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To: Bruce McIntosh, Chris Kern, Ed Bowles, Caren Braby, Dave Fox, and Troy Buell ODFW
From: Scott Groth and Steve Rumrill Marine Resources Program, ODFW
Subject: Analysis of red sea urchin fishery and survey data for March 18, 2015 OFWC commission meeting.

The following is a synopsis of information presented at the December 3, 2015 sea urchin industry meeting combined with other data prepared for a forthcoming report on Oregon's red sea urchin fishery.

Background:

Worldwide fisheries for sea urchins have a poor record of sustainability and have generally followed a trend of quick expansion followed by an equally rapid decline (Andrew et al., 2002). Red sea urchin fisheries exploded along the West Coast of North America in the 1980's, beginning in Oregon in 1986. Oregon's fishery for red sea urchins peaked in 1990 with 9.2 million pounds of landings, rivaling the iconic Dungeness crab fishery. Landings quickly reduced as stocks diminished, and the boom was over by the late 1990's. Since 1998, the red sea urchin fishery has been relatively stable with a small number of harvesters working consistently and landing around 500,000 lbs. annually.

Oregon's sea urchin fishery focuses on the red sea urchin (*Mesocentrotus franciscanus*). Harvest is exclusively by divers who make single day trips to rocky nearshore areas. The fishery product, "uni" is the gonad of sea urchins and is popular sushi fare.

Sea Urchin Biology:

An understanding of the biology of sea urchins is critical to management, and the reproductive biology of red urchins differs from the subjects of more familiar fisheries. Sea urchins have separate sexes (dioecious), and both sexes must broadcast gametes into the water column simultaneously. Adult sea urchins must be in close proximity (~ 1 meter) for successful fertilization to occur, and low densities of adult urchins typically result in poor fertilization success. Consequently, reproduction depends on high densities (Levins, 1969) of reproductively mature adults. In addition, the planktonic pluteus larvae are long-lived (i.e., 60-90 days adrift), and currents must be just right to bring larvae back to favorable habitats. In this way, sea urchin spawning can be considered as a lottery in which there are rare successful events. However, larval settlement events may be robust when successful. Greater number of high density groups of sea urchins improve the probability of successful events. This type of recruitment is known as "episodic." Given the low efficiency of spawning, sea urchins have adapted to live long lives. Individual red sea urchins may live more than 100 years (Ebert & Southon, 2003), and become more fecund as they age. Red sea urchins are generally considered sedentary, and maximum movement is restricted to the reef where settlement occurred. Genetic exchange between sub-populations is limited to the extent of larval transport. Red sea urchins primarily eat drift kelp, typically moving shallower when kelp is not available locally. Sea urchins biological attributes such as long lives, density dependence, and episodic recruitment are distinctive among common fishery subjects and should be considered in the level of caution used in management.

Fishery History:

Oregon's sea urchin fishery expanded quickly, then quickly reduced, and more recently has found stability in lower harvest rates and effort [Fig. 1]. Since 1998, effort has been stable and harvest has sustained at a consistent level.

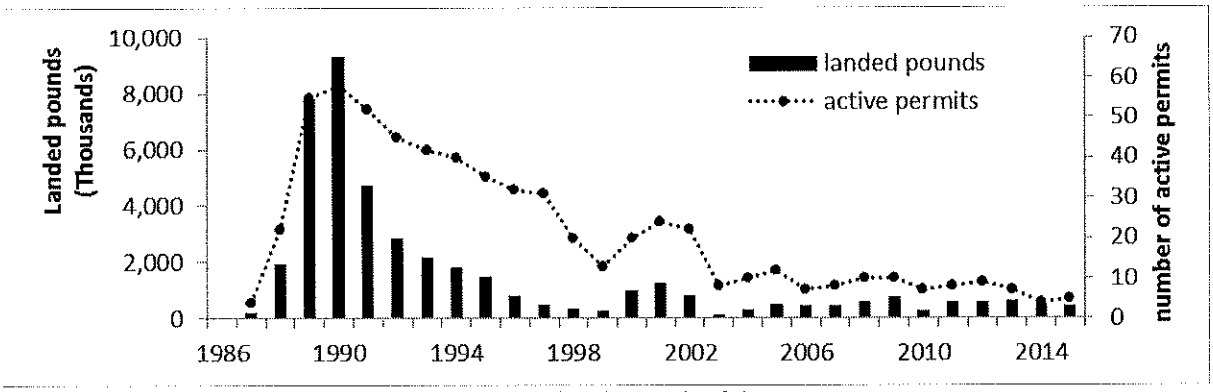

Figure 1: Landed pounds and active harvesters in Oregon's red sea urchin fishery, 1986-2015

