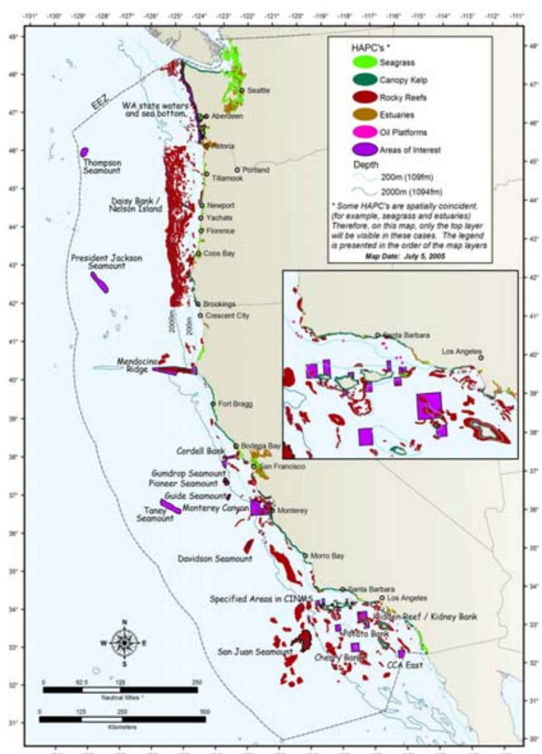
PROCEEDINGS

WORKSHOP ON ALTERNATE BALLAST WATER EXCHANGE AREAS: PHYSICAL AND BIOLOGICAL OCEANOGRAPHIC CONSIDERATIONS



JUNE 20 - 22 2006
SEATTLE, WASHINGTON

Workshop Sponsors:

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Thanks to David Kimbro, Dr. Ted Grosholz, and Bess Wong for assistance in compiling and editing this document

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WORKSHOP ON ALTERNATE BALLAST WATER EXCHANGE AREAS: PHYSICAL AND BIOLOGICAL OCEANOGRAPHIC CONSIDERATIONS

Grand Hyatt Hotel
721 Pine Street
Seattle, Washington

Edited by:

Stephen Phillips
Pacific States Marine Fisheries Commission
205 SE Spokane Street
Portland, Oregon

June 20-22, 2007

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JUNE 22

Executive Summary

The Pacific States Marine Fisheries Commission (PSMFC), in cooperation with the U.S. Coast Guard and National Oceanic and Atmospheric Administration, hosted the "Workshop on Alternate Ballast Water Exchange Areas: Physical and Biological Oceanographic Considerations" in Seattle, Washington from June 20-22, 2006. The Nonindigenous Aquatic Nuisance Prevention and Control Act defines Alternative Ballast Water Exchange Zones (ABWEA's) or back-up ballast exchange zones as "areas within the waters of the United States and the exclusive economic zone, if any, where the exchange of ballast water does not pose a threat of infestation."

The purpose of the workshop was to gain a greater understanding of biological and physical oceanography processes and the ecological risk posed by ballast water exchange within U.S. territorial waters of the eastern Pacific, specifically in the US Exclusive Economic Zone (EEZ) from 50–200 nm offshore. The discharge of ballast water from commercial vessels is the leading vector for the transfer of potentially harmful aquatic organisms and pathogens around the world.

The PSMFC invited academic researchers to present information on physical and biological oceanography and address the following questions:

1. How likely is it for organisms picked up in the ABWEA's to be problematic if they are discharged in-shore?

2. How problematic is it to discharge coastal organisms in the waters of the ABWEA's; what are their potential effects on water column or bottom assemblages and are there cascading effects on fisheries?

3. What is the likelihood of onshore transport and/or colonization with ballast water exchange at different distances from shore assuming the combination of transport and behavior?

4. What are the spatial and temporal patterns of water movement on, off, and along shore, over the distance scales appropriate for this discussion (200 miles, 200-50 miles, 50 miles inward, etc)?

The workshop was organized into four sessions: 1) Regional ABWEA considerations, in which state, federal and Canadian natural resource agency representatives discussed state ballast water management regulations and experiences regarding ABWEA's; 2) biological oceanography; 3) physical oceanography; and 4) threats to habitat and fisheries resources. A discussion panel was convened after each session that allowed the speakers to answer questions from the audience and to further explore session topics.

