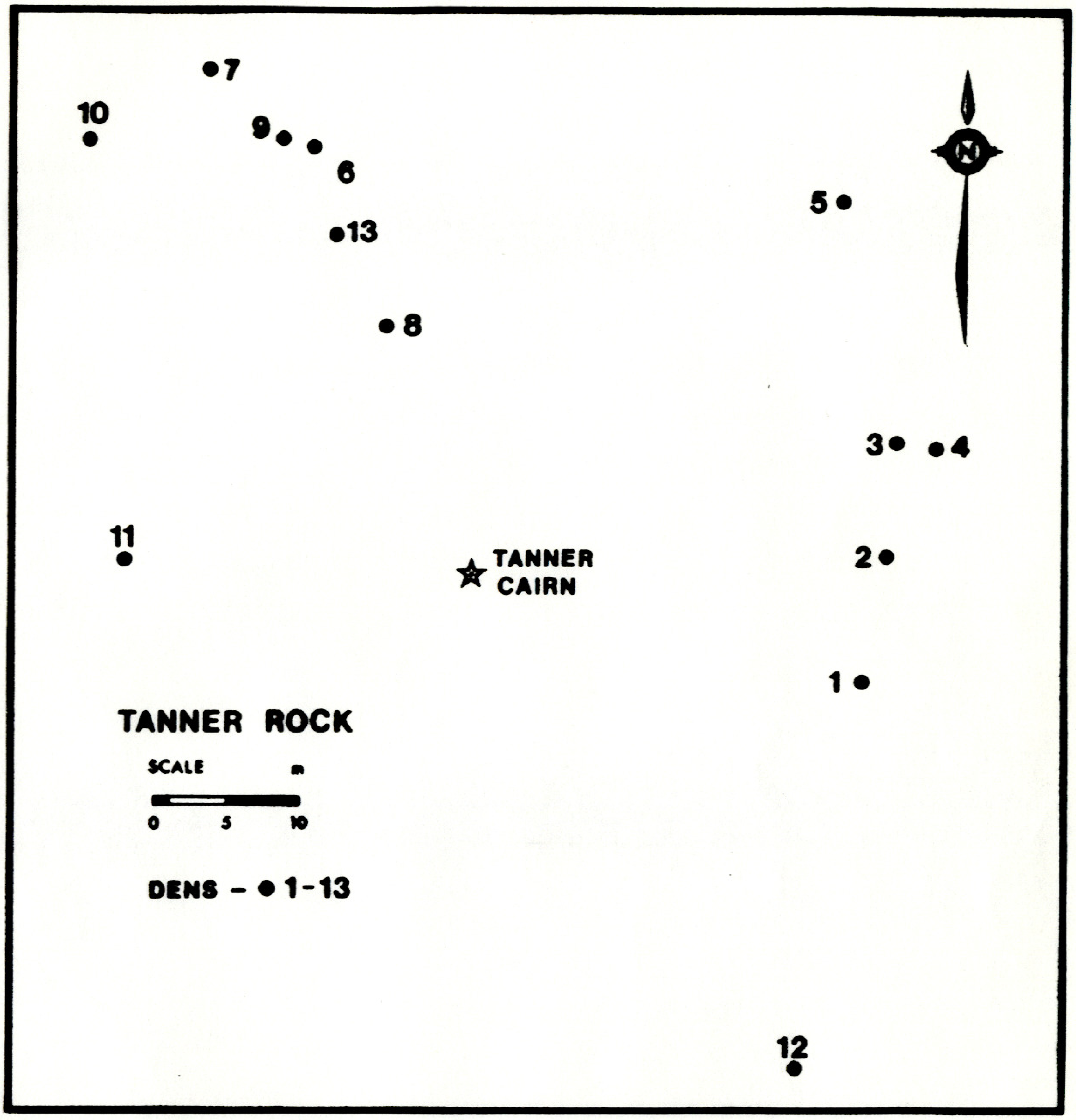

FIGURE 2. Den Sites at Tanner Rock (Site 1)

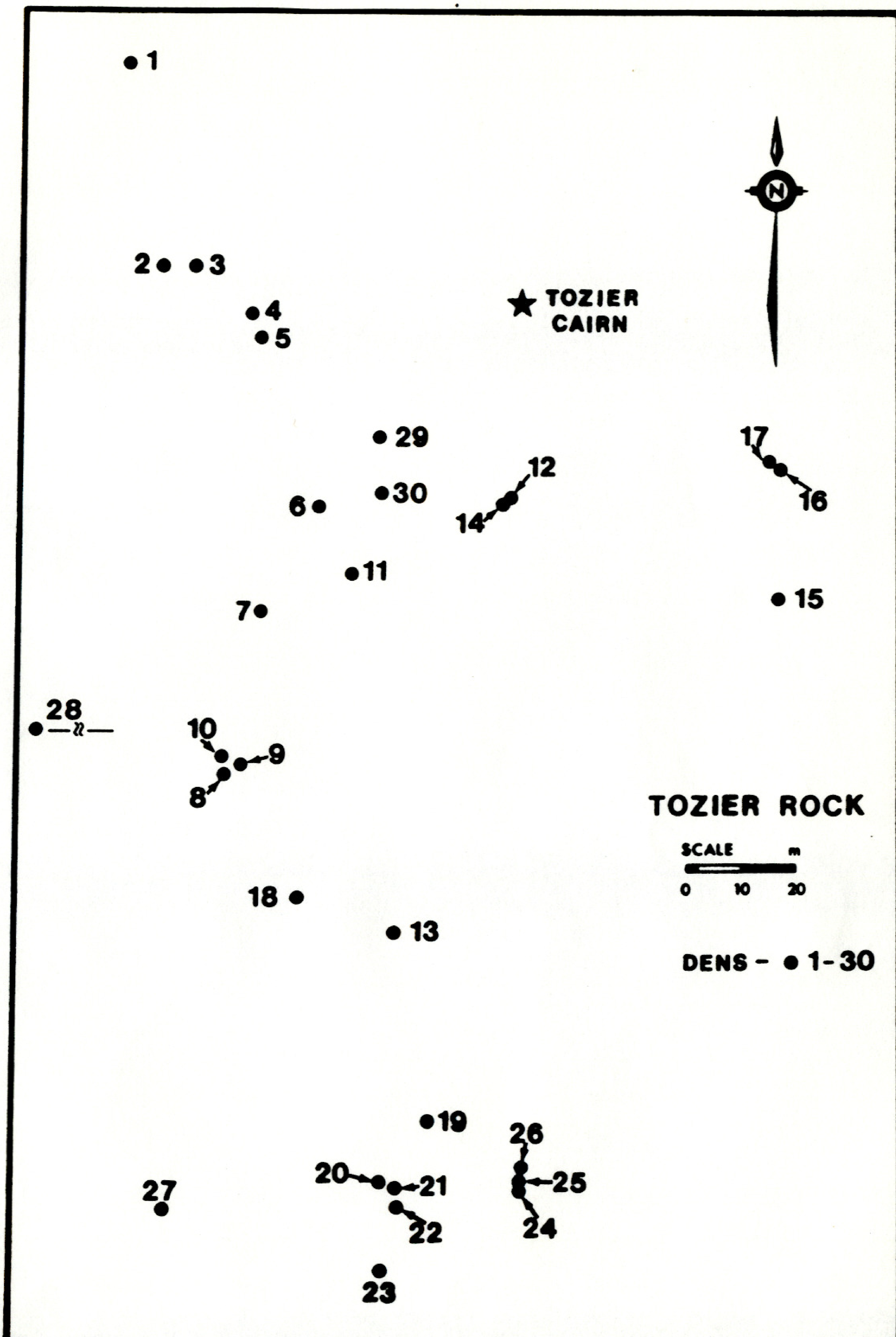

FIGURE 3. Den Sites at Tozier Rock (Site 2)

south and southeastern areas of the reef meet the sand flat at a depth of 14 meters. On the sand flat there were large rock formations and several contained dens or clusters of dens (24, 25, 26). Along the eastern side of the reef the sand rises to a depth of 8 meters but again there are separate areas of rock out on the flats and in deeper water (16-18 meters) where dens are located (15, 16, 17). The north-east part of the reef is a steeply descending smooth rock face which descends into water deeper than 50 meters. No dens were located on this slope.

The north and north-west part of the reef are a series of steep slopes with dens located under separate rocks (Dens 1, 2, 3) or in splits in the cliff face (Dens 4, 5). The sand flat commences at a depth of 20 meters and slopes up to a depth of 8 meters at the north-west corner of the reef.

Thirty dens containing _Octopus dofleini_ were located on Tozier Rock during the project.

Site 3 was Saxe Point (lat. 48° 25' 3"N, long. 123° 25' 4"W) located on Juan de Fuca Strait (Fig. 4). The large curved point contains small coves at either end of the point and a tight crown of rock and rubble around the crest of the point. Both the cove areas are characterized by having large single boulders along the edge of a cliff which meets a mud flat at a depth of 3 meters. The front of Saxe Point has a shelf of rock extending out into separate fingers of rock which form 2 meter high ridges. The rock fingers meet the mud flat at a depth of 4 meters and extend onto the flat to a depth of 9 meters. Dens were located under large boulders (Den 10) or in natural splits in the rocks

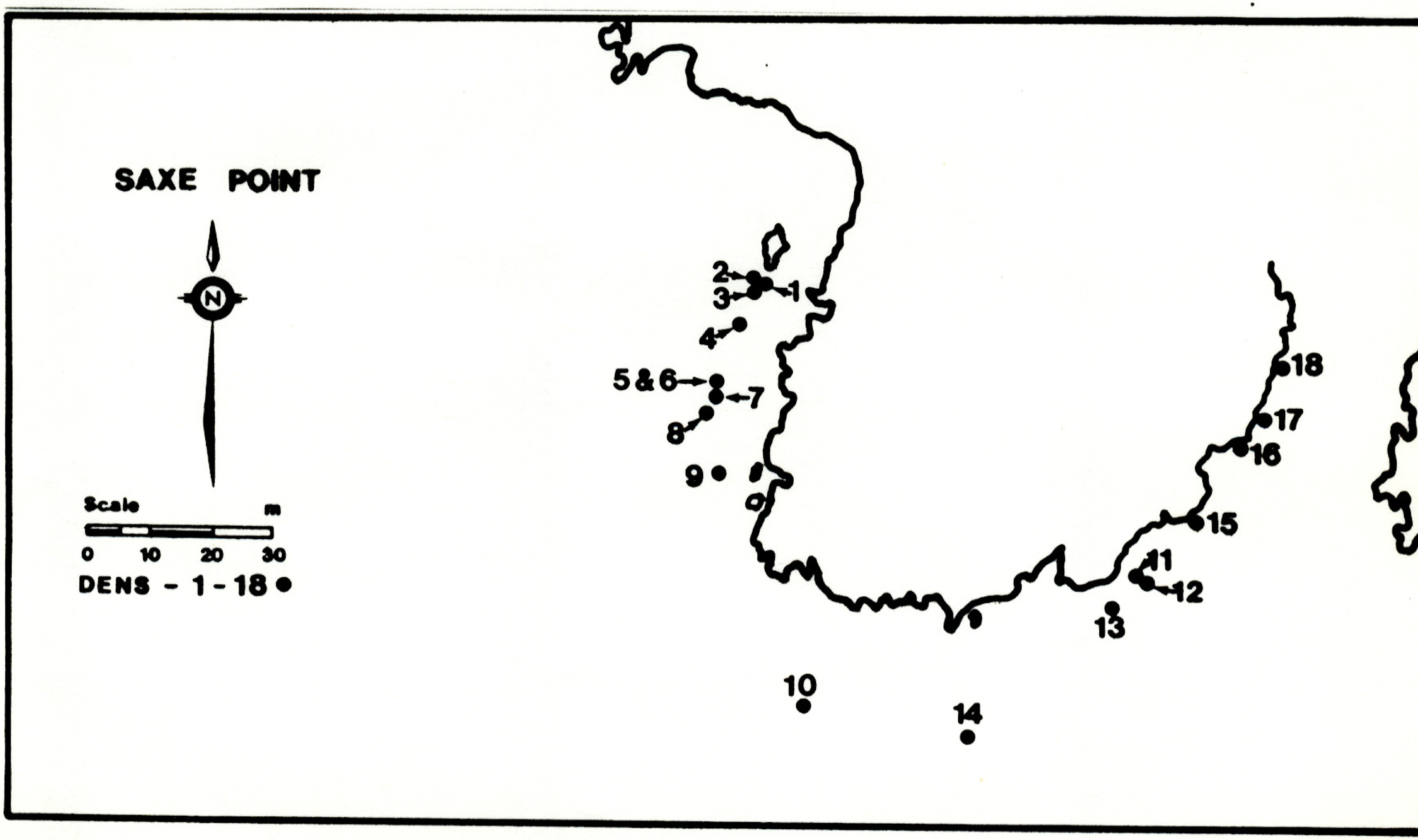

FIGURE 4. Den Sites at Saxe Point (Site 3)

(Den 14). The Saxe Point research area covered approximately 28,000 square meters and included eighteen den sites.

The three study sites were selected in order to answer questions regarding the effect of the environment on the numbers, sex ratio, weight distribution, den use, den types, animal condition and food types of resident Octopus dofleini.

Most of the previous tagging studies (Hartwick et al., 1981, 1984a, b; Robinson and Hartwick, 1986) have been carried out in areas of open ocean coastline where surge and currents existed. In the selection of two protected sites in Saanich Inlet the questions of population size, mean animal size, sex ratios, growth rates and migratory movements could be examined and compared to the more exposed Saxe Point and open coastline sites.

Saanich Inlet is a "fjord-like embayment" 24 km in length and 7.2 km wide (Herlinveaux, 1962). The sill at the mouth of the Inlet is 75 meters deep while the Inlet descends to 235 meters. During "most of the year" there is no oxygen below 150 meters (Herlinveaux, 1962). There are high concentrations of oxygen in the upper 10 meters but below this "the oxygen concentration decreased regularly with depth, and vanished in the bottom waters." (Herlinveaux, 1962). Wilbur and Yonge (1964) point out that octopuses require clean, well-oxygenated water and cannot survive in low oxygen levels. It was expected that if Octopus dofleini was as mobile an animal as the literature indicated there would be a tendency for animals in Saanich Inlet to move parallel to the shoreline rather than move down into deeper water where the oxygen levels were decreasing. By having two sites within 1.4 km of each other any movement along the shoreline would be detected by recapturing animals tagged and released on the other site. Kanamaru and Yamashita (1966, 1969) reported that the movement of animals was not parallel to the shore but in an onshore-offshore direction but several of their figures (Figs. 13 and 15) show movement parallel to the shoreline (Kanamaru and Yamashita, 1969).

Another factor for the selection of two sites in Saanich Inlet was the small tidal current and small tidal movement. Mean tidal range is 2.4 meters with a maximum of 3.8 meters (Canadian Hydrographic Service, Annual). Herlinveaux (1962) reported the current to be "small and variable" with "little or no consistent pattern". This small tidal movement and current would provide contrast to the more exposed Saxe Point site and the open coast sites of Hartwick *et al*.

Other factors favouring the selection of sites in Saaanich Inlet were protection from heavy weather, boat access only (although one could swim to Tanner Rock from shore) and a fisheries closure which prevented the commercial collecting of *Octopus dofleini*.

Saxe Point was selected because it was more like the open coast situation. While Saxe Point is not subject to large ocean swells it does receive heavy wave action during storms and has a stronger tidal current than found at the sites in Saanich Inlet. Mean tidal range at Saxe Point is 1.8 meters with a maximum of 3.1 meters (Canadian Hydrographic Service, Annual). The coves on either side of Saxe Point permitted shore access on all but the most stormy days and although commercial octopus hunters do work the Victoria waterfront area (including Saxe Point) and other divers frequent the Point, it was my experience that there were often octopuses there. The selection of Saxe Point allowed the comparison of populations to see what effect divers and commercial hunters were having upon the octopuses.

All three sites were selected because they were surrounded by a large sand or mud flat which provided no den sites for animals moving into or out of the study area. As each site could be completely searched in one dive it was assumed that all animals in the research area would be discovered.

Most dives were a complete survey of the site and took from 1-3 hours. Some surveys were incomplete due to weather or concerns for the divers' safety.

(b) Search and Handling Methods

On a weekly basis and during daylight hours each site was surveyed by at least one pair of divers using SCUBA and carrying underwater lights, white plastic bags for marking dens, a bleach bottle, an underwater slate, and a pair of large collecting sacks.

