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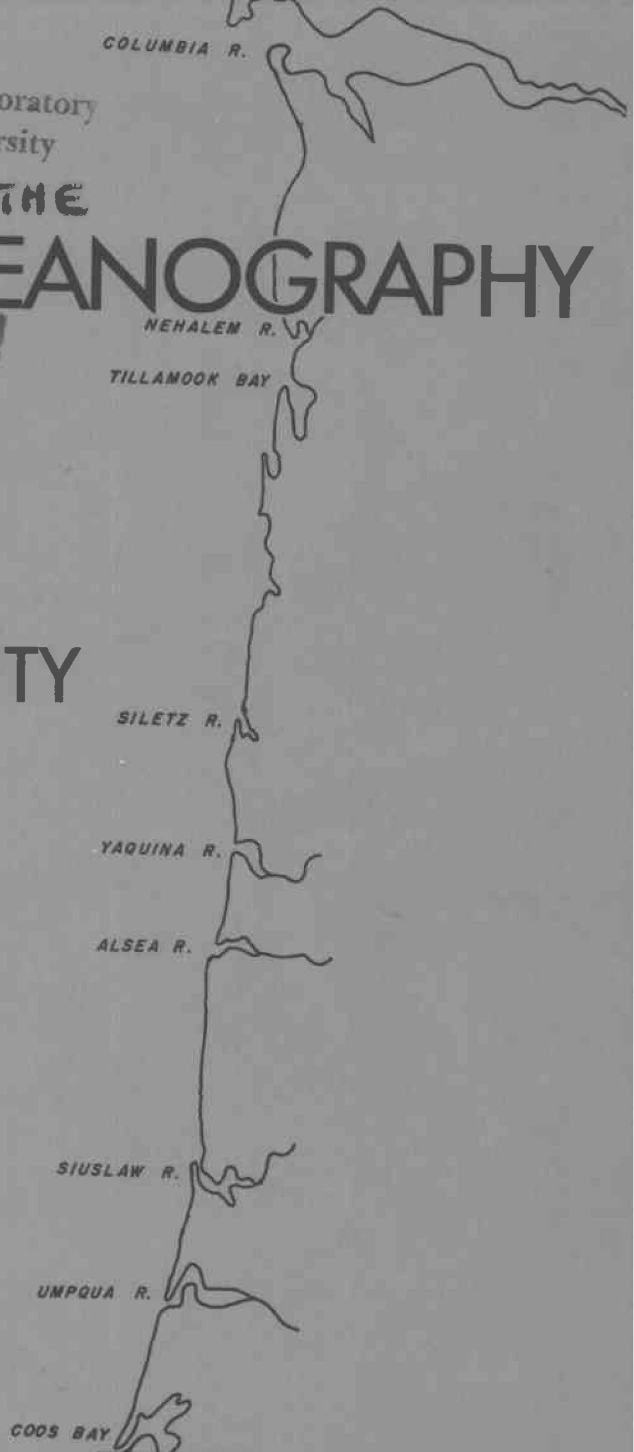

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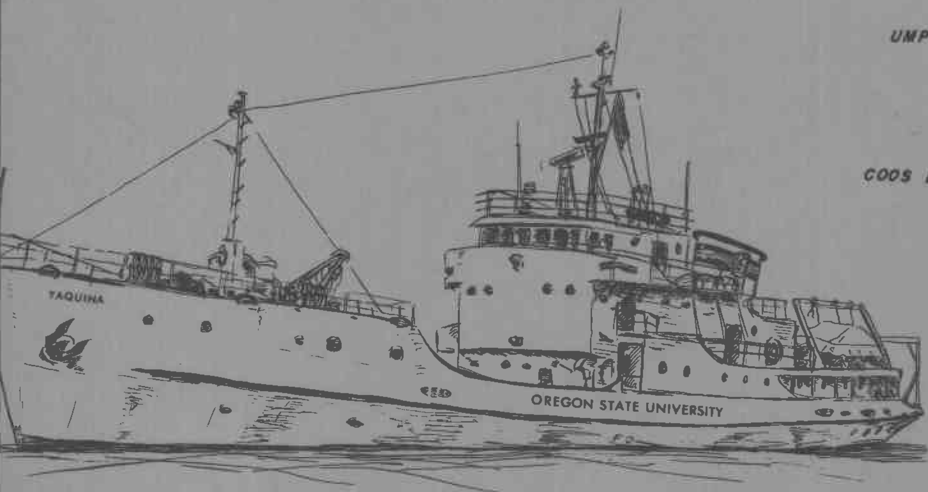

Temperature Relations of Central Oregon Marine Intertidal Invertebrates: A Pre-Publication Technical Report to the Office of Naval Research

by
Jefferson J. Gonor

OFFICE OF NAVAL RESEARCH
Contract N00014-67-A-0369-0001,
Project NR 104 936

Data Report No. 34 **Reference 68-38**

December 1968

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OREGON STATE UNIVERSITY
Corvallis, Oregon 97331

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John V. Byrne, Chairman
Dept. of Oceanography

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Introduction

Marine Ecological Studies, Project ONR 104-936, has as a long-range goal the detection of fluctuations in populations of marine organisms, analysis of their possible causes and the development of predictive analog systems describing these fluctuations. Evidence has accumulated that comparatively small, long term perturbations of the oceanic temperature regime is one of the major environmental factors influencing the distribution and abundance of marine animals. A direct causal relation has however never been objectively demonstrated and sometimes denied.

Since 1966, our studies have been concentrated on obtaining community and population data on the rocky intertidal biota of the central Oregon coast. The complex and varying regime of air and sea temperature in the intertidal has long been considered a major influence on the distribution and zonation of the intertidal biota with but little proof, largely from thermal tolerance studies, to support this. We have made the temperature relations of these intertidal organisms a recent focal point in our program designed to investigate the link between them and the physical environmental factors controlling their distribution and activities.

The temperature conditions experienced by the intertidal biota are almost equally the combination of atmospheric and ocean temperature conditions at mid-tidal horizons. At locations of intense upwelling, such as Cape Blanco in Oregon, the atmospheric temperature experienced at low tide may be a more important influence than the more constant cold sea temperatures. There is sufficient information available to indicate that the influence of air temperature on basic biological processes in intertidal species is of major importance to these animals. For example, spawning in British limpets and worms has been related more closely to air temperature than to sea temperature. The principal and associate investigators have prepared a review of the literature (Hedgpeth and Gonor, 1969, in press) on natural sea temperature changes, their effect on reproduction, growth, and other aspects of the biology of the marine biota, and the available information on temperature conditions in the intertidal. This review revealed a serious lack of information on temperature conditions at low tide. Air, substrate and organism internal temperatures and time course information about them are virtually unavailable and only a single important work has dealt with this subject (Southward, 1958).

In the last year we have attempted to secure such data at our study areas, concentrating on summer conditions. In May, June and July the water is warm and clear on the central Oregon coast. During this time low tides, especially springs, occur in mid-morning or early afternoon. Intertidal organisms are exposed to morning and mid-day insolation and the resulting temperatures are probably the highest they experience annually. Even on overcast or foggy days, appreciable infrared radiation penetrates the haze and warming of the animals can be measured.

In 1967 and 1968 we completed some 5,000 internal temperature measurements on intertidal invertebrates; other measurements on the substrate and intertidal algae were also made. We have also conducted some temperature tolerance experiments on adult animals based on these field measurements and calculated tidal exposure periods for their level of occurrence. From this work we have concluded that most of the ideas concerning the temperatures which intertidal animals on the Pacific Coast experience are in error and that a great deal of the experimental work on temperature tolerance and other heat effects on these animals is of very limited value because the methods commonly used in these experiments bear so little relation to the actual ecological circumstances. This program is still accumulating relevant data and the real annual temperature range for many of these animals will not be known until the winter work is completed. Because of the unique and extensive nature of this data, we present some of it here as a preliminary technical report to make it available to interested workers before formal publication.

Instrumentation

Sea surface temperature measurements were made at Agate Beach, Oregon with a calibrated bucket thermometer read to the nearest 0.10°C, in the same manner that the other shore station sea surface temperature data is taken. Temperature measurements of the air, sea surface, rock surface, algae, and animal internal temperatures were made with hypodermic, flat surface, and blunt-tipped fast response thermistor probes read on a Yellow Springs Instrument Co. portable telethermometer to the nearest 0.01°C.

Locations

The observations were made at Agate Beach, Boiler Bay, Depoe Bay, Shell Cove, Yaquina Head, and Yaquina Bay North Jetty near Newport, Ore. (44°37'N, 124°02'W).

Methods

1. Air. The thermistor probes were shaded and readings made at successive heights above the rock surface with the probe held away from the observer, unless otherwise noted above dry rock at the level of mean higher high water.

2. Substrate surface. Rock surface temperatures were made adjacent to animals being studied or separately at the level of MHHW, MHW, MSL, and MLW. Algal temperatures were read with the probe inserted into or covered by the algal tissue.

3. Animal internal temperature. Hypodermic probes were inserted in a consistent manner for each species. Mussels: probe inserted between the valves into the tissues. Sea urchins: probe inserted through periproct. Limpets: both through a hole drilled in the shell and by removing animals and immediately inserting probe through the foot. Chitons: probe inserted through the foot immediately after removing the animal. Balanid barnacles: probe inserted through membrane to side of valves. Gooseneck barnacles: probe inserted between valves into body and also separately into stalk. Turban snail: probe inserted through foot immediately after removing animal from substrate.

In all animal species care was taken to measure internal temperatures in animals of approximately the same size for each population or tidal level. Very large and small individuals were not used. Size frequency data for the populations measured is given under each species. Except for limpets, chitons and snails all animals were measured without otherwise disturbing or removing them. Repeated work in the same area appeared to cause no discernable harm to individuals.

The results are given in Tables and Figures at the end of this report. In each Table, the vertical height relative to MLLW is given for the location of each portion of the population studied separately.

These heights were directly measured in the field by means of surveying methods, using the nearest U.S. Coast and Geodetic Survey tidal bench marks. The tidal exposure time for the level of each measurement station, for the low tide on the day measurements were made, was taken from the tide gauge record for that day made at the OSU Marine Science Center dock on Yaquina Bay. In these Tables, the L column under exposure time lists, in hours and minutes, the exposure time which had lapsed when the measurement was made, and the R column lists the exposure time for that level remaining after the measurement was made.

Comments on results

1. Temperature and salinity observations

Temperature and salinity observations at many shore stations on the Oregon coast have been made at weekly intervals for several years by the OSU Department of Oceanography. Average monthly maximum and minimum and monthly mean temperatures derived from these measurements for several stations are given in Figs. 1 and 2. This type of data is usually considered adequate for correlating biological activities of the intertidal fauna with environmental temperature conditions. Disregarding for the moment the effect of air temperature at low tide, we have attempted to evaluate the effect of sampling frequency on shore station sea temperature curves during 1967 and 1968 by making daily afternoon measurements (ca 4 PM) at a single shore station near the site of some of our biological studies. During the summer of 1968 additional personnel made it possible to supplement the single measurement with additional measurements throughout the day. The data obtained are given in Table 1 and Fig. 3. The nature of the small scale hydrographic features at the study site remain unknown, but we have observed very variable and quite unexpected temperatures which could not have been predicted from the nearest shore station from which data had been previously available (Otter Rock), upholding the long-held opinion of physical oceanographers that sea surface temperature measurements without time course information are relatively meaningless. In the month of June, 1968 we recorded temperatures from 7.8°C to 14.6°C, spanning the entire annual range previously recorded in weekly measurements.

