HISTORY OF OLYMPIA OYSTERS (OSTREA LURIDA CARPENTER 1864) IN OREGON ESTUARIES, AND A DESCRIPTION OF RECOVERING POPULATIONS IN COOS BAY

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ABSTRACT  Historical evidence indicates that Olympia oysters (Ostrea lurida) are indigenous to at least three of Oregon’s estuaries. Populations of O. lurida occur in Yaquina Bay, Netarts Bay, and Coos Bay, although only the population in Yaquina Bay seems likely to have been continuous since prewestern settlement. The historical occurrence of Olympia (native) oysters in Yaquina and Netarts Bays is confirmed by numerous records of fishery landings. In contrast, historic populations in Coos Bay are inferred by the presence of large shell deposits buried in sediments throughout the polyhaline (salinity >18–30) region of the estuary. Other Oregon estuaries (such as Tillamook, Alsea, and Umpqua/Winchester Bay) may have had ambient environmental conditions suitable to support self-sustaining populations of O. lurida, but none of these estuaries are currently inhabited by natural populations, nor do they exhibit clear historical records of occupation in the past. We conducted searches of background information on many estuaries to summarize knowledge about the status of O. lurida populations in Oregon. The information presented here is based on a literature search, analysis of internal agency documents, and personal contacts with individuals most familiar with specific estuaries. As a case study, the Oregon Department of Fish & Wildlife (ODFW) repeated intertidal field surveys previously conducted in 1997 in an effort to document changes in O. lurida populations within Coos Bay. Field surveys conducted in 2006 followed methods that were similar to the 1997 intertidal surveys. Using previously published results as a baseline, we found that populations of native oysters exhibited spatial expansion throughout the mesohaline and polyhaline regions of the estuary, and that the intertidal oysters occurred at increased densities, over a wider range of sizes, and over a broader range of habitats. Further recovery of O. lurida populations in other regions of Coos Bay is most likely limited by the availability of suitable substratum for attachment and growth of the juvenile oysters.

KEY WORDS:  Olympia oyster, Native oyster, Yaquina Bay, Coos Bay, Netarts Bay, Oregon, Ostrea conchaphila, Ostrea lurida, oyster populations

INTRODUCTION

Olympia oysters (Ostrea lurida) were once abundant and ecologically important components of estuarine communities throughout the Pacific Northwest biogeographic region. Living beds of oysters occurred within the lower intertidal and subtidal regions of the estuaries where they most likely provided several key ecosystem services including: (a) maintenance of a hardened substratum that served as benthic habitat for many species; (b) biofiltration of phytoplankton and sediment particles from the water column; (c) pelagic-benthic coupling resulting in the secondary production of molluscan tissue and other organic materials; and (d) increased biotic diversity and foraging areas for invertebrates, fish, and shorebirds. In addition, the dense beds of Olympia oysters also provided local indigenous people with an important source of food, and larger-scale harvests of O. lurida constituted an economically valuable commercial fishery in Washington, California, and parts of Oregon (Gordon et al. 2001, Baker 1995). Regional popularity of the native oysters as a targeted fishery species led to massive removal of shells from the benthic substratum and over-harvests in the late 1800s, and these practices contributed to a region-wide collapse in many Pacific coast estuaries during the late 19th and early 20th centuries.

Upon the arrival of European settlers to coastal Oregon (1850s), populations of Olympia oysters were only found in Yaquina Bay and Netarts Bay (Marriage 1954, Baker 1995). Extensive shell deposits were observed in Coos Bay, however, and provide clear evidence that large populations of O. lurida occurred in the past. No living oysters were found in Coos Bay at the time of European settlement (Dall 1897). Based on water quality parameters and proximity to larval supply, other bays such as Tillamook, Alsea, Siletz, Siuslaw, Umpqua, Coquille, and others may have, over the course of geologic history, been suitable for O. lurida populations. However, conclusive evidence of the historical presence of O. lurida in these other estuaries is lacking. The overall purpose of this project was to document the historical and recent occurrence of O. lurida in Oregon estuaries, and to describe the spatial extent and recovery of Olympia oyster populations within Coos Bay.

