The effect of salinity on habitat selection of two Oregon chiton species (Katharina tunicata and Mopalia hindsii)

David Carl Rostal
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This Thesis is brought to you for free and open access. It has been accepted for inclusion in Dissertations and Theses by an authorized administrator of PDXScholar. For more information, please contact pdxscholar@pdx.edu.
Adult specimens of *Katharina tunicata* (mean weight = 10.23 grams) and *Mopalia hindsii* (mean weight = 10.90 grams) were tested for osmotic stress tolerance and oxygen consumption rates in a series of salinities (120%, 100%, 80%, 60%, and 40% seawater) at 11°C and 16L:8D photoperiod. *K. tunicata* and *M. hindsii* displayed similar trends in percent body weight variation and volume regulatory responses to osmotic stress. However, *K. tunicata* experienced a significantly higher percent body weight increase than did *M. hindsii* in response to hypo-osmotic conditions (80%, 60%, and 40% seawater). The mean rates of oxygen
consumption per salinity for the two species were not significantly different. Both species, however, showed reduced oxygen consumption rates and significantly increased weight gain in 40% seawater. SEM comparisons of radulae, ctenidia, and shape of the pallial groove revealed no significant differences between the species relevant to differences observed in habitat selection.

Salinity was measured bimonthly at the two study sites (K. tunicata - Indian Beach, open coast; M. hindsii - Tillamook Bay, brackish) during low tide from January 1985 to June 1985. Salinity measurements revealed a difference in mean salinity between study sites of 12% seawater.

Dominant macroalgal species were identified for the two study sites. Variation in dominant macroalgal species between study sites reflected published dietary preferences; K. tunicata feeds on Hedophyllum sessile, while M. hindsii feeds on Gigartina spp. and animal material. K. tunicata is generally restricted to open coast habitats and is considered stenohaline in nature, while M. hindsii is common to open coast as well as slightly brackish habitats and is considered euryhaline in nature.

The results of this study suggest that both species are osmoconformers with equivalent volume regulatory capabilities and are both euryhaline in nature. Other factors such as diet, larval settling responses, and interspecific competition may be involved in the difference observed in the habitat selection of K. tunicata and M. hindsii. Salinity appears not to be a major influence on habitat selection by these chiton species.
THE EFFECT OF SALINITY ON HABITAT

SELECTION OF TWO OREGON CHITON SPECIES

(Katharina tunicata AND Mopalia hindsii)

by

DAVID CARL ROSTAL

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

BIOLOGY

Portland State University

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TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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CHAPTER I

INTRODUCTION

The effect of salinity on the physiology and ecology of marine molluscs has received limited attention. Prosser (1973) stated that marine molluscs are osmoconformers with varying degrees of stenohalinity. However, more recent evidence suggests that many marine molluscs (Littorina neritoides, Collisella digitalis, Acmaea scutum, Modiolus spp., and Mopalia muscosa) possess mechanisms for active volume regulation and are euryhaline in nature (Burton, 1983).

Among the marine molluscs, the Class Polyplacophora is comprised of only one group of animals, the chitons. Chitons are characterized as a morphologically uniform group and are strictly marine. However, chitons display distinct variations in distribution, microhabitat, diet preferences, and behavior. Chitons occur along rocky shores predominantly in the intertidal zones in all seas and latitudes (Hyman, 1967). Andrus and Legard (1976) compared the habitats of 12 chiton species along the California coast and concluded that surf strength, light exposure, substrate composition, moisture, and biological associates were all important in determining habitat selection.