On the third day, a working group met to summarize the findings of the workshop, discuss the issues influencing the designation of ABWEA's, and evaluate the potential areas with the physical and biological characteristics that would prevent non-native species which reside in ballast water from surviving or migrating to the U.S. coastline. The working group's main recommendations are as follows:

1. In general, ABWEA's should be established no closer than 50 nm from shore and in waters at least 1000 m in depth.

2. A workshop should be convened that is modeled after this ABWEA workshop and includes Mexican officials as participants. The Proceedings from this workshop could be used to help establish recommendations and/or exclusion zones that reduce the number of non-native species introduced to both U.S. and Mexican waters.

3. Establishment of ABWEA's should avoid major estuary and oceanic river plumes, subsurface physical features (e.g. seamounts), and known fishery habitats.

The working group reviewed information on the historical frequency at which vessels originating outside the U.S. EEZ seek safety exemptions and exchange water between 50-200 nm of the U.S. shoreline. In 2005, for Oregon and Washington Columbia River ports, only a small fraction of vessels (only two out of approximately 800 vessels) originating outside the U.S. EEZ exchanged water within the 200 nm exclusion zone. However, the State of California reported that in 2004, approximately four percent of the ballast water discharges in California waters did not undergo any exchange or underwent exchange in areas other than 200 nautical miles from shore. In reviewing this data, about 92 percent of the noncompliant ballast water discharged originated from Mexican or Central American waters.

One of the products of the workshop was a map showing potential areas possessing the physical and biological characteristics that are important to consider in identifying Pacific Coast ABWEA's from 50–200nm offshore. These areas include the Southern California Bight, the Columbia River Plume and seamounts.

It is hoped that the Federal government and others will use the workshop's <u>process</u> and proceedings as a model that can be utilized in other regions of the country for similar analysis of the ABWEA issue. Any further work on ABWEA's on the West Coast must consider input from a broad range of interests, including all sectors of government, the maritime industry, environmental groups and the fishing industry. Integration of shipping lanes and transit times will also be critical in any ABWEA designation process.

Workshop PowerPoint presentations can be found on the Pacific Ballast Water Group website at http://www.psmfc.org/ballast/past_meetings.html.

Introduction and Background

1. Workshop Goals and Objectives: *Stephen Phillips Pacific States Marine Fisheries Commission, Portland, Oregon.*

***Abstract**:* The genesis of this workshop came about from discussions between the U.S. Coast Guard (LCDR Kathleen Moore and Dr. Richard C. Everett), National Oceanic and Atmospheric Administration (Tim Keeney, Deputy Assistant Secretary of Commerce for Oceans and Atmosphere) and the PSMFC (Randy Fisher, Executive Director and Stephen Phillips, ANS Program Manager) on the need to investigate the issue of Alternative Ballast Water Exchange Zones (ABWEA's). Additional impetus for this workshop occurred in 2005 when the Government Accountability Office (GAO) testified before Congress that U.S. waters remain vulnerable to invasive species carried in ballast water. The GAO reported that the "current [Federal] ballast water management exchange program is not a viable long-term approach to minimizing the risks posed by ballast water discharges." Further, according to the testimony, one of the primary reasons cited for the vulnerability to invasion is that ABWEA's have not been established for use by ships that, for a variety of reasons, are unable to conduct ballast water exchange in mid-ocean.

Overview of Ballast Water Management

Cargo ship operation requires ballasting, which is done by transferring water in or out of dedicated ballast water tanks, empty cargo and fuel tanks or some combination of the three. Ballasting is required to:

- reduce stresses on the ship hull,
- aid in transverse stability,
- aid propulsion by controlling propeller submergence,
- aid maneuverability by submerging the rudder and reducing hull surface exposure (freeboard or windage), and
- compensate for weight loss from fuel or water consumption.

The discharge of ballast water from commercial vessels is the leading vector for the transfer of potentially harmful aquatic organisms and pathogens around the world. It has been estimated that 21 billion gallons of ballast water are discharged into U.S. ports each year (EPA 2001), and globally, 10,000 organisms or more may be transported around the world daily (Carleton 1999).

Preventing or reducing the risk of species transfers and associated invasions through ballast water discharge is a significant challenge. Federal law requires that all vessels equipped with ballast water tanks entering U.S. waters after operating beyond the EEZ to employ at least one of the following BWM practices: (a) Prior to discharging ballast water in U.S. waters, perform complete ballast water exchange in an area no less than 200 nautical miles (nm) from any shore; (b) retain ballast water onboard the vessel; (c) prior to the vessel entering U.S. waters, use an alternative environmentally sound method of BWM that has been approved by the US Coast Guard.