The divers would swim a route between previously marked dens and search for possible new dens along the way. The most obvious feature of an octopus den is the presence of a midden containing excavated sand or mud from the den as well as the discarded remains of food items such as crab shells, bivalve shells and fish bones.

When a den was discovered and the presence of an animal confirmed the den was examined carefully to determine the number and direction of exits available to the animal. Once the exit direction was determined, all traces of our materials were hidden from view and the diver with the collecting bag took up a position where he was not likely to be seen by the octopus when it emerged.

A solution of 50% fresh water and 50% household chlorine bleach was introduced into the den via the exit farthest from the one you wanted the animal to use. The diver then positioned himself in such a way as to permit the observation of the den but to prevent himself from being seen or touched by the octopus. Past experience had shown that an octopus would not leave the den, in spite of the use of bleach if it could see or touch the divers outside. The bleach solution was purposely made weak so as not to damage the animal.

Once the octopus was out of the den the diver quickly moved between the animal and the den to prevent the octopus from reentering into the den. The diver then placed himself close enough to the octopus to force the animal to release its hold on the bottom and start moving away. Often the animal would jet into the water column as soon as the first diver appeared and this would allow the catcher to bag the animal in midwater. If the octopus did not jet, then the first diver had to scoop the animal clear of the bottom and hold it until the catch diver arrived with the bag.

Care had to be taken to allow the octopus an area to escape to. If the divers got too close or boxed the octopus in it would simply flatten out on the bottom and freeze. Even a small animal of 3-5 kg cannot, when on a rock surface, be pulled loose in this position.

Once the animal was secure, it was brought to the surface and taken to shore or the boat.

On shore the animal was removed from the capture bag and placed in a large plastic basket. This allowed water to drain from the mantle cavity. The overall appearance of the animal was noted with scars and amputations recorded. Sex was determined by examining the distal portion of the third right arm which is modified to form a hectocotylus in the male (Pickford, 1964). The sex was recorded (Appendix 1 Data Sheet).

The third left arm of the octopus was examined for the presence of a previous tag. If one was found the number was recorded and the tag examined to see that it was not damaging the animal. If no tag was found then a yellow numbered plastic Petersen disc (manufactured by the Floy Tag Co. of Seattle, Wa.) was attached near the base of the third left arm. A 7.5 cm nickle pin was placed through the center of the 2 cm diameter Petersen disc and then run through the arm of the octopus so that it emerged in the centre of the area between four suckers. A second blank 2 cm diameter disc was then threaded onto the nickle pin. The tip of the pin was then cut off and the pin folded over to hold the discs snug. Enough of the pin was left to allow for expansion as the animal grew. The tag number was recorded.

The animal was then returned to the capture bag and weighed using a spring scale accurate to ± 0.5 kg. The animal was then returned to the water.

The whole process of sexing, tagging and weighing normally took less than 5 minutes and in no case did an animal appear to suffer from the procedures.

The divers then returned to the den where the den was marked by a small white plastic garbage bag weighted with some rocks.

The use of plastic garbage bags on Saxe Point was discontinued when it was discovered that commercial octopus hunters were using them as a fast search method and were finding dens unknown to them previously. A second problem was that some of the more environmentally conscious members of the diving community were removing the bags thinking them to be trash even though signs had been posted at all dive shops telling of the project.

The actual depth of the den as registered on the divers' depth gauges was recorded. Water temperature at the den was recorded $\pm$ 0.5°C using a hand held field thermometer.

The remains of previous meals left in the midden heap were collected and sorted as to number and species and this information was recorded. The material was then scattered some distance from the den entrance.

By removing a swim fin and using it as a fan the diver was able to force clean water through the interior of the den in an attempt to flush out all traces of the bleach solution. The octopus was then released and allowed to re-enter the den. In all cases the octopus did re-enter the den but there were several occasions where the animal was found out in the open 10 to 30 minutes later. Whether this movement was due to traces of bleach remaining in the den is not known but it is assumed that the trauma of the capture and tagging procedure was a more likely motivation.

If a very small octopus (less than 1 kg body weight) was discovered then den number, depth, temperature and midden heap contents were recorded but the animal was not captured. It was felt that the tags were too large for the arm of such a small animal and would seriously compromise the animal's movement and ability to resist predation.

If a den was found unoccupied then the midden was examined for signs of recent use. The major prey item of Octopus dofleini in the study areas was the Red Rock Crab, Cancer productus. Experience from a previous study (Mather et al., 1986) where middens were examined daily showed that the carapace of a crab consumed within the last 2 or 3 days was still very hard and required considerable effort to break. The carapaces still appeared clean and often had the eye stalks still in place.

Carapaces older than 3 days but less than approximately two weeks no longer looked fresh. The colour would have changed from a shiny brick red to a rather dull brown and the inside of the carapace would have changed from a shiny white to a dull cream colour. The older carapace could be easily broken by one hand and the carapace shattered into many small sharp-edged pieces.

Carapaces older than two weeks were often covered by what was assumed to be a fungus, in fact often the whole midden was covered. The carapace was extremely fragile and often crushed to powder when picked up.

The internal lengths of some of the dens as well as the complexity of the den often made it difficult or impossible to visually confirm the presence of an animal. By examining the midden for fresh refuse the divers could subjectively evaluate the den and often were able to flush an octopus out even when it was not seen.

The tag and recapture part of the project ran from July 1, 1981 to June 30, 1984 with weekly dives being made at each site. There were occasions where storms, zero visibility or illness prevented the inspection but these were few in number.

(c) Den Descriptions

After June 30, 1984 the dens were examined in detail using SCUBA.

Each den was assigned a number and was described in terms of site, number of exits, type of den, type of surroundings, internal measurements, distances and angles to the two nearest dens and mean den depth (Appendix II).

Den numbers were assigned as each new den was discovered. For the purpose of this thesis the dens have been renumbered to make reading easier.

The number of exits was ascertained by independent visual examination and mutual agreement of the dive team.

The type of den was described in terms of being excavated, in a natural split in the rock, in rock rubble or a combination of features.

Den surroundings were described in terms of being sand, monument rock (a larger, often isolated rock, commonly bearing a number of white sea anemones, *Metridium senile*), cliff (with a den at the base of the rock face), rubble, rock, mud or a combination of two or more features.

Internal measurements (± 1 cm) were made using a flexible steel (3 meter) measuring tape. There were great irregularities in the internal dimensions of the individual dens and also some dens could not be seen completely from the outside. In some cases (Tozier Rock Dens 8, 9, 10 and 24, 25, 26, Saxe Point Dens 5 and 6) the dens were known to be interconnected but animals were found only in certain areas of the complex. In several cases the dens had not been used in some time and the dens were heavily silted in. In all cases a best guess estimate was made but it is recognized that considerable error may be present. In one case the length of the den exceeded the 3 meter length of the tape (Tozier Rock Den 25) but because of the external dimensions of the rock it was felt that the 3 meter measurement was reasonable. The den volume estimate was calculated by multiplying the average values for the den's height, width and length.

The distance between dens was measured (± 0.1 metre) using a fine line which was laid on the bottom and conformed to the contours of the area. The line was marked and then measured on shore. Only the distances between consecutive dens were physically measured. With angles taken using a diver's compass (± 5°) and measured distances from charted objects, a plot of the dens of each site was drawn (Figs. 2, 3, 4). Nearest neighbour distances were then measured off the drawings. It is recognized that some of the distances could be in error by several meters due to the flat plane measurement rather than following the true topography of the area. It was felt, however, that because most of the measurements at Tanner Rock (Site 1) were physical ones the only major differences would be for the longer distances on Tozier Rock (Site 2). In comparing measured distance to drawing distance the errors appeared to be less than 10%. In the case of Saxe Point (Site 3) where the dens were in a curve around the point an arbitrary curved line of best fit was used to predict the shortest path an animal would have to travel to contact its nearest neighbour. It was felt that because of the fairly flat topography of Saxe Point and the need to use predicted paths that minor errors in actual measurement were of little consequence.

The actual depth of each den was obtained by having one diver swim directly to the surface with the measuring line and release the line at the interface. The second diver held the measuring line at the entrance of the den allowing the line to be pulled through his fingers by the ascending diver. When the line went slack it was marked and measured on shore (± 0.1 m). The exact date and time of measurement was recorded (Appendix II). By use of the Canadian Tide and Current Tables (Canadian Hydrographic Service, Annual) the mean depth of each den was calculated.

During the period of time when dens were being measured the presence of octopuses in dens were recorded. Animals were not removed during this time unless it was necessary to measure the inside of the den. In those few cases the animal was flushed out, sexed and then released. The data were recorded.

It was recognized that unequal effort could bias the results of much of the analysis and for that reason some data were weighted by effort per month per site per project year to produce uniform effort.

Analysis on Effort, Distribution of Animals, Sex Ratios, Weight and Den Usage was conducted using data weighted to normalize effort.

The data were weighted according to SPSSX weighting procedures (pages 184 to 186) described in the SPSSX User's Guide (anonymous, 1986).

Analysis on Growth Rate, Nearest Neighbour, Den Volume, Den Type, Den Surroundings, Number of Den Exits, Food, Octopus Condition and Water Temperature used unweighted data.

Data analysis was done using the extended version of Statistical Package for the Social Sciences (SPSSX) on a VAX 11780 computer.

RESULTS

EFFORT

From July 1, 1981 to June 30, 1984 (Part I of the study) a total of 616 dives were completed (Table 1).

In total, 320 octopuses were sighted during Part I of the study and 151 of those were tagged or recaptured. When the data was weighted for effort it was predicted that a total of 352 octopuses would have been sighted and 161 of those would have been captured or recaptured (Table 2).

During Part II of the study (July 1, 1984 to December 31, 1986), a further 126 dives were completed (Table 1). An additional 127 octopuses were sighted during Part II of the study and 11 were recaptured (Table 1).

The overall ratio of dives per animal sighted (Part I) was 1.93:1 while the ratio for dives per animal tagged or recaptured was 4.08:1 (Table 3).

A full description of effort per month per site (Parts I & II) and octopuses sighted and captured per month per site (Parts I & II) is found in Appendix III.

The overall ratio of dives per animal sighted during Part II of the study (Table 2) was 0.99:1. A ratio of dives per animal tagged or recaptured was not calculated as animals were not being routinely captured during Part II of the study.

The ratio of dives per animal sighted for all sites (Parts I and II) was 1.66:1 (Table 3).

TABLE 1. Summary of Effort and Octopuses Sighted/Captured.

	SITE 1	SITE 2	SITE 3	TOTAL
DIVES (PART I)	174	212	230	616
DIVES (PART II)	24	74	28	126
DIVES (TOTAL)	198	286	258	742
OCTOPUSES (PART I)				
SIGHTED	26	177	117	320
CAPTURED/RECAPTURED	15	70	66	151
OCTOPUSES (PART II)				
SIGHTED	17	93	17	127
CAPTURED/RECAPTURED	0	10	1	11
OCTOPUSES (TOTAL)				
SIGHTED	43	270	134	447
CAPTURED/RECAPTURED	15	80	67	162

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

TABLE 2. Octopuses Sighted/Captured per Month with Uniform Effort.

MONTH	SITE 1 S	SITE 1 C	SITE 2 S	SITE 2 C	SITE 3 S	SITE 3 C	TOTAL S	TOTAL C
JANUARY	1	0	10	4	6	1	17	5
FEBRUARY	0	7	18	1	13	7	31	15
MARCH	0	4	16	7	14	4	30	15
APRIL	0	0	15	4	5	7	20	11
MAY	0	1	8	6	1	5	9	12
JUNE	1	2	4	8	3	6	8	16
JULY	1	1	10	15	5	4	16	20
AUGUST	2	2	7	5	4	10	13	17
SEPTEMBER	2	2	5	5	3	4	10	11
OCTOBER	1	0	9	4	2	5	12	9
NOVEMBER	1	0	7	3	3	9	11	12
DECEMBER	0	3	11	9	3	6	14	18
TOTAL	9	22	120	71	62	68	191	161

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

S = OCTOPUSES SIGHTED BUT NOT CAPTURED.
C = OCTOPUSES CAPTURED OR RECAPTURED.

TABLE 3. Ratio of Effort per Octopus.

SITE	TANNER ROCK S	TANNER ROCK C	TOZIER ROCK S	TOZIER ROCK C	SAXE POINT S	SAXE POINT C	AVERAGE S	AVERAGE C
PART I	6.69:1	11.60:1	1.20:1	3.03:1	1.97:1	3.48:1	1.93:1	4.08:1
PART II	1.41:1		0.80:1		1.65:1		0.99:1	
TOTAL*	4.60:1		1.06:1		1.93:1		1.66:1	

* = PART I (SIGHTED) AND PART II (SIGHTED) COMBINED.
S = OCTOPUSES SIGHTED BUT NOT CAPTURED.
C = OCTOPUSES CAPTURED OR RECAPTURED.

Captures:

Of the 15 octopuses tagged or recaptured at Tanner Rock during Part I of the study, 12 animals were tagged and of those, 1 animal was recaptured once and another twice for a total of 3 recaptures. This resulted in a recapture rate of 16.6% (Table 4).

Tozier Rock had 70 octopuses tagged or recaptured during Part I of the study and 41 of those animals were tagged. Six animals were recaptured once, 5 animals twice, 1 animal three times, 1 animal four times and 2 animals were recaptured five times for a total of 33 recaptures. This resulted in a recapture rate of 36.59% (Table 4).

Of the 66 octopuses tagged or recaptured at Saxe Point during Part I of the study 45 were tagged. There were 9 animals recaptured once, 2 recaptured twice, 1 animal three times and 1 animal six times for a total of 22 recaptures. This resulted in a recapture rate of 28.89% (Table 4).

In total, 98 octopuses were tagged and released during Part I of the study. Thirty animals were recaptured one or more times (a total of 58 recaptures) to produce a 30.61% recapture rate (Table 4).

DISTRIBUTION OF ANIMALS

To examine the hypothesis (Ho) that there was no difference between the numbers of animals sighted or tagged/recaptured within each site during each of the three years (1981-1984) of the tagging study a series of Chi-square tests were run. The results were nonsignificant at the $\alpha = .05$ level and the hypothesis was accepted (Site 1 $\lambda^2 = 2.56875$, P =

TABLE 4. Octopuses Tagged and Recaptured (PART I: July 1, 1981 - June 30, 1984).

SITE	NUMBER TAGGED	NUMBER OF RECAPTURES 1	2	3	4	5	6	TOTAL RECAPTURES	% ANIMAL RECAPTURE
1	12	1	1					3	16.67
2	41	6	5	1	1	2		33	36.59
3	45	9	2	1			1	22	28.89
TOTAL	98	16	8	2	1	2	1	58	30.61
TOTAL CAPTURES (animals + recaptures)								156	

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

0.2768, D.F. = 2; Site 2 λ^2 = 3.04291, P = 0.2185, D.F. = 2; Site 3 λ^2 = 1.05218, P = 0.5909, D.F. = 2).

The hypothesis (Ho) that there was no difference between the numbers of animals sighted or tagged/recaptured between sites over the study period was tested using Chi-square. A significant difference was found at the α = .05 level (λ^2 = 16.11091, P = 0.0003, D.F. = 2) and Ho was not accepted.

In order to determine where the differences were a series of Chi-square tests were run.

A comparison of Tozier Rock (Table 5B) and Saxe Point (Table 5C) (both sites of similar area) again showed a significant difference at the α = .05 level (λ^2 = 6.90655, P = 0.0086, D.F. = 1).

When, however, a test using only tagged or recaptured animals was conducted using data from Tozier Rock and Saxe Point there were no differences between the numbers of animals at each site (λ^2 = 0.00000, P = 1.000, D.F. = 1).

The major difference between the animals found at Tozier Rock and Saxe Point appears to be the large number of very small (< 0.5 kg) octopuses found on Tozier Rock. Fifty-one animals found on Tozier Rock were less than 0.5 kg in body weight. This represents 26.6% of all animals sighted at Tozier Rock and 42.3% of all animals weighed at Tozier Rock. In contrast, only 15 animals weighing less than 0.5 kg body weight were found at Saxe Point. Those animals were 11.5% of all the animals sighted and 17.9% of the weighed animals at Saxe Point.

Tanner Rock (Table 5A) appeared to have larger octopuses than the other two sites.

TABLE 5A. Octopus Body Weight per Month (Tanner Rock). PART I: July 1, 1981 - June 30, 1984.

