

Northwest Science Notes

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Preliminary studies on the gonadal enhancement of giant red sea urchins taken from barrens in British Columbia

Abstract

We collected giant red sea urchins in urchin barrens habitat with the intent of enhancing them for market. We placed the urchins in enclosures and provided them with giant kelp for the 83-day period between 20 March 1998 and 12 June 1998. Sea urchins that were fed giant kelp had a final gonad index of 8.3, whereas the donor population had initial and final gonad indices of 2.9 and 3.5, respectively. In addition, the proportion of individuals displaying a state of starvation via dark brown gonads was significantly lower after feeding compared to the donor population at the end of the experiment (2% and 17%, respectively). These results suggest that food limitation is an important factor in the gonadal development of this urchin population. Moreover, the findings suggest that the urchin resource can be expanded to include barren habitats. Urchins taken from barrens can be quickly enhanced before being sent to market.

Introduction

Foreign demand for sea urchin gonads, called *uni* on the Japanese market, led to the development of the sea urchin fishery in British Columbia during the 1970s (Farr and Bunnell 1980). The harvest has grown rapidly since 1982 with stable landings since 1994 (DFO 1998). In 1997, total landings for Clayoquot Sound (our study site) consisted of over 124,000 kg of red sea urchins (*Stongylocentrotus franciscanus*) (J. K. Davidson, Department of Fisheries and Oceans, Canada, personal communication).

Sea urchin feeding habits (Leighton 1960) and preference for macrophytic algae species (Leighton 1966, 1971) can lead to the conversion of many marine rocky bottom habitats from kelp forest to "barren grounds" (Pearse et al. 1970; Farr and Bunnell 1980). The ability of sea urchins to survive on very low nutritional inputs (Ebert 1967, 1968) and the absence of effective urchin predators, such as sea otters (*Enhydra lutris*) (Estes and

Palmisano 1974, Watson 1993), enables the persistence of barren grounds in some areas. Under these conditions of little food, giant red sea urchins resorb gametes, and the gonads become dark brown (Bernard 1977).

The red sea urchin has the highest commercial potential of naturally occurring sea urchins in British Columbia (Breen 1980). The potential periods of spawning are between March and September in southern British Columbia (Bernard 1977). The fishery operates between October and March or April during the period when urchins are recovering from spawning but before the gonads become milky with gametes (Breen 1980). Unfortunately, much of the harvesting occurs before the annual bull kelp (*Nereocystis luetkeana*) has recruited. Thus, in years when over-wintering kelp species are scarce, the fisheries value of urchins will be low (Breen 1980). Enhancement techniques can resolve many problems associated with poor fisheries quality of wild stocks, while providing the harvester with the ability to time sales to maximize and maintain stable profits during much of the year.

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Harvesters ignore many urchin barrens habitats because the urchins present often have low quality roe (poor color and mass). Many researchers have shown through field and laboratory studies that the growth and reproduction of strongylocentrotid sea urchins is directly related to the quality and quantity of consumed food items (Ebert 1968; Lawrence 1975; Vadas 1977; Larson et al. 1980; Thompson 1982; Lemire and Himmelman 1996; Meidel and Scheibling 1999). The objective of this experiment was to test the hypothesis that mass and color of gonads in giant red sea urchins were food limited in this area of Clayoquot Sound. We also wished to determine if food supplementation could enhance urchins for the *uni* market. Under the hypothesis of food limitation, providing a supplement of a natural food source should increase the relative gonad size (measured as an index of gonad mass to total mass) and decrease the number of individuals with dark brown gonads (an indication of starvation). To test this hypothesis, we penned urchins from barrens habitat and provided them with giant kelp (*Macrocystis integrifolia*).

Materials and Methods

We collected giant red sea urchins at Hot Springs Cove in Clayoquot Sound on the west coast of Vancouver Island, British Columbia (49° 21' N, 126° 16' W). This area is zoned as part of an aboriginal fishing zone by the Department of Fisheries and Oceans, Canada. That designation prevents commercial harvesting of the resources present and allows the resident Hesquiaht First Nation to study their environment without fishing pressure.