Although the long-term goal is to develop treatment technologies to remove organisms, there are currently no treatment methods, either on the ship or shore side that are both universally applicable and proven effective at preventing introductions of organisms. Therefore mid-ocean ballast water exchange for transoceanic voyages is the preferred method of ballast water management to reduce invasions. It will likely remain as an important tool for another decade or more until new treatment technologies are developed, tested and installed on the worldwide fleet of cargo vessels.

Alternative Ballast Water Exchange Zones

What are ABWEA's? The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 (Public Law 101-646, section 1102(a)(1)(b)) defines alternative or back-up exchange zones as "areas within the waters of the United States and the exclusive economic zone, if any, where the exchange of ballast water does not pose a threat of infestation."

Alternative exchange zones are written into federal law and international convention. Section 1001 of the National Invasive Species Act contains a provision requiring vessels to conduct ballast water exchanges where the exchange does not pose a threat to spread of aquatic nuisance species. Also, the International Maritime Organization, in the "Convention for the Management of Ships' Ballast Water and Sediments" (Section B), states that "in cases where the ship is unable to conduct ballast water exchange as above, this should be as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 metres in depth." We are fortunate to have Dr. Richard Everett of the U.S. Coast Guard's Environmental Standards Division here with us today. He will discuss international and U.S. federal ballast water issues in further detail in his presentation, which is next on the agenda.

This workshop is not intended to be a forum on policy and regulatory issues surrounding the potential establishment of ABWEA's on the West Coast. Designation of ABWEA's will require numerous determinations that will at least include biological, logistical, and regulatory issues. Rather, the goal is to gain a greater understanding of the biological and physical oceanographic processes that control cross/along-shelf plankton transport in U.S. waters. The information and processes developed from this workshop will be provided to the United States Coast Guard (USCG) and National Oceanic and Atmospheric Administration (NOAA) for potential use in future deliberations on ABWEA's on the West Coast and in other regions of the country. In addition, we hope this information will be beneficial to management and regulatory decision-making processes for coastal and estuarine ecosystems; and that it will also be valuable for fisheries and biodiversity management.

As we go through the workshop presentations, please keep in mind the following questions:

1. How likely is it for organisms picked up in the ABWEA's to be problematic if they are discharged in-shore?

2. How problematic is it to discharge coastal organisms in the waters of the ABWEA's; what are their potential effects on water column or bottom assemblages and are there cascading effects on fisheries?

3. What is the likelihood of onshore transport and/or colonization with ballast water exchange at different distances from shore assuming the combination of transport and behavior?

4. What are the spatial and temporal patterns of water movement on, off, and along shore, over the distance scales appropriate for this discussion (200 miles, 200-50 miles, 50 miles inward, etc)?

Previous work done on exchange zones was helpful in developing the agenda for this workshop, most notably the document entitled, "West Coast Oceanography: Implications for Ballast Water Exchange." There are other important reference documents that will help gain further perspective on the issue. Below is a list of those studies and workshop proceedings. They will also be listed on our website (http://www.psmfc.org/ballast/, go to "Past Meetings"):

1. Barth, J., Collins, C. and B. Hickey. 2002. West Coast Oceanography: Implications for Ballast Water Exchange. Draft Report. Edited by K. McDowell and M. Sytsma. 36 pp.

2. Levings, Colin and Mike Foreman. 2004. Ecological and Oceanographic Criteria for Alternate Ballast Water Exchange Zones in the Pacific Region. Fisheries and Oceans, Canada. 37 pp.

3. Gramling, Jessica. 2000. Ballast Water and Shipping Patterns in Puget Sound: Considerations for Siting of Alternative Ballast Water Exchange Zones. Puget Sound Water Quality Action Team. Olympia, Washington. 62pp.

4. Pederson, Judith. 2004. Ballast Water Exchange: Exploring the Feasibility of Alternate Ballast Water Exchange Zones in the North Atlantic - Report from a Workshop held October 27 & 28, 2003 Halifax, Nova Scotia. Massachusetts Institute of Technology Sea Grant College Program.