HISTORICAL AND RECENT OCCURRENCE OF OLYMPIA OYSTERS IN OREGON ESTUARIES

Estuaries with Confirmed Populations of Olympia Oysters

Netarts Bay

Netarts Bay is a small (930 ha), marine-dominated, bar-built estuary located along the northern shoreline of Oregon (Fig. 1). The mouth of the estuary has not been stabilized by jetties, and the shallow tidal basin contains extensive sand flats, mudflats, and eelgrass beds as well as primary and secondary tidal channels. The watershed drainage basin for Netarts Bay is

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†The taxonomy of the Olympia oyster has been in dispute since Harry (1895) proposed synonymy of Ostrea lurida Carpenter 1864 and Ostrea conchaphila Carpenter 1857. Polson et al. (2009) provide molecular evidence that the Olympia oyster refers to the nominal species, Ostrea lurida Carpenter 1864. In view of their genetic data, and for consistency, the original taxon, Ostrea lurida, is used throughout this volume to refer to the Olympia oyster, which is distributed from approximately Baja California (Mexico) to southeast Alaska.
approximately 3,626 ha, and input of freshwater occurs through numerous small creeks.

Netarts Bay historically supported a commercial fishery for *O. lurida* beginning in the 1860s, but overall landings and duration of the fishery were always substantially lower than that of Yaquina Bay. Commercial harvest of Olympia oysters took place in the upper region of Netarts Bay where water quality parameters are most favorable (Stout 1976, Bonacker et al. 1979). In the 1930s native oysters were believed to exist in low numbers in Netarts Bay, and the remaining populations may have been affected by localized introduction in 1957 of *Ocenebra japonica* (Dunker 1860), a nonindigenous gastropod predator, (Stout 1976) concurrent with the introduction of Pacific oysters (*Crassostrea gigas*) from Japan. Olympia oysters were found to be “present in very small numbers upbay” in the mid-century (Marriage 1954), and the oysters were considered to be “locally extinct” by 1979, although many areas of the upper bay where oysters would be expected to survive were not surveyed (Kraeg 1979). Qualitative surveys of Netarts Bay conducted by the Oregon Department of Fish and Wildlife in 1992 did not discover any living oysters (J. Johnson, pers. comm.). An attempt was made by ODFW to re-establish the oysters in Netarts Bay over the period from 1993–1998. The reintroduction effort included establishment of approximately 9 million spat set on 150 sacks of nonindigenous Pacific oyster (*C. gigas*) cultch (ODFW, unpublished records). This effort likely re-established ephemeral populations of *O. lurida* that were detected in 2004 during surveys carried out by The Nature Conservancy (TNC). A field experiment was undertaken within Netarts Bay in 2005 to 2006 to investigate the ecological effect of cultch (i.e., *O. lurida* juveniles on nonliving *C. gigas* shell) on native oyster survival, growth, and eelgrass abundance (Archer 2008). Currently, TNC is continuing their efforts to restore populations of Olympia oysters in Netarts Bay (D. Vander Schaaf, pers comm.).

**Yaquina Bay**

Yaquina Bay is a moderately-sized (1,700 ha), drowned river-mouth estuary located along the central Oregon coast (Fig. 1). The mouth of the bay is protected by rock jetties and rip-rap, and the estuarine tidal basin contains a primary navigational channel, extensive sand flats and mudflats, subsidiary sloughs, and an elongated riverine region. The watershed drainage basin for Yaquina Bay is about 65,526 ha, and the Yaquina River provides the primary source of freshwater inputs.

Environmental conditions within Yaquina Bay have been suitable over long time periods to allow for persistent populations of *O. lurida*. The most productive commercial harvests of native oysters were limited to a three-mile stretch of polyhaline (salinity >18–30) and mesohaline (salinity >5–18) waters (Fasten 1931). Oyster stocks within this confined region of the estuary were considerable in the past, and success of the oyster harvest contributed to colonization of the Newport area by European settlers (Dimick 1939). Harvests of Olympia oysters began to decrease in the 1890s, and significant commercial operations ended in the 1940s. Populations of *O. lurida* were not supplemented in Yaquina Bay throughout the years of the commercial fishery. The eventual decline of Olympia oysters in Yaquina Bay is attributed primarily to over fishing, although other factors such as pollution and habitat loss were also factors.
Various habitat enhancement efforts have taken place in Yaquina Bay from the early years of the fishery to the present. Like many habitat enhancement projects related to *O. lurida*, they focused on the addition of culch as a means to replace habitat loss associated with harvest and removal of shell rubble.