We collected 90 giant red sea urchins (>80 mm) 20 March 1998 and separated them into two groups. We sampled gonad mass of one group (n=45) immediately, and penned the second group (n=45) with 15 urchins in each of three chicken wire pens measuring 127 cm X 79 cm X 51 cm. We suspended pens 2-3 m below the ocean surface within Hot Springs Cove. The penned urchins were fed giant kelp *ad libitum* for 83 days. The congeneric giant kelp (*M. pyrifera*) has been shown to be a preferred algal food (Leighton 1966) and other studies on food preference in strongylocentrotids have shown that preferred foods increase gonad production (Larson et al. 1980; Lemire and Himmelman 1996). Moreover, giant kelp is a

perennial canopy-forming species, making collection for this and future enhancements relatively simple. On 12 June 1998, we dissected the supplemental feeding group and a second collection (n=30) of free-ranging urchins (>80 mm). All urchins were collected from the same barren at approximately 8 m. We measured test diameter, wet body mass, and wet gonad mass, and recorded gonad color. Gonad indices were calculated as the percentage of the gonad mass to the total body mass. Since the urchins were not maintained as independent replicates (Hurlbert 1984), we did not use ANOVA to compare treatments. Rather we present parameter means and standard errors for test diameter, wet body mass, wet gonad mass, and gonad index. Comparisons are made among the initial donor group (March group), the final donor group (June group), and the experimental group (supplemental feeding). No effort was made to control for cage effects as the applied nature of the experiment makes such comparisons irrelevant. Statistica™ statistical software for Windows™ version 5.5 (StatSoft Inc., Tulsa, OK, USA) was used to graph the data.

Results

Giant red sea urchins removed from urchin barrens and penned readily consumed the algae provided. The resulting data (Figure 1) show considerable differences in mean gonad wet mass and gonad index for the feeding group as compared to either of the field collections. Moreover, there appear to be no biologically meaningful differences in gonad mass and gonad index among the March and June field collections. Urchins from the March, June, and supplemental feeding groups had average gonad masses of 11.0 ± 1.1 , 12.9 ± 1.2 g, and 34.4 ± 1.5 g respectively. Gonad indices in the same order were 2.9 ± 0.3 , 3.5 ± 0.3 , and 8.3 ± 0.4 . Horizontal test diameter and total wet mass varied little among groups and arguably display no biological differences between the three groups.

Plots of gonad index and gonad wet mass versus test diameter illustrate different relationships between gonad mass and body size within the field and fed collections (Figure 2). No significant correlations were noted between gonad mass or index and test diameter for either of the field collections. However the supplemental feeding group displayed significant correlation between diameter

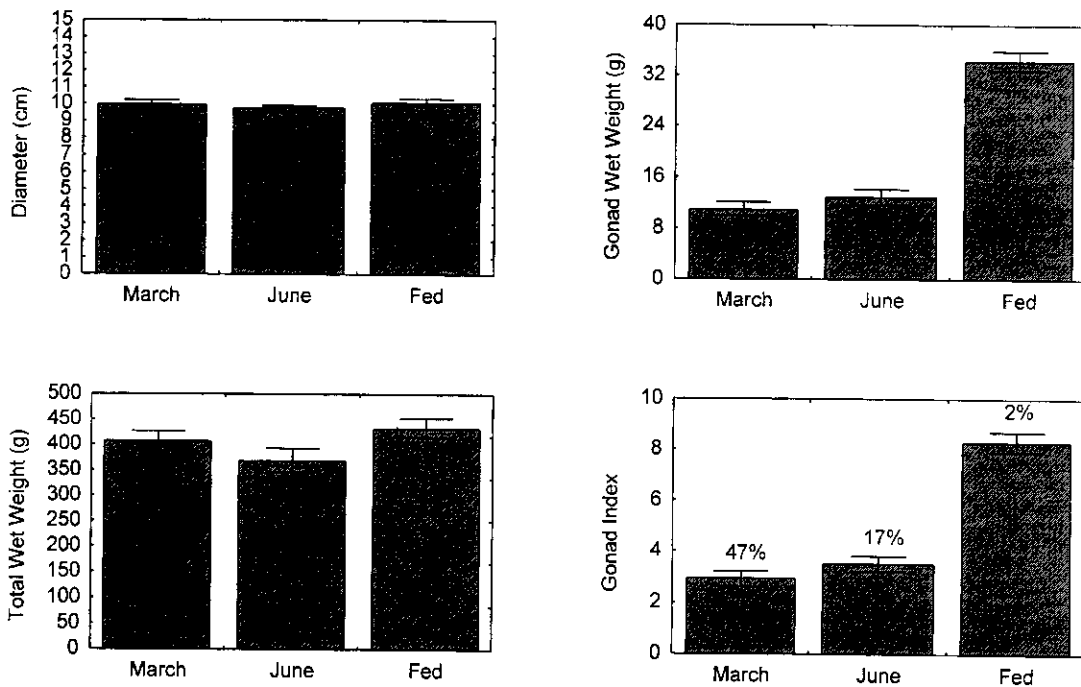


Figure 1. Results of the feeding experiment compared to field populations before (March; $n = 45$) and after (June; $n = 30$) the supplemental feeding (Fed; $n = 43$). Data are presented as means \pm 1 SE for horizontal test diameter, total wet mass, gonad wet mass, and gonad index. Values above error bars in the gonad index plot are the proportions of individuals with dark brown gonads in each sample.