In preparation for the workshop, PSMFC GIS Specialist Van Hare developed a draft ballast water exchange exclusion area map that will be modified in the coming three days with information presented by our speakers. The information on this map includes ports, 50 and 200 mile boundaries, bathymetry, seamounts, marine sanctuaries and ballast water exclusion zones as recommended by several relevant studies. Hopefully the map will be of use in future ABWEA deliberations and should be seen as a work in progress. For reference, **Figure 1** shows the proposed alternate ballast water exchange zone within the Gulf of Maine for traffic from Boston and Portland to ports in the Bay of Fundy. This was developed at the Ballast Water Exchange workshop held in Halifax, Nova Scotia in 2003 and will be discussed further this morning by Judith Pederson of the MIT Sea Grant College Program.

On Thursday, following our two-day plenary session, we will convene a smaller working group to summarize the workshop findings, discuss the proceedings format, identify future research direction, and discuss and revise the ABWEA exclusion area map. Many of you have indicated that you will be attending this session. Everyone is welcome to attend.

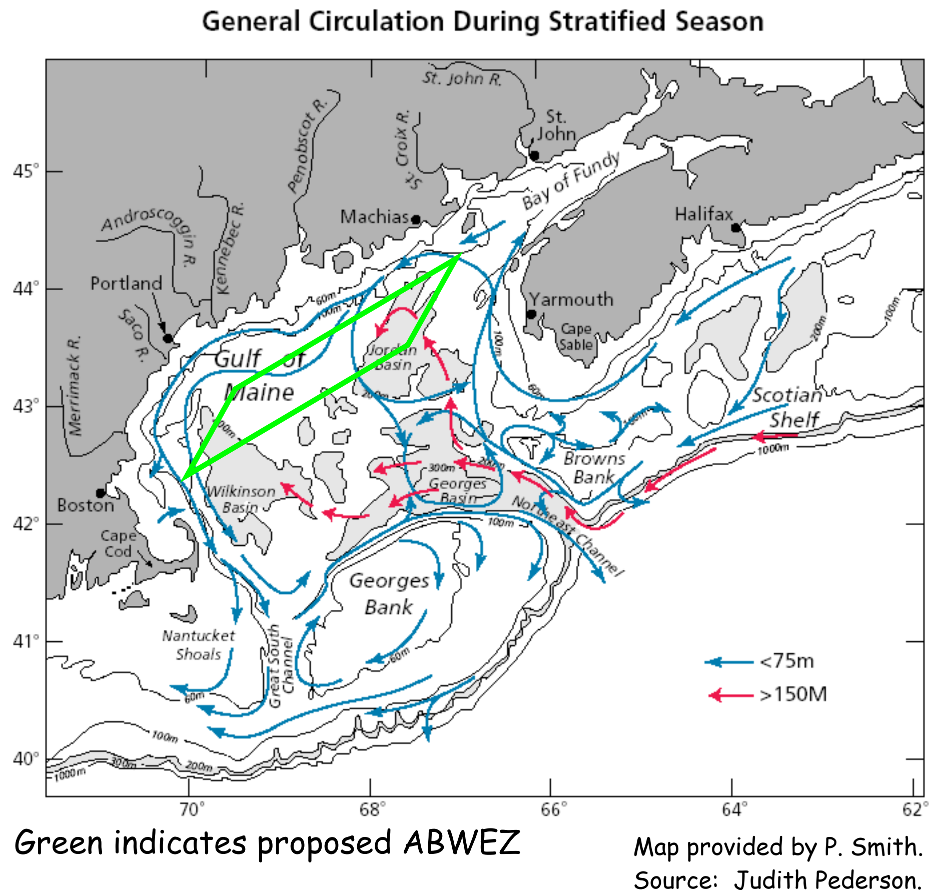

Figure 1: Proposed alternate ballast water exchange zone within the Gulf of Maine for traffic from Boston and Portland to ports in the Bay of Fundy. The region identified is an area where currents are more likely to carry particles out to sea rather than retain them in the Gulf or move them shoreward (see recommendations for criteria). Note that the blue arrows indicate within the top 75 m and the red arrows (Pederson 2004).

And finally, why is the PSMFC concerned about ballast water? The discharge of ballast water from commercial vessels is the leading vector for the transfer of potentially harmful aquatic organisms and pathogens around the world as evidenced by the numerous ballast water mediated invasions documented on the West Coast of North America (**Table 1**). The PSMFC is particularly concerned about ballast water-mediated invasive species that affect fisheries resources. These invasive species include tunicates (e.g. *Didemnum sp.),* red tide (*Prorocentrum mexicanum),* *and Pseudo-nitzschia spp.* (the cause of Amnesic Shellfish Poisoning), “killer algae” (*Pfiesteria spp.)* and the European green crab (*Carcinus maenas*).