The diet and feeding habits of many chiton species have been documented. Certain species are reported to display specific preference; e.g., Katharina tunicata feeds on Hedophyllum sessile and diatoms (Dayton, 1975; Himmelman, 1978), Tonicella lineata feeds on
crustose coralline algae (Steneck and Watling, 1982), and _Placiphorella velata_ is predatory on amphipods (McLean, 1962). Other species are reported as indiscriminate or nonselective grazers, e.g., _Mopalia_ spp. feed on _Gigartina_ spp., _Endocladia_ spp., _Gelidium_ sp., (Dayton, 1975; Steneck and Watling, 1982) as well as animal material (Morris et al., 1980), _Cyanoplax hartwegii_ feeds on _Pelvetia_ sp., _Hildenbrandia_ sp., _Petrocelis_ sp., _Endocladia_ sp., and _Cladophora_ (Robb, 1976; Steneck and Watling, 1982), and _Nuttallina californica_ feeds on bluegreen algae and diatoms (Nishi, 1976).

The activity patterns and behavior of chitons has been related to their ecology. Chelazzi et al. (1983) reported that variation in movement patterns of two sympatric species (_Acanthopleura brevispinosa_ and _A. gemmata_) minimizes zonal overlap and reduces interspecific competition. Gómez (1976) observed a commensal association between two sympatric species (_Nuttallina californica_ and _Cyanoplax hartwegii_) along the California coast.

The physiology of several chiton species has been investigated. Boyle (1969) studied the survival of _Sypharochiton pelliserpentis_ exposed to osmotic stress conditions and concluded this species could osmoconform to salinities ranging from 50% to 150% seawater. McGill (1976) reported that _Cyanoplax hartwegii_ is an osmoconformer over a salinity range of 75% to 125% seawater and capable of volume regulation. Simonsen (1976) found that environmental acclimation to varying salinities affected osmotic stress tolerances in _Nuttallina californica_. Stickle and Denoux (1976) reported that hemolymph osmotic concentration of _Katharina tunicata_ fluctuated with tidal fluctuation in osmotic
concentration but did not vary during exposure to air. Stickle and Ahokas (1975) postulated that Mopalia muscosa is less susceptible to osmotic stress than K. tunicata. Lebsack (1976) determined that temperature and variation in salinity from normal seawater affect oxygen consumption rates in Mopalia lignosa.

In this study, the effects of salinity on habitat selection was investigated in two Oregon chiton species, Katharina tunicata and Mopalia hindsii. K. tunicata is generally restricted to open coast habitats and is considered stenohaline in nature, while M. hindsii is common to open coast as well as slightly brackish habitats and is considered euryhaline in nature. The objectives of this study were to compare these two species with regard to their osmotic stress tolerance; their volume regulatory capabilities; the influence of salinity on oxygen consumption rates; variations in the morphology of their radulae, ctenidia, and shape of the pallial groove; and to relate physiological and morphological adaptations of K. tunicata and M. hindsii to difference in their ecology and habitat selection.
Katharina tunicata range in body length to 12 cm, are elongate to oval in shape, and have valves deeply embedded in the girdle. K. tunicata possess a thick, leathery girdle which is shiny and black. They are common in the middle and low intertidal zones clinging to the sides and upper surfaces of rocks along the unprotected outer coast where they are exposed to strong wave action and direct sunlight (Fig. 1A; Morris et al., 1980).

Mopalia hindsii range in body length to 10 cm, are oval and depressed in shape, and have well exposed valves. M. hindsii possess a "mossy" girdle which is dull and brown. They are common under rocks, on inward-sloping rock faces, or in crevices in the middle and low intertidal zones on the outer coast where surf is strong, as well as on wharf pilings in bays and even in slightly brackish waters (Fig. 1B; Morris et al., 1980).
Figure 1. Adult specimens of *Katharina tunicata* (A) and *Mopalia hindaii* (B).
Study Sites

An open coast and a brackish water study site were chosen for *K. tunicata* (Indian Beach, Ecola State Park) and *M. hindsii* (Garibaldi, Tillamook Bay) respectively. Site selection was based on salinity and temperature characteristics as well as common intertidal indicator species.

Indian Beach, Ecola State Park, Clatsop County, Oregon (45°55'N latitude) has a large rock and boulder outcropping at the south end of the beach where wave action is strong (Fig. 2A). *K. tunicata* is common in this location with *M. hindsii* and *Tonicella lineata* also present. Other common open coast organisms present are *Pisaster ochraceous*, *Mytilus californianus*, *Hemigrapsus nudus*, and *Pollicipes polymerus*. Mean annual salinity is 29.06 ppt (85% seawater) and mean annual temperature is 12.4°C (Fig. 3, Seaside Aquarium Data; Bourke and Glenne, 1971).