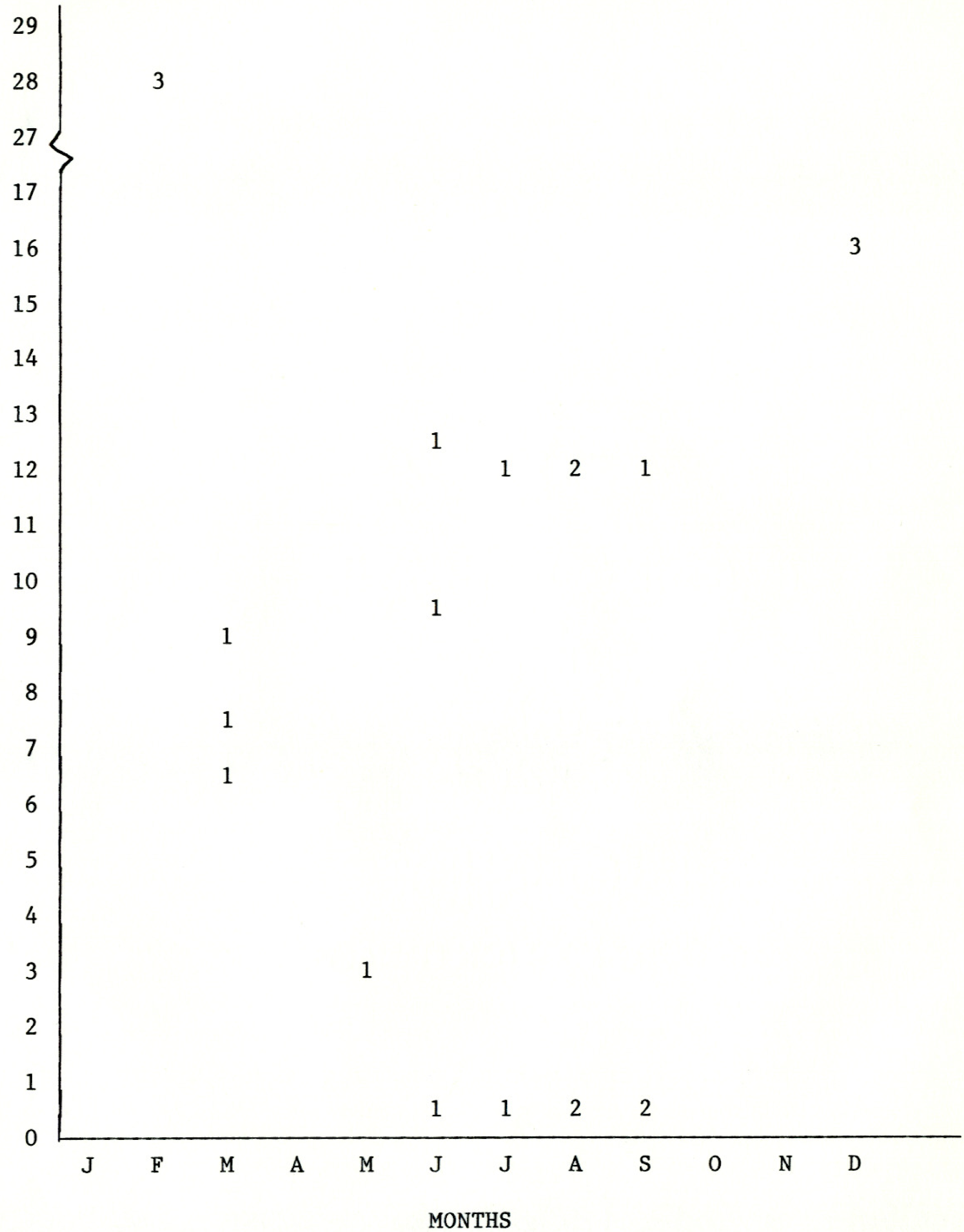

TABLE 5B. Octopus Body Weight per Month (Tozier Rock). PART I: July 1, 1981 - June 30, 1984.

	J	F	M	A	M	J	J	A	S	O	N	D
20									1			
19												
18												
17												
16												
15							1					4
			1				2					
14												
										1		
13			1						1			
12											1	1
11												
						1	1	1				
10					1		1		1			
						2						
9			1	1		1	7	2			1	
					1	1						
8												
7					1							
			1			1	2					
6	1	1	2				1					
			1	1		1						
5			1			1						
	1			1								1
4			1									1
										1		
3	2									1		2
2												
1									1			
	5	7	10	6	4	4	1	1	2	5	3	3
0												

MONTHS

TABLE 5C. Octopus Body Weight per Month (Saxe Point). PART I: July 1, 1981 - June 30, 1984.

OCTOPUS BODY WEIGHT IN KILOGRAMS	J	F	M	A	M	J	J	A	S	O	N	D
25						1						
24				1								
23			2									
22												
21												
20					1							
							1					
19												
18												
17												
16						1					2	
15					1							
				1					1			
14						1			1			1
13						1			1	1		1
12				2		1		2			1	
										1		
11				1	1	1	1				1	1
			1									
10						1						
9		4		1			1	1		1		
									1			
8				2			1	2				
			1									
7							1				2	2
			1									
6							1					
		4	1						1	1		
5	1							1			2	
												1
4					1						1	
			1					1		1		
3												
								2				
2												
1												
		7	2	2		1	2					1
0												

MONTHS

SEX RATIOS

To test the hypothesis (Ho) that there were no differences in the ratio of male and female octopuses within each site over the project period a series of Chi-square tests were run. Only an animal's first capture was included to eliminate bias due to any potential differences in behaviour. All octopuses captured were large enough to sex.

Both Tanner Rock and Saxe Point animals were found to have no significant differences at the $\alpha = .05$ level ($\lambda^2 = 1.23144$, P = 0.5403, D.F. = 2 and $\lambda^2 = 1.77186$, P = 0.4123, D.F. = 2 respectively) and Ho was accepted for those sites (Table 6).

Tozier Rock, however, was found to have significantly different sex ratios at the $\alpha = .05$ level ($\lambda^2 = 6.50744$, P = 0.0386, D.F. = 2). This difference in the sex ratio resulted from the reversal of sex ratios in year two of the study (Table 6).

A Chi-square test was run to examine the hypothesis (Ho) that there was no significant difference in the octopus sex ratio between sites. The result was nonsignificant at the $\alpha = .05$ level ($\lambda^2 = 0.84687$, P = 0.6548, D.F. = 2) and the hypothesis was accepted.

WEIGHT AND GROWTH RATE

An examination of the weights of all animals captured and recaptured (Table 7) showed continuous recruitment throughout the year. Recruitment peaked in February (14 animals) and March (11 animals) with the appearance of small octopuses weighing between 100 and 500 grams to reach pre-adult weights of 14-16 kg at which point most of the octopuses of that size disappeared from the study sites.

TABLE 6. Distribution of Sexes per Site (PART I: July 1, 1981 - June 30, 1984).

	SITE	TANNER ROCK		TOZIER ROCK		SAXE POINT		TOTAL	
YEAR	SEX	M	F	M	F	M	F	M	F
1		3	4	2	4	4	4	9	12
2		1	1	10	3	6	13	17	17
3		4	1	7	13	7	7	18	21
TOTAL		8	6	19	21	17	23	44	50
%		57.1	42.9	47.5	52.5	42.5	57.5	46.8	53.2

YEAR 1 = JULY 1, 1981 - JUNE 30, 1982
YEAR 2 = JULY 1, 1982 - JUNE 30, 1983
YEAR 3 = JULY 1, 1983 - JUNE 30, 1984

M = MALE
F = FEMALE

TABLE 7. Octopus Body Weight per Month (All Sites). PART I: July 1, 1981 - June 30, 1984.

OCTOPUS BODY WEIGHT IN KILOGRAMS	J	F	M	A	M	J	J	A	S	O	N	D
28		3										
27												
26												
25						1						
24				1								
23			2									
22												
21												
20					1				1			
							1					
19												
18												
17												
16						1					2	3
15					1		1					4
				1	1		2		1			
14						1			1			1
										1		
13					1	1			2	1		1
						1						
12				2		1	1	5	1		2	1
										1		
11				1	1	1	1				1	1
			1			1	1	1				
10					1	1	1		1			
						3						
9		4	2	2		1	8	3		1	1	
					1	1			1			
8				2			1	2				
			2									
7					1		1				2	2
			3			1	3					
6	1		2				1					
			2	1		1			1	1		
5	1	1	1			1		1			2	
		4		1								2
4	1		1		1						1	1
			1					1		2		
3	2				1					1		2
								2				
2												
1									1			
0	5	14	11	8	4	6	4	3	4	5	3	4

MONTHS

Only one large female (19.5 kg) and nine large males (20-28 kg) were captured and none of these animals were ever recaptured. Table 7 shows the occurrence of large octopuses to be scattered throughout the year with the peak occurrences during February (3 animals) and March (2 animals).

From recapture data (Table 8) a growth rate was obtained. A linear regression of the type y = mx + b was fitted to the plot of WTC/WT vs. DBC where:

WTC = weight change from previous capture

WT = initial weight

DBC = days between capture

A correlation examining the relationships between WTC/WT and DBC was highly significant (correlation coefficient 0.85229, P = 0.0001, N = 51).

The regression line (Figure 5) accounts for approximately 73% of the error (R-SQUARE = 0.7264) with an intercept at -0.0168 and a growth rate of 0.91% increase in body weight per days (D.F. Model = 1, ERROR = 49, P = 0.0001) between the weights of 2 1/2 and 16 kg.

It was realized that the one outlying data point (WTC = 8 kg, DBC = 202) would influence the slope of the regression line and so a second regression was done with that one data point excluded (Figure 6).

The difference in the slopes (0.0091 and 0.0056) was not considered significant as they fell within 2 standard errors.

Because there was as much confidence in the outlying point as there was in any other data point it was included and it is noted that the slope of the regression line has changed only slightly.

TABLE 8. Octopus Recapture Data and Growth Rate Calculation (PART I: July 1, 1981 - June 30, 1984).

TAG #	ORIGINAL WEIGHT Kg	RECAPTURE WEIGHT Kg	DAYS BETWEEN CAPTURE	WTC	MONTH	% BODY WEIGHT/DAY
207	13	13	36	0	NOV	0
219	5	6	14	1	JULY	1.43
219	6	9	31	3	AUG	1.61
219	9	13	31	4	SEPT	1.43
219	13	14	30	1	OCT	0.26
229	11	11	32	0	SEPT	0
229	11	16	81	5	OCT-JAN	0.56
231	10	12	42	2	SEPT-OCT	0.48
231	12	16	49	4	NOV-DEC	0.68
244	11	14	69	3	APR-JUNE	0.40
000	9	12	36	3	JULY-AUG	0.93
002	6.5	9	21	2.5	JULY-AUG	1.83
003	9	11	21	2	JULY-AUG	1.06
003	11	12.5	13	1.5	AUG	1.05
008	5	5.5	9	0.5	SEPT	1.11
009	3.5	5	94	1.5	SEPT-DEC	0.46
012	5.5	7	64	1.5	OCT-DEC	0.43
016	7	7	36	0	NOV-DEC	0
016	7	9	54	2	DEC-FEB	0.53
016	9	10.5	22	1.5	FEB-MAR	0.76
016	10.5	12	19	1.5	MAR	0.75
016	12	12	8	0	APR	0
020	5	5.5	34	0.5	JAN-FEB	0.29
020	5.5	6.5	22	1	FEB-MAR	0.83
022	7.5	8	22	0.5	MAR-APRIL	0.30
023	14.5	15	30	0.5	APR-MAY	0.11
021	3.5	11.5	202	8	MAR-SEPT	1.13
027	9.5	12	35	2.5	JUNE-JULY	0.75

TABLE 8. Continued.

TAG #	ORIGINAL WEIGHT Kg	RECAPTURE WEIGHT Kg	DAYS BETWEEN CAPTURE	WTC	MONTH	% BODY WEIGHT/DAY
034	10	10.5	8	0.5	JULY	0.63
034	10.5	10.5	28	0	AUG	0
038	7	8	21	1	AUG	0.68
039	2.5	3.5	57	1	AUG-OCT	0.70
039	3.5	5	27	1.5	OCT-NOV	1.59
042	3	3.5	28	0.5	OCT-NOV	0.60
042	3.5	6	69	2.5	NOV-JAN	1.04
042	6	9	77	3	JAN-MAR	0.65
042	9	13	49	4	MAR-MAY	0.91
042	13	14.5	14	1.5	MAY	0.82
044	5	5	8	0	NOV	0
046	4.5	6	63	1.5	DEC-FEB	0.53
052	3	5	48	2	JAN-MAR	1.39
052	5	5.5	8	0.5	MAR	1.25
052	5.5	5.5	20	0	MAR-APRIL	0
052	5.5	10	86	4.5	APR-JUNE	0.95
058	6	6.5	7	0.5	MAR	1.19
062	8	9	7	1	APR	1.79
062	9	10	48	1	APR-JUNE	0.23
063	7	8.5	14	1.5	MAY	1.53
063	8.5	10.5	7	2	MAY	3.36
068	5	6.5	15	1.5	JUNE	2.00
070	8.5	9	15	0.5	JUNE	0.39
AVERAGE $\overline{X}$	7.6	9.3	36.9	1.7		0.81
VAR.	3.1	3.4	32.7	1.6		0.65

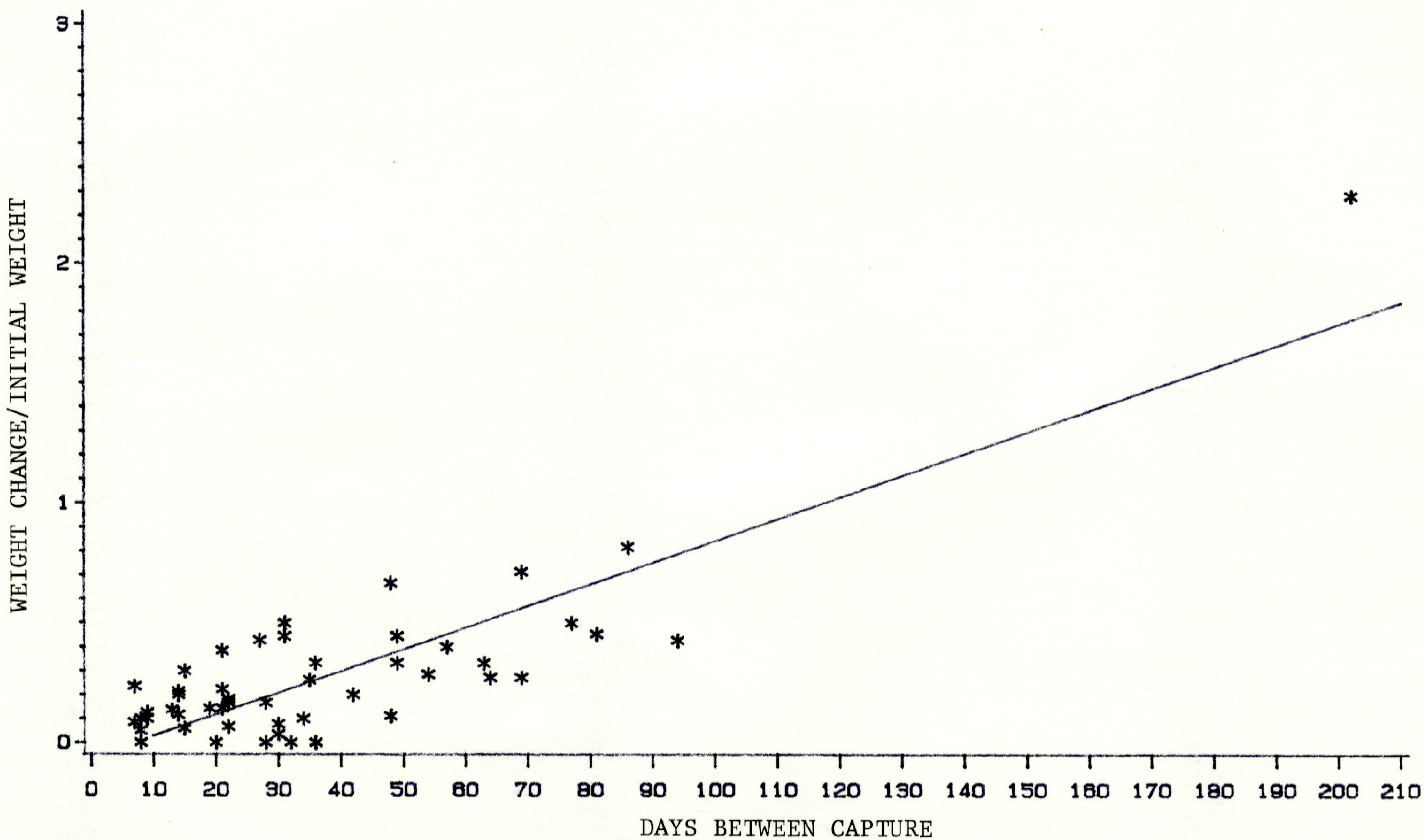

FIGURE 5. Plot and Linear Regression of Weight Change/Initial Weight vs. Days Between Capture, For All Recaptures.