Some biological correlations may be made with temperature curves drawn from daily measurements. For example, at Yaquina Head, a rocky intertidal study site adjacent to the beach temperature measuring station, spawning in the chiton *Tonicella lineata* coincided with a rising temperature in late February and March. The temperature at that time also showed greater fluctuation than the preceeding winter temperatures (Fig. 4).

2. Air and rock temperatures

In summer at low tide these are significantly higher than the adjacent sea (Table 2). In winter, sea temperature may be higher than that of the air, and the intertidal rock temperature at low tide is often higher than the air, indicating that the heat taken up at high tide is not all lost at low tide before the sea again covers the intertidal. Because of greater specific heat rock reaches a higher temperature than the air in summer.

3. Limpets and Chitons

Six species of limpets and three species of chitons are considered together because of similarity of body shape. The vertical ranges (Fig. 5) of the limpet species overlap from mean lower low water to mean higher high water. Tables 3 and 4 summarize the data on limpet and chiton internal temperatures and Fig. 6 compares them to the adjacent rock surface temperatures. Animal and substrate temperatures are in general directly correlated and significantly above sea temperatures. The greatest divergence from straight line correlation to rock surface temperatures is a preponderance of animal internal temperatures below those of the adjacent rock in the mid ranges. If differences in specific heat and absorptivity are ignored for the moment, this may indicate that despite the general correlation, limpets and chitons do not passively heat like the rock but in some way regulate their heat load at low tide.

4. *Mytilus californianus*

At the Boiler Bay site studied the mussel band spans approximately 4 vertical feet. An exposure time difference of 105 minutes between the upper and lower areas of this occurred on a low tide of -2.3 ft. on 6/12/68, resulting in a difference in mean internal temperatures of one degree between upper and lower sections of the population. Mean internal temperature (Table 5) in the population was commonly found to be between 19 and 24°C and occasionally between 27 and 31°C while the sea surface temperature ranged between 9 and 14°C at the study location. Individual internal temperatures as high as 34°C have been recorded without signs of lethal effects in this population.

The rate of internal warming was calculated for several summer days from the mean temperatures read at approximately 2 hour intervals at each level.

Date	Part of bed	Observed temperature increase C°	/time in min.
5/18/68	Lower	5.44°	130 min.
5/29/68	Upper	9.79°	165 min.
	Lower	11.53°	160 min.
6/12/68	Upper	9.72°	219 min.
	Lower	9.34°	212 min.
6/14/68	Upper	8.27°	168 min.
	Lower	9.74°	160 min.
6/25/68	Upper	4.1°	97 min.
	Lower	8.68°	115 min.

On 8/8/68 the warming of two mussels was followed continuously by inserting hypodermic probes and reading temperatures at five minute intervals for two hours (Fig. 7). The animals were typical of the larger, lower, and smaller upper individuals in the bed, with the larger weighing twice as much as the smaller. The smaller animal warmed faster (mean increase in 2 hr., 0.41°C / 5 min.) and more erratically than the larger (mean increase in 2 hr., 0.29°C / 5 min.). Warming was not closely related to air shaded temperature, indicating that warming is primarily due to direct incident radiation rather than conduction and convection from the air. Back radiation scatter from the mussels appears to warm the air 3 inches above the bed.

5. Balanus cariosus (Table 6)

This large acorn barnacle occurs at the study site in three situations as full size individuals: in sheet-like colonies on high, horizontal rock; as isolated individuals (not touching); and on shells of Mytilus. The animals in the colonies are closely appressed so that there is no appreciable space between individuals.

Isolated individuals were found to have a mean internal temperature approximately four degrees above that of adjacent colonies. At the +5 ft. level the colony mean ranged to 28°C during the summer study period.

Colony warming rates were as follows:

5/29/68	8.0°C	145 min.
6/12/68	4.29°C	172 min.
6/25/68	5.74°C	110 min.

These rates are similar to those observed for Mytilus, despite the great difference in body size, form and color. The animals in the colony studied had a mean (N = 33) opercular diameter of 1.16 cm., with a range from 1.22 to 1.11 cm.

6. Pollicipes polymeris (Mitella polymeris) (Table 7)

Because of differences in height of wave splash caused by irregularities in the rock formations at the study site, gooseneck barnacles have a large vertical range, permitting low (+2.0 ft. MLLW) and high (+6 ft.) as well as shaded and sun exposed colonies to be compared. Temperatures of stalk and body inside the mantle cavity can also be compared.

Average internal temperatures ranged from 13.4 in shaded low animals to 29°C in high animals exposed to the sun, where a maximum of 33°C was recorded after six hours of exposure.

Observed rates of warming were:

5/18/68	Lower (+3 ft.)	Mantle	2.11°	123 min.
		Stalk	3.15°	
6/14/68	Upper (+6 ft.)	Mantle	2.55°	105 min.
		Stalk	4.25°	

Three of the Pollicipes colonies studied had the following capitulum length measurements:

	Mean	Max.	Min.	N
Colony A.	2.64 cm	2.75	2.54	30
B.	2.51	2.62	2.40	30
C.	1.84	1.92	1.76	58

7. Strongylocentrotus purpuratus (Table 8)

The sea urchin, Strongylocentrotus purpuratus, usually inhabits hemispherical burrows in rock and is thus kept cool on the bottom side. This species showed a population mean internal temperature from 15 to 23°C at low tide during the day in early summer. On several successive days in May, 1968 mean internal temperatures above 25°C were recorded in beds of urchins exposed to the sun and maximums of 27 to 30°C were measured in some urchins. Successive days of this type of heating at low tide for periods of three to five hours led to a heat kill at the study site and other areas along the central Oregon coast, with many urchins dying at each place.

On 6/15/68 urchins exposed to the morning sun and not in burrows were found to have a mean temperature above 26°C. A sample (N = 27) of urchins whose internal temperature was above that of the population was transported to the laboratory in an insulated container, and placed in running sea water. All of these animals died within 24 hours. Burrows in horizontal rock where water does not drain out of the concavity protect this species for the mean of animals in such burrows was 22°C that day. Burrows in vertical rock drained and animals in such a situation had a mean internal temperature of 26°C, a critical temperature for this species.

Measured rates of warming for animals in different situations are as follows:

5/29/68	0.0 ft. In burrows, horizontal	5.22°C	135 min.
6/11/68	0.0 ft. In burrows, horizontal	1.48°C	106 min.
6/15/68	0.0 ft. In burrows, horizontal and shaded	0.06°C 0.69°C Total: 0.75°C	46 min. 54 min. 100 min.
	+1. ft. In sun, not in burrows	6.00°C	110 min.

Several important things can be learned from this example. Heat kills of marine animals are usually noted when they are massive and spectacular (Brongersma-Sanders, 1957) and are often thought to be characteristic of the tropics, such as the mass heat kill of reef echinoids in Puerto Rico recently reported in an excellent study by Glynn (1968). Even in cold-temperate seas natural heat kills may occur, and while perhaps less spectacular than the cold kills of these latitudes such as that of 1962-63 (see Helgol. Wiss. Meeresunters. 10, (1964), they may be a regular occurrence. We do not have an estimate of the percent of the total S. purpuratus population killed in May, 1968, but hundreds of dead animals could be seen near the end of the period. Dead and damaged urchins have been noticed in early summer in past years here but we had not noted the cause. Before this event in May, the urchin beds were very crowded, many animals were without burrows, on bare rock and some were in burrows high on vertical rock faces; these animals were the ones showing progressive heat damage on successive days.

Discussion

There are many implications of these observations for the study of littoral populations. The true natural annual temperature regime experienced by the animals can only be known from long term studies which include measurement of sea, intertidal surface and animal internal temperatures. Natural events such as the heat kill described above must be noted by regular ecological monitoring.

Information on the temperature tolerance of marine benthic animals is of importance to both general marine ecology and to assessing the biological effects of thermal effluents. Our studies on the normal increase in internal temperature upon tidal exposure indicates that such experimental work must be based on the natural situation if it is to have any ecological relevance. For intertidal forms, the rate of heating of experimental animals must correspond to naturally occurring rates of change and the durations of exposures to test temperatures should be selected to at least correspond to the periods of shortest, average and longest summer tidal exposure for the level of occurrence of the species. Parallel studies on animals totally immersed and in air of controlled humidity are essential for intertidal forms if ecological predictions are to be made from the work.

Of even greater ecological significance would be temperature tolerance and acclimation experiments modeled after those of Heath (1967) who simulated the natural thermal curve measured in the habitat where the animals were actually seen. These experiments with fish in the northern Gulf of California demonstrated, among other things, that the fishes normally experience for short periods of time, water temperatures that are lethal for longer intervals. For intertidal species, simulation of tidal curves would allow examination of the effects of tidal exposures which occur for varying periods of time at different parts of the day throughout the year.

Experiments designed along these lines would permit examination of the role the normal range of environmental temperature plays in the life of animals. The venerable idea that marine intertidal organisms 'tolerate' the normal seasonal temperature extremes of their habitat is prejudicial to development of new ideas and should be abandoned. These animals cannot be less than adequately adapted to their present environment since they have survived selection and fluorish there. It is equally likely that they require the seasonal variations in temperature, including both low and high extremes and that they utilize rather than tolerate them.

There is some evidence in support of this idea. Bartholomew (1966) found that the body temperature of the Galapagos marine iguana fell to that of the sea while feeding upon submerged algae, but was maintained

10 to 15°C above this on shore by a basking behavior. The large black intertidal chiton Katharina tunicata feeds on algae at high tide but remains motionless, tightly affixed to the rock at low tide when it may be exposed 6 or more hours during a summer day. We have measured mean internal body temperatures of this chiton in June and July 10 to 15°C above the sea surface temperature. In both of these herbivores, the gut is filled with algae when the animal is at the higher temperature. Digestive enzymatic reactions generally have a Q_{10} value between 2 and 3. In both of these otherwise dissimilar animals, having a body temperature 10°C or more above sea temperature must facilitate digestion since the reaction rate at this temperature level would be some 96% faster than at sea temperature. Short term exposure to summer low tide temperatures could be required by intertidal invertebrates because it would increase digestive and assimilative efficiency at this season when the greatest increase in gonad reserve storage is taking place.

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Brongersma-Sanders, Margaretha
1957. Mass Mortality in the Sea. Treatise on Marine Ecology and Paleoecology. Ch. 29 Mem. Geol. Soc. Amer., 67(1): 941-1010, Figs. 1-7.

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Heath, Wallace G.
1967. Ecological significance of temperature tolerance in Gulf of California shore fishes. J. Ariz. Acad. Sci. 4(3): 172-178, 5 fig.

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1958. Notes on the temperature tolerances of some intertidal animals in relation to environmental temperatures and geographical distribution. J. Mar. Biol. Ass. (U.K.), 37: 49-66.