The time-series relationship between fishery effort (number of annual trips) and efficiency (daily average landing) includes three distinct phases for the red sea urchin fishery in Oregon [Fig. 2]. These phases are: (1) ramp up of the new fishery (1986-1989); (2) fishing down of the virgin stocks (1990-1997); and (3) stabilization of a small fishery characterized by medium efficiency and low effort [Fig.2].

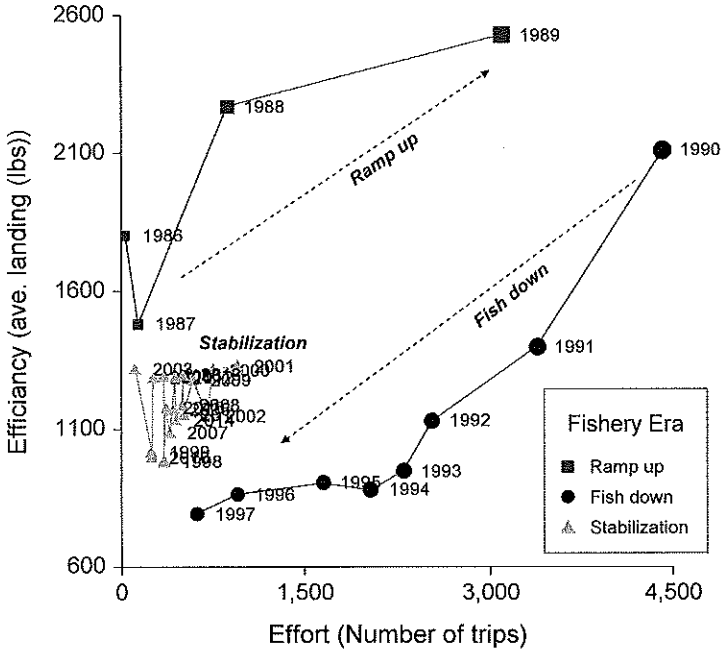

Figure 2: Efficiency compared to effort in Oregon's red sea urchin fishery from 1986-2015

When the number of active permits are taken into consideration and compared to stability of the fishery (changes of efficiency), recent years with a low number of active permits are strongly associated with stability, which is characterized by consistent in efficiency over recent years [Fig.3].

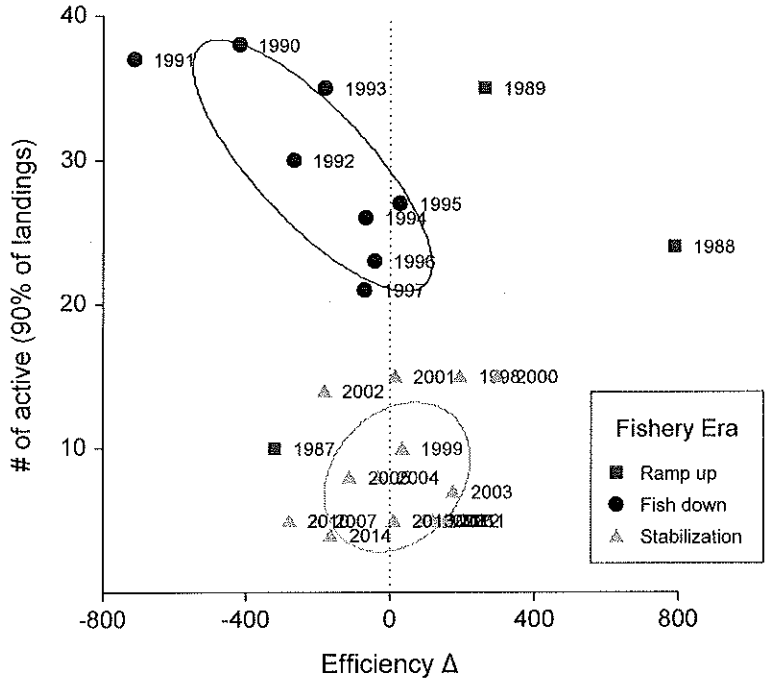

Figure 3: Number of active harvesters compared to changes to annual efficiency in Oregon's red sea urchin fishery, 1986-2015