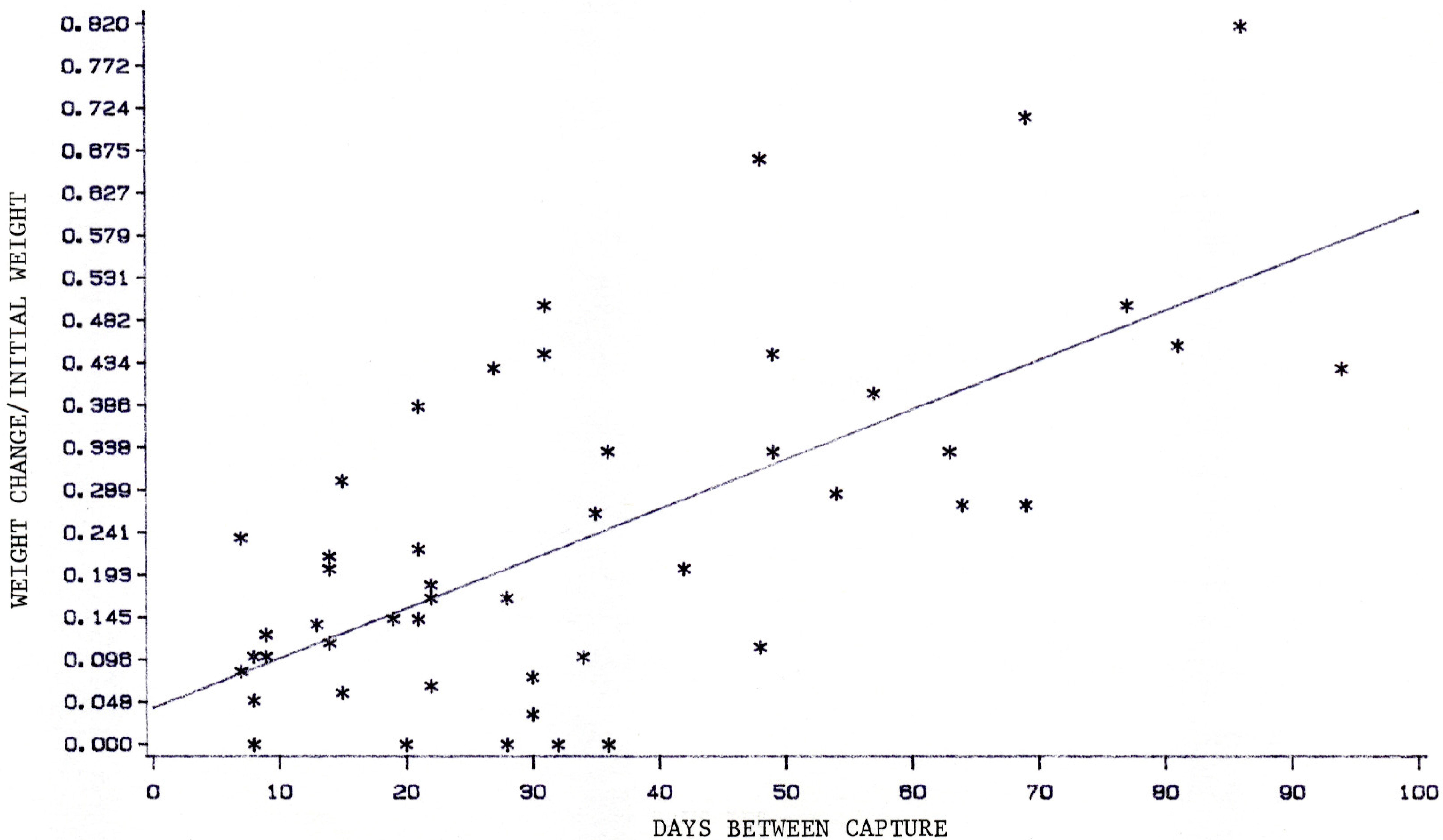

FIGURE 6. Plot and Linear Regression of Weight Change/Initial Weight vs. Days Between Capture Excluding Data Point 8,202.

Using data from the literature and the present study a growth model was constructed (Figure 7).

Assuming a hatching weight of 21.65 mg (Hartwick, 1986) and a settling weight of 3 grams (Kanamaru & Yamashita, 1967) seven months later (Mottet, 1975) a growth rate of 2.34% increase in body weight per day was calculated.

From settling to approximately 250 grams spans a nine month period and requires a growth rate of 1.63% increase in body weight per day.

The growth rate found in the present study indicated a 0.91% increase in body weight per day for octopuses between 2.5 kg and 16 kg. It is recognized that there is no evidence to generate a growth rate for the period between 250 grams and 2.5 kg. It was felt, however, that it would not be unreasonable to use the 0.91% per day figure to approximate that period of growth. It is recognized that the true growth rate value may be higher and that a slightly shorter growth period would result.

Figure 7 indicates that it would take an average *Octopus dofleini* 31 months to reach a weight of 16 kg from hatching.

The line in Figure 7 was compared to a power function of the type $y = ax^b$. The R-SQUARE value was 0.6951 where $a = 9.585 \times 10^{-6}$ and $b = 3.838$.

The line in Figure 7 was also compared to the exponential function of the type $y = ae^{bx}$. The R-SQUARE value was 0.6498 where $a = 3.305 \times 10^{-4}$ and $b = 0.3758$.

A breakdown of monthly growth rates using recapture data indicated a generally slower rate of growth in the winter and a more rapid rate of growth in the summer (Table 9).

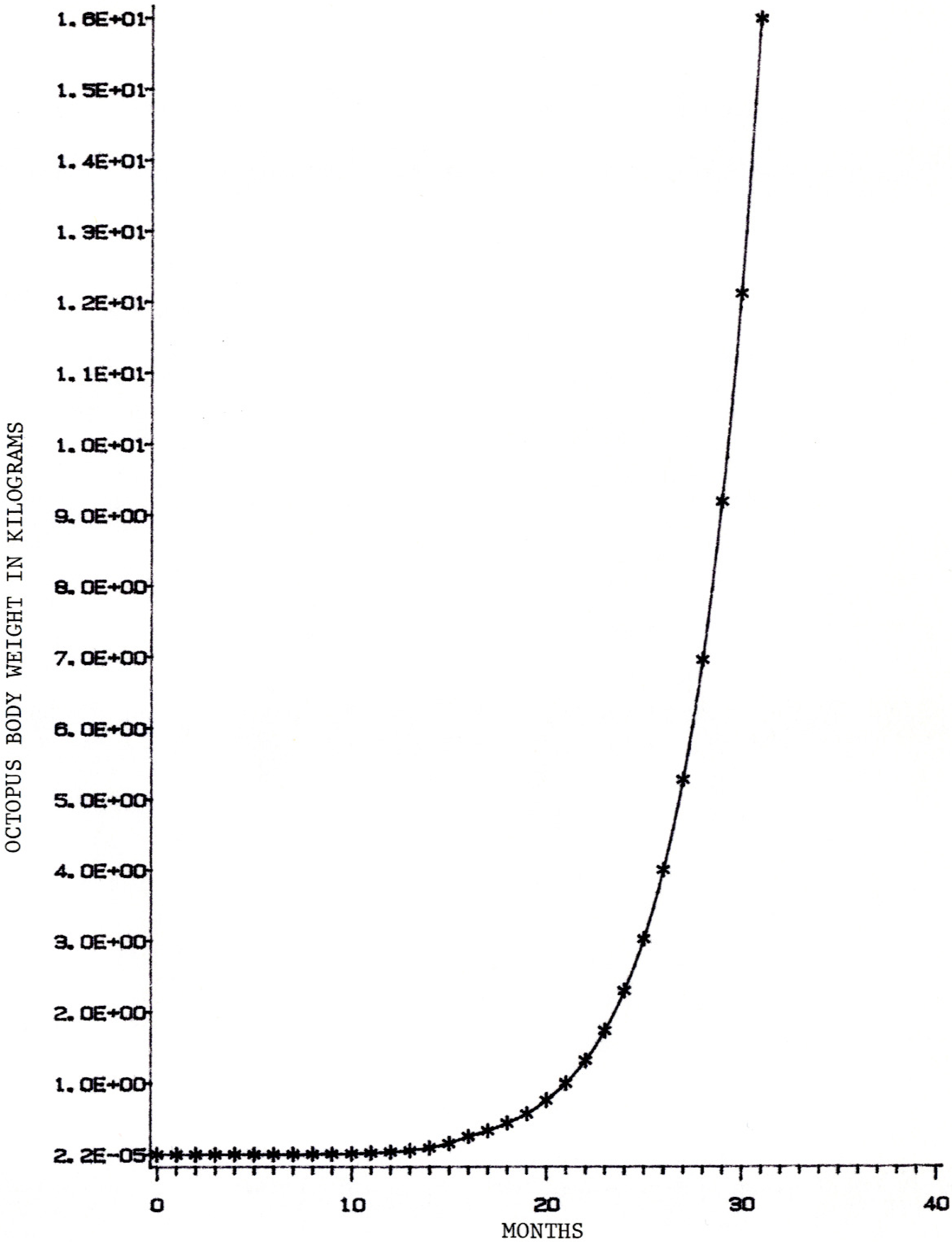

FIGURE 7. Growth Model for _Octopus dofleini_

TABLE 9: Average Growth per Month Expressed in Percent Body Weight Increase Per Day.

MONTH	$\overline{X}$	VAR	S.D.
JANUARY	0.71	0.12	0.35
FEBRUARY	0.71	0.10	0.32
MARCH	0.83	0.16	0.40
APRIL	0.58	0.31	0.56
MAY	1.05	0.85	0.92
JUNE	0.84	0.32	0.56
JULY	1.11	0.15	0.38
AUGUST	1.00	0.25	0.50
SEPTEMBER	0.76	0.21	0.46
OCTOBER	0.64	0.15	0.38
NOVEMBER	0.60	0.22	0.47
DECEMBER	0.53	0.07	0.27
AVERAGE	0.78		

It was noted that the calculated average growth rate from Table 9 (0.78% increase in body weight per day) was between the values obtained from Figure 5 (0.91% increase in body weight per day) and Figure 6 (0.57% increase in body weight per day). The significance of the calculated value will be explained in the discussion section of this thesis.

To test the hypothesis (Ho) that there were no differences between the average weights of the octopuses found at each site a oneway analysis of variance was calculated. The results showed that animals from Tanner Rock and Saxe Point were similar but both were significantly different from the animals found on Tozier Rock (α = 0.05, F = 12.5467, P = 0.0000, D.F. Between = 2, Among = 225). The hypothesis was not accepted.

To further examine the differences between the weights of octopuses at each site a second ANOVA was run with the data for octopuses weighing less than 1 kg removed. Again there proved to be a significant difference between the average body weights found at the three sites (α = .05, F = 7.9951, P = 0.0005, D.F. Between = 2, Within = 154). This analysis, however, showed that the animals from Tanner Rock were now different from those found at Tozier Rock and Saxe Point.

A third ANOVA including only values for octopuses weighing more than 3.00 kg and less than 18 kg (i.e. only assumed 3 year old animals) showed the animals of all three sites to be similar at the α = .05 level (F = 2.447, P = 0.0901, D.F. Between = 2, Within = 144).

An analysis of variance using only data from male octopuses showed the animals of Tanner Rock to be significantly larger (α = .05, F =

4.0376, P = 0.0225, D.F. Between = 2, Within = 62) than the males of Tozier Rock or Saxe Point.

All three sites showed similar average weights for the female octopuses (α = .05, F = 1.2203, P = 0.30, D.F. Between = 2, Within = 90).

A correlation between growth rate and water temperature was nonsignificant (r = .1389, P = .198, N = 39).

NEAREST NEIGHBOUR

A previous study at Tanner Rock and Tozier Rock (Mather et al., 1985) had shown assumed three year old animals to have home ranges of approximately 250 square meters with large overlaps in area.

To test the hypothesis (Ho) that there was no relationship between nearest neighbour distance and octopus weight, a correlation using only data where nearest neighbour distance was less than 20 meters, was run. The results were nonsignificant (α = .05, r = .1676, P = .095, N = 63) and the hypothesis was accepted.

A correlation between nearest neighbour distance and sex proved nonsignificant (r = -.0563, P = .394, N = 25) as did a correlation between nearest neighbour and water temperature (r = -.0344, P = .384, N = 76).

DEN VOLUME

The den sites on Tanner Rock had estimated volumes of 0.002 cubic meters to 0.864 cubic meters (Table 10). Of the octopuses sighted on Tanner Rock, 87.3% were found in dens and 12.7% were found in the open. The dens with the largest and smallest estimated volumes were the most frequently used. The largest den was the location of 16.6% of the sightings and the smallest den was the location of 15.1% of the sightings.

Tozier Rock had dens with estimated volumes ranging from 0.005 cubic meters to 0.720 cubic meters (Table 10). On Tozier Rock, 98.5% of the octopuses sighted were in dens and only 1.5% were sighted in the open. The den with the second largest estimated volumes (0.546 cubic meters) was the location of 10.9% of the octopuses sighted and was the only den to have more than 10% of the sightings.

The den sites on Saxe Point had estimated volumes of 0.011 cubic meters to 0.450 cubic meters (Table 10). Of the octopuses sighted on Saxe Point, 94.9% were found in dens and 5.1% were sighted in the open. One den (estimated volume = 0.035 cubic meters) was the location of 22.8% of the sightings. Two larger dens (estimated volume = 0.081 cubic meters and 0.083 cubic meters) were the location of 12.3% and 10.9% of the sightings.

A correlation examined the hypothesis (Ho) that there was no relationship between octopus body weight and den volume index. The results were highly significant ($r = .4262$, $P = .000$, $N = 215$) and the hypothesis was not accepted.

DEN TYPE

At Tanner Rock, 35.7% of the octopuses sighted were in dens formed by natural splits in the rock while 38% of the octopuses sighted were located in dens which had been excavated (Table 11).

TABLE 10. Estimated Den Volume by Site.

SITE 1: TANNER ROCK

DEN NUMBER	VOLUME (cubic meters)	DEN NUMBER	VOLUME (cubic meters)
1	0.864	8	0.056
2	0.070	9	0.413
3	0.108	10	0.770
4	0.024	11	0.160
5	0.002	12	0.640
6	0.300	13	0.180
7	0.240		

SITE 2: TOZIER ROCK

DEN NUMBER	VOLUME (cubic meters)	DEN NUMBER	VOLUME (cubic meters)
1	0.088	16	0.108
2	0.144	17	0.144
3	0.060	18	0.168
4	0.005	19	0.036
5	0.054	20	0.026
6	0.480	21	0.033
7	0.083	22	0.096
8	0.054	23	0.116
9	0.007	24	0.083
10	0.546	25	0.120
11	0.306	26	0.378
12	0.019	27	0.036
13	0.176	28	0.020
14	0.008	29	0.138
15	0.720	30	0.047

SITE 1: SAXE POINT

DEN NUMBER	VOLUME (cubic meters)	DEN NUMBER	VOLUME (cubic meters)
1	0.095	10	0.083
2	0.143	11	0.078
3	0.132	12	no data
4	0.030	13	0.076
5	0.011	14	0.080
6	0.120	15	0.189
7	0.035	16	0.432
8	0.081	17	0.048
9	0.042	18	0.450

The majority of octopuses sighted at Tozier Rock were located in dens where some excavating had been done (75.6%) while 22.8% of the octopuses sighted were located in natural splits in the rock (Table 11).

At Saxe Point, 23.3% of the octopuses sighted were in excavated dens. 21.1% of the octopuses were sighted in dens formed by natural splits in the rock and 24.6% were sighted in dens consisting of natural cavities in rock rubble (Table 11).