Garibaldi, Tillamook Bay, Tillamook County, Oregon (45°34'N latitude) has a shale outcropping with small to large loose rocks at the north end of the bay with weak wave action (Fig. 2B). *M. hindsii* and *M. muscosa* are found under rocks and in crevices. Other common brackish water organisms present are *Hemigrapsus oregonensis*, *Mytilus edulis*, *Pagurus* spp., and *Nucella emarginata*. Mean annual salinity is 25.47 ppt (75% seawater) and mean annual temperature is 10.9°C (Fig. 3, raw data from the State of Oregon, Department of Environmental Quality).
Figure 2. Indian Beach, Ecola State Park study site (A) and Garibaldi, Tillamook Bay study site (B) during low tide.
Figure 3. Mean monthly salinity (A, ppt) and mean monthly water temperature (B, °C) for Indian Beach and Garibaldi study sites.
Osmotic Stress Tests

Adult *K. tunicata* (mean weight = 10.23 grams) and *M. hindsii* (mean weight = 10.90 grams) were collected and acclimated to 34 ppt synthetic seawater (100% SW, Instant Ocean Synthetic Sea Salts, Aquarium Systems, Inc.) at 11°C and 16L:8D photoperiod for two weeks prior to testing. Eight animals of each species were subjected to a test salinity (120%, 100%, 80%, 60%, and 40% SW) for 36 hours in osmotic test apparatus (Fig. 4). Individual animals were held in separate chambers and monitored individually throughout the test. At time intervals of 0, 1, 2, 4, 6, 8, 12, 24, and 36 hours, animals were removed from chambers, blotted dry with absorbent towels, and then weighed using a Mettler PC 2200 scale. Animals were allowed 5 minutes to readhere in the chambers before being resubmerged in test salinity. Percent body weight changes due to osmotic stress gradient and volume regulation were calculated.

Oxygen Consumption Tests

Oxygen consumption rates for four animals of each species were measured using a modified Scholander's respirometer (Scholander, 1950). Animals were monitored in test salinities (120%, 100%, 80%, 60%, and 40% SW) for 3-4 hours at 11°C and 16L:8D photoperiod following 48 hours of acclimation to the test salinity (normally post-osmotic stress testing). Oxygen consumption rates (µl/g/hr) were calculated for each species per salinity.
Figure 4. Osmotic stress test apparatus used to measure osmotic stress tolerance and volume regulatory rates of adult specimens of Katharina tunicata and Mopalia hindsii. Specimens (8 per test) were held in individual chambers which allowed free movement and continuous circulation of seawater.
Morphological Comparisons

Radulae, ctenidia, and shape of the pallial groove were examined and compared using an AMR Model 1000 scanning electron microscope and an ISI-SS40 scanning electron microscope.

Specimens of *K. tunicata* and *M. hindsii* were anesthetized using an isotonic MgCl₂ solution (73 g/l DH₂O) for 1-2 hours. Desired structures were dissected and prepared. Radulae were cleaned and rinsed with cacodylate buffer (pH 7.4) in an ultrasonic cleaner and then allowed to air dry. Gill tissue and whole specimens were fixed in 6% glutaraldehyde at 4°C for one and four hours respectively (Bell et al., 1969). Specimens were then dehydrated through 25%, 50%, 70%, 95%, and two changes of 100% ethanol. Gill tissue and whole specimens were freeze-fractured in 100% ethanol using liquid nitrogen in order to expose lamellar structure and pallial groove organization respectively (Humphreys et al., 1974). Next, specimens were flushed with liquid freon (50% and 100%) and then dried using an Omar SPC-900/EX Critical Point Dryer. Specimens were mounted on stubs and coated with 200 Å of gold using a Technics Sputter Coater.