Survey Results:

ODFW tracked the relative density and size distributions of red sea urchins over time within four areas that are of critical importance to the sea urchin fishery [Fig. 4]. Subtidal belt transect surveys were conducted at areas that are important to the sea urchin fishery from 1984 to 2015. Divers counted and measured sea urchins [Fig. 5] at sites that were repeated over time, and the results are presented by area. We found reduced densities and less recruitment over time.

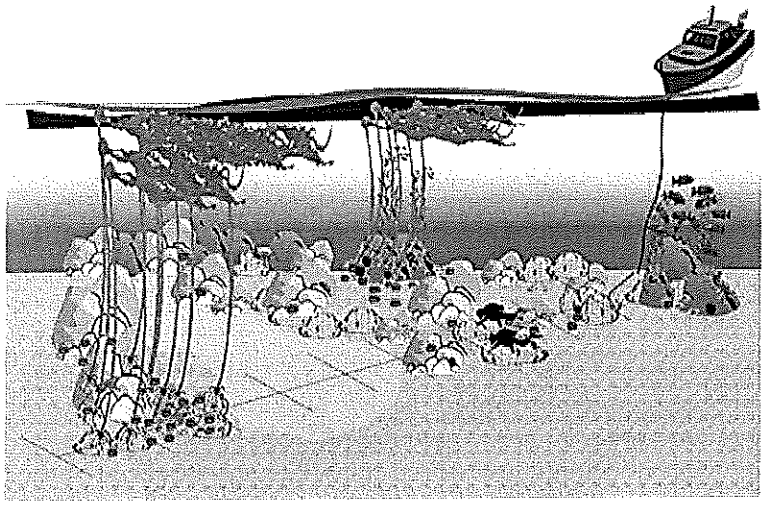

Figure 5: Illustration of red sea urchin belt transect method

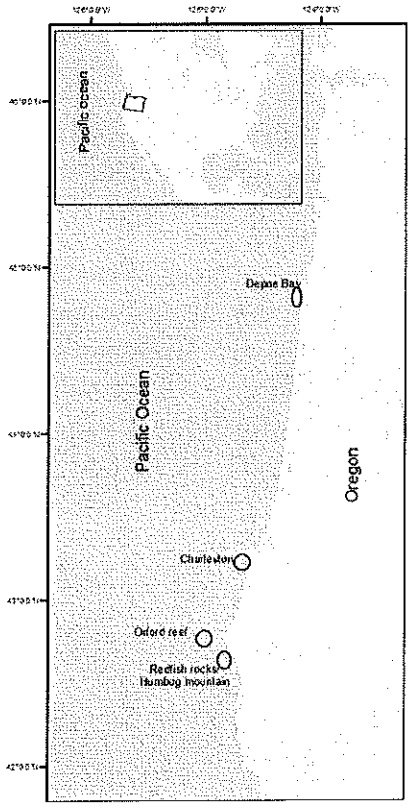

Figure 4: Areas surveyed for red sea urchins in Oregon

Orford Reef:

Orford Reef is Oregon's largest offshore rocky reef [Fig. 6 (a)] and is the most important site for the harvest of red sea urchins. Landings from Orford Reef account for about half of the total annual landings through time. Surveys show that the densities of red sea urchins have decreased substantially over time [Fig. 6(b)]. In addition, the datasets indicate a shift in size distributions toward increased sizes and fewer small sea urchins. These observations are indicative of a long-term trend of decreased recruitment [Fig. 6(c)].