and gonad index ($r=0.51$; $P<0.001$) as well as between diameter and gonad mass ($r=0.49$; $P<0.01$). We have fitted all relationships as linear although gonad index has been shown to be non-linear in relation to test size (Gonor 1972). Our decision to use linear correlation is due to the narrow size range of urchins sampled for this study.

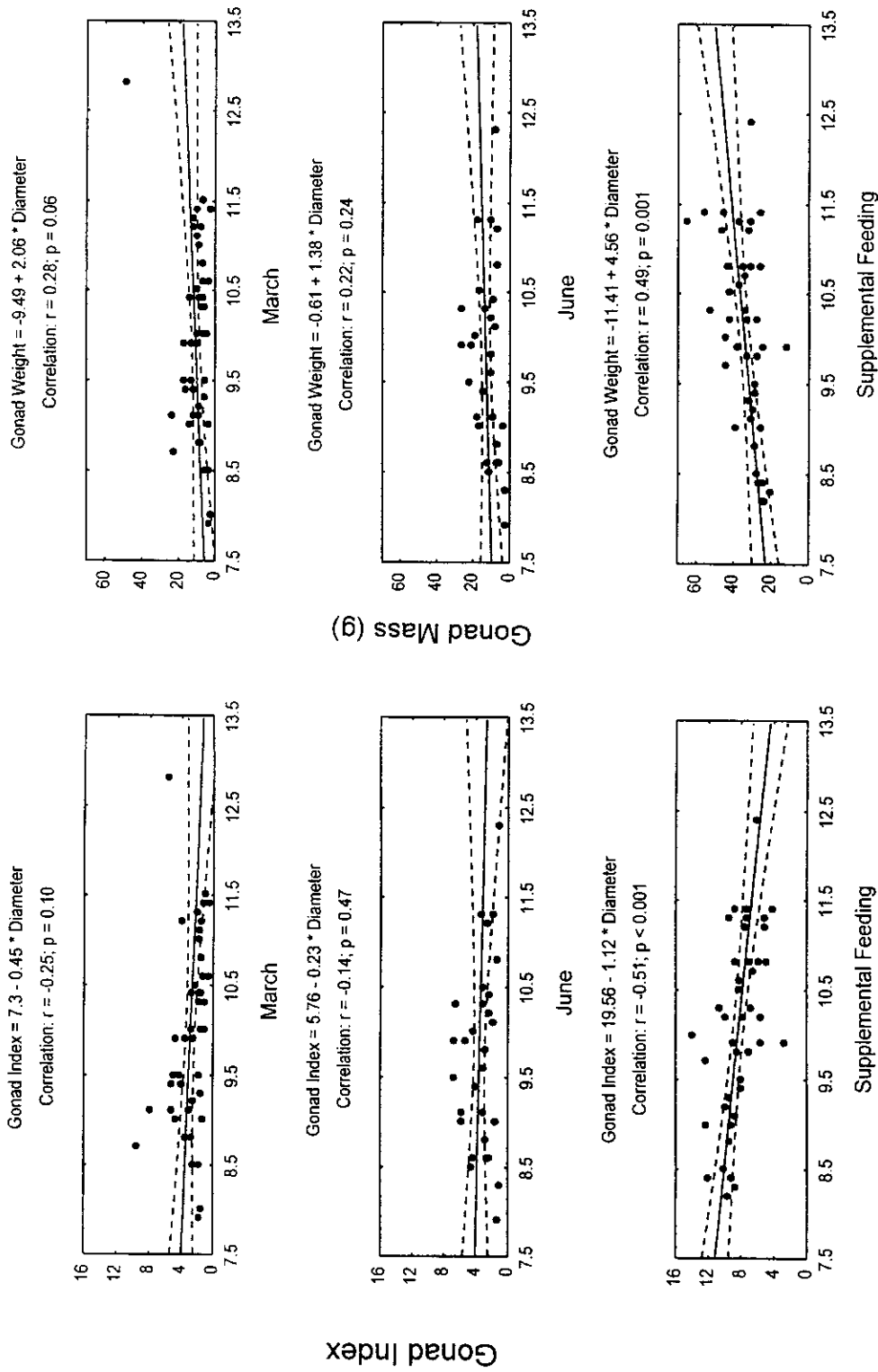
We noted the presence of dark brown gonads among the field collections and the supplemental feeding group. The March and June field samples had a high percentage of individuals with very dark brown gonads (March sample = 47%, June sample = 17%) compared to the supplemental feeding group (2%) (Chi-squared = 25.29, $P<0.001$). The importance of gonad color is discussed below.