Habitat Characteristics

Seawater samples were collected bimonthly at the two study sites during low tide from January 1985 to June 1985. Salinity (ppt) of seawater samples was determined using a YSI-33 Salinity-Conductivity-Temperature (S-C-T) Meter.
Dominant macroalgal species were collected from each study site and identified (Smith, 1969; Guberlet, 1956). Macroalgal species present were compared with published diet preferences of the chitons (Steneck and Watling, 1982; Morris et al., 1980).

**Statistical Analysis**

Significant differences in osmotic stress response between *K. tunicata* and *M. hindsii* were analyzed using a Multifactor Analysis of Variance (repeated measures; Winer, 1971). Significance level was $p < 0.05$.

Significant differences in oxygen consumption rates between *K. tunicata* and *M. hindsii* were analyzed using an Independent t-Test (Bruning and Kintz, 1977). Significant differences in oxygen consumption rates between salinities within each species were analyzed using an Analysis of Variance (completely randomized design; Bruning and Kintz, 1977). Significance level was $p < 0.05$. 
CHAPTER III

RESULTS

Osmotic Stress Tests

_**K. tunicata** and *M. hindsii* displayed similar trends in percent body weight (\% BW) variation and volume regulatory responses to osmotic stress (Fig. 5). However, *K. tunicata* experienced a significantly higher percent body weight increase than did *M. hindsii* in response to hypo-osmotic conditions (80\% SW, df = 1,14, F = 6.17, p < 0.05; 60\% SW, df = 1,14, F = 16.85, p < 0.005; 40\% SW, df = 1,14, F = 17.89, p < 0.001). Following maximum percent body weight variation, both *K. tunicata* and *M. hindsii* displayed similar volume regulatory rates. Maximum percent body weight variation was measured within 4 hours of exposure to 120\%, 100\%, 80\%, and 60\% seawater (Table I). However, maximum percent body weight variation in 40\% seawater was not reached until 24 hours following exposure (*K. tunicata* = 57.91 ± 1.57 \% BW, *M. hindsii* = 49.32 ± 1.86\% BW). Both species displayed reduced activity and adherence capabilities in 40\% seawater compared with other salinities tested.
Figure 5. Mean percent body weight change (% BWΔ) and volume regulatory rates of adult specimens of Katharina tunicata and Mopalia hindsii in various test salinities over a 36 hour test period at 11°C and 16L:8D photoperiod.
TABLE I

MAXIMUM PERCENT WEIGHT CHANGE FOR TWO OREGON CHITON SPECIES
(Katharina tunicata AND Mopalia hindsii)
IN VARIOUS SALINITIES

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<th>% SW</th>
<th>K. tunicata</th>
<th>M. hindsii</th>
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<tr>
<td>120</td>
<td>-7.899 ± 0.181 (8)</td>
<td>-7.165 ± 0.248 (8)</td>
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<tr>
<td>100</td>
<td>2.276 ± 0.156 (8)</td>
<td>1.835 ± 0.325 (8)</td>
</tr>
<tr>
<td>80</td>
<td>11.456 ± 0.402 (8)</td>
<td>10.000 ± 0.527 (8)</td>
</tr>
<tr>
<td>60</td>
<td>31.423 ± 0.739 (8)</td>
<td>26.115 ± 0.907 (8)</td>
</tr>
<tr>
<td>40</td>
<td>57.906 ± 1.573 (8)</td>
<td>49.321 ± 1.864 (8)</td>
</tr>
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Results are mean values ± SE (n).