DEN SURROUNDINGS

The majority of dens at Tanner Rock were surrounded by rock (20.6%), a combination of sand around a monument rock (18.1%) or at a cliff (15.1%) (Table 12).

At Tozier Rock the largest number of dens were located at the base of a cliff surrounded by sand (36.4%). The second greatest number of dens were surrounded by clusters of rocks (18.6%) (Table 12).

Saxe Point had a greater diversity of den surroundings with 27.5% of the dens being surrounded by rock and rubble. Of the dens 17.3% were surrounded by rock and rubble at the base of a monument rock and 11.9% of the dens had surroundings of sand, rubble and rock (Table 12).

NUMBER OF DEN EXITS

The dens on Tanner Rock had from one to three exits. Dens with multiple exits were involved in 56% of the sightings while dens with only one exit were responsible for the other 44% of the octopuses sighted (Table 13).

TABLE 11. Den Types by Site.

SITE 1: TANNER ROCK

DEN #	TYPE CODE	DEN #	TYPE CODE
1	2	7	9
2	6	8	7
3	1	9	4
4	7	10	2
5	2	11	7
6	7	12	4
		13	4

SITE 2: TOZIER ROCK

DEN #	TYPE CODE	DEN #	TYPE CODE
1	1	16	1
2	1	17	1
3	6	18	1
4	5	19	1
5	6	20	2
6	5	21	2
7	1	22	2
8	6	23	5
9	1	24	1
10	1	25	1
11	1	26	1
12	2	27	3
13	1	28	2
14	4	29	5
15	2	30	1

SITE 3: SAXE POINT

DEN #	TYPE CODE	DEN #	TYPE CODE
1	1	10	4
2	1	11	4
3	1	12	1
4	3	13	1
5	2	14	2
6	2	15	4
7	3	16	8
8	4	17	4
9	2	18	2

TYPE CODE

1 = Excavated
2 = Split
3 = Rubble
4 = Other
5 = Excavated, Split
6 = Excavated, Rubble
7 = Excavated, Other
8 = Split, Rubble
9 = Split, Other

TABLE 12. Den Surroundings by Site.

DEN #	SURROUNDINGS CODE	DEN #	SURROUNDINGS CODE
SITE 1: TANNER ROCK			
1	05	7	05
2	16	8	16
3	08	9	17
4	16	10	05
5	03	11	04
6	11	12	02
		13	20
SITE 2: TOZIER ROCK			
1	16	16	18
2	04	17	18
3	04	18	10
4	03	19	16
5	05	20	08
6	08	21	08
7	02	22	08
8	05	23	08
9	03	24	09
10	05	25	09
11	17	26	09
12	05	27	02
13	08	28	02
14	09	29	09
15	16	30	08
SITE 3: SAXE POINT			
1	02	10	12
2	06	11	12
3	04	12	21
4	19	13	19
5	14	14	22
6	02	15	20
7	13	16	23
8	15	17	12
9	13	18	12

SURROUNDINGS CODE
01 = Sand
02 = Monument Rock
03 = Cliff Face
04 = Rubble
05 = Rock
06 = Mud/Shell
07 = Cliff Face, Rock
08 = Sand, Cliff Face
09 = Sand, Rock
10 = Monument Rock, Rock
11 = Sand, Rubble
12 = Monument Rock, Rubble, Rock
13 = Rubble, Rock
14 = Cliff Face, Rubble
15 = Sand, Rubble, Rock
16 = Sand, Monument Rock
17 = Sand, Monument Rock, Rubble
18 = Sand, Monument Rock, Cliff Face
19 = Rubble, Mud/Shell
20 = Monument Rock, Rubble
21 = Monument Rock, Rubble, Rock, Mud/Shell
22 = Cliff Face, Mud/Shell
23 = Sand, Cliff Face, Rubble, Rock

On Tozier Rock, 53.2% of the octopuses sighted in dens were found in dens with multiple exits. Dens with only one exit were involved in 46.8% of the octopuses sighted. Tozier Rock had dens with from one to five exits (Table 13).

The majority of octopuses sighted in dens on Saxe Point were found in dens with multiple exits (79.4%). Dens with one exit were involved in only 20.6% of the octopus sightings. The dens on Saxe Point had exits ranging from one to seven in number (Table 13).

The data from octopuses found in the open was not included in the calculations.

DEN USAGE

The most frequently used of the thirteen dens at Tanner Rock was Den 1. It was the location of 20% of the octopuses sighted in dens. Den 5 was the location of 16% of the octopuses sighted and Dens 6, 8 and 12 were the sites of 12% of the animal sightings respectively (Table 14).

Den 1 was located in a natural split in the rock at a mean depth of 8.9 meters. It had 2 exits, an estimated volume of 0.864 cubic meters and was surrounded by rock.

Den 3 was a small natural split in the face of a cliff. It had only one exit, an estimated volume of 0.002 cubic meters and was located at a mean depth of 13.5 meters.

Of the thirteen dens at Tanner Rock, seven dens had only one octopus sighted in them. Those dens were Dens 2, 3, 4, 7, 9, 10 and 11.

At Tozier Rock the most frequently occupied of the thirty dens was Den 10. It had the largest estimated volume of a complex of dens (Dens

TABLE 13. Number of Exits per Den by Site.

SITE 1: TANNER ROCK

DEN #	NUMBER OF EXITS	DEN #	NUMBER OF EXITS
1	2	7	2
2	2	8	2
3	1	9	3
4	1	10	1
5	1	11	3
6	1	12	2
		13	2

SITE 2: TOZIER ROCK

DEN #	NUMBER OF EXITS	DEN #	NUMBER OF EXITS
1	3	16	1
2	5	17	3
3	3	18	3
4	1	19	2
5	2	20	1
6	3	21	1
7	2	22	1
8	2	23	1
9	3	24	3
10	1	25	2
11	3	26	1
12	2	27	1
13	1	28	1
14	1	29	3
15	2	30	1

SITE 3: SAXE POINT

DEN #	NUMBER OF EXITS	DEN #	NUMBER OF EXITS
1	2	10	2
2	1	11	1
3	1	12	1
4	2	13	4
5	3	14	1
6	2	15	3
7	8	16	2
8	3	17	2
9	1	18	7

8, 9 and 10) that were very close to each other and were suspected to be interconnected. Of the octopuses sighted in dens on Tozier Rock, 11.3% were located in Den 10 (Table 16).

Den 10 had one exit that was seen but was suspected of having at least one other. The den was an excavation under a rock bluff. Den 10 had an estimated volume of 0.546 cubic meters and was located in 7.8 meters of water.

Dens 20 and 22 were the locations of 8.1% of the octopus sightings each. Both dens were characterized by having only one exit and being found in natural splits in the rock. Den 20 had an estimated volume of 0.026 cubic meters and was located in 7.9 meters of water while Den 22 had an estimated volume of 0.096 cubic meters and was found in 9.4 meters of water.

Of the thirty dens at Tozier Rock there were five dens where only one octopus was sighted. Those were Dens 2, 3, 15, 17 and 27.

Of the 18 dens located at Saxe Point the most frequent sightings of octopuses were at Den 7 (23.1%) (Table 14).

Den 7 was located at a depth of 4.6 meters of water in a den in rubble and surrounded by rock and rubble. The den had an estimated volume of 0.035 cubic meters and had two exits.

Only two dens, besides Den 7, were involved in more than 10% of the octopus sightings at Saxe Point. Den 8 was the location of 12% of the octopus sightings and Den 10 was the location of 11.1% of the octopus sightings.

Of the 18 dens located at Saxe Point only Dens 17 and 18 were the locations where octopuses were sighted just once.

TABLE 14. Octopus Sightings per Den per Site (Weighted). PART I: July 1, 1981 - June 30, 1984.

SITE 1: TANNER ROCK

DEN #	NUMBER OF SIGHTINGS	%	DEN #	NUMBER OF SIGHTINGS	%
1	5	20	7	1	4
2	1	4	8	3	12
3	1	4	9	1	4
4	1	4	10	1	4
5	4	16	11	1	4
6	3	12	12	3	12
			13		

SITE 2: TOZIER ROCK

DEN #	NUMBER OF SIGHTINGS	%	DEN #	NUMBER OF SIGHTINGS	%
1	5	2.7	16		
2	1	0.5	17	1	0.5
3	1	0.5	18	10	5.4
4	3	1.6	19	8	4.3
5	3	1.6	20	15	8.1
6	12	6.5	21	9	4.8
7	10	5.4	22	15	8.1
8	6	3.2	23	3	1.6
9	12	6.5	24	2	1.1
10	21	11.3	25	14	7.5
11	8	4.3	26	6	3.2
12	3	1.6	27	1	0.5
13	10	5.4	28		
14			29	2	1.1
15	1	0.5	30	4	2.2

SITE 3: SAXE POINT

DEN #	NUMBER OF SIGHTINGS	%	DEN #	NUMBER OF SIGHTINGS	%
1	10	9.26	10	12	11.1
2	4	3.7	11	3	2.8
3	3	2.8	12	4	3.7
4	3	2.8	13	6	5.6
5	7	6.48	14	3	2.8
6	3	2.8	15		
7	25	23.1	16	1	0.9
8	13	12.0	17	1	0.9
9	6	5.6	18	4	3.7

N.B.--Some values missing due to weighting.

During the second part of the study, while the physical data of the dens was being collected, the sightings of octopuses were recorded. That data, unweighted for effort, showed Den 8 to be the location of 16.2% of the sightings on Tanner Rock. Dens 11 and 12 remained the only two dens on Tanner Rock to have just one octopus sighted in them.

At Tozier Rock, Den 10 continued to be the location of the largest number of octopus sightings (11.3%). Dens 15, 16 and 21 had only one sighting each.

Den 7, again, was the location of the greatest number of animal sightings (19.6%) at Saxe Point. Dens 17 and 18 did not have any octopuses sighted in them during Part II of the study and remained with only one sighting each.

A full description of the physical characteristics of the dens can be found in Appendix IV.

When a captured octopus was released it was returned to the den from which it was taken. In several cases the newly released octopus was found in the open and moving away from its den within half an hour of release.

It was felt that the fact an animal had been forced from a den may influence how satisfactory that den would be as a shelter again.

An examination of the data from octopuses that had been recaptured showed that the two animals recaptured a total of three times at Tanner Rock were always in a different den on recapture (Table 15).

There were 15 octopuses recaptured a total of 33 times at Tozier Rock. Thirteen recaptures (39.4%) came from dens in which the previous capture had occurred while 20 recaptures (60.6%) came from different dens (Table 15).

Saxe Point was the location of 22 recaptures involving 13 octopuses. Ten recaptures (45.5%) came from the same den as the animals' previous capture while twelve recaptures (54.5%) came from different dens (Table 15).

In total, thirty octopuses were recaptured a total of 58 times. Thirty-six of the recaptures (61%) came from dens different than the location of the previous capture and 23 of the recaptures (39%) came from the same den as the previous capture (Table 15).

If the data from octopuses captured only once (51 animals) were included then 79.1% of the octopuses captured left the den they were sighted in and only 20.9% of the octopuses were recaptured in the den where they were previously captured.

FOOD

The major prey item at all three sites was the red rock crab, *Cancer productus* (86.13%) (Table 16). The remains of *C. productus* were found in almost all midden heaps and were the only prey items found in the possession of octopuses captured in the open.

For the very small octopuses the most common prey item was still *C. productus* juveniles but other crabs such as *Pugettia* sp. and *Scyra acutifrons* were eaten.

The heart cockle, *Clinocardium nuttallii* (2.19%), the swimming scallop *Chlamys* sp. (0.73%) and assorted clams (0.73%) represented the bulk of the bivalve mollusks consumed. Only two of the bivalve shells

TABLE 15. Reuse of Dens by Captured Octopuses.

TAG #	NO. OF CAPTURES	SITE	CAPTURED IN	RECAPTURED IN
27	2	1	08	09
229	3	1	00	11,06
0	3	2	10	12,25
2	2	2	23	26
3	3	2	18	18,18
34	3	2	06	12,15
42	6	2	04	06,06,06,10,17
46	2	2	11	30
52	5	2	11	11,11,11,07
58	2	2	13	05
61	2	2	10	00
63	3	2	30	11,11
68	3	2	05	05,05
70	2	2	10	10
205	6	2	06	07,07,10,07,10
221	4	2	23	00,26,26
231	2	2	18	10
8	2	3	01	06
9	2	3	04	06
12	2	3	09	08
16	7	3	01	01,08,05,05,05,09
20	3	3	02	01,01
21	2	3	07	01
22	2	3	11	11
23	2	3	10	10
38	2	3	13	13
39	4	3	07	07,07,08
62	3	3	18	?,00
207	2	3	13	13
239	3	3	00	08

recovered showed signs of drilling and neither shell was drilled completely through.

It was difficult, at times, to determine what had been consumed by the octopus and what had been brought to the den, out of what one assumes must be curiousity. A three-wood golf club was recovered from one midden heap and the plastic den marking bags were moved into the middens occasionally.

Fish and bird remains occurred in several middens. Whether the octopuses had caught and killed the animals is not known.

At no time did there appear to be a shortage of *Cancer productus* and it was felt that food was not a limiting factor at any site.

There did not appear to be any obvious difference between the food items selected by the octopuses at each site.

Midden heap contents were counted and recorded only when an octopus was sighted in the den.

OCTOPUS CONDITION

During a one-year period (July 1, 1983 - June 30, 1984) there were 66 octopuses captured or recaptured. Of those animals, 14 (21.2%) had visible damage (Table 17).

Two of the octopuses had only scars on the skin. One of those animals was attacked as it emerged from the den. A male ling cod (*Ophiodon elongatus*) defending a nearby egg mass caused several large cuts in the mantle and one arm of a female octopus. When the octopus was recaptured 48 days later all trace of the cuts were gone.

TABLE 16. Midden Heap Contents (July 1, 1983 - June 30, 1984).

PREY ITEM	NUMBER	PERCENT OF DIET
Cancer productus	354	86.13
Pugettia sp.	17	4.14
Scyra acutifrons	13	3.16
Clinocardium nuttallii	9	2.19
Chlamys sp.	3	0.73
Fusitriton oregonensis	3	0.73
Clams	3	0.73
Cancer magister (Juvenile)	2	0.49
Acmaea mitra	1	0.24
Hemigrapsus nudus	1	0.24
Haliotis kamtschatkana	1	0.24
Mytilus sp.	1	0.24
Strongylocentrotus droebachiensis	1	0.24
Sea gull	1	0.24
Telmessus cheiragonus	1	0.24

Six of the octopuses (42.9% of the damaged animals) had amputations of one or more arms. In one case the distal portion of the third right arm was missing and thus the sex of the octopus could not be determined. Many of the amputations were in various stages of regeneration.

Six of the octopuses (42.9% of the damaged animals) had both scars and amputations.

Of the 14 octopuses with visible damage 7 were male, 6 were female and one was not determined due to the loss of the distal portion of the third right arm.

As this data is unweighted for effort it is difficult to tell if animals are more likely to be damaged during any specific part of the year but Table 17 does not show any trends to suggest that this would be the case.

Kanamaru and Yamashita (1966, 1969) state that canniblism is common for O. dofleini. It was assumed, however, that the majority of damage observed during the present study came from interspecific conflicts rather than intraspecific events.

A unique situation of unusual abundance was observed, once in 1967 and again in 1985. As the deeper portion of Saanich Inlet is anoxic for much of the year (Herlinveaux, 1962) octopuses cannot live below 150 meters. Herlinveaux (1962) states that periodically, dense, well oxygenated water from Haro Strait spills over the sill at the mouth of Saanich Inlet and displaces the less dense water of the Inlet. This "flush" forces the anoxic water towards the surface and may force octopuses into shallower water. At both Tanner and Tozier Rocks there were much larger than normal numbers of octopuses and on Tanner Rock

TABLE 17. Octopuses with Visible Damage (July 1, 1983 - June 30, 1984).

DATE	SEX	SCAR(S)	AMPUTATION(S)	BOTH
JULY 9	F			✓
JULY 23	M		✓	
JULY 23	F			✓
JULY 30	F		✓	
AUGUST 20	M		✓	
SEPTEMBER 3	M			✓
OCTOBER 1	?		✓	
OCTOBER 16	M			✓
DECEMBER 12	F			✓
DECEMBER 17	F			✓
JANUARY 21	F	✓		
MAY 26	M	✓		
MAY 26	M		✓	
JUNE 17	M		✓	

TOTAL CAPTURED OR RECAPTURED = 66

TOTAL DAMAGED = 14 (21.2%)

SCAR(S) ONLY = 2 (14.3%)

AMPUTATION(S) ONLY = 6 (42.9%)

BOTH SCAR(S) AND AMPUTATION(S) = 6 (42.9%)

MALES = 7 (50%)

FEMALES = 6 (42.9%)

they occupied almost every den for two weeks. There were several cases where two 10-12 kg animals occupied opposite sides of a rock, only centimeters from each other, and yet no aggressive behaviour was seen. Perhaps when forced to by circumstances or when food is not a limiting factor the level of aggression declines rapidly.