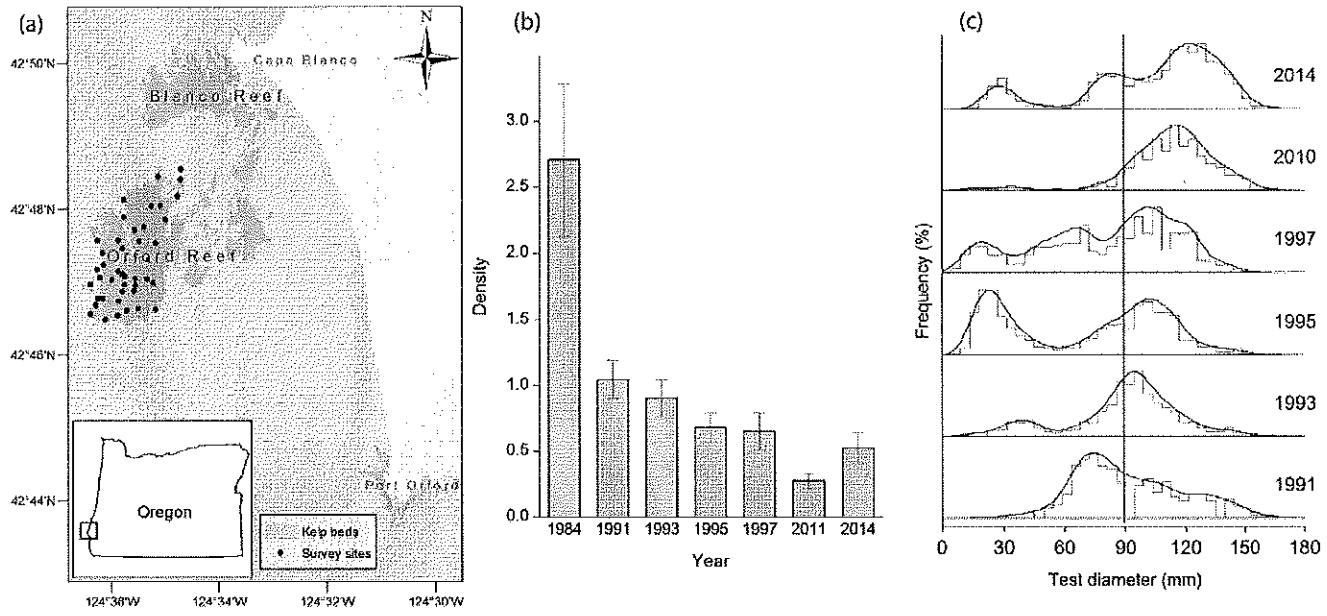

Figure 6. (a) Location of Orford Reef, OR red sea urchin survey sites (b) Density of red sea urchins by year (error bar indicates standard error), and (c) size distribution of red sea urchins at Orford Reef, OR (vertical red line indicates minimum size limit).

Depoe Bay:

The nearshore areas of Depoe Bay, OR [Fig. 7(a)] have supplied a substantial amount of historic landings (9%). Surveys at this site also show a recent reduction in density [Fig. 7(b)] and highlight the importance of a single recruitment event which occurred in the early 1990's. The recruitment event first appeared in 1994 when many very small (~1") red sea urchins were observed, and these urchins constitute the primary year class of red sea urchins to date [Fig. 7(c)].

important to the sustainability nearby fished populations. In recent years (2010-2015) we examined the reserve effects at these sites, and made the comparison to neighboring fished areas.

Results of these surveys indicate the no-harvest reserves areas are functioning well and providing the effects that may support fishery sustainability. Densities of urchins are generally greater within reserve areas than fished areas [Fig. 9(a)], with the exception of Depoe Bay. The population of red sea urchins in Depoe Bay is large and the urchins are poorly fed with low amounts of gonadal tissue. Consequently, these populations are not valuable to the commercial fishery, and they have been largely untouched for ~20 years. Reserve effects are illustrated further when urchin biomass (weight) is examined for the different areas [Fig. 9(b)]. Mean size at harvested versus reserve sites was significantly larger at ports with older reserves (i.e., Depoe Bay, Charleston (both $p>0.001$, k-s test)), and not significant at Port Orford, where a reserve was just implemented in 2012 [Fig. 9(c)].