Individuals tested in 40% seawater were held in test salinity for 5 days following standard test time to measure survival rates. Both species were able to volume regulate to pre-test range (K. tunicata - starting mean weight ± SE = 9.87 ± 0.92 grams, ending mean weight ± SE = 10.94 ± 0.90 grams; M. hindsii - starting mean weight ± SE = 10.03 ± 0.81 grams, ending mean weight ± SE = 10.12 ± 0.81 grams). All animals survived this period, however, K. tunicata were inactive and adhered poorly to the holding tank sides. When returned to 100% seawater, 50% of the K. tunicata specimens were unable to reacclimate and died, whereas 100% of the M. hindsii were able to reacclimate and survived. Results suggest that 40% seawater is below the ecological tolerance of both species, but M. hindsii appears to be more tolerant of the osmotic stress.
Oxygen Consumption Tests

Oxygen consumption rates per salinity were not significantly different between *K. tunicata* and *M. hindsii* (Table II). *K. tunicata* and *M. hindsii* displayed similar trends in response to salinity variation (Fig. 6). The mean rate of oxygen consumption by *K. tunicata* was found to decrease significantly with the decrease in salinity to 40% seawater (df = 4,14, F = 3.24, p < 0.05). The mean rate of oxygen consumption by *M. hindsii* was also found to decrease similarly to *K. tunicata* in response to decrease in salinity to 40% seawater; however, the decrease observed for *M. hindsii* was not found to be significant (df = 4,14, F = 0.88, not sig.). The reduction in mean rates of oxygen consumption in 40% seawater by both *K. tunicata* and *M. hindsii* is similar to the trend in body weight variation and decrease in activity observed during osmotic stress tests.

<table>
<thead>
<tr>
<th>% SW</th>
<th><em>K. tunicata</em></th>
<th><em>M. hindsii</em></th>
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<tr>
<td>120</td>
<td>11.9 ± 2.2 (4)</td>
<td>10.6 ± 2.3 (4)</td>
</tr>
<tr>
<td>100</td>
<td>13.5 ± 1.3 (4)</td>
<td>12.7 ± 1.2 (3)</td>
</tr>
<tr>
<td>80</td>
<td>11.3 ± 0.6 (4)</td>
<td>11.7 ± 2.9 (4)</td>
</tr>
<tr>
<td>60</td>
<td>10.6 ± 1.7 (4)</td>
<td>12.4 ± 2.7 (4)</td>
</tr>
<tr>
<td>40</td>
<td>5.7 ± 0.9 (3)</td>
<td>7.6 ± 1.0 (4)</td>
</tr>
</tbody>
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Results are mean ± SE (n)
Figure 6. Mean oxygen consumption rates (VO₂) of adult specimens of *Katharina tunicata* and *Mopalia hindsii* in various test salinities at 11°C and 16L:8D photoperiod. Results are mean values ± SE.
Morphological Comparisons

Comparisons of radular morphology of *K. tunicata* and *M. hindsii* revealed only minor variations. Radulae of both species are comprised of seventeen teeth per row with major adaptation of the $l_2$ and $l_5$ teeth (Grasse, 1960) for grazing purposes (Fig. 7). The grazing teeth ($l_2$ and $l_5$) of both species are similar in structure (Fig. 8). The primary difference observed between *K. tunicata* and *M. hindsii* is a variation in the anterior end of the median (m) teeth (Fig. 9).

Differences in ctenidial morphology between *K. tunicata* and *M. hindsii* are related to differences in the shape of the pallial grooves of the two species. Ctenidia of *K. tunicata* are rounded and blunt while those of *M. hindsii* are more pointed and laterally flattened (Fig. 10). Ctenidial surfaces revealed no major interspecific differences in organization; both species possess a prominent lateral bands of cilia (Fig. 11; Hyman, 1967). The ctenidial lamellae of the two species have similar organization of vascular bed and respiratory epithelium comprised of a simple cuboidal to columnar epithelium (Fig. 12; Hyman, 1967).