WATER TEMPERATURE

Water temperature was recorded at the den exit whenever an animal was sighted or captured. As the number of octopuses sighted on Tanner Rock was low there was only data for six months of the year. In all of the six months there were 4 or fewer observations and it was felt that these numbers were too small to be useful.

A oneway analysis of variance was used to test the hypothesis (Ho) that there were no differences in water temperature between sites. The results showed that there was a significant difference between the average water temperature of Tozier Rock and that of Saxe Point (α = .05, F = 3.3610, P = .0365, D.F. Between = 2, Within = 223). The hypothesis was not accepted.

Figure 8 showed that Tozier Rock was warmer than Saxe Point from May to January.

Correlations examining the relationship between water temperature and (a) growth rate, (b) octopus body weight, (c) octopus sex, and (d) nearest neighbour distance were nonsignificant at the α = .05 level.

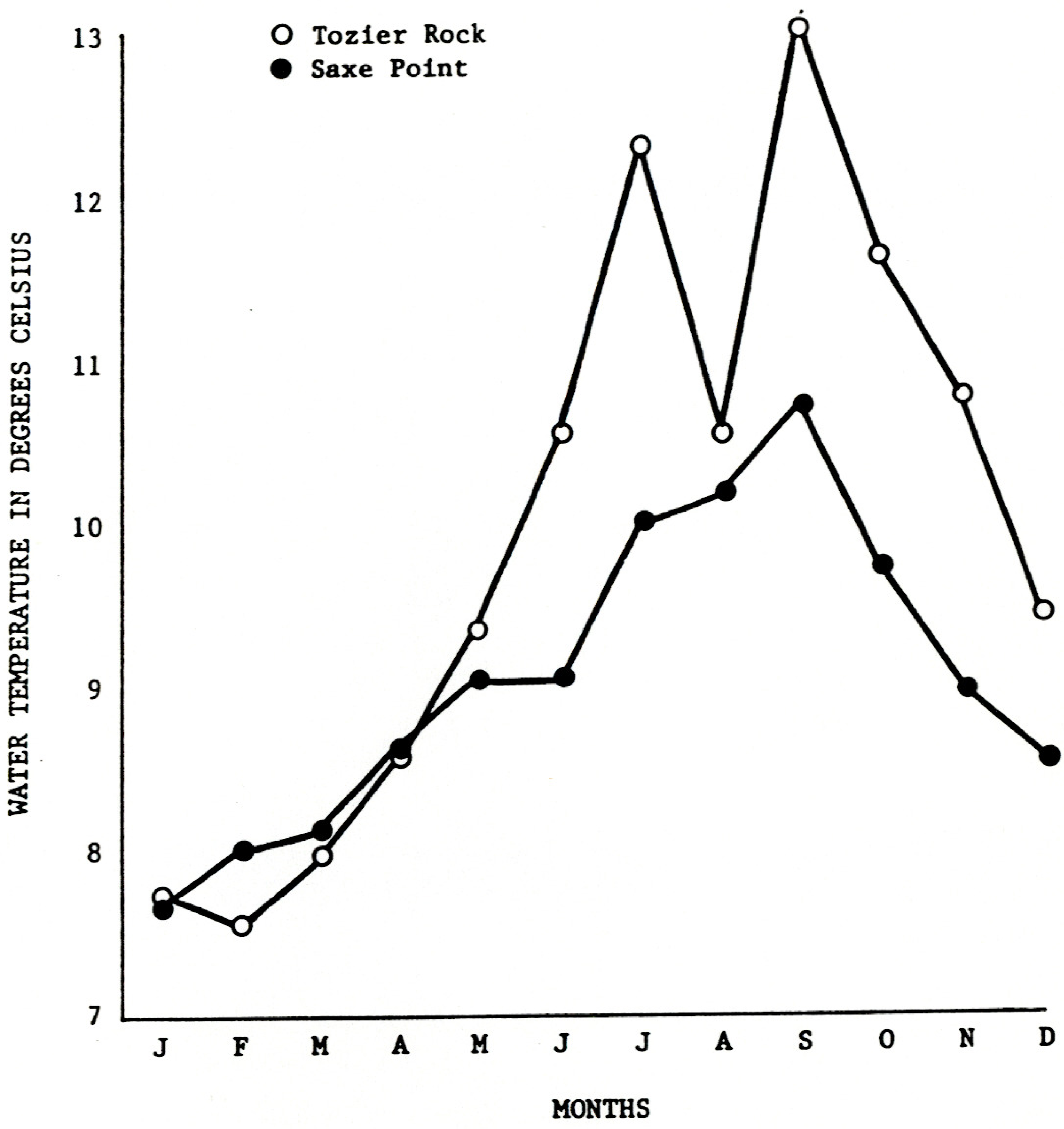

FIGURE 8. Average Monthly Water Temperatures for Tozier Rock and Saxe Point (July 1, 1981 - June 30, 1984).

DISCUSSION

AGE AND GROWTH

As Octopus dofleini is a large cephalopod with increasing potential for a fishery on the west coast of North America a number of researchers have looked at the natural history of the species but no clear picture has yet emerged.

Kanamaru and Yamashita (1967) reported that the peak breeding period in Japan for Octopus dofleini is from November to December but that breeding continues to April and May, and may in fact, occur at any time of year. Kanamaru and Yamashita (1967) also report the peak spawning period to be in May and June. That means that a period of six months passes between mating and egg laying.

Gabe (1975) reported two cases where Octopus dofleini were mated in March and laid eggs 42 days later. Gabe (1975) also reported that the eggs were brooded for 5 1/2 months to hatching while Mottet (1975) reported a 6 1/2 month brood period. Both Gabe (1975) and Marliave (1981) reported that hatching occurred in October. It would appear that there is a behavioural difference between the western and eastern Pacific subspecies of Octopus dofleini.

Gabe (1975) reported that hatching continued from October to December but noted that the majority of the hatch occurred in the first two weeks of the hatch.

Robinson and Hartwick (1986) report that newly hatched Octopus dofleini have a body weight of 21.65 mg and Marliave (1981) has observed that young adhere to the surface tension film. Marliave further reported that this behaviour disappeared in 30 days (approximately December).

Since the juveniles are heavier than water at hatching and can only maintain their position in the water column by constant swimming they cannot remain in the plankton for any great length of time. Mottet (1975) cites evidence from Halibut Commission plankton tows that show a peak of juvenile octopuses (dorsal mantle length 3-14 mm) in the water column during April. Mottet also states that an octopus with a dorsal mantle length of 10 mm has a total body length of 20 mm. From this information one would speculate that the largest of the planktonic specimens found in April (dorsal mantle length 14 mm) would have a total body length of approximately 28 mm.

Kanamaru and Yamashita (1967) report the capture of settled juvenile octopuses with total lengths of 30 to 50 mm and weights of 3 to 5 grams.

It would appear that settling should occur in April or May at a body weight of approximately 3 grams and a total body length of 30 mm.

Assuming these small octopuses hatched in October and settled in May then a growth rate of 2.34% increase in body weight per day is required.

If, in fact, the juveniles are settling in May then almost nothing is known about the animals epibenthic existence.

The present study found a peak number of small (approximately 250 grams) octopuses in February and March (Table 7). Assuming that these small octopuses are those that hatched the previous October (Gabe, 1975; Marliave, 1981) and had settled in May (Kanamaru & Yamashita, 1967) then they are now 16 months old and have increased in weight from 21.65 mg (Hartwick, 1986) to approximately 250 grams.

A calculated growth rate over a 9 month epibenthic period (May-February) produced a value of 1.63% increase in body weight per day.

This is not in agreement with the statement by Mottet (1975) who reported that it was unlikely that it would require more than a year for Octopus dofleini to grow to 1 kg.

Using data from recaptured octopuses (Table 8) a linear regression produced a growth rate of 0.91% increase in body weight for animals between 2.5 kg and 16 kg (the lower and upper limits for recaptured animals) (Figure 5).

A plot of these growth rates (Figure 7) indicated that it would take an average Octopus dofleini 31 months to reach a weight of approximately 16 kg.

Based on the growth model (Figure 7) an individual octopus hatched in October would be expected to reach a weight of 16 kg in May (2 years and 7 months after hatching).

The distribution of animals (Table 7) shows a small peak of 14-16 kg animals in May with a larger peak of similar animals in November and December.

There are several possible explanations for this 6 month variation between predicted and observed peaks in octopus body weight. The most parsimonious answer is that the rate of increase proposed for the time between 250 grams and 2.5 kg was too large. It may also be speculated that more recapture data may have altered the 0.91% increase in body weight per day. It is calculated that a rate of increase of 0.76% per day for animals between 250 grams and 16 kg would result in a 16 kg octopus in November.

This rate of 0.76% increase in body weight per day is almost exactly the average growth rate value obtained in Table 9 and is within two Standard Errors of the values found in Figures 5 and 6.

One must also consider variations in hatching time and note that an El Nino occurred in 1982 which may have influenced hatching and growth rates.

As noted in the results section, the growth rate described in Figure 7 was best characterized by the power function $y = ax^b$. The R-SQUARE value ($r^2 = 0.6951$) is lower than one would expect due to the fact that there are three separate growth rates involved.

A breakdown of recapture data into monthly divisions showed a difference between slower winter rates and faster summer rates (Table 9).

It appears, however, that Japanese octopuses display a slower growth rate for animals heavier than 2.5 kg than do eastern Pacific *Octopus dofleini*. Mottet (1975) reported a case where a tagged octopus increased in body weight from 1 kg to 10 kg in one year. This result would be duplicated, using the growth rate postulated from this study, in a period of nine months.

Robinson and Hartwick (1986) have calculated growth rates which would have an octopus increasing from 1 kg in body weight to 18 kg in body weight in just one year. While that growth rate does not match the data from the present study it is only in disagreement by a matter of fractions of a per cent.

Robinson and Hartwick (1986) have constructed two growth curves for eastern Pacific octopus having a fast and slow component. January to June was a period of slow growth and July to December was the period of fast growth. As a 1.6 kg animal was the smallest octopus recaptured in the Robinson and Hartwick (1986) study it is suggested that their growth rates represent two portions of the growth of an older animal and does not show the much faster growth of the smaller animals.

In general, this study is in agreement with the Robinson and Hartwick (1986) study concerning the rapid and slow phases of growth. While the evidence is not clear cut, there is generally a slower period of growth during the months from February to June and a faster period of growth from July to November.

Kanamaru and Yamashita (1967) state that female *Octopus dofleini* mature sexually at a body weight of approximately 13 kg. Mottet (1975) says that the gonads start to mature at a body weight of 10-15 kg and are fully mature at a body weight of 15-20 kg (gonad weight of 1-3 kg). Robinson and Hartwick (1986) present evidence that *Octopus dofleini* begins to mature sexually at a size as small as 7.5 kg body weight and presumably are fully mature at 13 kg.

It is important to note that as the octopuses began to reach what was assumed to be sexual maturity they left the study areas and presumably moved into deeper water where breeding is believed to take place. The timing of this movement is very similar to that reported for the Japanese octopuses (Kanamaru and Yamashita, 1967).

Kanamaru and Yamashita (1967) reported that breeding takes place in water less than 100 meters deep and that spawning occurs in water 50 meters deep or less. In the 742 dives done for this project and in more than 3,000 dives done by this investigator a nesting octopus has not been discovered nor a mating observed. This evidence would support the statement that both breeding and spawning occur at depths in excess of 30 meters. Hartwick _et al_. (1984b) also reports the failure to discover any nests during their many west coast research projects using SCUBA in water less than 30 meters deep.

It is noted, however, that large, sexually mature octopuses (predicted by this study to be four years old or older) are occasionally found in shallow water (<30 m). Hartwick _et al_. (1984b) also records the presence of small numbers of animals greater than 16 kg at various times of year in shallow water.

Of the animals over 18 kg found during the study only one was female and the other nine were male. The reason for these large animals being in shallow water is not clear. It may be that they were simply feeding. It is important to note, however, that none of the larger animals was ever recaptured. That leads one to conclude that their forays to shallow water were normally for a period of less than a week.

The presence of large males in deep water (40-100 m) poses the question as to how large the animals do get and how long they live.

It is presently held that female _Octopus dofleini_ die after brooding their eggs (Gabe, 1975) or may, in fact, die shortly after the eggs are laid (Mottet, 1975). There does not appear to be any literature suggesting that a female _Octopus dofleini_ can survive to breed a second time. It is hypothesized on the basis of growth and weight data presented here that a female Octopus dofleini is between three and one-half to four years of age when she dies.

It is also held that male Octopus dofleini die after breeding (Kanamaru and Yamashita, 1967). Gabe (1975) reported two cases at the Vancouver Public Aquarium where mating was observed and the males died; one after 54 days, the second after a "similar" time. It is known, however, that male Octopus dofleini do grow to be much larger than the females. Commercial octopus hunters (A. Crow, personal communication) report that males in excess of 50 kg, while not common, are found and some are considerably heavier. The largest personally observed was 71 kg and had an arm span of almost 7 meters. It is speculated, therefore, that male Octopus dofleini may live to four or perhaps five years old. Whether a lack of breeding success is responsible for an extended life is not clear at this time.

SEASONAL MIGRATION

In 1966 a biannual migration of Octopus dofleini was described by S. Kanamaru and Y. Yamashita. This movement to deep water (February to April and August to October) and to shallow water (May to July and November to December) by the octopuses of Hokkaidō was supported by evidence from 824 tagged Octopus dofleini captured and released over a five year period (1960-1965).

A detailed examination of the tag-release-recapture data in the 1966 paper gives little support for the seasonal movement theory. Of the 824 animals tagged and released from June 1960 to October 1965 only 45 were recaptured. Of the seven animals recaptured from 1960 to 1962, five were recaptured within four days of release. Of the remaining two animals, one was recaptured in 227 meters of water 84 days after its release in 60 meters of water. This animal had moved 17.7 km from June to September. This would appear to support the theory of movement.

The second animal was recaptured a year (360 days) after its release and was found in 40 meters of water. It had been released in 120 meters of water. The paper makes no mention of how far the release and recapture sites were apart but if one follows the proposed migration theory then the octopus should have returned to the same depth as it was released in.

The 1965 release-recapture data showed only general movement south and offshore but no specific cases were cited to show what times and distances were involved.

The paper, in general, did not support the hypothesis of seasonal movement.

A second paper published in 1969 by the same authors provided more evidence from other tag-release-recapture studies to support the biannual movement theory. Their conclusions were that all populations, both deep and shallow water, moved, but not at the same time or all in the same direction.

Hartwick _et al_. (1984b) investigated the dynamics of shallow water populations of _Octopus dofleini_ in the northeastern Pacific. They noted a seasonal peak of immigrants in early summer (the opposite of the Japanese) and noted that this peak did not correspond to peaks of the small animals. It was also stated that "If migrations do occur in this population of *Octopus dofleini* they apparently include only a portion of the population at one time."

The results of the present study suggest that there may be three movements of animals but clearly these are not migrations of the entire population but rather movements of one segment or age class of the population for behavioural reasons.

The first movement was that of the small animals between 500 grams and 2 1/2 kg. It was felt that because the search method was effective enough to find the small animals between 100-500 grams originally there was no reason not to continue finding them as they grew, yet only one animal in the one to two and one half kg range was sighted. Other investigators (Hartwick *et al.*, 1981, 1984b; Robinson and Hartwick, 1986) also reported very few animals of that size in water less than 30 meters. This movement of animals from shallow water to deeper water in April and May does partially coincide with one of the Japanese migrations from shallow water to deep and the Japanese (Kanamaru and Yamashita, 1969) report many small animals in 60-70 meters of water. It must be noted, however, that because recruitment happens throughout the year the movement of small animals would be expected to be continuous also with only a peak of movement in April and May. It must also be noted that the average weight of the small Japanese animals (collected in mid-May) was 2-3 kg (range 0.5-11 kg) which is about four times the weight the present study would predict.