The presence of *O. lurida* in Yaquina Bay is well documented in historical accounts to the present, indicating adequate larval supplies and the persistence of self-sustaining populations (Dimick et al. 1941, Baker 1995). Occurrence of natural populations of *O. lurida* has recently been confirmed by a coast-wide survey to document peak densities of Olympia oysters in the intertidal zone (M. Polson, pers. comm.). Efforts to enhance populations of *O. lurida* in Yaquina Bay have been undertaken by the United States Army Corps of Engineers (mid 1990s) and by the Confederated Tribe of Siletz (2005–2006, S. Van De Wetering, pers. comm.).

**Coos Bay**

Coos Bay is a large (5,383 ha), drowned river-mouth estuary located along the shoreline of south-central Oregon (Fig. 1). The mouth of the bay is protected by a rocky headland, rock jetties, and rip-rap. The estuarine tidal basin contains a primary navigational channel, extensive sand flats and mudflats, several subsidiary inlets and sloughs, and an elongated riverine region. The watershed drainage basin for Coos Bay is about 157,470 ha, and the Coos and Millicoma Rivers provide the primary source of freshwater inputs.

The shoreline and bottom of Coos Bay contain massive shell deposits of *O. lurida*. However, no live *O. lurida* were observed at the time of European settlement (1850s). Absence of living oysters has been attributed to a local extinction event (Baker 1995, Baker et al. 2000); the Olympia oysters were most likely decimated by the excessive inputs of sediments that resulted from a “big fire” in 1846 (Dimick et al. 1941), and/or because of sedimentation associated with a subduction zone earthquake and tsunami in 1700 (Nelson et al. 1996). Contemporary re-establishment of Olympia oysters in Coos Bay has been described by Baker (1995) and Baker et al. (2000).

A few living individuals of *O. lurida* were found in 1986 in Haynes Inlet (northern region of Coos Bay) near commercial aquaculture plats (*Crassostrea gigas*). Small individuals of *O. lurida* were commonly observed on the bottom of Isthmus Slough (southern region of upper Coos Bay) in 1988 (Carlton 1989, Baker 1995). By 1997, self-sustaining populations of *O. lurida* had also become established within the East Arm of Coos Bay (Baker et al. 2000). Because that time, the populations of *O. lurida* in Coos Bay have expanded in spatial distribution and abundance. To date, these populations have reached intertidal densities of >60/m² (documented by quantitative surveys along transect lines), although higher localized densities have been observed during qualitative surveys (S. Groth, pers. obs.).

No deliberate attempts to further establish or enhance populations of *O. lurida* have occurred in Coos Bay subsequent to their recent return. Anecdotal evidence exists for unsuccessful introductions of *O. lurida* in the early 1900s (Baker et al. 2000) and mid 1960s. These attempts have not been quantified or fully substantiated. A new project supported by the NOAA Community-Based Restoration Program will investigate factors that contribute to recovery of Olympia oysters in the South Slough estuary (S. Rumrill, pers. obs.). The project will evaluate the survivorship, growth, and ecological interactions for an experimental population of *O. lurida* in the polyhaline region of the South Slough tidal channel.

**Estuaries with Potential for Populations of Olympia Oysters**

We are confident that populations of *O. lurida* occurred historically within Netarts Bay, Yaquina Bay, and Coos Bay (Baker 1995). Given the tendency of *O. lurida* populations to undergo localized extinction followed by re-establishment, it is clear that further evaluation is needed to provide diagnostic evidence of oyster presence or absence for other Oregon estuaries. Many other Oregon estuaries were examined for possible existence of historic populations of *O. lurida*, based on a review of their characterization and suitability for aquaculture of *C. gigas* (Osis & Demory 1976). Contradictory information was discovered for some estuaries. In particular, it is possible that Olympia oysters were historically harvested from Tillamook Bay. The close proximity of Tillamook Bay to Netarts Bay may be responsible for documented exportation of Olympia oysters during the period of intensive commercial harvest of *O. lurida* in Oregon. It is known that oysters were harvested from Netarts Bay, and then transported and shipped through Tillamook Bay, thereby providing a logical avenue for their documented records of export through Tillamook Bay (Stout 1976). No evidence of the natural presence of *O. lurida* populations was found for any estuaries other than Yaquina, Netarts, and Coos Bays (Baker 1995, this study).