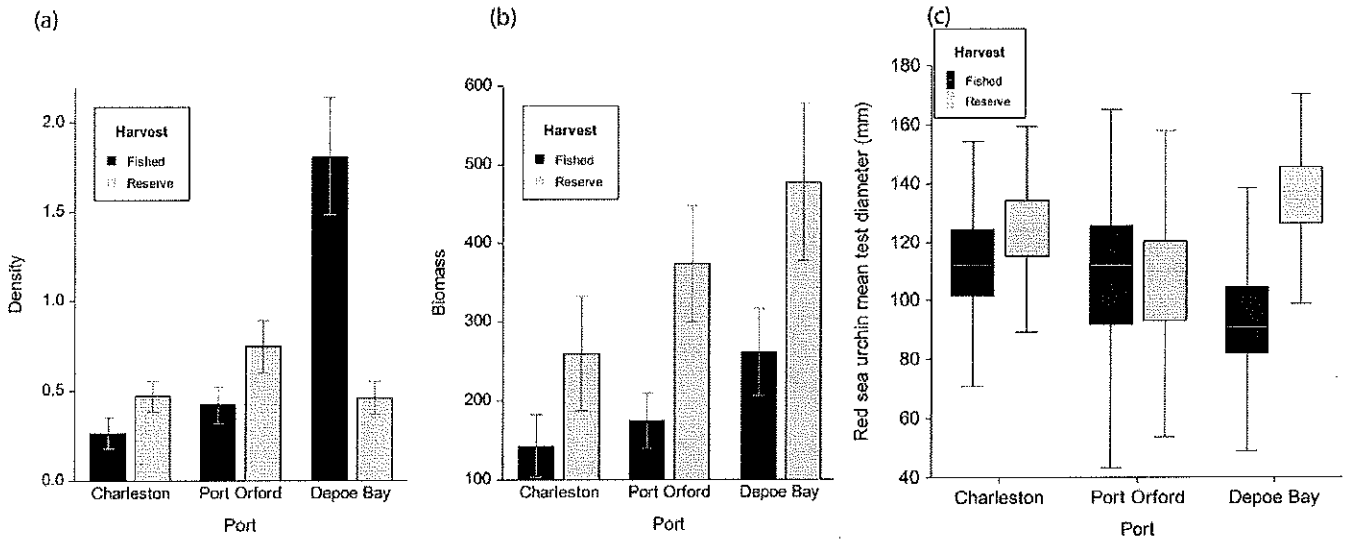

Figure 9. (a) Density (mean density of red sea urchins/m^2) in fished vs reserve areas by port (b) Biomass (mean grams of red sea urchins/ m^2) in fished vs reserve areas by port, (c) Box plot of mean red sea urchin size of fished vs reserve areas of Oregon (vertical red line indicates minimum size limit).

References:

Andrew, N. L., Agatsuma, Y., Ballesteros, E., Bazhin, a G., Creaser, E. P., Barnes, D. K. a, … Xiaoqi, Z. (2002). Status and management of world sea urchin fisheries. *Oceanography And Marine Biology An Annual Review*. http://doi.org/10.1201/9780203180594.ch7

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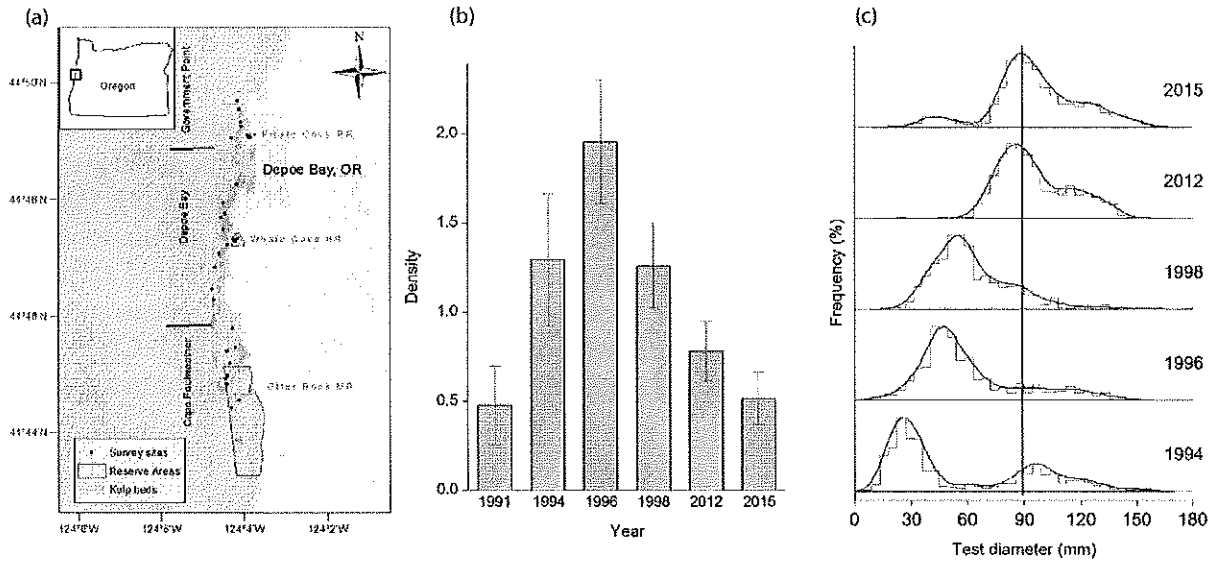