The second movement is that of 3-5 kg animals presumably moving from deep water to shallow in August. This onshore movement does not parallel the Japanese situation and in fact is exactly opposite to the case described by Kanamaru and Yamashita (1969). From August to the fall of the following year animals continue to grow in shallow water until they begin to mature sexually.

The third movement seen in this study was that of sexually maturing males and females (Figure 7) leaving shallow water (September and December respectively) for deeper water. Hartwick _et al_. (1984b) found similar movements at MacIntosh Rock near Tofino, B.C. for the years 1978-1981 although the exact month of the movement varied from year to year. This third movement is again the exact opposite of the Japanese situation.

One question on which all investigators have agreed is the direction of movement from place to place. Movement is either from deep water to shallow water or from shallow water to deep water. At no time in the present study was movement along the shore seen. No animal tagged at one site was recaptured at another site. Hartwick (unpublished data) had similar results and in trapping experiments in deeper water found that an octopus caught in one trap may be recaptured in another trap on that line but not on parallel trap lines. Why movement should be limited to this strictly vertical plane is not clear. Further studies, perhaps with sonic tags on sexually mature males, would help to provide answers.

SEX RATIOS

Female octopuses were slightly more common than males over the length of the study (Table 6) but there was no significant difference between the two. When examining sites, and individual years at each site, there is considerable variation. Tanner Rock had more males than females in 1983 while Tozier Rock had a significantly larger number of males in 1982. A sex ratio of 1:1 was not found in Octopus dofleini at the open ocean sites. Hartwick et al. (1978, 1981, 1984b) reported females outnumbering males by between three and four to one on their open coast study. Robinson and Hartwick (1986) continued to find this skew toward females at the same sites. Both investigators note, however, the variability in month to month and year to year measurements. At times males outnumbered females and at other times no males were found. The present study has provided no insight as to why the sex ratio in protected waters should be significantly different than open coast sites.

NEAREST NEIGHBOUR

It was speculated that if octopuses were territorial, their nearest neighbour distance would increase as size (body weight) increased. The correlation examining this hypothesis was nonsignificant. It would appear, therefore, that Octopus dofleini is not territorial but rather an opportunist, taking shelter where it is found.

Kanamaru and Yamashita (1966, 1969) observed that cannibalism was common for Octopus dofleini, especially for specimens larger than 4-5 kg.

Hartwick (unpublished data) reported that many animals had scars or amputated arms and the present study showed a 21.2% incidence of octopuses with visible damage.

While reports of aggressive behaviour between Octopus dofleini in the wild are very rare (Kyte and Courteney, 1977) cannabalism has been observed in aquaria. It is speculated that limited food or overcrowding may be contributing factors to what appears to be an unusual behaviour.

In large public displays such as Sealand of the Pacific or the Pacific Undersea Gardens, both of Victoria, B.C., Octopus dofleini are kept in crowded conditions but there are few problems with cannabalism (personal observation).

Mather et al. (1985) established that a typical range, for what were presumed to be three year olds, was approximately 250 square meters but that ranges overlapped by as much as 94% in those sexually immature animals.

As reported in RESULTS, when octopuses moved into shallow water perhaps because of lowered oxygen levels in deeper water they were able to establish very small nearest neighbour distances with no aggressive behaviour observed.

DENS

A comprehensive examination of dens and surroundings was undertaken to try and establish the criteria an octopus would use when selecting a den.

One hypothesis examined was the premise that octopuses would occupy the first suitable den they came to as they moved into an area. It was expected, therefore, that the deeper dens would be occupied more often than shallow dens. No such pattern was seen.

A second hypothesis tested was the relationship between the size of the octopus (body weight) and the estimated volume of the den from which it was captured. It was expected that small animals would prefer dens with small estimated volumes and larger animals would prefer dens with larger estimated volumes. A correlation strongly suggested that was true.

When the den data (Appendix IV) was examined for trends it was found that very few trends existed.

At Tanner Rock the types of dens established were fairly evenly divided between dens in natural splits in the rock (35.7%) and excavated dens (38%).

The dens at Tozier Rock were mainly excavated (75.6%) while only 22.8% were in natural splits.

The dens at Saxe Point were evenly divided between those which were excavated (23.3%), those in natural splits in the rock (21.1%) and those formed by stacked rock rubble (24.6%).

Clearly the octopuses made use of whatever sites were most available in the locality. It was noted, however, that in several cases individual octopuses had specific requirements for a den. Several times octopuses were observed spending a great deal of time and effort creating new dens only a meter or two from dens which had been used many times previously and were not then occupied.

In other cases, there were dens in which only one animal was ever found. Why that den was acceptable to only that one animal and no others was not detected.

When examining the estimated volumes of the most commonly occupied dens it was found that dens with the largest and smallest estimated volumes were most often occupied at Tanner Rock while the den with the second largest estimated volume was the most commonly occupied at Tozier Rock. At Saxe Point, however, the dens with the mid-range estimated volumes were most commonly occupied. Again, there was no trend across sites.

One trend which was seen was the preference for dens with more than one exit. Fifty-six percent of the dens at Tanner Rock and 53.2% of the dens at Tozier Rock had multiple exits. At Saxe Point 79.4% of the dens had multiple exits. It was also observed that all the most frequently occupied dens had multiple exits with the exception of the very small den on Tanner Rock.

A problem faced by all researchers is that of collecting data without influencing the very data being collected.

It was necessary to capture the octopuses to obtain weight and sex information as well as to put on tags for positive identification. Although the octopus was stressed as little as possible there was still enough stress produced to cause the octopus to usually abandon its den, when released, and in many cases to abandon the site entirely.

When looking at recapture data it was observed that 61.0% of the recaptures came from dens different than where the previous capture occurred. When the 'one time only' captures were included then only 20.9% of the octopus captured were recaptured in the same den.

What part of this movement was due to the divers and what part was normal could not be determined.

FOOD

Cancer productus, the red rock crab, was the major food item consumed at all three sites. Cancer productus was seen in abundance during all parts of the year and did not appear to be limiting.

Where bivalve mollusks were taken as prey items there was very little evidence of drilling and no completely drilled shells were found.

Hartwick et al. (1981) reported that octopuses in Barkley and Clayoquot Sounds preferred to forage more on soft bottoms than on rock surfaces. For Octopus dofleini in Barkley Sound the major food items were Protothaca staminae (28%) and Cancer productus (19%).

In Clayoquot Sound the major prey items were Clinocardium nuttallii (41%) followed by assorted crabs.

Hartwick also noted that much of the foraging done by Octopus dofleini on the open coast was done in eel grass beds.

An observation made during the study was that there were areas, which were not den sites, where the remains of octopus meals were frequently found. These snacking spots were commonly found in a protected area along the edge of a large rock or cliff.

Hartwick et al. (1981) reported that food items were consumed at the den only 70% of the time and that the existance of feeding sites away from dens have been noted in other studies.

At Saxe Point it was observed that newly captured octopuses were a much lighter shade of red (almost pink) than were the octopuses recaptured at Saxe Point or those sighted in Saanich Inlet. It is known that at some deep water locations (30-40 meters) found in the Strait of

Juan de Fuca the octopuses feed almost entirely on the swimming scallop *Chlamys* sp.

No research has been done to prove that the color of *Octopus dofleini*'s skin is influenced by the food consumed but it was noted that the pink color was lost in a matter of weeks and was replaced by the typical dark red-brown seen on the octopuses of Saanich Inlet. Perhaps this was due to the change in diet.

SUMMARY

Octopus dofleini, the giant octopus of the north Pacific, appears to have a number of complex behavioural patterns.

While animals of small body weight (<.5 kg) were sighted on a regular basis, there was only one octopus captured that weighed between 1 and 2.5 kg. That fact indicated a movement of those animals, out of the study sites and presumably into deeper water.

At a weight of approximately 3 kg the octopuses returned to shallow water where they probably remain while growing to sexual maturity at a weight of approximately 13-15 kg.

Upon reaching sexual maturity the animals again left the study sites. It was assumed that they moved into deeper water where breeding and egg laying are thought to take place.

From the use of recapture data and information from other studies a life span and developmental hypothesis was proposed.

It was suggested that mature female *Octopus dofleini* most frequently mated in March and then laid eggs in May. The eggs were brooded until October when hatching occurred.

The juvenile octopuses with body weights of approximately 20 mg then moved into the plankton where they lived until May of the following year. Growing at a proposed rate of 2.34% weight increase per day the juvenile octopuses reached a body weight of approximately 3 grams and then settled to become epibenthic.

The newly settled octopuses continue growing at an estimated rate of 1.63% weight increase per day until February of the following year (now 1 year and 4 months old) when they weigh approximately 250 grams.

Growth continues at an average rate of 0.91% weight increase per day to October (2 years old) and on to the following April (2 years and 6 months) when sexual maturity is thought to occur.

The mature female probably breeds shortly thereafter and dies at approximately four years of age.

Little is known of the natural history of the mature male Octopus dofleini. It was assumed that up to sexual maturity the growth of the male was the same as the female. After maturity, however, the males appeared to continue growing, reaching weights in excess of 60 kg. It is clear that to reach those weights the octopus would have to be at least one year older and perhaps several years older. The relationship between male breeding success and extended life span in unclear.

Octopus dofleini appeared to be a very opportunistic animal in terms of the location, and type of den selected. The octopuses appeared to utilize whatever type of den the particular site provided and would modify the den if necessary.

Two trends that were detected were the preference for dens with more than one exit and the fact that small size animals preferred dens with a small estimated volumes while larger animals preferred dens with larger estimated volumes.

The major food item at all sites was the red rock crab, Cancer productus.

This study was successful in gaining insight into some aspects of the natural history of the giant Pacific octopus, Octopus dofleini.

As with all studies, of course, the study posed as many questions as it answered. Questions such as: What do the juvenile stages feed on in both the planktonic and benthic stages? Where do the small octopuses go in the 1 to 2.5 kg stage and why do they move? Where do females go to breed and nest? How long do males live and what part does reproductive success play in life span?

This thesis documents that in situ observation of large animals such as Octopus dofleini may be the most reliable way to pursue the knowledge required for full understanding of their natural history.

The use of advanced technology such as Remote Operated Vehicles (ROV's) will increase safety and observation time by providing a continuous video record of an octopus's activity without the researcher actually being in the water.

Octopus dofleini remains a fascinating and challenging creature to study.

BIBLIOGRAPHY

Adkins, B.E., P.A. Gee and P.A. Breen. 1980. Experimental Octopus Trap Fishing in Barkley Sound, February - March 1979. Fisheries and Marine Services Manuscript Report No. 1548.

Canadian Hydrographic Service. Annual. Canadian Tide and Current Tables, Volume 5. Fisheries and Oceans, Ottawa.

Crow, A. Commercial Octopus Hunter.

Fukuda, T. and T. Takahashi. 1960. On the Drift-cast Fisheries of Octopus on the Coast of Wakkanai. Monthly Report of the Hokkaidō Marine Research Center, 17(10): 20-23.

Gabe, S.H. 1975. Reproduction in the Giant Octopus of the North Pacific, *Octopus dofleini martini*. The Veliger, 18(2): 146-150.

Green, M.G. 1973. Taxonomy and Distribution of Planktonic Octopods in the Northeastern Pacific. M.Sc. Thesis, University of Washington.

Hartwick, E.B., P.A. Breen and L. Tulloch. 1978. A Removal Experiment with *Octopus dofleini* (Wülker). Journal of the Fisheries Research Board of Canada, 35: 1492-1495.

Hartwick, E.B. and G. Thorarinsson. 1978. Den Associates of the Giant Pacific Octopus, *Octopus dofleini* (Wülker). The Veliger, 24(2): 129-138.

Hartwick, E.B. 1982. An Experimental Fishery. Unpublished.

Hartwick, E.B., R.F. Ambrose and S.M.C. Robinson. 1984a. Dynamics of Shallow-water Populations of *Octopus dofleini*. Marine Biology, 82: 65-72.

Hartwick, E.B., R.F. Ambrose and S.M.C. Robinson. 1984b. Den Utilization and the Movements of Tagged *Octopus dofleini*. Marine Behavior and Physiology, 11(2): 95-110.

Herlinveaux, R.H. 1962. Oceanography of Saanich Inlet in Vancouver Island, British Columbia. Journal of the Fisheries Research Board of Canada, 19: 1-36.

High, W.L. 1963. Preliminary Notes on Tag Retention for the Pacific Octopus (*Octopus dofleini*) in Puget Sound. Unpublished.

High, W.L. 1976. The Giant Pacific Octopus. Marine Fisheries Review, 38(9): 17-22.

Itami, K., Y. Izawa, S. Maeda and K. Nakai. 1963. Notes on the Laboratory Culture of the Octopus Larvae. Bulletin of the Japanese Society of Scientific Fisheries, 29(6): 514-519.

Kanamaru, S. and Y. Yamashita. 1965. Problems with the Gear Used in the Octopus Box Fishery (Part 1). Monthly Report of the Hokkaidō Marine Research Center, 22(6): 269-308.

Kanamaru, S. and Y. Yamashita. 1966. The Results of Tagging Studies of Mizudako which were carried out from 1960-1965 in the Northern Part of the Japan Sea. Monthly Report of the Hokkaidō Research Center, 23(11): 542-554.

Kanamaru, S. and Y. Yamashita. 1967. The Octopus Mizudako (Part 1). Investigations of the Marine Resources of Hokkaidō and Development of the Fishing Industry. 1961 - 1965. Chapter 12.

Kanamaru, S. and Y. Yamashita. 1969. The Fishery Biology for the Octopus, "Mizu-dako" (Paraoctopus hongkongensis (Hoyle)). (I) Summer Movements in the Onishika Area of North-western Part of Hokkaidō. Report of the Hokkaidō Marine Research Center, March: 178-197.

Kyte, M.A. and G.W. Courteney. 1977. A Field Observation of Aggressive Behavior Between Two North Pacific Octopus, Octopus dofleini martini. The Veliger, 19(4): 427-429.

Marliave, J.B. 1981. Neustonic Feeding in Early Larvae of Octopus dofleini (Wülker). The Veliger, 23(4): 350-351.

Mather, J.A., S. Resler and J. Cosgrove. 1985. Activity and Movement Patterns of Octopus dofleini. Marine Behavior and Physiology, 11: 301-314.

Mottet, M.G. 1975. The Fishery Biology of Octopus dofleini (Wülker). Washington State Department of Fisheries Technical Report No. 16: 1-39.

Pennington, H. 1979. Octopus Fishing Techniques and Gear. Alaska Seas and Coasts, 7(3): 1-5.

Pickford, G.E. 1964. Octopus dofleini (Wülker). Bulletin of the Bingham Oceanographic Collection, 19(1): 1-70.

Robinson, S.M.C. and E.B. Hartwick. 1986. Analysis of Growth Based on Tag-Recapture of the Giant Pacific octopus, Octopus dofleini martini. Journal of Zoology, London, (A) 209: 559-572.

Satō, H. 1959. Sanranyo Tako Tsubo no Ichi Rei (An Example of the Use of Octopus Pots). Suisan Shigen, 5(7): 12-16.

Snow, C.D. 1970. Two Accounts of the Northern Octopus, *Octopus dofleini*, Biting S.C.U.B.A. Divers. Fish Commission of Oregon, pp. 103-104.

SPSSX User's Guide, 2nd Edition. McGraw-Hill Book Company, Toronto. 1986.

Tanaka, J. 1963. Tosoku Rui no Yōshōku (Rearing Cephalopods). Zōshoku Rinji, 2: 27-32.

Tauchi, M. and I. Matsumoto. 1954. On the Protection of Spawners of Octopus (*Polypus vulgaris* Lamarck) in Hugo Prefecture. Bulletin of the Society of Scientific Fisheries, 20(6): 479-482.

Wilbur, K.M. and C.M. Yonge. 1964. Physiology of Mollusca. New York.

Yamashita, Y. and H. Toshida. 1973. The Migrations of Mizudako During the Winter Fishing Season Near Onishika and Mashike. Hoku Suishi Geppō, 30(7): 1-10.

Yamashita, Y. 1974. Spawning and Hatching in Mizudako. Hoku Suishi Geppō, 31(7): 10-22.