Figure 1. Sea Surface Temperature

1961-63 Otter Rock and 1963-64 Cape Arago, Oregon

Fig 1

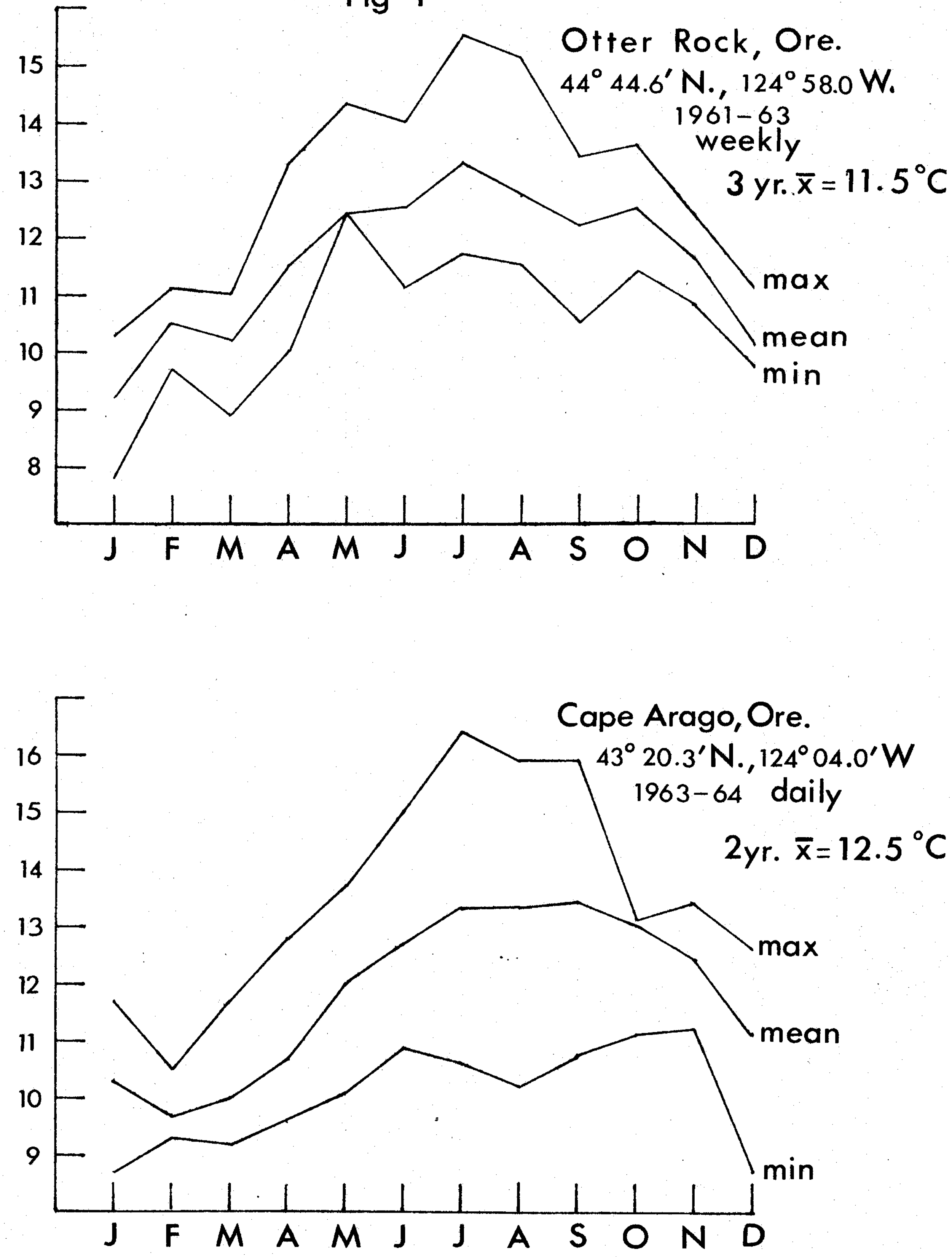
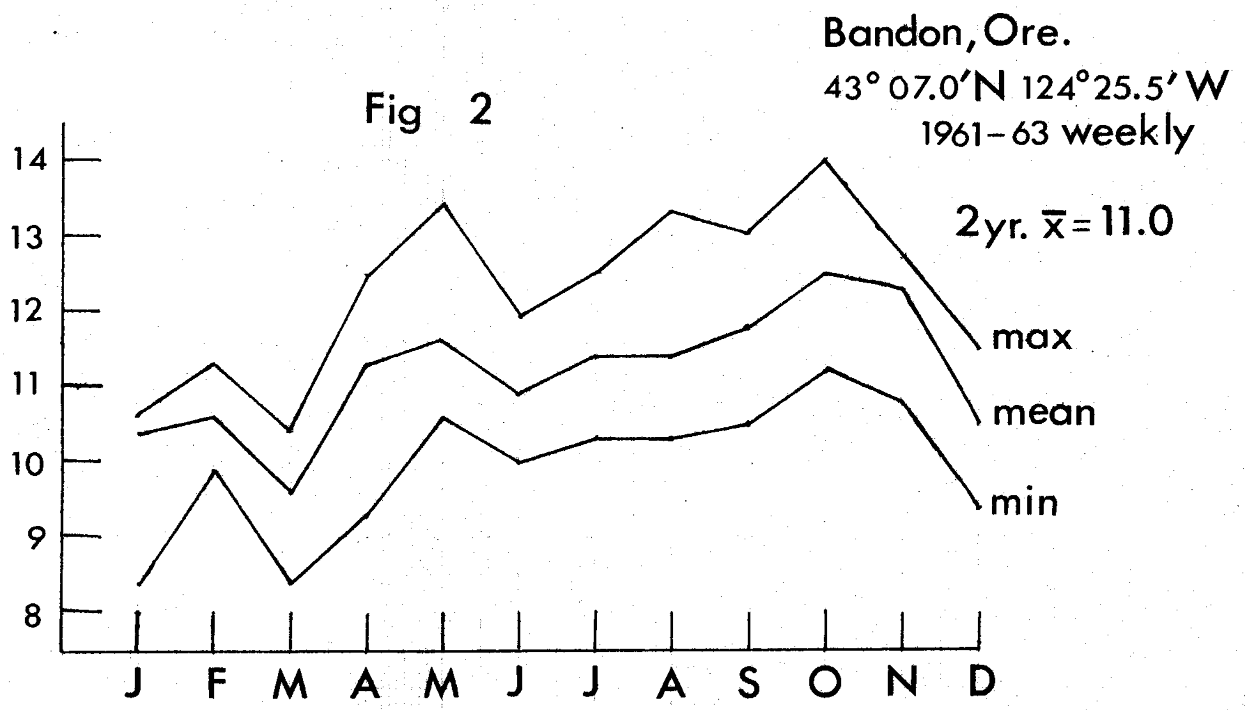

Otter Rock, Ore.
44° 44.6′ N., 124° 58.0 W.
1961–63
weekly
3 yr. x̄ = 11.5°C
max
mean
min
15
14
13
12
11
10
9
8
J F M A M J J A S O N D
Cape Arago, Ore.
43° 20.3′ N., 124° 04.0′ W
1963–64 daily
2yr. x̄ = 12.5 °C
max
mean
min
16
15
14
13
12
11
10
9
J F M A M J J A S O N D

Figure 2. Sea Surface Temperature

1961-63 Bandon and Humbug Mt., Oregon

Fig 2


Bandon, Ore.
43° 07.0'N 124°25.5'W
1961–63 weekly
2yr. x̄ = 11.0
14
13
12
11
10
9
8
max
mean
min
J F M A M J J A S O N D

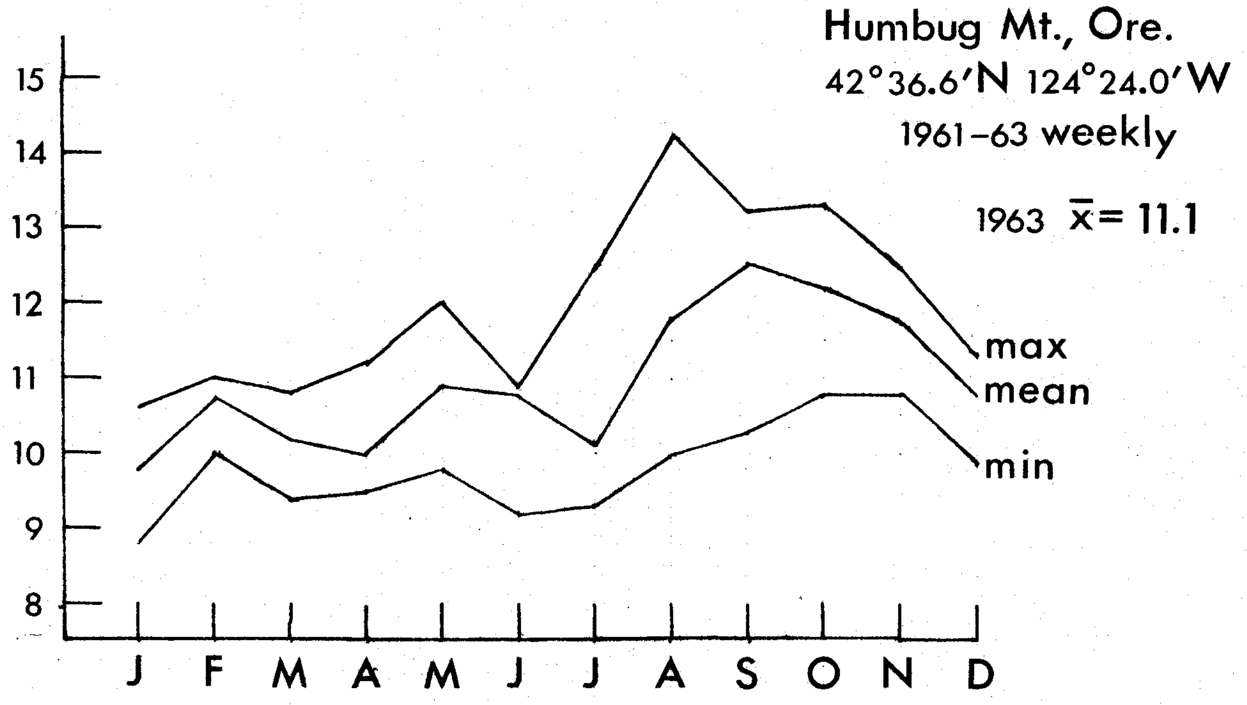
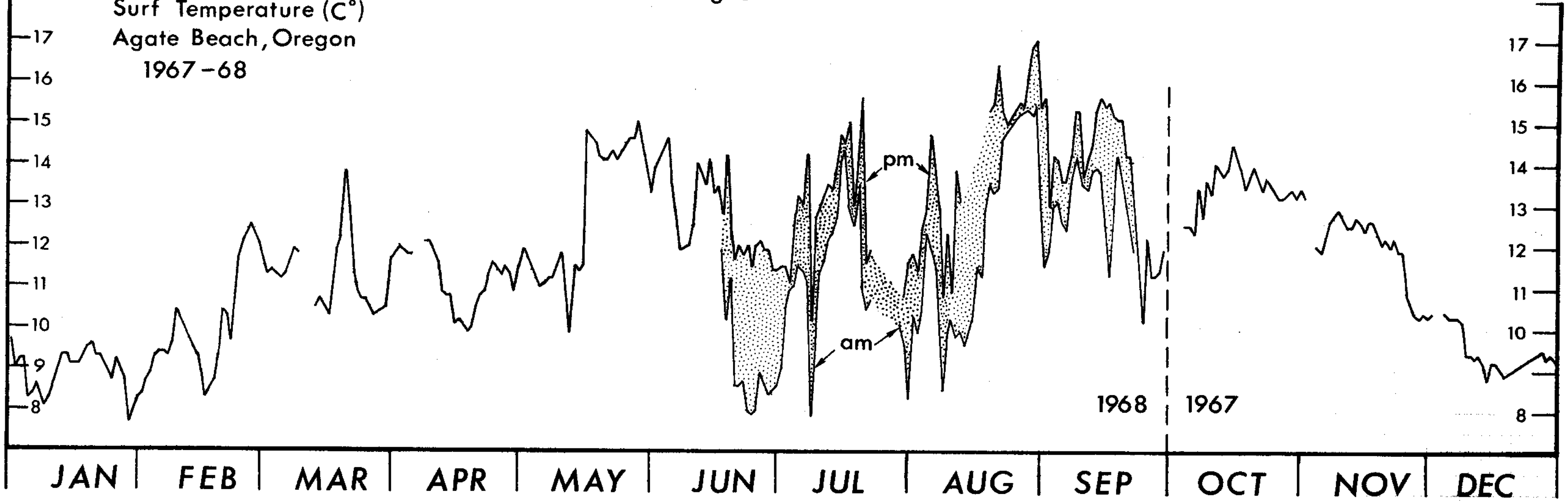