Figure 7. (a) Location of Depoe Bay, OR red sea urchin survey sites (b) Density of red sea urchins by year (error bar indicates standard error), and (c) size distribution of red sea urchins at Depoe Bay, OR (vertical red line indicates minimum size limit).

Port Orford South:

The areas directly South of Port Orford, OR have accounted for about 4% of historic harvest. Sea urchin surveys were conducted at these sites in 1992, 2010, and 2014 [Fig. 8(a)]. In 2012, Redfish Rocks Marine Reserve was implemented and created the second substantial reserve area within the red sea urchins habitat range. Like other areas, surveys at this site also show a reduction in density [Fig. 8(b)] and the populations were comprised primarily of large red sea urchins [Fig. 8(c)]. These observations are also indicative of low recruitment at these sites.

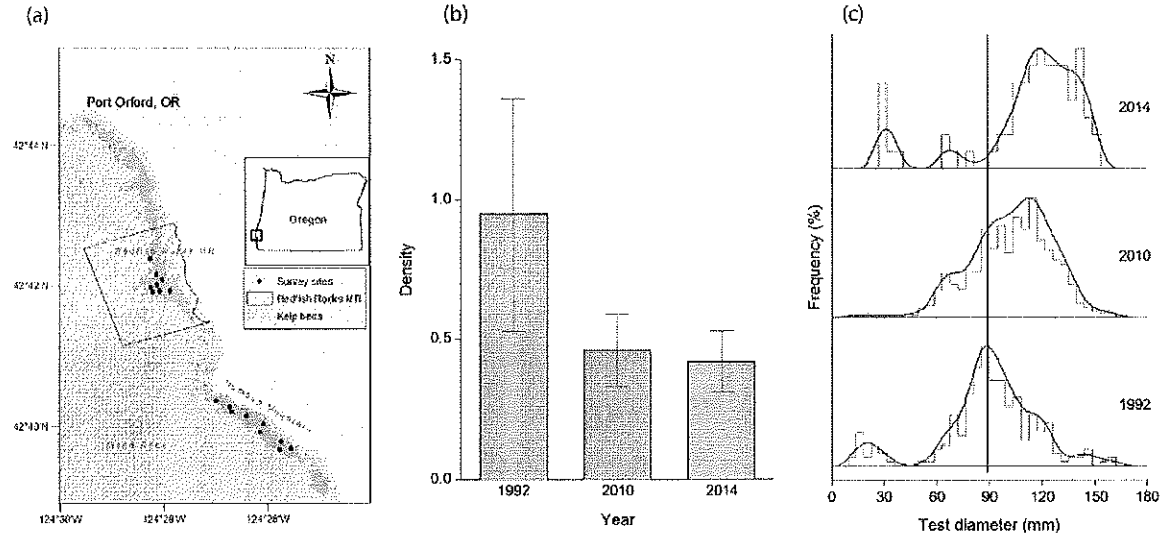

Figure 8. (a) Location of Port Orford south red sea urchin survey sites (b) Density of red sea urchins by year (error bar indicates standard error), and (c) size distribution of red sea urchins south of Port Orford, OR (vertical red line indicates minimum size limit).

Reserve areas:

Refuge from harvest is an important fishery management tool for sedentary animals such as red sea urchins (Quinn Wing, S.R. and Botsford, L.W., n.d.). Relevant to red sea urchins, Oregon has three very small reserve areas located near Depoe Bay (Whale Cove HR, Pirate Cove RR, and Otter Rock MR), and two more substantial reserve areas in Charleston (Gregory Point RR) and Port Orford (Redfish Rocks MR). These reserves provide areas for the accumulation of biomass for spawning stock free of harvest effects, and they are