**SPATIAL EXTENT AND RECOVERY OF OLYMPIA OYSTERS IN COOS BAY**

**Description of Study Sites in Coos Bay**

The Coos estuary (Coos Bay) is the sixth largest estuary along the Pacific coast of the contiguous United States (Proctor et al. 1980). As the largest estuary located completely within Oregon state lines, the Coos estuary is an important coastal industrial center and shipping port with direct commercial ties to San Francisco, the Columbia River, Puget Sound, and other major port facilities throughout the Pacific rim (Fig. 1). The Coos estuary is classified by the Oregon Department of Land Conservation and Development as a Deep Draft Development Estuary (Cortright et al. 1987; Jennings, et al. 2003) and its entrance is stabilized and protected by a pair of 1 km rock jetties. The navigational channel within the Coos estuary is routinely dredged to maintain adequate depths for commercial shipping, and the shoreline contains special zoning units for: (a) urban and industrial development, (b) conservation of natural resources, and (c) natural management of significant fish and wildlife habitats. Like many other Pacific northwest estuarine systems, the Coos estuary is a drowned river-mouth that was inundated by tidal waters during the most recent transgression of sea level (beginning ca. 20,000 y ago; Thompson et al. 1993; Rumrill 2006).

**Pony Point**

The Pony Point study site (43°25′26.16″N/124°14′20.74″W) is located in the polyhaline region of the estuary near the lower bay range extent of Olympia oysters in Coos Bay (Fig.2, Fig. 3). The upper intertidal substratum is characterized by large basalt rip-rap that secures adjacent fill deposited to form the runway
for the local airport. Dense eelgrass beds (*Zostera marina*) occur in muddy-sand in the lower intertidal area north of the airport. Rocky rip-rap is the primary substrate used by *O. lurida* at this location and a diverse community of invertebrates co-occurs, including arthropods (*Cancer magister, C. productus, Carcinus maenas, Hemigrapsus oregonensis, Neotrypaea californiensis,* and *Pachygrapsus crassipes*), bivalves (*Tresus capax, Clinocardium nuttallii, C. gigas, Mya arenaira, Macoma sp., Mytilus sp.*), and gastropods (*Euspira lewisii, Nucella sp.*).

**Haynes Inlet**

The Haynes Inlet study site (43°26′38.79″N/124°12′48.07″W) is located in the polyhaline region of the estuary within a subestuary at the northern bend of Coos Bay (Fig. 2, Fig. 3). The intertidal substratum is characterized by sandstone and rip-rap along the shoreline adjacent to tide flats used for commercial oyster production. Hard surfaces (shell rubble, gravel, rip-rap and rock) that are the preferred substratum for settlement of *O. lurida* in Coos Bay are not readily available in Haynes Inlet. Macro-invertebrates common to this area include arthropods (*C. magister, C. maenas, H. oregonensis, and N. californiensis*), bivalves (*C. nuttallii, C. gigas, M. arenaira, Macoma sp., Mytilus sp.*), and gastropods (*Nucella sp.*).

**Downtown Coos Bay**

The Coos Bay study site (43°23′30.17″N/124°13′2.42″W) is located in the mesohaline/polyhaline region of the estuary near the City of Coos Bay (Fig. 2, Fig. 3). The intertidal zone is characterized by steeply sloped rip-rap banks adjacent to a deep (>30′ deep) dredged navigational channel. The preferred substratum for settlement of *O. lurida* at this site is primarily rip-rap, and the narrow lower intertidal area below the rip-rap is extremely soft mud and likely not suitable to support Olympia oysters. Invertebrates common to this area include arthropods (*C. magister, C. maenas, H. oregonensis, and N. californiensis*); bivalves (*C. gigas, M. arenaira, Macoma sp., Mytilus sp.*); and gastropods (*Nucella sp.*).

**Eastside**

The Eastside study site (43°21′38.98″N/124°11′33.28″W) is located in the mesohaline/polyhaline region of the estuary near the municipality of Eastside (Fig. 2, Fig. 3). The narrow intertidal zone is characterized by a shallow gradient slope between the banks and deep channel where the substratum is a mixture of gravel, rock, and mud. The preferred substratum for settlement of *O. lurida* at this site is primarily gravel discarded from an adjacent quarry storage area. Invertebrates common to this area include arthropods (*C. magister, C. maenas, H. oregonensis, and N. californiensis*); bivalves (*C. gigas, M. arenaira, Macoma sp., Mytilus sp.*); and gastropods (*Nucella sp.*).