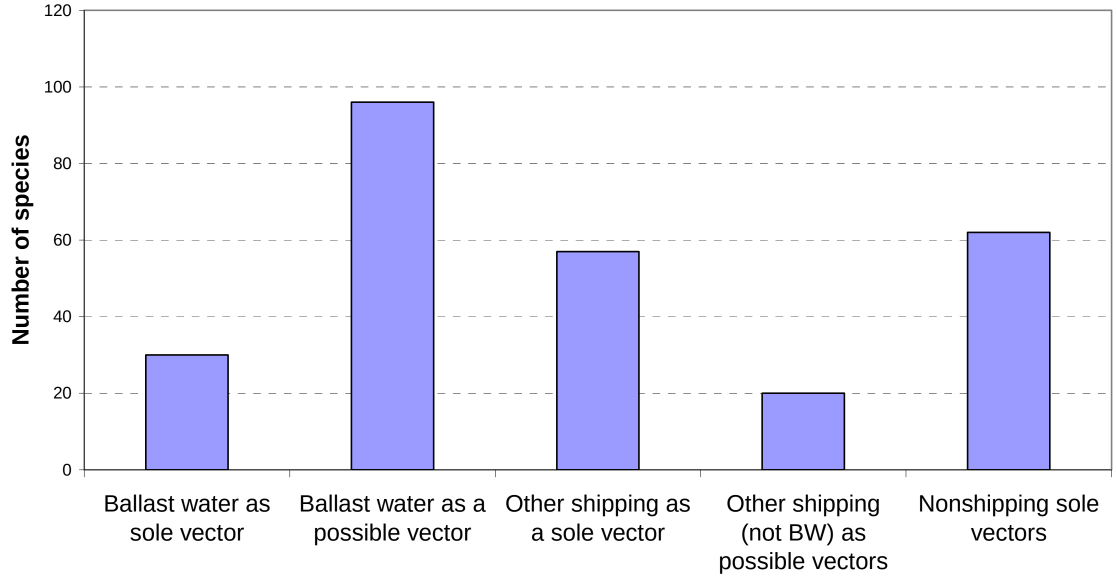

Table 1: Invertebrates and algae introduced to the West Coast of North America (n=262) by shipping and non-shipping vectors (Source: Fofonoff et al. 2006).

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Carleton, J.T. and L.B. Geller. 1993. Ecological roulette: The global transport of nonindigenous marine organisms. *Science*. 261:pp. 78-82.

EPA. 2001. U.S. Environmental Protection Agency (EPA). Petition to EPA to regulate ballast water. http://www.epa.gov/owow/invasive_species/petition.html.

Fofonoff, P., Steves, B., and G. Ruiz. 2006. unpublished data. Smithsonian Environmental Research Center. Edgewater, Maryland.

Pederson, J. 2004. Ballast Water Exchange: Exploring the Feasibility of Alternate Ballast Water Exchange Zones in the North Atlantic — Report from a Workshop held October 27 & 28, 2003 Halifax, Nova Scotia, Massachusetts Institute of Technology Sea Grant College Program.

2. Alternative Exchange Areas: Federal and International Regulation and Policy

Rich Everett, U.S. Coast Guard, Washington, D.C.