The pallial groove of *K. tunicata* differs from *M. hindsii* in two aspects. The pallial groove of *K. tunicata* is taller with ctenidia suspended perpendicularly to the substrate. The pallial groove of *M. hindsii* is shallower and broader with gill ctenidia curved and suspended at an angle to the substrate (Figs. 13 and 14).
Figure 7. Radulae of Katharina tunicata (A, mag. = 78X) and Mopalia hindsii (B, mag. = 53X) revealing general organization plus grazing teeth (l₂ and l₅) and median teeth (m).
Figure 8. Grazing teeth (2nd lateral - 1₂, and 5th lateral - 1₅) from radulae of Katharina tunicata (A, mag. = 130X) and Mopalia hindsii (B, mag. = 130X).
Figure 9. Median teeth (m) from radulae of Katharina tunicata (A, mag. = 322X) and Mopalia hindsii (B, mag. = 308X) revealing the variation in the anterior tip.
Figure 10. Ctenidia (ct) from Katharina tunicata (A, mag. = 113X) and Mopalia hindsii (B, mag. = 113X) revealing variation in shape.
Figure 11. Surfaces of ctenidia from Katharina tunicata (A, mag. = 1100X) and Mopalia hindsii (B, mag. = 1125X) revealing ciliation (ci) and respiratory surface (rs).
Figure 12. Lamellar structure of ctenidia from Katharina tunicata (A, mag. = 1400X) and Mopalia hindsii (B, mag. = 1700X) revealing the hemocoel (hc), respiratory epithelium (re), and interlamellar water channel (wc).
Figure 13. Pallial groove and ctenidia (ventral view) of Katharina tunicata (A, mag. = 53X) and Mopalia hindsii (B, mag. = 28X) revealing variation in shape of groove and orientation of ctenidia (ventral surface of mantle - ma, ctenidia - ct, and foot - ft).
Figure 14. Pallial groove (X - section) and ctenidia of Katharina tunicata (A, mag. = 70X) and Mopalia hindsii (B, mag. = 70X) revealing variation in shape of pallial groove, mantle valve, and orientation of ctenidia (mantle - ma, mantle valve - v, ctenidia - ct, and pallial groove - pg).
Habitat Characteristics

Salinity measurements at low tide from January 1985 to June 1985 yielded a mean salinity of 25.63 ± 0.85 ppt (75% seawater) for the Indian Beach study site and a mean salinity of 21.04 ± 1.05 ppt (63% seawater) for the Garibaldi study site. During April 1985, there was an overlap in the salinities of the study sites. However, Garibaldi consistently reached lower extremes in salinity (February = 19.2 ppt, April = 16.7 ppt, and June = 15.5 ppt) than Indian Beach (April = 20.8 ppt; Fig. 15). Although mean salinities during the study were found to be lower than mean annual salinities for study sites (Indian Beach = 29.06 ppt, Garibaldi = 25.47 ppt), the variation in mean salinities between study sites during the study (4.59 ppt, 12% seawater) parallels the variation in mean annual salinities (3.59 ppt, 10% seawater).

Measurements were taken primarily during the winter months when freshwater runoff from coastal land is greatest.

Identification of dominant macroalgal species revealed variation between the Indian Beach site (six Rhodophyta, three Phaeophyta) and the Garibaldi site (four Rhodophyta, three Phaeophyta, and one Chlorophyta) in species present (Table III). Three macro-algal species (Laminaria setchelli, Fucus distichus, and Iridaea cordata) were common to both study sites. The coralline algae (crustose coralline alga and Bossiella orbigniana), Gymnogongrus linearis, Plocamium oregonum, Prionitis lanceolata, P. linearis, and Hedophyllum sessile were identified at the Indian Beach site only. Hedophyllum sessile is reported as a major dietary constituent of K. tunicata (Steneck and Watling, 1982). Gigartina exasperata, G. volans, Gracilaria verrucosa, Halosaccion
glandiforme, and Ulva taeniata are common to the Garibaldi site. Gigartina spp. as well as animal material are reported as common dietary constituents of Mopalia spp. (Steneck and Watling, 1982; Morris et al., 1980).
Figure 15. Bimonthly salinity measurements during low tide from January 1985 to June 1985 for Indian Beach and Garibaldi study sites.
<table>
<thead>
<tr>
<th>Macroalgal Species</th>
<th>Indian Beach</th>
<th>Garibaldi</th>
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<tbody>
<tr>
<td><strong>Rhodophyta</strong></td>
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<tr>
<td>Crustose Coralline Alga</td>
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<tr>
<td><em>Bossiella orbigniana</em></td>
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<tr>
<td><em>Gigartina exasperata</em></td>
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<td><em>Gigartina volans</em></td>
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<td><em>Gracilaria verrucosa</em></td>
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<td><em>Gymnogongrus linearis</em></td>
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<tr>
<td><em>Iridea cordata</em></td>
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<td>****</td>
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<tr>
<td><em>Plocamium oregonum</em></td>
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<tr>
<td><em>Prionitis lanceolata</em></td>
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<tr>
<td><em>Prionitis linearis</em></td>
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<tr>
<td><strong>Phaeophyta</strong></td>
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<tr>
<td><em>Fucus distichus</em></td>
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<tr>
<td><em>Halosaccion glandiforme</em></td>
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<tr>
<td><em>Hedophyllum sessile</em></td>
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<tr>
<td><em>Laminaria setchelli</em></td>
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<td><strong>Chlorophyta</strong></td>
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<tr>
<td><em>Ulva taeniata</em></td>
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</table>