**Millington**

The Millington study site (43°19′56.69″N/124°11′31.59″W) is located in Isthmus Slough (mesohaline region of the estuary)
near the municipality of Millington (Fig. 2, Fig. 3). This site, and nearby Shinglehouse Slough, establish the upper bay range limit for Olympia oysters in Coos Bay. The narrow intertidal zone is characterized by soft sediments and woody debris that transitions quickly to the deep navigational channel. The preferred substratum for settlement of *O. lurida* at this site is primarily wood bark and other wood materials discarded from local lumber operations. Invertebrates common to this area include arthropods (*C. magister, C. maenas, H. oregonensis*, and *N. californiensis*); bivalves (*C. gigas, M. arenaria, Macoma sp., Mytilus sp.*); and gastropods (*Nucella* sp.).

**Survey Methods**

We used three survey methods to document changes in the distribution, abundance, and size of *O. lurida* in Coos Bay.

**Qualitative Surveys**

The goal of this sampling effort was to revisit previous study sites to determine any changes in the distributional range of *O. lurida* populations in Coos Bay. Study sites were chosen strategically throughout Coos Bay based on previously described oyster habitat and areas that offered potentially suitable habitats. During each qualitative survey, the intertidal zone was thoroughly examined at times when the low tides were below 0° Mean Lower Low Water (MLLW). In addition to the study sites described above, we also included 20 sites examined in previous surveys to establish the baseline distribution of oysters in Coos Bay (Baker et al. 2000).

**Quantitative Surveys**

The goal of this sampling effort was to re-examine the abundance of *O. lurida* at different locations throughout Coos Bay. Quantitative surveys of oyster densities were conducted in the intertidal zone following previous methods (Baker et al. 2000) at the five study sites described above (Pony Point, Haynes Inlet, Downtown Coos Bay, Eastside, and Millington; Figure 2). At each site a 10-m transect line was laid out along the intertidal zone, parallel to shoreline, and six 0.25-m² quadrats were placed at random intervals along the line. All adult oysters (shell length ≥ 20 mm) that occurred within the quadrats were counted and measured. Juvenile oysters (<20 mm) were omitted from the quantitative surveys because of the lack of comparability based on time of year and because of time constraints required to complete the surveys within a single low tide event. Notably, juvenile oysters, (<20 mm) were a significant component (~97% of total) of the oyster population surveyed in 1997 and were excluded from 2006 surveys because of time constraints.

**Index Survey**

The goal of this sampling effort was to establish a repeatable index of oyster density in an area of high abundance for future monitoring. The oyster index area was established at the Eastside (Isthmus Slough) study site where populations of *O. lurida* occur consistently on the gravel substrata (Fig. 2). A 50-m section of the eastern shoreline of Isthmus Slough was examined and identified as suitable oyster habitat. Randomly chosen transects (0.5-m width) were run perpendicular to the 50 m line beginning at the highest oyster found and ending at the water line. All field surveys were performed at tides lower than -1.0 MLLW, and all oysters (≥20 mm) within transects were counted. The Downtown Coos Bay study site (Fig. 2) was initially explored as a potential index site, but this area proved unsuitable because of the extremely high and patchy densities of oysters, primarily caused by the highly variable availability of rock as a suitable substrata.

**Changes in Oyster Distribution, Abundance, and Size**

**Distribution in Coos Bay**

The spatial distribution of *O. lurida* within Coos Bay in 2006 was generally similar to the distribution described earlier by Baker (1987) and by Baker et al. (2000), with a few notable changes. In 1986 and 1997, the lower bay distribution of *O. lurida* ended near the North Bend airport (near the Pony Point study site; Fig. 2) and the upper bay range limit was found in Isthmus slough near Millington (Fig. 2). In 2006, the lower bay range extended to rip-rap at the end of the airport runway and the upper bay range had increased slightly to include Shinglehouse Slough and a short distance further up Isthmus Slough (Fig. 2).