Abstract : Statutory authorization for the regulation by the Coast Guard of ballast water management and discharges is provided by two Acts of Congress. The Nonindigenous Aquatic Prevention and Control Act of 1990 (NANPCA) directed the Coast Guard to promulgate ballast water management regulations for the Great Lakes and the Hudson River north of the George Washington Bridge. The National Invasive Species Act of 1996 (NISA) reauthorized and amended NANPCA, and extended the ballast water management regulatory regime to cover U.S. waters outside of the Great Lakes. Under current Coast Guard regulations, ships entering U.S. waters from outside the 200 nm Exclusive Economic Zone are required to exchange ballast water at least 200 nm from any shore, although there is a safety exemption if sea conditions or vessel design do not permit the safe conduct of exchange operations. The potential need for alternative ballast water exchange areas (ABWEA's) has several driving forces. Recognizing that mid-ocean exchange is not always feasible, NISA contains provision for vessels to conduct exchanges of ballast water "…in other waters where the exchange does not pose a threat of infestation or spread of aquatic nuisance species in the Great Lakes and other waters of the United States…". Several pending bills in the U.S. Congress that would reauthorize and amend NISA, such a S.363, contain similar language. Finally, the International Convention for the Management of Ships' Ballast Water and Sediments provides that port States may designate such areas. Designation of ABWEA's will require numerous determinations, regarding issues that include at least the following areas: biological, logistical, and regulatory. Biologically, there is the potential for adverse effects on receiving communities. Logistically, the designation of ABWEA's raises issues related to vessel traffic management (safety), and practicability (sufficient area). From a regulatory perspective, several issues must be assessed, including cost (to establish the regulation and to the public), regulation life-time (given that BWE is "expected" to be phased out over the next decade), and the enforceability of the requirements. The primary objective of this workshop is to begin to discuss objectively the biological issues attending the designation of ABWEA's.

Questions and Answers:

Question 1 (Q1): From a ship operator's perspective, is it easier to exchange ballast water closer to shore?

Answer 1 (A1): For a ship operator, deciding when and where to exchange ballast water is more complicated than most realize. For example, if a ship operator exchanges ballast within a port containing turbid water, the operator's vessel will take on additional sediment and weight that provide no revenue. As a result, a ship operator will exchange little, if any, ballast within turbid ports. Other factors that determine when and how a ship operator will exchange ballast include the vessel's age, the weather, and a vessel's cargo distribution. Because these factors can all vary and interact with each other, ship operators frequently change when and where they exchange ballast water.

Q2: In this presentation, you suggested that approximately 60% of international vessels fail to exchange ballast beyond 200 nautical miles (nm) from shore. If the Federal exchange regulation of 200 nm was reduced to 50 nm, would this percentage decrease.

A2: If the U.S. changed its regulation so that vessels could exchange anywhere beyond 50 nm from shore, the exact percentage of vessels failing to exchange ballast may decrease. While a greater percentage of vessels would be exchanging ballast, exchanging ballast this close to shore (~ 50 nm) may also decrease the effectiveness of exchanging ballast if non-native species are subsequently transported to shore. Whether or not exchanging ballast at 50 nm increases introductions will be determined by local oceanography. As a result, a global or federal regulation of exchanging ballast beyond 50 nm around all coasts will not effectively minimize ballast water mediated introductions.

***Q3*:** Most of the discussions thus far have concerned locating areas to release ballast that pose no threat of introducing non-native species. If we assume that the ocean is one big washing machine and that ballast dumped at one point will eventually end up everywhere else, then would we think about locating ABWEA's differently or would we just give up since no location has zero risk?

A3: As the question stated, no situation lacks risk. Instead situations differ by having a low or high risk probability, and this question identified an important issue. If we look at Senate Bill 363, the Bill's statutory language inhibits citing ABWEA's. For example, the Bill states that NOAA will designate ABWEA's, but the Bill also states that NOAA will not establish an ABWEA if doing so could create adverse impacts. Because no location in the ocean is risk-free, the Bill's statutory language inhibits establishing ABWEA's. As a result, this workshop should discuss the degree of certainty and uncertainty that surrounds our forthcoming recommendations. By identifying the degree of certainty and uncertainty, the workshop can create a stronger case for why assuming some risk may be okay. Ultimately, a stronger case that acknowledges uncertainty will help us circumnavigate the statutory language of 'no risk' in Senate Bill 363.

SECTION 1: East Coast, West Coast, and Canada: ABWEA Considerations

1. Ship-Mediated Invasions and Geographic Spread Along the West Coast

Greg Ruiz, Smithsonian Environmental Research Center, Edgewater, MD.

Abstract: Commercial ships are a leading transfer mechanism (vector) for non-native organisms in coastal ecosystems, where resulting populations can have significant impacts and spread geographically. Over 300 non-native species of marine invertebrates and algae are known to be established (as self-sustaining populations) in North America, and commercial shipping is considered the mechanism of introduction for > 50% of initial populations for these species. The vast majority of invasions are known from coastal bays and estuaries, and relatively few non-native species are reported from more exposed outer coasts. Although estuaries are separated by tens to hundreds of kilometers, existing as island-like habitats along coastlines, most non-native species spread from their initial site of introduction. Since many of the spreading organisms have limited dispersal ability, due to the mode of reproduction and habitat distribution, it appears that shipping may also play a significant role in coastwise spread.