TABLE III
DOMINANT MACROALGAL SPECIES OF INDIAN BEACH, ECOLA STATE PARK STUDY SITE AND GARIBALDI, TILLAMOOK BAY STUDY SITE
CHAPTER IV

DISCUSSION

Variation in habitat selection by marine chitons is thought to be influenced by salinity. However the influence of salinity on the physiology and ecology of chitons has received limited attention. Boyle (1969) reported that S. pelliserpentis is exposed to salinity fluctuations of 40% (14 ppt) to 130% (45 ppt) seawater for short periods of time. Stickle and Denoux (1976) observed that in many marine invertebrates, including K. tunicata, hemolymph osmoconcentrations fluctuate with tidal fluctuation but do not vary during exposure to air.

The influence of salinity on variation in habitat selection of K. tunicata and M. hindsii appears to be minimal. Although K. tunicata displayed significantly higher variation in percent body weight than did M. hindsii in response to hypotonic stress conditions (80%, 60%, and 40% SW), both species displayed similar rates of weight gain and volume regulation in all salinities tested. Both species, however, experienced drastically increased weight gain in response to 40% seawater compared with other salinities tested. The percent weight changes observed for both K. tunicata and M. hindsii in 60% to 120% seawater are similar to those reported by McGill (1976) for C. hartwegii in 75% to 125% seawater. Boyle (1969) tested the osmotic stress tolerance of S. pelliserpentis in 0% to 150% seawater and found that species tolerant of salinity ranging from 50% to 150% seawater.
However, the response of *S. pelliserpentis* to 50% seawater was similar to that observed for *K. tunicata* and *M. hindsii* in 40% seawater. The results support the hypothesis that *K. tunicata* and *M. hindsii* are osmoconformers with volume regulatory capacities and are similar in osmotic stress tolerance to *S. pelliserpentis, C. hartwegii,* and *N. californica* (Boyle, 1969; McGill, 1976; and Simonsen, 1976).

Lebsack (1976) reported that deviation in salinity from normal seawater results in a decrease in oxygen consumption rate by *Mopalia lignosa,* although the salinities Lebsack tested ranged only from 90% to 120% seawater. Oxygen consumption rates for *K. tunicata* were observed to decrease significantly in response to salinity variation from 100% seawater, while *M. hindsii* oxygen consumption rates did not. Both *K. tunicata* and *M. hindsii,* however, displayed equally reduced oxygen consumption rates in response to 40% seawater. This reduction in oxygen consumption in 40% seawater parallels the increased weight gain observed in the osmotic stress tolerance results.