Humbug Mt., Ore.
42°36.6'N 124°24.0'W
1961–63 weekly
1963 x̄ = 11.1
15
14
13
12
11
10
9
8
max
mean
min
J F M A M J J A S O N D

Figure 3. Surf Temperature

Agate Beach, Oregon 1967-68

Fig 3



Surf Temperature (C°)
Agate Beach, Oregon
1967–68
17
16
15
14
13
12
11
10
9
8
pm
am
1968
1967
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 4. Gonad Index, *Tonicella lineata* and Sea Temperature, Yaquina Head, Oregon

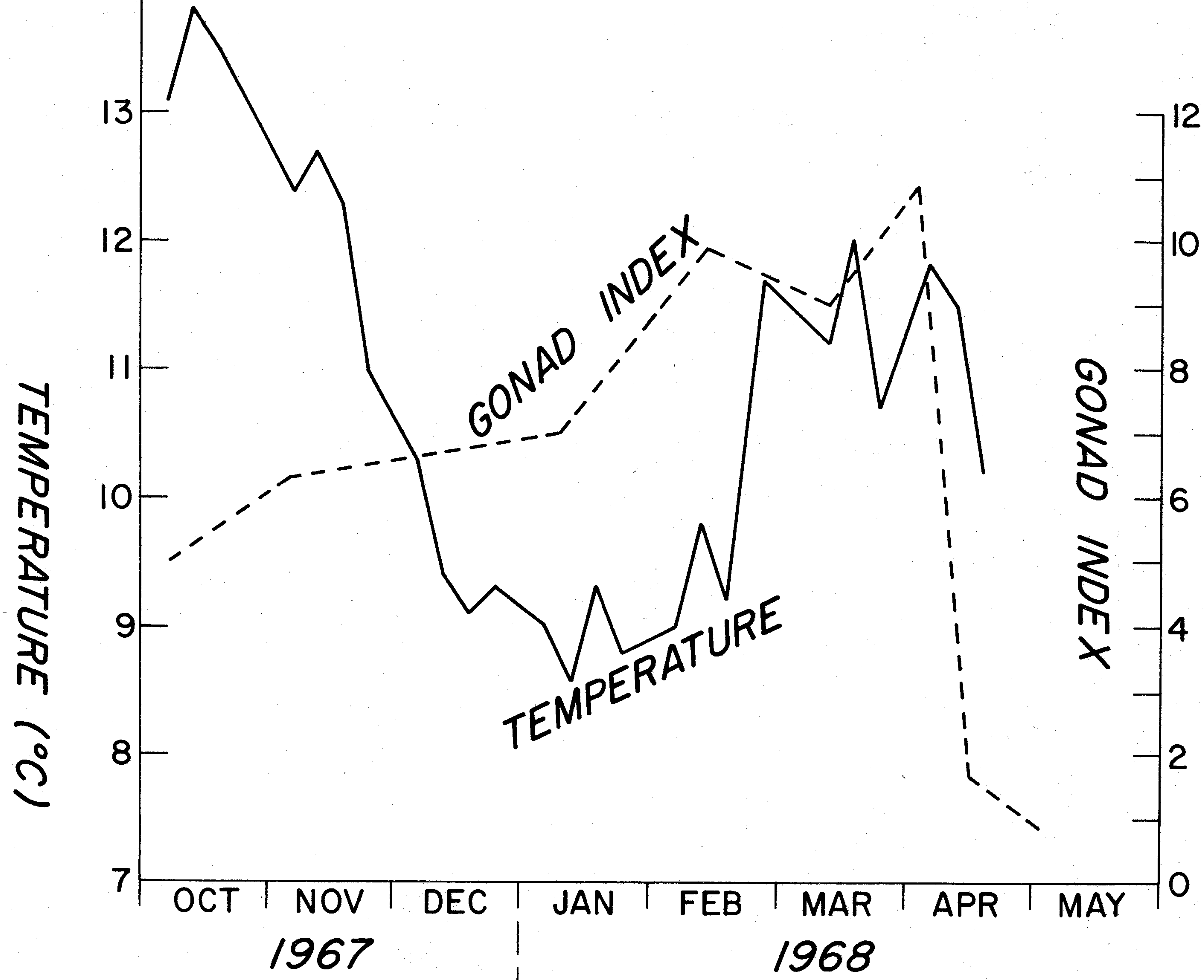

TEMPERATURE (°C)
GONAD INDEX
7
8
9
10
11
12
13
0
2
4
6
8
10
12
GONAD INDEX
TEMPERATURE
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1967
1968

Fig 4

Figure 5. Limpet vertical range, percent emersion and environment temperatures

Fig 5

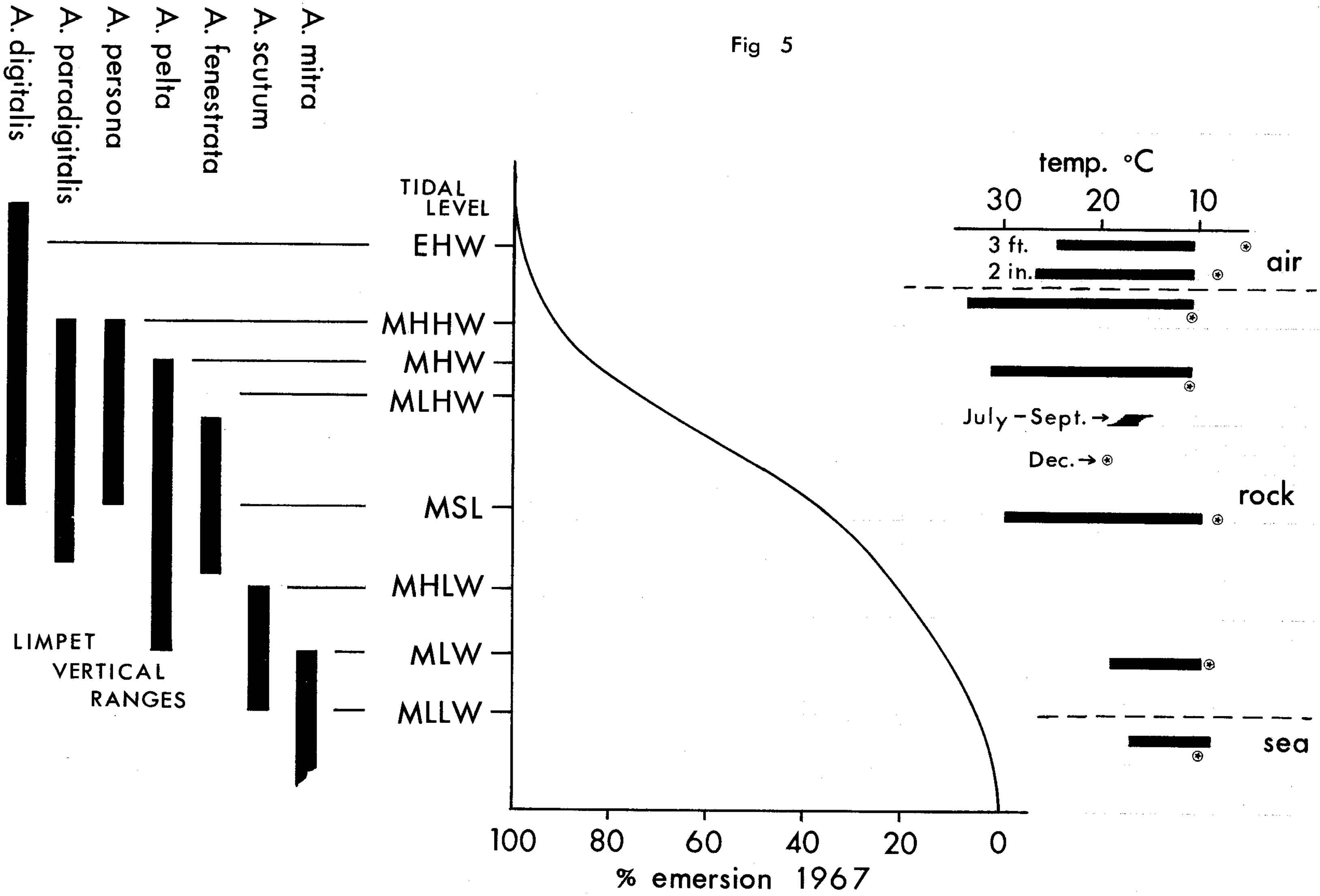
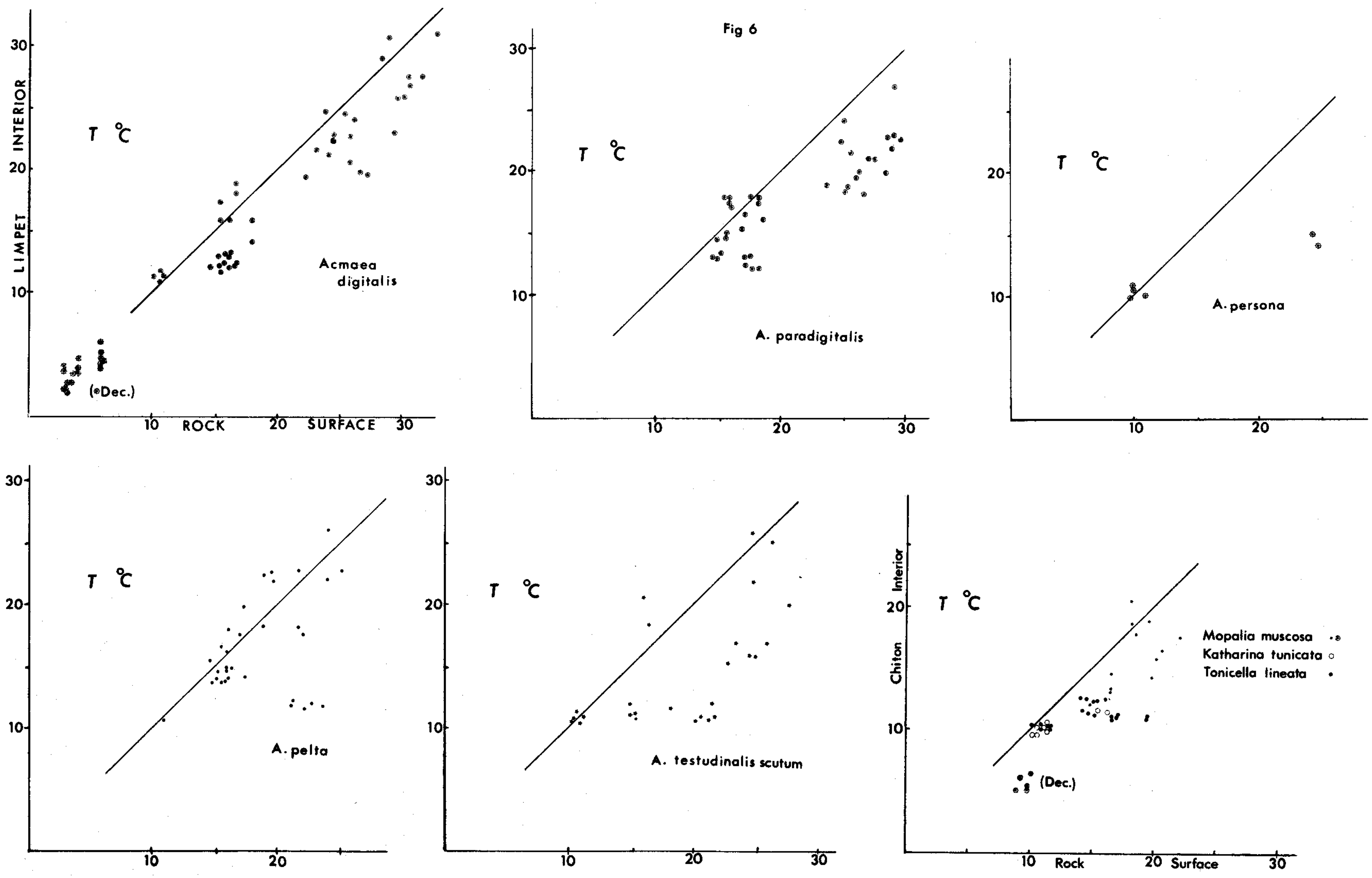