**Notable Areas of Population Change**

**Haynes Inlet and North Slough**

Two subestuaries are located in the northern portion of Coos Bay, roughly where the bay is separated into the western and eastern arms. The re-established population of *O. lurida* was first discovered in Haynes Inlet (Baker et al. 2000). The oysters are evenly distributed and occur at densities that are similar to those found in the quantitative surveys. High densities of *O. lurida* are limited to locations where substrate is suitable. Hard substrate (i.e., sandstone, shell, bark, basalt, and gravel) is readily available throughout this area and lends to the even distribution. Adult *O. lurida* were absent in North Slough during the surveys conducted in 1997, but they were present in the qualitative surveys conducted in 2006 when their range extended 2.8 km upstream.

**Marshfield Channel**

In the area east of the entrance of Isthmus Slough oysters are currently found commonly attached to decaying bark, the primary available substrate of the area. Fossil shells of *O. lurida* are dense in the fill material and banks of this area, but live oysters were absent here in 1997. Optimal settlement substrate is lacking throughout this area.

**Shinglehouse Slough**

In 2006, a dense intertidal population of Olympia oysters was found within Shinglehouse Slough in an area noted in 1997 as “marginal/incidental.” This area is the site where a highway bridge was replaced in 1988 and substantial amounts of gravel were added below the bridge to help stabilize the sediments. The gravel provides a suitable substratum for *O. lurida* and the oysters were attached directly to the small rocks embedded in the soft mud.

**South Slough**

The South Slough tidal inlet forms the primary subestuary of lower Coos Bay. Several large adult *O. lurida* were observed attached to floating docks located throughout the Charleston
Boat Basin during the qualitative surveys conducted in 2006. In a result similar to the 1997 surveys, these adults were the only living *O. lurida* found in the lower bay area. Although other areas in South Slough are potentially suitable for *O. lurida* (i.e., Collver Point, Joe Ney Slough, Long Island Point), oysters were absent. South Slough National Estuarine Research Reserve is currently undertaking a project to evaluate the viability of habitats further upstream in areas that are potentially suitable for settlement and recovery of oyster populations on benthic substrata.

### Changes in Oyster Abundance

Quantitative surveys of oyster abundance in Coos Bay conducted in 2006 revealed much higher densities of *O. lurida* than those found previously (Table 1). In general, large oysters ($\geq 20$ mm) had become much more abundant within the mid region of their range (Eastside, Coos Bay), and they also increased in abundance at the upper region (Millington and Haynes Inlet) extensions of the bay (Fig. 2).

The most notable areas of population change occurred in Millington and at the Eastside/Downtown Coos Bay study site (Fig. 2).

**Millington**

During the 1997 surveys this area was noted for the absence of living oysters. In 2006, we observed that a small but apparently viable population had become established on the woody debris embedded in the soft mud. Very little substratum that is suitable for settlement of *O. lurida* occurs at this site, and further recovery of the oyster populations appears to be limited by the availability of hard surfaces.

**Eastside/Downtown Coos Bay**

Dense populations of *O. lurida* were observed in 2006 throughout the intertidal areas of lower Isthmus Slough and the downtown shoreline of Coos Bay wherever suitable substrate was available. Oyster densities of 46.7 per m$^2$ and 61.3 per m$^2$ were observed at the Eastside and Downtown Coos Bay locations, respectively. These high densities of oysters are typical of the adjoining areas and are greater than the densities observed in 1997 (Table 1, Baker et al. 2000).

### Changes in oyster sizes

Populations of adult oysters observed in our 2006 quantitative surveys included a broader range of smaller size classes in comparison with the sizes of oysters measured in 1997 (Fig. 4). In 2006, the average shell length for adult oysters ($\geq 20$ mm) was 32.8 (S.D. 7.4) mm compared with 38.1 (S.D. 4.5) mm in 1997. Despite the small number of adult shells measured in 1997 ($n = 17$) compared with the larger number measured in 2006 ($n = 177$), a single-factor ANOVA of the size frequencies of oyster shell lengths (20 mm bins) revealed that the difference between the populations was highly significant ($F = 8.3755; P = 0.0042$). Pearson’s coefficient of skewness also differed substantially between the populations measured in 1997 (0.0775) when the modal shell length was 44.0 mm, and the population measured in 2006 (-0.0662) when the modal shell length was 33.0 mm. Negative skew in favor of smaller size classes in 2006 indicates that the populations of *O. lurida* probably experienced substantial and repeated episodes of recruitment during the preceding years.