Stickle and Ahokas (1975) suggested that *Mopalia muscosa* may be more resistant to osmotic stress than is *K. tunicata* because *M. muscosa* may be able to isolate its pallial groove and ctenidia from the external medium more effectively than can *K. tunicata.* *M. muscosa* and *M. hindsii* overlap in distribution and both are common in the Garibaldi study site. The two species are morphologically similar, differing primarily in the dorsal surface of the mantles. Comparison of the shape of the pallial groove, mantle valve size, and ventral surface of the mantles of *K. tunicata* and *M. hindsii,* however, suggested no significant variation between these two species in their ability to isolate the pallial groove.
and ctenidia. The differences observed in the shape of the pallial
groove and ctenidia reflect differences in general body morphology which
correlate more directly with micro-habitat preferences than differences
observed in habitat selection of these species.

The variation in mean salinity (4.59 ppt, 12% SW) observed between
the Indian Beach and Garibaldi study sites from January 1985 to June
1985 is within the physiological tolerances of both K. tunicata and M.
hindsii. The increase in body weights and decrease in oxygen con-
sumption rates of K. tunicata and M. hindsii in 40% seawater dilution,
and their reduced adherence capabilities suggests that this salinity is
near or below the ecological tolerances of both species even though it
is physiologically tolerable under laboratory conditions. Salinities
below 40% seawater were not measured for either study site. Although K.
tunicata is capable of tolerating 40% seawater for a limited period, the
data suggest that M. hindsii may be more tolerant of this extreme dilu-
tion. Boyle (1969) reported that S. pelliserpentis could survive dilu-
tion to 50% seawater for at least 24 hours. Simonsen (1976) suggested
that long term acclimation to variation in salinity may influence os-
motic stress tolerance in N. californica. Thus, acclimation may account
in part for the observed variation in osmotic tolerance to extreme
dilution (40% SW) between K. tunicata and M. hindsii.

The diet preferences of K. tunicata and M. hindsii may influence the
difference observed in habitat selection. Hedophyllum sessile, a
major dietary constituent of K. tunicata, is restricted to open coast
habitats such as the Indian Beach site (Himmelman, 1978; Steneck and
Watling, 1982). Several Gigartina spp. plus animal material, major
dietary constituents of *M. hindsii*, are less restricted and are common at the Garibaldi site (Morris et al., 1980; Steneck and Watling, 1982). Comparison of radular morphology and structure of grazing teeth (12 and 15), however, revealed no clear difference between *K. tunicata* and *M. hindsii* related to adaptation to different diets. Radular morphology of both these species support the "multi-purpose tool" description of Steneck and Watling (1982).

Boyle (1969) suggested, "that microhabitat osmotic fluctuations are unlikely to limit the distribution of *S. pelliserpentis*", due to its euryhaline characteristics. The data support a similar conclusion for *K. tunicata* and *M. hindsii* in that both are euryhaline in character and display similar physiological capabilities.

Although salinity may not influence the difference in habitat selection observed between *K. tunicata* and *M. hindsii*, it still may influence habitat selection in two ways: 1) the tolerance to osmotic stress of larval stages may vary significantly; and 2) the influence of salinity on macroalgal species may affect the settling responses of veliger stage. Barnes and Conor (1973) reported that *T. lineata* larvae display a selective settling response to crustose coralline algae, *Lithothamnium* and *Lithophyllum* spp.

In conclusion, these results suggest that other factors are involved in the difference in habitat selection between *K. tunicata* and *M. hindsii*, and that chitons display a high level of physiological plasticity.
Summary

1. *Katharina tunicata* and *Mopalia hindsii* are osmoconformers in salinities ranging from 40% (13.7 ppt) to 120% (41.0 ppt) seawater with equivalent volume regulatory capabilities.

2. Both species showed reduced oxygen consumption rates and significantly increased weight gain in 40% seawater.

3. SEM comparisons of radulae, ctenidia, and shape of the pallial groove revealed no significant differences between the species relevant to differences observed in habitat selection.

4. Variation in dominant macroalgal species between study sites reflected published dietary preferences; *K. tunicata* feeds on *Hedophyllum sessile*, while *M. hindsii* feeds on *Gigartina* spp. and animal material.

5. Salinity does not appear to be a major influence on habitat selection in chitons within the intertidal zone.
BIBLIOGRAPHY