A. digitalis
A. paradigitalis
A. persona
A. pelta
A. fenestrata
A. scutum
A. mitra
TIDAL LEVEL
EHW
MHHW
MHW
MLHW
MSL
MHLW
MLW
MLLW
LIMPET VERTICAL RANGES
100
80
60
40
20
0
% emersion 1967
temp. °C
30
20
10
3 ft.
2 in.
air
July – Sept. →
Dec. →
rock
sea

Figure 6. Limpet, chiton, and rock surface temperatures, 1967

Fig 6



T °C
LIMPET INTERIOR
ROCK SURFACE
Acmaea digitalis
(•Dec.)
A. paradigitalis
A. persona
A. pelta
A. testudinalis scutum
Chiton Interior
Rock Surface
(Dec.)
Mopalia muscosa
Katharina tunicata
Tonicella lineata

Figure 7. <u>Mytilus californianus</u> internal temperature, August, 1968

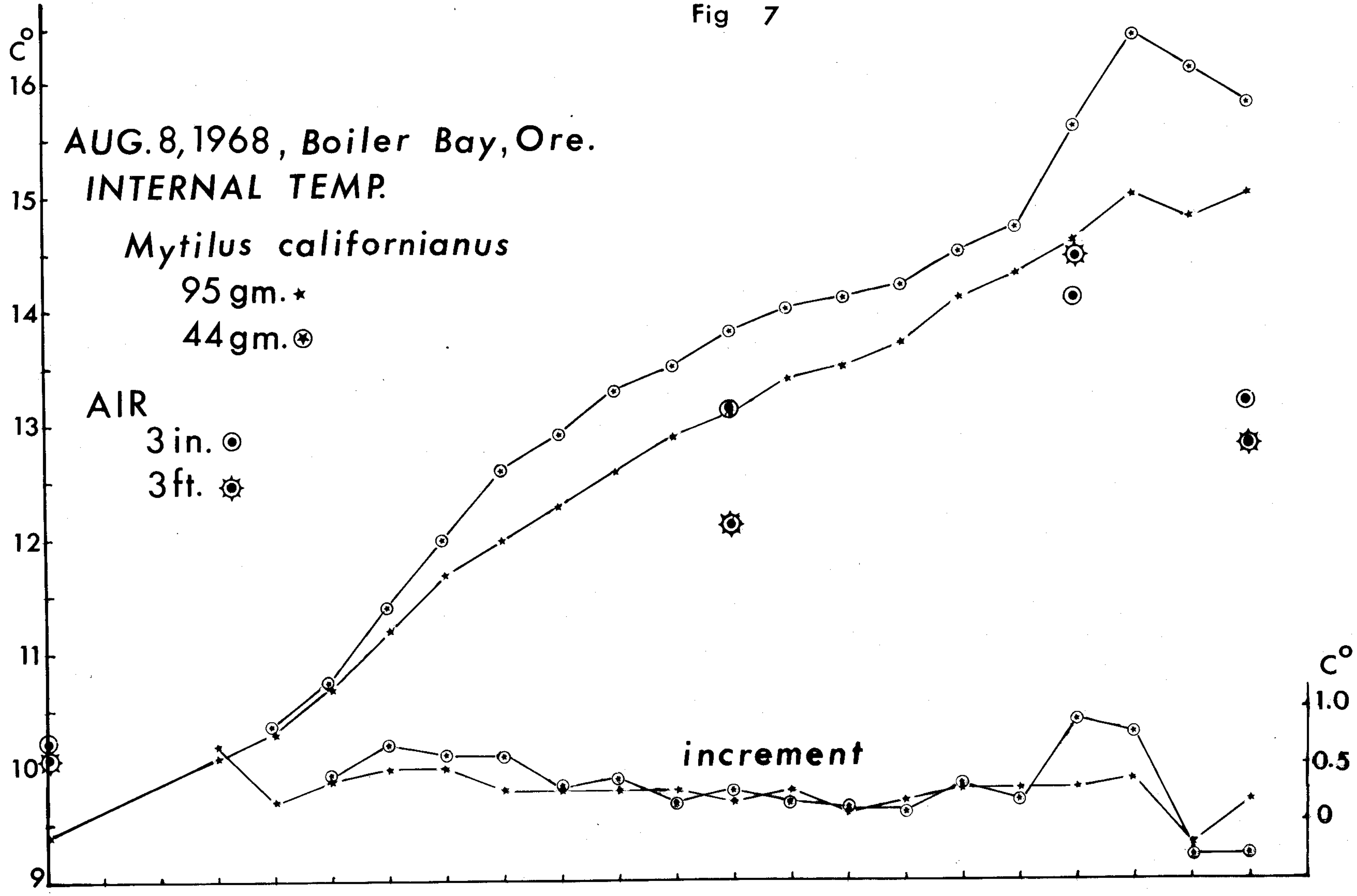


Fig 7
C°
16
15
14
13
12
11
10
9
AUG. 8, 1968, Boiler Bay, Ore.
INTERNAL TEMP.
Mytilus californianus
95 gm.
44 gm.
AIR
3 in.
3 ft.
increment
C°
1.0
0.5
0

TABLE 1

DAILY SURF TEMPERATURE

AT

AGATE BEACH, OREGON

A.M. measurements made at 8:00 A.M.

P.M. measurements made at 4:00 P.M.

1967 Date		T.°C.	S °/oo
Oct.	4	12.5	-
	5	12.5	-
	6	12.3	-
	7	13.4	-
	8	12.7	-
	9	13.6	-
	10	13.3	-
	11	14.0	-
	12	13.9	-
	13	13.7	-
	14	13.9	32.59
	15	14.4	32.64
	16	14.4	32.57
	17	13.9	32.61
	18	13.4	32.17
	19	13.7	32.25
	20	13.4	32.26
	21	13.9	31.90
	22	13.4	31.76
	23	13.7	31.99
	24	13.4	31.81
	25	13.4	32.04
	26	13.2	32.14
	27	13.2	30.04
	28	-	32.39
	29	13.4	31.92
	30	13.2	32.13
	31	13.4	32.09

1967 Date		T.°C.	S °/oo
Nov.	1	13.2	32.17
	2	-	-
	3	-	-
	4	12.0	32.25
	5	11.9	32.28
	6	-	-
	7	12.6	31.58
	8	12.7	31.03
	9	12.9	31.59
	10	12.8	31.00
	11	12.5	31.69
	12	12.5	31.68
	13	12.7	-
	14	12.6	-
	15	12.4	31.67
	16	12.6	31.48
	17	12.6	35.02
	18	12.3	32.14
	19	12.1	32.22
	20	12.2	32.32
	21	12.0	32.35
	22	12.2	32.41
	23	11.9	32.48
	24	11.9	32.22
	25	10.9	32.69
	26	10.4	32.82
	27	10.4	31.97
	28	10.3	31.97
	29	10.4	29.84
	30	10.3	29.89

1967			
Dec.	1	10.4	29.67
	2	-	-
	3	-	-
	4	10.4	30.51
	5	10.3	30.79
	6	10.3	31.19
	7	10.3	31.14
	8	10.2	30.78
	9	9.4	29.16
	10	9.4	30.79
	11	9.3	28.04
	12	9.4	31.86
	13	9.2	32.27
	14	8.8	32.32
	15	9.2	32.40
	16	9.2	32.20
	17	9.1	32.22
	18	8.9	31.38
	19	9.0	31.40
	20	9.0	31.33
	21	9.1	31.30
	22	9.2	31.35
	23	9.2	17.66*
	24	9.3	31.52
	25	-	-
	26	9.4	31.71
	27	9.5	32.16
	28	9.3	32.04
	29	9.4	32.14
	30	9.3	32.44
	31	9.2	32.43

1968			
Jan.	1	-	-
	2	9.7	32.43
	3	9.0	30.46
	4	9.2	32.10
	5	9.2	-
	6	8.3	8.72*
	7	8.4	27.4
	8	8.6	31.03
	9	8.4	31.18
	10	8.1	31.17
	11	8.3	30.72
	12	8.6	31.31
	13	8.9	31.24
	14	9.3	30.48
	15	9.3	30.48
	16	9.1	29.24
	17	9.1	29.21
	18	9.1	30.28
	19	9.3	30.29
	20	9.5	30.49
	21	9.6	30.49
	22	9.3	30.39
	23	9.3	32.06
	24	9.1	31.98
	25	8.9	32.05
	26	8.7	32.41
	27	9.2	31.87
	28	8.9	31.85
	29	8.5	31.87
	30	7.7	31.88
	31	8.3	30.14