APPENDIX I

OCTOPUS RESEARCH PROJECT

DATE: ______________________ LOCATION: ______________________

TIME OF DAY: ________________ FOUND BY: ______________________

DEPTH: _____________________ IN A DEN?: _____________________

WEIGHT: ____________________ SEX: ___________________________

TAG NUMBER: ________________ TEMPERATURE: ___________________

REMARKS: ____

____

____

OCTOPUS RESEARCH PROJECT

DATE: ______________________ LOCATION: ______________________

TIME OF DAY: ________________ FOUND BY: ______________________

DEPTH: _____________________ IN A DEN?: _____________________

WEIGHT: ____________________ SEX: ___________________________

TAG NUMBER: ________________ TEMPERATURE: ___________________

REMARKS: ____

____

____

APPENDIX II

OCTOPUS RESEARCH PROJECT

LOCATION? ____________ DEN NUMBER? ____________ EXISTS? ____________

TYPE OF DEN: (1) EXCAVATED (2) SPLIT (3) RUBBLE (4) ________________

DEN SURROUNDINGS: (1) SAND (2) MONUMENT ROCK (3) CLIFF FACE (4) RUBBLE

(5) ROCK

INTERNAL DIMENSIONS: DEPTH ________ WIDTH ________ HEIGHT ________

DEPTH? ________ METERS DATE MEASURED? _______ TIME MEASURED? _______

DISTANCE TO DEN # ______ = ______ METERS. ANGLE = _________

DISTANCE TO DEN # ______ = ______ METERS. ANGLE = _________

REMARKS: ____

____

____

OCTOPUS RESEARCH PROJECT

LOCATION? ____________ DEN NUMBER? ____________ EXISTS? ____________

TYPE OF DEN: (1) EXCAVATED (2) SPLIT (3) RUBBLE (4) ________________

DEN SURROUNDINGS: (1) SAND (2) MONUMENT ROCK (3) CLIFF FACE (4) RUBBLE

(5) ROCK

INTERNAL DIMENSIONS: DEPTH ________ WIDTH ________ HEIGHT ________

DEPTH? ________ METERS DATE MEASURED? _______ TIME MEASURED? _______

DISTANCE TO DEN # ______ = ______ METERS. ANGLE = _________

DISTANCE TO DEN # ______ = ______ METERS. ANGLE = _________

REMARKS: ____

____

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APPENDIX III. Effort per Year per Site (PART I: July 1, 1981 - June 30, 1984).

YEAR	1981-82			1982-83			1983-84			TOTAL/SITE/YEAR			TOTAL/MONTH
	SITE			SITE			SITE			SITE			
MONTH	1	2	3	1	2	3	1	2	3	1	2	3	
JULY	23	40	0	2	2	3	10	11	12	35	53	15	103
AUGUST	3	7	0	9	9	6	4	4	4	16	20	10	46
SEPTEMBER	7	6	0	9	9	11	6	6	8	22	21	19	62
OCTOBER	6	7	6	9	9	10	6	6	7	21	22	23	66
NOVEMBER	0	6	3	2	2	8	4	4	11	6	12	22	40
DECEMBER	2	2	6	6	2	6	6	6	10	14	10	22	46
JANUARY	0	0	2	4	4	6	6	6	5	10	10	13	33
FEBRUARY	2	2	0	2	2	2	6	6	4	10	10	6	26
MARCH	0	4	4	2	2	10	4	6	10	6	12	24	42
APRIL	4	2	11	2	2	6	6	6	12	12	10	29	51
MAY	6	13	12	2	2	5	4	4	3	12	19	20	51
JUNE	0	2	5	6	6	12	4	5	10	10	13	27	50
TOTAL/SITE/YEAR	53	91	49	55	51	85	66	70	96	174	212	230	
TOTAL/YEAR		193			191			232			616		616

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

APPENDIX III. Effort per Year per Site (PART II: July 1, 1984 - December 31, 1986).

YEAR	1984-85			1985-86			1986			TOTAL/SITE/ YEAR			TOTAL/ MONTH
	SITE			SITE			SITE			SITE			
MONTH	1	2	3	1	2	3	1	2	3	1	2	3	
JULY	11	5	0	0	0	0	0	5	0	11	10	0	21
AUGUST	0	9	0	0	0	0	6	8	0	6	17	0	23
SEPTEMBER	3	16	0	0	4	0	2	7	2	5	27	2	34
OCTOBER	0	11	2	0	0	0	0	2	0	0	13	2	15
NOVEMBER	0	0	6	0	0	0	0	0	0	0	0	6	6
DECEMBER	0	0	6	0	0	2	0	2	6	0	2	14	16
JANUARY	0	0	1	0	0	3				0	0	4	4
FEBRUARY	0	0	0	0	0	0				0	0	0	0
MARCH	2	2	0	0	3	0				2	5	0	7
APRIL	0	0	0	0	0	0				0	0	0	0
MAY	0	0	0	0	0	0				0	0	0	0
JUNE	0	0	0	0	0	0				0	0	0	0
TOTAL/SITE /YEAR	16	43	15	0	7	5	8	24	8	24	74	28	
TOTAL/YEAR		74			12			40			126		126

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

APPENDIX III. Effort per Site (TOTALS: July 1, 1981 - December 31, 1986).

MONTH	SITE 1	SITE 2	SITE 3	TOTAL/YEAR
JULY	46	63	15	124
AUGUST	22	37	10	69
SEPTEMBER	27	48	21	96
OCTOBER	21	35	25	81
NOVEMBER	6	12	28	46
DECEMBER	14	12	36	62
JANUARY	10	10	17	37
FEBRUARY	10	10	6	26
MARCH	8	17	24	49
APRIL	12	10	29	51
MAY	12	19	20	51
JUNE	10	13	27	50
TOTAL/SITE	198	286	258	
GRAND TOTAL		742		742

SITE 1 = TANNER ROCK
SITE 2 = TOZIER ROCK
SITE 3 = SAXE POINT

APPENDIX III. Octopuses Sighted and Captured at Tanner Rock (PART I: July 1, 1981 - June 30, 1984).

YEAR	1981-82		1982-83		1983-84		TOTAL/MONTH	
MONTH	S	C	S	C	S	C	S	C
JULY	3	2	0	0	3	1	6	3
AUGUST	1	1	1	0	1	0	3	1
SEPTEMBER	2	1	0	0	2	1	4	2
OCTOBER	1	0	0	0	0	0	1	0
NOVEMBER	1	0	0	0	0	0	1	0
DECEMBER	1	1	0	0	0	0	1	1
JANUARY	0	0	0	0	1	0	1	0
FEBRUARY	2	2	0	0	0	0	2	2
MARCH	0	0	0	0	3	3	3	3
APRIL	0	0	0	0	0	0	0	0
MAY	1	1	0	0	0	0	1	1
JUNE	0	0	1	1	2	1	3	2
TOTAL/YEAR	12	8	2	1	12	6		
GRAND TOTAL			26	15			26	15

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Tozier Rock (PART I: July 1, 1981 - June 30, 1984).

YEAR	1981-82		1982-83		1983-84		TOTAL/MONTH	
MONTH	S	C	S	C	S	C	S	C
JULY	21	9	8	5	7	4	36	18
AUGUST	6	1	4	4	2	1	12	6
SEPTEMBER	5	3	0	0	3	1	8	4
OCTOBER	2	1	5	4	9	1	16	6
NOVEMBER	3	1	0	0	4	1	7	2
DECEMBER	2	1	1	1	10	3	13	5
JANUARY	0	0	3	1	11	3	14	4
FEBRUARY	1	0	4	0	7	1	12	1
MARCH	2	0	1	0	17	7	20	7
APRIL	1	0	0	0	15	4	16	4
MAY	2	1	0	0	9	4	11	5
JUNE	0	0	3	2	9	6	12	8
TOTAL/YEAR	45	17	29	17	103	36		
GRAND TOTAL			177	70			177	70

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Saxe Point (PART I: July 1, 1981 - June 30, 1984).

YEAR / MONTH	1981-82 S	1981-82 C	1982-83 S	1982-83 C	1983-84 S	1983-84 C	TOTAL/MONTH S	TOTAL/MONTH C
JULY	0	0	2	0	7	6	9	6
AUGUST	0	0	5	5	4	2	9	7
SEPTEMBER	0	0	4	3	4	2	8	5
OCTOBER	2	1	4	2	2	2	8	5
NOVEMBER	2	1	5	5	4	3	11	9
DECEMBER	2	1	3	3	5	2	10	6
JANUARY	0	0	3	1	2	0	5	1
FEBRUARY	0	0	5	2	1	0	6	2
MARCH	4	1	10	3	7	1	21	5
APRIL	3	2	7	4	3	2	13	8
MAY	3	1	2	2	2	2	7	5
JUNE	3	2	3	3	4	2	10	7
TOTAL/YEAR	19	9	53	33	45	24		
GRAND TOTAL			117	66			117	66

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Tanner Rock (PART II: July 1, 1984 - December 31, 1986).

YEAR	1984-85		1985-86		1986		TOTAL/MONTH	
MONTH	S	C	S	C	S	C	S	C
JULY	0	0	0	0	0	0	0	0
AUGUST	0	0	0	0	13	0	13	0
SEPTEMBER	0	0	0	0	4	0	4	0
OCTOBER	0	0	0	0	0	0	0	0
NOVEMBER	0	0	0	0	0	0	0	0
DECEMBER	0	0	0	0	0	0	0	0
JANUARY	0	0	0	0			0	0
FEBRUARY	0	0	0	0			0	0
MARCH	0	0	0	0			0	0
APRIL	0	0	0	0			0	0
MAY	0	0	0	0			0	0
JUNE	0	0	0	0			0	0
TOTAL/YEAR	0	0	0	0	17	0		
GRAND TOTAL			17	0			17	0

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Tozier Rock (PART II: July 1, 1984 - December 31, 1986).

YEAR	1984-85		1985-86		1986		TOTAL/MONTH	
MONTH	S	C	S	C	S	C	S	C
JULY	9	5	0	0	3	0	12	5
AUGUST	12	0	0	0	16	0	28	0
SEPTEMBER	12	0	7	0	14	4	33	4
OCTOBER	8	0	0	0	2	1	10	1
NOVEMBER	0	0	0	0	0	0	0	0
DECEMBER	0	0	0	0	2	0	2	0
JANUARY	0	0	0	0			0	0
FEBRUARY	0	0	0	0			0	0
MARCH	5	0	3	0			8	0
APRIL	0	0	0	0			0	0
MAY	0	0	0	0			0	0
JUNE	0	0	0	0			0	0
TOTAL/YEAR	46	5	10	0	37	5		
GRAND TOTAL			93	10			93	10

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Saxe Point (PART II: July 1, 1984 - December 31, 1986).

YEAR	1984-85		1985-86		1986		TOTAL/MONTH	
MONTH	S	C	S	C	S	C	S	C
JULY	0	0	0	0	0	0	0	0
AUGUST	0	0	0	0	0	0	0	0
SEPTEMBER	0	0	0	0	1	1	1	1
OCTOBER	2	0	0	0	0	0	2	0
NOVEMBER	5	0	0	0	0	0	5	0
DECEMBER	3	0	1	0	4	0	8	0
JANUARY	1	0	0	0			1	0
FEBRUARY	0	0	0	0			0	0
MARCH	0	0	0	0			0	0
APRIL	0	0	0	0			0	0
MAY	0	0	0	0			0	0
JUNE	0	0	0	0			0	0
TOTAL/YEAR	11	0	1	0	5	1		
GRAND TOTAL			17	1			17	1

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Tanner Rock (TOTALS: July 1, 1981 - December 31, 1986).

MONTH	S	C
JULY	6	3
AUGUST	16	1
SEPTEMBER	8	2
OCTOBER	1	0
NOVEMBER	1	0
DECEMBER	1	1
JANUARY	1	0
FEBRUARY	2	2
MARCH	3	3
APRIL	0	0
MAY	1	1
JUNE	3	2
GRAND TOTAL	43	15

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Tozier Rock (TOTALS: July 1, 1981 - December 31, 1986).

MONTH	S	C
JULY	48	23
AUGUST	40	6
SEPTEMBER	41	8
OCTOBER	26	7
NOVEMBER	7	2
DECEMBER	15	5
JANUARY	14	4
FEBRUARY	12	1
MARCH	28	7
APRIL	16	4
MAY	11	5
JUNE	12	8
GRAND TOTAL	270	80

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX III. Octopuses Sighted and Captured at Saxe Point (TOTALS: July 1, 1981 - December 31, 1986).

MONTH	S	C
JULY	9	6
AUGUST	9	7
SEPTEMBER	9	6
OCTOBER	10	5
NOVEMBER	16	9
DECEMBER	18	6
JANUARY	6	1
FEBRUARY	6	2
MARCH	21	5
APRIL	13	8
MAY	7	5
JUNE	10	7
GRAND TOTAL	134	67

S = Octopuses sighted but not captured.
C = Octopuses captured or recaptured.

APPENDIX IV

SITE 1: TANNER ROCK DATA

DEN #	EXITS	TYPE	SURROUNDINGS	ESTIMATED VOLUME (M^3)	MEAN DEPTH (M)
1	2	2	05	.864	8.9
2	2	6	16	.070	11.5
3	1	1	08	.108	12.7
4	1	7	16	.024	12.9
5	1	2	03	.002	13.5
6	1	7	11	.300	8.5
7	2	9	05	.240	9.4
8	2	7	16	.056	4.6
9	3	4	17	.413	7.1
10	1	2	05	.770	4.9
11	3	7	04	.160	7.0
12	2	4	02	.640	7.8
13	2	4	20	.180	7.5

SITE 2: TOZIER ROCK DATA

DEN #	EXITS	TYPE	SURROUNDINGS	ESTIMATED VOLUME (M^3)	MEAN DEPTH (M)
1	3	1	16	.088	19.9
2	5	1	04	.144	18.6
3	3	6	04	.060	14.6
4	1	5	03	.005	11.5
5	2	6	05	.054	9.4
6	3	5	08	.480	3.9
7	2	1	02	.083	7.2
8	2	6	05	.054	7.8
9	3	1	03	.007	7.3
10	1	1	05	.546	7.8
11	3	1	17	.306	5.3
12	2	2	05	.019	6.5
13	1	1	08	.176	10.2
14	1	4	09	.008	5.6
15	2	2	16	.720	17.9
16	1	1	18	.108	16.6
17	3	1	18	.144	15.9
18	3	1	10	.168	9.5
19	2	1	16	.036	9.5
20	1	2	08	.026	7.9
21	1	2	08	.033	8.5
22	1	2	08	.096	9.4
23	1	5	08	.116	12.5
24	3	1	09	.083	13.9
25	2	1	09	.120	13.9
26	1	1	09	.378	13.9
27	1	3	02	.036	8.9
28	1	2	09	.020	16.1
29	3	5	09	.138	2.5
30	1	1	08	.047	4.4

APPENDIX IV continued.

SITE 3: SAXE POINT DATA

DEN #	EXITS	TYPE	SURROUNDINGS	ESTIMATED VOLUME (M^3)	MEAN DEPTH (M)
1	2	1	02	.095	2.2
2	1	1	06	.143	3.1
3	1	1	04	.132	2.5
4	2	3	19	.030	3.1
5	3	2	14	.011	4.4
6	2	2	02	.120	4.3
7	2	3	13	.035	4.6
8	3	4	15	.081	6.1
9	1	2	13	.042	5.4
10	2	4	12	.083	9.0
11	1	4	12	.078	3.5
12	1	1	21	NO DATA	2.8
13	4	1	19	.076	6.5
14	1	2	22	.080	7.1
15	3	4	20	.189	3.4
16	2	8	23	.432	1.7
17	2	4	12	.048	2.3
18	7	2	12	.450	0.6

TYPE OF DEN

0 = In open
1 = Excavated
2 = Split
3 = Rubble
4 = Other
5 = Excavated, Split
6 = Excavated, Rubble
7 = Excavated, Other
8 = Split, Rubble
9 = Split, Other

DEN SURROUNDINGS

00 = In open
01 = Sand
02 = Monument rock
03 = Cliff face
04 = Rubble
05 = Rock
06 = Mud/Shell
07 = Cliff face, Rock
08 = Sand, Cliff face
09 = Sand, Rock
10 = Monument rock, Rock
11 = Sand, Rubble
12 = Monument rock, Rubble, Rock
13 = Rubble, Rock
14 = Cliff face, Rubble
15 = Sand, Rubble, Rock
16 = Sand, Monument rock
17 = Sand, Monument rock, Rubble
18 = Sand, Monument rock, Cliff face
19 = Rubble, Mud/Shell
20 = Monument rock, Rubble
21 = Monument rock, Rubble, Rock, Mud/Shell
22 = Cliff face, Mud/Shell
23 = Sand, Cliff face, Rubble, Rock

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(Date)