Discussion

We conducted the feeding trial using giant red sea urchins collected from severely grazed urchin barrens habitat. Gonad indices for the March and June collections were 2.9 ± 1.9 ($n=45$) and $3.5 \pm$

1.8 ($n=30$) respectively. The lack of a biologically meaningful difference between the two time periods is unusual because giant red sea urchins would normally be increasing in gonad index during this time, with a peak achieved in May (Bernard 1977). However, urchins are known to exhibit plastic responses in the allocation of resources to body components (Ebert 1980; Thompson 1982; Edwards and Ebert 1991; Levitan 1991). The lower percentage of individuals displaying a state of starvation in the June sample may mean that urchins are reallocating resources to prepare for spawning. The relatively low values for gonad indices (compare to McBride et al. 1997) of the free-ranging red sea urchins reflects the poor quality of habitat at this site. The much increased gonad index for the supplemental feeding group, 8.3 ± 2.3 , suggests food availability was limiting.

There are two interesting trends in the correlation data of Figure 2. First, the urchins sampled from the field (March and June) display no relationships between test diameter and gonad mass or index. This suggests that in starved urchins above 8.0 cm, gonad mass is relatively constant and



Test Diameter (cm)

Figure 2. Gonad index (left) and gonad wet mass in grams (right) versus horizontal test diameter (cm) for each of the urchin groups. Lines represent the fitted regression equations with 95% confidence intervals. Sample sizes are 45, 30, and 43 for the March, June and supplemental feeding urchin groups respectively.

probably at a minimum value that is independent of size. Conversely, urchins in the supplemental feeding group show a positive correlation between size and gonad mass. Second, the trends between size and gonad index and between size and gonad mass are opposite. The positive correlation between size and gonad mass indicates that larger urchins increased their gonad mass significantly more than smaller urchins did. However, the negative association between size and gonad index indicates that as a proportion to total mass, larger urchins are increasing their gonad mass less than smaller urchins. Given this diminishing return in gonad index, along with a market preference for smaller urchins (Sloan 1986; Rogers-Bennett et al. 1995) and the importance of larger urchins for the recruitment of juveniles (Tegner and Dayton 1977; Breen et al. 1985; Rogers-Bennett et al. 1995), managers should consider setting upper size limits for any urchin harvesting or enhancement program.

Understanding the relationship between food supply and gonad index is critical to the development of sea urchin aquaculture and harvesting programs (Minor and Scheibling 1997). Recent work evaluating aquaculture techniques for sea urchins (Klinger et al. 1986; Lawrence et al. 1997; McBride et al. 1997) has relied on the use of artificial feeds to improve the quality of fishery urchins. Klinger et al. (1986) and Lawrence et al. (1997) both reported enhancement after offering artificial feeds to green sea urchins (*S. droebachiensis*) and to the urchin *Loxechinus albus*. McBride et al. (1997) showed no significant difference between giant red sea urchins fed bull kelp versus an artificial diet. McBride et al. (1997) observed greater gonad indices for urchins fed bull kelp (17.3 ± 4.7 , SD), than we obtained for urchins fed giant kelp (8.3 ± 2.3 , SD). Two factors may explain this difference. We fed urchins for a total of 83 days as opposed to 120 days reported in McBride et al. (1997). Also, our selection of urchins from barrens habitat means that we used urchins of lower initial body condition than the urchins used by McBride et al. (1997).

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This lower body condition would result in more time being required to increase gonad mass.

By supplementing the food available to giant red sea urchins, we were able to increase gonad mass and indices above those found in field-collected specimens. Moreover, the number of individuals displaying a state of starvation through the presence of dark brown gonads (Bernard 1977) was reduced in the supplemental feeding group. The current study demonstrates that free-ranging urchins of low commercial fisheries value can be quickly enhanced for market. With an expansion of the methods employed in this study, the enhancement of urchins from barrens habitat may be viewed as an economical alternative to pure aquaculture techniques (rearing from seed). We suggest that urchins from barrens habitat can be enhanced and sold to market, thereby placing less harvesting pressure on other areas. We suggest that before artificial feeds are accepted for use on this species that the cost/benefit ratio of readily available natural kelp, be more closely examined.

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