1968 Date		T.°C.	S °/oo
Feb.	1	8.4	25.65
	2	8.7	30.21
	3	8.8	31.28
	4	9.3	30.86
	5	9.4	31.12
	6	9.4	31.31
	7	9.3	31.14
	8	9.6	32.13
	9	10.4	32.14
	10	10.2	31.86
	11	10.0	33.32
	12	9.7	31.86
	13	9.5	32.31
	14	9.3	32.31
	15	8.9	32.11
	16	8.3	31.87
	17	8.5	10.11*
	18	8.7	23.54
	19	9.3	28.78
	20	10.4	14.62
	21	10.3	25.68
	22	9.7	25.98
	23	10.8	28.61
	24	11.7	33.25
	25	12.1	33.24
	26	12.4	29.72
	27	12.5	29.73
	28	12.4	29.52
	29	12.0	29.50

1968 Date		T.°C.	S°/oo
Mar.	1	11.5	-
	2	11.3	29.30
	3	11.4	29.25
	4	11.3	29.34
	5	11.2	29.31
	6	11.3	31.11
	7	11.6	31.16
	8	11.9	31.12
	9	11.8	-
	10	-	-
	11	-	-
	12	-	-
	13	10.5	-
	14	10.7	-
	15	-	-
	16	10.3	-
	17	-	-
	18	11.9	31.25
	19	12.2	30.58
	20	13.8	30.99
	21	12.9	30.78
	22	11.3	30.81
	23	10.9	30.53
	24	10.7	30.52
	25	10.7	30.52
	26	10.5	30.69
	27	10.3	30.75
	28	10.4	30.44
	29	10.5	30.44
	30	11.7	31.09

1968 Date		T.°C.	S °/oo
Apr.	1	11.8	31.54
	2	12.0	31.18
	3	11.9	31.00
	4	11.8	31.19
	5	11.8	29.22
	6	-	-
	7	-	-
	8	12.1	32.07
	9	12.1	32.39
	10	11.9	31.82
	11	11.6	33.07
	12	10.9	33.14
	13	10.8	32.56
	14	10.8	32.64
	15	10.1	-
	16	10.2	32.23
	17	10.1	32.23
	18	9.9	32.35
	19	10.0	32.97
	20	10.5	33.31
	21	10.8	33.32
	22	10.9	33.27
	23	11.3	32.80
	24	11.6	32.71
	25	11.4	32.70
	26	11.3	31.78
	27	11.5	32.19
	28	11.3	32.97
	29	10.9	32.95
	30	11.5	32.14

1968 Date		T.°C.	S°/oo
May	1	11.9	32.73
	2	11.7	32.76
	3	11.4	32.69
	4	11.2	33.41
	5	11.0	33.43
	6	11.1	33.42
	7	11.1	33.38
	8	11.2	33.62
	9	11.5	32.99
	10	11.8	33.40
	11	10.9	-
	12	9.9	31.32
	13	11.5	32.91
	14	11.4	31.64
	15	11.5	32.37
	16	14.8	32.55
	17	-	-
	18	14.5	31.67
	19	14.2	31.76
	20	14.1	31.75
	21	14.1	31.67
	22	14.3	31.75
	23	14.1	29.93
	24	14.2	29.40
	25	14.5	32.77
	26	14.6	30.55
	27	14.6	30.56
	28	15.0	29.55
	29	14.5	30.50
	30	13.9	30.92
	31	13.3	30.93

1968 Date		T.°C. AM	T.°C. PM	S°/oo
June	1	-	13.9	30.21
	2	-	14.1	30.20
	3	-	14.3	31.36
	4	-	14.6	31.36
	5	-	13.6	31.08
	6	-	12.8	32.62
	7	-	11.9	32.63
	8	-	-	-
	9	-	12.0	32.55
	10	-	12.5	32.31
	11	-	14.0	-
	12	-	13.8	32.04
	13	-	13.5	31.76
	14	-	14.1	32.39
	15	-	13.3	32.34
	16	-	13.4	32.83
	17	11.9	12.8	32.75
	18	10.2	14.2	32.95
	19	11.2	12.2	-
	20	8.6	11.7	33.56
	21	8.6	12.0	33.46
	22	8.7	11.8	32.75
	23	8.0	12.0	32.81
	24	7.9	11.5	33.22
	25	8.0	12.0	33.43
	26	8.9	12.1	33.24
	27	8.7	11.9	33.31
	28	8.4	11.9	33.58
	29	8.4	11.4	33.58
	30	8.6	11.4	33.59

1968 Date		T.°C. AM	T.°C. PM	S°/oo
July	1	9.0	11.5	33.58
	2	10.5	11.5	33.24
	3	10.9	11.1	33.14
	4	11.0	12.5	32.65
	5	11.5	13.2	33.64
	6	11.4	13.0	33.64
	7	11.2	14.2	33.58
	8	7.9	10.2	33.57
	9	10.8	12.7	33.40
	10	11.3	13.0	29.94
	11	11.6	13.2	29.32
	12	12.2	13.5	32.29
	13	12.3	13.4	32.77
	14	12.7	13.8	32.78
	15	14.2	14.7	32.77
	16	14.3	14.5	32.77
	17	14.3	15.0	32.62
	18	13.0	13.0	32.60
	19	12.5	13.8	33.09
	20	14.0	15.6	33.07
	21	11.0	11.6	33.50
	22	10.5	11.9	33.45
	23	-	-	-
	24	-	-	-
	25	-	-	-
	26	10.4	-	32.03
	27	-	-	-
	28	-	-	-
	29	10.1	-	-
	30	9.6	10.8	33.78
	31	8.3	11.6	33.78

1968 Date		T.°C. AM	T.°C. PM	S°/oo
Aug.	1	10.3	11.8	33.27
	2	9.9	11.4	33.56
	3	10.4	12.4	33.56
	4	12.3	12.8	33.56
	5	12.0	14.7	33.40
	6	11.6	-	-
	7	-	12.9	-
	8	8.5	10.8	33.57
	9	9.8	12.3	33.63
	10	10.2	10.9	33.44
	11	9.8	13.8	33.60
	12	9.9	13.1	33.62
	13	9.6	-	33.60
	14	9.8	-	-
	15	10.2	-	-
	16	11.5	-	-
	17	11.3	-	-
	18	12.9	-	-
	19	13.5	15.3	33.92
	20	13.3	15.5	32.91
	21	13.4	16.4	-
	22	14.6	15.3	32.39
	23	14.8	15.0	25.77
	24	-	-	-
	25	-	-	-
	26	15.3	15.5	30.85
	27	15.3	15.4	31.29
	28	-	16.3	31.70
	29	16.3	16.8	31.92
	30	16.2	17.0	-
	31	-	-	-

1968 Date		T.°C. AM	T.°C. PM	S°/oo
Sep.	1	-	-	-
	2	-	-	-
	3	13.5	15.4	-
	4	11.5	15.6	31.86
	5	11.9	13.0	32.99
	6	13.3	14.2	32.88
	7	13.1	14.1	32.85
	8	12.6	13.6	32.84
	9	12.4	13.6	32.79
	10	13.6	14.2	32.33
	11	14.0	15.3	32.45
	12	14.3	15.4	32.37
	13	13.6	13.7	32.57
	14	13.4	14.1	31.98
	15	13.8	14.4	32.24
	16	13.9	15.3	32.29
	17	13.8	15.6	30.29
	18	12.5	15.4	32.38
	19	11.3	15.5	32.32
	20	13.0	15.2	32.21
	21	14.1	15.1	32.35
	22	13.8	15.1	32.50
	23	13.2	14.2	-
	24	12.6	14.2	-
	25	12.1	-	-
	26	-	-	-
	27	9.3	10.2	33.12
	28	-	12.2	33.12
	29	-	11.3	33.14
	30	-	11.3	33.04

TABLE 2

ENVIRONMENT TEMPERATURES - 1967

Date/Location	Time	Air Shade 3'	Air Shade 2"	Rock surface A. digitalis zone	Rock surface B. glandula zone	Mussel bed	Hedophyllum	Sea	Comment
Boiler Bay									
7/20/67	2:15PM	21.8	23.0	32.7	31.0	-	-	16.5	3/4 cloud cover
7/27/67	4:30PM	17.4	21.2	28.8	26.4	-	-	-	-
7/28/67	1:00PM	18.5	21.8	30.4	27.0	29.6	18.5	13.3	-
8/4/67	7:15AM	14.7	17.5	21.3	19.1	12.1	11.1	10.0	-
8/6/67	7:00AM	16.0	21.7	23.2	-	-	-	9.8	cloudy, no sun
8/24/67	8:45AM	12.3	12.5	13.2	11.5	9.2	9.3	8.5	windy
8/24/67	9:30AM	12.2	14.2	14.8	-	-	11.8	9.2	-
8/29/67	2:15PM	18.2	22.8	-	-	-	-	10.7	-
12/15/67	4:00PM	5.2	8.0	10.5	10.6	7.9	8.9	9.9	ice present
Yaquina Head									
7/22/67	7:30AM	13.3	13.3	12.8	13.0	11.4	11.4	8.9	fog - light breeze
7/29/67	2:00PM	22.4	25.3	31.7	28.2	-	13.1	-	-
8/19/67	7:00AM	10.5	10.4	10.3	10.3	9.3	10.2	9.8	fog, windy
9/3/67	7:30AM	11.6	11.8	12.8	13.0	11.8	11.6	11.7	foggy
9/14/67	2:30PM	24.2	26.5	33.1	-	-	-	14.6	-
Shell Cove									
7/27/67	2:30PM	19.2	20.4	27.3	25.1	-	-	10.0	no clouds, slight wind
Depoe Bay Channel									
7/27/67	3:30PM	20.1	24.2	29.0	29.0	-	-	10.0	-
North Jetty									
8/1/67	3:00PM	16.2	18.2	25.7	-	-	-	10.4	-
8/3/67	3:30PM	13.0	13.4	15.6	-	-	-	-	fog, light breeze

TABLE 3

LIMPET INTERNAL TEMPERATURES - 1967

Location/date	Time	Air(2" shade)	Sea T.	Adjacent rock surface	Internal T. Limpet
Acmaea digitalis					
Vertical range - above mean higher high water to mean sea level.					
Yaquina Head 7/29/67	2 PM	25.3°C	13.1°C	n = 8 mean = 24.9°C	n = 8 m = 25.4°C
North Jetty 8/1/67	3 PM	18.2	10.4	n = 9 mean = 29.06	n = 9 m = 24.23
8/3/67	3:30PM	13.4	-	n = 5 mean = 15.62	n = 5 m = 14.14
Boiler Bay 8/4/67	7:15AM	17.5	10.0	n = 12 mean = 18.93	n = 12 m = 15.95
Yaquina Head 8/19/67	7 AM	10.4	9.8	n = 7 mean = 10.56	n = 7 m = 11.47
Boiler Bay 8/24/67	9:15AM	14.2	9.2	n = 6 mean = 16.70	n = 6 m = 16.68
12/15/67	4:30PM	8.0	9.9	n = 18 mean = 4.41	n = 18 m = 3.89
Acmaea fenestrata					
Vertical range - below mean high water to above mean low water.					
Boiler Bay 8/4/67	7:15AM	17.5	10.0	14.5	17.2
Acmaea persona					
Vertical range - mean higher high water to mean sea level.					
North Jetty 8/1/67	3 PM	18.2	10.4	n = 2 mean = 24.5	n = 2 m = 14.5
Yaquina Head 8/19/67	7 AM	10.4	9.8	n = 4 mean = 10.13	n = 4 m = 10.35
Acmaea pelta					
Vertical range - mean high water to mean low water.					
Yaquina Head 7/9/67	2 PM	25.3	13.1	n = 3 mean = 22.73	n = 3 m = 19.37
North Jetty 8/3/67	3:30PM	13.4	-	n = 14 mean = 16.23	n = 14 m = 15.33
Boiler Bay 8/4/67	7:15AM	17.5	10.0	n = 11 mean = 21.99	n = 11 m = 18.08