**Index Survey**

The oyster index survey site established near Eastside (Fig. 2) yielded an average *O. lurida* density of 56.4 oysters per m$^2$. This high density of adult oysters is comparable to the high densities of *O. lurida* observed nearby at the Eastside study site and at the Coos Bay study site (Table 1). Our initial measurements of high and consistently occurring oyster densities at this site establish the baseline for future measurements of *O. lurida* populations within the mesohaline region of the estuary.

**DISCUSSION**

Beds of *O. lurida* were historically abundant in the Coos estuary and South Slough (Oregon) where they were used extensively as a food source by the indigenous people. Several shell middens that contain native oysters occur along the shoreline of the South Slough (Moss & Erlandson 1995) and they have radiocarbon ages of about 400 ± 60 y before present. Olympia oyster shells are commonly included in the dredged materials removed from the estuarine channels. Beds of *O. lurida* probably became locally extinct in Coos Bay and South Slough prior to written history caused by basin-wide changes in...
the inputs and distribution of fine sediments associated with fire
and/or a tsunami (Nelson et al. 1996, Rumrill 2006). Over the
first century after colonization of the shoreline of the Coos
estuary by euro-western settlers (ca. 1850–1950), aquatic and
estuarine habitats within portions of Coos Bay were chronically
degraded by growing urbanization and the cumulative effects of
sedimentation, log storage, bark decay, dredging, deposition of
dredge spoils, diking, filling, domestic and industrial pollution,
commercial mariculture, and by the colonization of estuarine
habitats by nonindigenous aquatic species. Despite these alter-
ations and degradation of the shoreline, and reduction of the
entire wet surface area of the Coos estuary by 26% (Borde et al.
2003), water column and benthic habitat conditions have
improved considerably over the past 30 years within particular
regions of the tidal basin; conditions are now conducive to the
recovery of Olympia oysters. In 1988, after several years of
inadvertent inoculations via commercial shellfish culture activi-
ties, discontinuous populations of Olympia oysters became re-
established at low intertidal and subtidal elevations within the
polyhaline (salinity 22–28 ppt) region of the Coos estuary (Baker et al. 2000). Baker hypothesized that changes in O.
lurida range were dependent on changes to salinity intrusion,
primarily attributed to deepening of the navigational channel.
Additional channel deepening occurred roughly simultaneous
with the previous surveys and may be responsible for the increased
spatial distribution of O. lurida observed in 2006. It is anticipated
that further changes to the navigational channel will result in
alterations in salinity intrusion and thus may dictate future
changes in the distribution and range of O. lurida populations.

Although isolated populations of Olympia oysters have
become marginally established within the Coos estuary,
widespread recovery of O. lurida has not occurred because of
several potentially limiting factors. These factors include: (a)
suboptimal biotic and physical conditions that may hamper
feeding, survivorship, growth, and reproduction; (b) inadequate
production and larval retention; (c) decreased availability of
adequate shell substratum for settlement; (d) poor survival of
postsettled juveniles; and (e) predation, competition, and
ecological interactions with other established Olympia and
nonnative species. It is anticipated that once these hurdles are
understood and perhaps overcome, it may be possible to initiate
recovery of Olympia oyster beds in Coos Bay and South Slough
in a manner that will allow the oyster populations to become
self-sustaining. Re-establishment of self-sustaining populations
of O. lurida is desirable because, in addition to the recovery of
the oysters, the growing physical structure of the oyster beds
will serve to restore some of the lost ecological functions to the
estuarine tidal basin, and the living oyster beds may reach a
point in the future where they can provide substantial benefits
for diverse communities of invertebrates, fish, shorebirds, and
humans.

CONCLUSION

Populations of O. lurida currently exhibit spatial expansion
and increased abundance in parts of Coos Bay, and also provide
evidence of recruitment by juveniles into the established pop-
ulations of adults. Olympia oysters seem to have become a viable
species and it is possible that they may continue to expand their
distribution and fulfill their former role in the estuarine ecosys-
tem at some time in the future. However, our field observations
indicate that the availability of suitable substratum is likely a
key limiting factor that hinders further recovery in Coos Bay.
The potential of oyster populations to recover in Netarts and
Yaquina Bay is currently being explored via enhancement
projects. These projects include ecological assessment work that
will provide guidance for the future of Olympia oysters in
Oregon’s historically productive bays and estuaries.

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