TABLE 3

LIMPET INTERNAL TEMPERATURES - 1967

Location/date	Time	Air(2" shade)	Sea T.	Adjacent rock surface	Internal T. Limpet
Acmaea pelta (cont'd)					
Yaquina Head 8/19/67	7 AM	10.4	9.8	10.9	10.7
Boiler Bay 8/24/67	9:15AM	14.2	9.2	n = 3 mean = 15.90	n = 3 m = 17.36
Acmaea paradigitalis Vertical range - mean higher high water to mean sea level.					
Yaquina Head 7/29/67	2 PM	25.3	13.1	n = 3 mean = 24.87	n = 3 m = 22.90
North Jetty 8/1/67	3 PM	18.2	10.4	n = 12 mean = 27.23	n = 12 m = 21.34
8/3/67	3:30PM	13.4	-	n = 13 mean = 16.52	n = 13 m = 15.75
Boiler Bay 8/4/67	7:15AM	17.5	10.0	n = 8 mean = 21.05	n = 8 m = 15.36
8/24/67	9:15AM	14.2	9.2	n = 5 mean = 16.14	n = 5 m = 18.04
Acmaea testudinalis Vertical range - mean high water to mean low water.					
North Jetty 8/1/67	3 PM	18.2	10.4	n = 7 mean = 24.77	n = 7 m = 17.66
Boiler Bay 8/4/67	7:15AM	17.5	10.0	n = 13 mean = 19.60	n = 13 m = 13.49
Yaquina Head 8/19/67	7 AM	10.4	9.8	n = 7 mean = 10.50	n = 7 m = 10.91
Boiler Bay 8/24/67	9:15AM	14.2	9.2	n = 4 mean = 16.28	n = 4 m = 19.25

LIMPET INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	Exposure Time R	Internal Temp. °C. Mean	Internal Temp. °C. Min.	Internal Temp. °C. Max.	No.	Sea T. °C.
Acmaea pelta Boiler Bay									
6/11/68	8:15AM	-	-	-	12.73	11.71	14.1	17	9.4
6/11/68	8:34AM	-	-	-	12.33	11.46	13.4	40	

TABLE 4

CHITON INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	Exposure Time R	Internal Temp. °C. Mean	Min.	Max.	No.	Sea T. °C.
Katharina tunicata									
Boiler Bay									
5/29/68	10:30AM	+3.0	4:55	1:45	22.32	16.94	26.89	35	14.6
5/31/68	11:40AM	1.0	3:50	:20	16.21	14.7	17.6	36	13.0
6/11/68	7:58AM	+3.0	3:40	3:15	11.55	10.84	12.8	36	9.4
6/11/68	8:07AM	+3.0	3:50	3:05	12.26	11.46	13.80	9	
6/12/68	7:52AM	+3.0	2:45	4:15	11.09	9.72	13.8	30	11.7
6/12/68	10:14AM	+4.0	5:20	2:25	14.86	12.7	16.8	30	11.2
6/12/68	10:21AM	+3.0	5:10	1:50	13.54	12.4	16.4	13	
6/14/68	10:00AM	+3.0	3:10	3:40	21.62	17.3	26.3	30	13.8
6/14/68	11:47AM	+3.0	4:55	1:55	26.97	21.5	30.2	30	14.4
Tonicella lineata									
Boiler Bay									
6/15/68	9:18AM	+1.0	:45	4:10	17.81	15.9	20.9	30	14.1
6/15/68	10:45AM	+1.0	2:10	2:45	23.28	18.5	25.6	30	
Mopalia muscosa									
Boiler Bay									
6/12/68	11:30AM	+3.0	6:20	:40	18.13	14.2	21.0	12	11.2
Cryptochiton									
Boiler Bay									
6/12/68	-	-	-	-	14.82	12.08	17.6	40	11.7
6/12/68	-	-	-	-	13.24	12.21	15.0	40	

TABLE 4

CHITON INTERNAL TEMPERATURES - 1967

Location/date	Time	Air(2" shade)	Sea T.	Adjacent rock surface	Internal T. Chiton
Tonicella lineata					
Vertical range - mean low water to subtidal.					
Yaquina Head 8/6/67	7:15AM	17.8	9.8	n = 17 mean = 15.76	n = 17 m = 11.55
8/19/67	7 AM	10.4	9.8	n = 4 mean = 11.05	n = 4 m = 10.25
Katharina tunicata					
Vertical range - above mean low water to mean low low water.					
Yaquina Head 8/6/67	7:15AM	17.8	9.8	n = 2 mean = 15.7	n = 2 m = 16.6
8/19/67	7 AM	10.4	9.8	n = 6 mean = 10.92	n = 6 m = 10.05
Mopalia muscosa					
Vertical range - mean sea level to mean low water.					
Boiler Bay 8/24/67	11 AM	-	9.2	n = 13 mean = 18.43	n = 13 m = 16.17
12/15/67	5 PM	8.0	9.9	n = 5 mean = 9.54	n = 5 m = 5.72

TABLE 5

MYTILUS INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	Exposure Time R	Internal Temp. °C. Mean	Internal Temp. °C. Min.	Internal Temp. °C. Max.	No.	Sea T. °C.
Mytilus californianus									
Boiler Bay									
Site #4									
5/17/68	-	+4.0	-	-	20.12	17.93	22.91	23	12.8
5/18/68	10:20AM	+3.0	1:10	5:20	19.39	16.19	23.67	46	12.1
5/18/68	10:40AM	+7.0	4:00	8:05	23.65	20.67	26.64	38	
5/18/68	12:30PM	+3.0	3:10	3:20	24.83	23.03	27.13	41	
5/27/68	8:02AM	+3.0	3:15	2:35	13.14	12.83	13.70	31	13.1
5/27/68	8:23AM	+7.0	6:15	5:15	14.14	13.70	14.57	33	
5/29/68	8:15AM	+3.0	2:40	4:00	15.77	12.46	18.93	32	13.4
5/29/68	8:45AM	+7.0	5:20	-	18.20	15.94	22.16	33	
5/29/68	11:00AM	+3.0	5:25	1:15	27.30	23.28	30.62	42	
5/29/68	11:30AM	+7.0	8:05	-	27.99	25.77	30.37	34	14.6
5/30/68	10:08AM	+3.0	4:05	1:30	23.76	20.10	28.30	31	13.0
5/31/68	11:55AM	+3.0	5:10	1:25	19.58	18.00	20.50	30	13.0
5/31/68	-	+7.0	-	-	19.93	18.60	20.90	30	
6/10/68	7:05AM	+3.0	3:30	3:20	11.74	11.21	12.21	30	9.8
6/11/68	9:30AM	+3.0	5:10	1:45	13.80	13.20	14.8	30	9.4
6/11/68	9:40AM	+7.0	6:50	4:10	16.86	14.90	18.60	30	10.0
6/12/68	7:23AM	+3.0	2:15	4:45	10.26	9.35	12.08	30	11.5
6/12/68	7:31AM	+7.0	4:50	6:05	10.90	10.09	12.21	30	
6/12/68	10:55AM	+3.0	5:45	1:15	19.60	15.90	22.60	30	
6/12/68	11:03AM	+5.0	6:30	2:10	19.98	16.50	21.50	30	
6/12/68	11:10AM	+7.0	7:30	3:25	20.62	19.8	23.4	30	
6/14/68	9:20AM	+3.0	4:15	2:35	21.01	17.9	24.1	30	13.8
6/14/68	9:27AM	+7.0	4:25	7:15	22.77	18.4	24.9	30	13.8
6/14/68	12:00PM	+3.0	5:10	1:40	30.75	27.6	32.9	30	14.3
6/14/68	12:15PM	+7.0	7:10	4:30	31.04	29.0	34.40	30	14.3
6/25/68	7:15AM	+3.0	3:30	3:30	9.52	8.98	10.97	30	9.4
6/25/68	7:50AM	+7.0	6:10	-	13.4	12.58	16.94	30	9.6
6/25/68	9:10AM	+3.0	5:25	1:35	18.2	14.57	22.28	30	9.9
6/25/68	9:27AM	+7.0	7:50	-	17.5	16.69	20.92	30	10.4
Site #4A									
5/30/68	10:30AM	+5.0	5:25	3:45	25.85	21.9	28.1	30	12.9
5/31/68	10:58AM	+2.0	3:45	1:40	19.02	17.0	21.6	33	13.0
5/31/68	11:05AM	+5.0	5:25	3:35	20.80	19.6	22.0	32	13.0

TABLE 6

TEGULA, BALANUS, SEA ANEMONE INTERNAL TEMPERATURES -1968

Place, species, date	Time	Level	Exposure Time L	Exposure Time R	Internal Temp. °C. Mean	Internal Temp. °C. Min.	Internal Temp. °C. Max.	No.	Sea T. °C.
Tegula funebralis									
Boiler Bay									
5/18/68	11:49AM	+4.0	3:10	4:30	22.33	17.81	25.89	55	12.1
6/11/68	-	+4.0	-	-	18.86	17.0	24.1	30	9.4
6/12/68	7:14AM	+4.0	2:20	5:25	9.66	9.35	9.97	30	11.7
6/12/68	10:04AM	+1.0	4:05	1:15	17.72	16.9	19.3	30	
6/12/68	11:22AM	+4.0	6:35	1:10	20.08	17.1	21.9	32	
6/14/68	9:05AM	+4.0	2:35	5:05	18.70	16.1	21.6	30	13.8
6/14/68	11:08AM	+1.0	3:30	1:35	29.04	25.3	32.6	30	
6/14/68	12:25PM	+4.0	5:55	1:45	28.84	24.4	32.7	30	
Site #6									
5/29/68	11:48AM	+4.0	6:40	:55	24.82	20.42	28.63	38	14.6
Balanus cariosus									
Boiler Bay									
Site #4A									
5/18/68	11:10AM	+5.0	3:05	5:50	20.00	18.56	21.41	34	12.1
5/18/68	11:20AM	+5.0	3:15	5:40	23.49	25.60	27.40	34	
5/27/68	8:48AM	+5.0	5:00	3:00	13.54	13.33	13.83	34	13.10
5/29/68	9:00AM	+5.0	5:25	3:30	16.00	14.45	17.43	33	
5/29/68	9:10AM	+5.0	5:35	3:20	20.16	15.94	25.14	31	13.4
5/29/68	11:25AM	+5.0	6:50	2:05	24.00	20.67	25.77	35	14.6
5/30/68	8:55AM	+5.0	3:50	5:20	24.50	22.6	26.2	30	12.9
5/31/68	11:35AM	+5.0	5:55	3:05	18.30	17.10	18.60	31	13.0
5/31/68	11:50AM	+5.0	6:10	2:50	16.72	15.90	17.80	19	
6/11/68	9:45AM	+5.0	6:05	2:30	15.41	14.4	16.9	30	10.3
6/12/68	7:40AM	+5.0	3:10	5:30	10.26	9.60	11.22	30	11.7
6/12/68	10:27AM	+5.0	5:55	2:45	15.43	13.70	16.44	30	11.2
6/12/68	10:32AM	+5.0	6:00	2:40	14.55	14.0	15.1	30	
6/14/68	9:35AM	+5.0	3:30	5:10	19.04	17.1	22.2	30	13.8
6/17/68	11:40AM	+5.0	3:40	5:20	27.74	24.9	30.1	30	14.4
6/25/68	7:30AM	+5.0	4:40	6:10	10.36	9.85	11.46	30	9.6
6/25/68	9:20AM	+5.0	6:30	4:20	16.10	14.20	18.05	30	9.9
Site #9									
5/31/68	11:00AM	+2.0	3:45	1:40	18.19	17.0	18.9	34	
Anthopleura xanthogrammica									
Boiler Bay									
Site #10									
6/11/68	7:48AM	-	-	-	11.12	10.72	11.71	36	9.4
6/12/68	8:29AM	-	-	-	15.03	10.59	19.1	30	11.7

TABLE 7

POLLICIPES INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	R	Internal Temp. °C. Mean	Min.	Max.	No.	Sea T. °C.
Pollicipes polymerus									
Boiler Bay									
Site #4A									
5/17/68	-	+6.0	-	-	*M17.94	15.94	20.17	34	12.8
					S17.66	15.44	20.42	34	
5/18/68	10:40AM	+3.0	1:30	5:00	M21.48	17.56	24.15	32	12.1
					S17.93	14.82	20.67	32	
5/18/68	12:43PM	+3.0	3:35	2:55	M23.59	19.55	26.14	36	
					S21.08	18.30	24.90	36	
5/18/68	1:00PM	+6.0	5:40	4:45	M25.84	24.40	27.39	32	
					S23.98	20.67	26.64	32	
5/18/68	11:20AM	+6.0	4:00	6:25	M18.17	15.82	21.79	31	
					S16.66	15.07	19.42	31	
5/27/68	8:52AM	+6.0	5:35	3:45	M-	-	-	12	13.15
					S13.66	13.20	13.95	12	
5/29/68	9:25AM	+2.0	3:25	2:10	M19.71	16.19	22.41	31	13.4
					S18.68	14.32	21.42	31	
5/29/68	9:35AM	+2.0	3:35	2:00	M13.37	12.58	13.95	38	
					S12.53	12.09	13.06	38	
5/29/68	9:50AM	+6.0	5:50	4:45	M26.18	21.91	29.00	31	
					S25.57	21.91	29.50	31	
5/29/68	11:15AM	+6.0	7:15	3:20	M23.61	20.04	28.38	35	14.6
					S23.91	20.04	28.75	35	
5/31/68	10:40AM	+2.0	3:25	2:00	M18.39	16.6	16.0	31	13.0
					S17.50	19.4	18.6	31	
5/31/68	11:15AM	+6.0	6:15	4:20	M17.91	16.50	16.1	11	
					S17.93	19.1	19.3	11	
5/31/68	11:20AM	+2.0	4:05	1:20	M17.67	15.8	20.0	42	14.4
					S17.76	15.8	20.0	42	
6/14/68	9:40AM	+6.0	4:05	5:45	M13.81	10.59	14.5	30	13.8
					S-	-	-		
6/14/68	9:45AM	+6.0	4:10	5:40	M24.51	20.7	28.3	30	13.8
					S24.80	20.1	29.1	30	
6/14/68	11:30AM	+6.0	5:55	3:55	M27.06	22.9	22.1	30	14.3
					S29.04	31.3	33.2	30	

*M = Mantle
S = Stalk

TABLE 8

SEA URCHIN INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	R	Internal Temp. °C. Mean	Min.	Max.	No.	Sea T. °C.
Strongylocentrotus purpuratus									
Boiler Bay									
Site #4									
5/16/68	11:00AM	+1.0	3:15	2:00	23.09	19.67	26.39	30	12.0
5/16/68	11:15AM	+1.0	3:30	1:45	23.3	19.6	26.5	27	
5/17/68	10:40AM	+1.0	1:40	3:05	18.78	15.82	21.91	14	12.8
5/17/68	-	+1.0	-	-	15.73	15.10	17.10	16	
5/18/68	10:20AM	+1.0	:05	3:45	15.42	13.20	19.67	46	12.1
5/18/68	12:15PM	+2.0	2:25	3:55	19.91	16.44	21.79	67	
5/27/68	7:15AM	0.0	:45	1:20	12.96	12.84	13.02	29	13.15
5/27/68	7:26AM	+2.0	2:10	2:35	12.83	12.71	12.96	31	
5/27/68	7:40AM	+3.0	2:55	2:55	12.8	12.7	12.9	10	13.1
5/29/68	7:45AM	0.0	:40	2:30	14.45	12.71	16.94	35	13.4
5/29/68	8:00AM	+2.0	2:00	3:35	15.21	12.71	17.68	33	
5/29/68	10:00AM	+1.0	3:30	1:00	19.67	16.31	23.65	31	
5/29/68	10:15AM	+2.0	4:15	1:20	24.07	15.69	25.14	52	
5/29/68	10:20AM	+3.0	4:25	2:15	19.87	18.43	23.53	36	
5/30/68	9:15AM	0.0	1:40	1:45	18.49	15.80	22.50	54	12.9
5/30/68	9:30AM	+1.0	2:30	2:10	19.42	16.1	23.7	37	
5/31/68	9:55AM	0.0	1:25	1:15	16.41	15.6	17.4	49	13.2
5/31/68	10:15AM	+1.0	1:45	:55	17.45	15.9	18.3	35	13.0
6/10/68	6:55AM	0.0	2:20	2:05	10.90	10.72	11.09	30	
Site #4B									
5/17/68	11:50AM	+1.0	2:50	1:55	16.34	13.95	20.17	8	
5/17/68	11:55AM	+1.0	2:55	1:50	15.55	14.32	16.69	23	
5/17/68	12:00PM	+1.0	3:00	1:45	20.70	16.94	23.28	48	
Site #10									
6/11/68	7:14AM	0.0	2:50	1:40	10.55	10.34	10.84	36	
6/11/68	7:25AM	+2.0	2:40	3:25	10.88	10.22	11.46	36	9.4
6/11/68	7:47AM	+2.0	3:05	3:00	11.00	10.47	11.71	42	
6/11/68	9:00AM	0.0	3:35	:55	12.03	11.46	12.4	30	
6/11/68	9:20AM	0.0	3:55	:35	11.86	11.46	12.21	14	
6/12/68	8:12AM	+1.0	2:15	3:05	14.62	12.33	16.9	30	11.7
6/12/68	9:33AM	+1.0	3:35	1:45	13.64	12.4	16.0	30	
6/12/68	9:40AM	0.0	3:25	1:05	14.00	12.08	17.8	21	
6/12/68	9:45AM	+2.0	5:15	1:00	15.48	13.2	16.6	30	
6/14/68	10:25AM	+1.0	2:45	2:20	22.94	19.9	26.1	30	13.8
6/14/68	10:25AM	+1.0	2:45	2:20	14.56	14.0	15.5	30	
6/14/68	10:40AM	0.0	2:35	1:30	26.09	21.1	30.4	30	
6/15/68	9:00AM	+1.0	:25	4:30	16.14	14.1	18.9	30	13.6
6/15/68	9:17AM	+1.0	:40	4:15	16.87	14.8	22.9	30	
6/15/68	9:50AM	0.0	:45	2:55	13.99	13.7	14.9	30	14.1
6/15/68	10:00AM	+1.0	1:25	3:30	20.65	16.4	27.3	30	

TABLE 8

SEA URCHIN INTERNAL TEMPERATURES - 1968

Place, species, date	Time	Level	Exposure Time L	Exposure Time R	Internal Temp. °C. Mean	Min.	Max.	No.	Sea T. °C.
Strongylocentrotus purpuratus (cont'd)									
6/15/68	10:30AM	+1.0	1:55	3:00	22.28	18.4	23.9	30	
6/15/68	10:36AM	+1.0	1:55	3:00	14.05	13.7	14.5	30	
6/15/68	11:05AM	+1.0	2:20	2:35	25.97	22.9	28.0	30	
6/15/68	11:30AM	+1.0	2:55	2:00	14.74	14.2	15.3	30	
6/15/68	11:37AM	+2.0	3:30	2:20	26.23	22.4	30.0	30	
6/15/68	11:50AM	+1.0	3:15	1:40	26.65	21.9	28.1	30	

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Perth, Australia

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Smithsonian Tropical Research Institute
Fort Amador,
Balboa, Canal Zone, Panama

Abstract

This report is concerned with environmental and animal internal temperatures in the intertidal zone at low tide. Daily sea surface temperatures at Agate Beach, Ore., are compared to weekly measurements made near-by. Greater range and fluctuations are revealed by daily measurements. Data are provided on animal internal temperatures at low tide in early summer for 16 common invertebrates of the rocky intertidal, and some heating rates for 4 of these species. Internal temperature and heating rates were obtained for the sea urchin, *Strongylocentrotus purpuratus*, in June, 1968, during a heat-kill period. All species were found to normally sustain as much as 10°C increases above sea surface temperatures at low tide in early summer. Implications of this for other aspects of the biology of the intertidal fauna are discussed. The hypothesis is advanced that intertidal invertebrates require a temperature regime which includes as seasonal variations both the low and high temperatures experienced at low tide. The increased digestive and assimilative efficiency produced by summer low tide high internal temperatures may be necessary for successful food utilization and gonad reserve build-up.

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13. ABSTRACT

This report is concerned with environmental and animal internal temperatures in the intertidal zone at low tide. Daily sea surface temperatures at Agate Beach, Ore., are compared to weekly measurements made near-by. Greater range and fluctuations are revealed by daily measurements. Data are provided on animal internal temperatures at low tide in early summer for 16 common invertebrates of the rocky intertidal, and some heating rates for 4 of these species. Internal temperature and heating rates were obtained for the sea urchin, Strongylocentrotus purpuratus, in June, 1968, during a heat-kill period. All species were found to normally sustain as much as 10°C increases above sea surface temperatures at low tide in early summer. Implications of this for other aspects of the biology of the intertidal fauna are discussed. The hypothesis is advanced that intertidal invertebrates require a temperature regime which includes as seasonal variations both the low and high temperatures experienced at low tide. The increased digestive and assimilative efficiency produced by summer low tide high internal temperatures may be necessary for successful food utilization and gonad reserve build-up.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
U.S. Pacific Coast, Intertidal						
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Sea Surface Temperature and Salinity						
Intertidal Environment						
Intertidal Invertebrates, Pacific Coast						
Temperature and Reproductive Cycles						
Internal Temperatures, Invertebrates						
Heating rates, marine invertebrates						
Heat Kill, Marine Animals						
Mussles						
Limpets						
Chitons						
Barnacles						
Snails						
Sea Urchins						