Ships move aquatic organisms by two major ways, in the ballast tanks and on the hulls of vessels. Both of these shipping subvectors are important, leading to invasions with significant ecological and economic effects. However, it is also the case that many invasions attributed to shipping may have resulted from transfers by ballast tanks or hulls, since many organisms have waterborne life stages (such as larvae) that can be entrained in ballast tanks as well as benthic life stages that can occur on hulls. Thus, although the movement of ballast water (and associated materials) is an important vector in the movement of non-native organisms, ships' hulls also play a role.

Ships are now being required to manage their ballast water to reduce the risk of biological invasions. At the present time, ships are required to exchange (flush out) their ballast tanks at sea before discharging ballast water near to shore, thereby reducing the concentration of coastal organisms from bays and estuaries. This ballast water exchange (BWE) is thought to reduce the likelihood of invasions, since (a) most invasions appear restricted to estuaries and bays, and (b) it is thought these species are much less likely to survive offshore. Although ships take on oceanic water (and organisms) during the exchange process, most of these are also considered unlikely to survive and colonize bays and estuaries. In the long-term, it is expected that other treatment methods will be implemented to replace BWE, but this is likely to be several years away.

Several key issues remain unresolved about the implementation of BWE, involving both the efficacy of the treatment method and the effect of distance from shore on invasion risk. In terms of efficacy, it is clear the BWE reduces the transfer of estuarine organisms among bays by lowering their concentrations in ballast tanks. Some residual organisms remain, but the magnitude of residual invasion risk is still unknown and an active area of research. In general, it is expected that invasion risk should decrease with (a) decreasing concentrations of coastal organisms in ballast water and (b) increasing distance from shore. The shape of the latter function, and how it varies geographically, is the focus of this workshop, considering especially expert knowledge and critical data gaps about both physical and biological oceanographic processes.

While this workshop evaluates potential risk of transfers associated with BWE at various distances from shore and locations, it is also important to not lose sight of information needed for enforcement. For example, if there is not an effective means to distinguish and verify the ballast water source in the first 50 nautical miles (nm) from shore, any regulations requiring BWE may not be enforceable. The concentrations of chemical constituents of seawater, including chromophoric dissolved organic matter (CDOM) and trace metals, can discriminate between bay from ocean water (> 200 nm from shore) and may be an effective enforcement tool. This suggests an important role of chemical oceanography in considering distance requirements for verifiable BWE. We are now sampling along western North America to characterize changes in the concentrations of these chemical tracers with distance from shore, as a possible method of BWE verification.

<u>Questions and Answers:</u>

***Q1*:** If a vessel exchanges ballast 50 nm offshore versus close to shore, can trace metals be used to verify this vessel's exchange location?

A1: From an estuary to 50 nm offshore, trace metals concentrations decay rapidly creating extremely steep decay functions. As a result, examining trace metal concentrations within a vessel's ballast to assess an exchange location seems promising. But the trace metal decay functions mentioned in this presentation were quantified from only a few voyages, locations, and seasons. To improve these decay functions, we will collect samples along nearshore-offshore transects that will be replicated across seasons (summer and winter). We will also increase transect numbers within North America to 15, and these transects will span from Alaska and southern California. While this research may quantify decay functions of planktonic species from estuaries to offshore, anomalies such as plumes, upwelling, jets, and eddies could change these decay functions in time and space. Over the course of this workshop, I would like to explore such outcomes.

***Q2*:** With regards to decay functions, has any research established a correlation between decay functions and the presence of particular coastal species?

A2: On 6 of the 15 transects mentioned in A1, will investigate this question. In addition to collecting plankton and analyzing how the abundance of all plankton species declines as distance from shore increases, we will also examine how the taxonomic representation of planktonic species changes along these transects.

***Q3*:** Natural events such as hurricanes can alter how and where organisms are transported. Can these events also alter particular chemical signals in the ocean and decrease the utility of tracers?

***A3*:** These events are likely important but I do not know how these events may alter chemical oceanography and the utility of trace metals to monitor exchange patterns.

2. Ballast Water Exchange: Exploring the Feasibility of AEZs in the North Atlantic

Judith Pederson, MIT Sea Grant College Program, Cambridge MA.

Abstract: Concern about ballast water release by coastal traffic has been a high priority for the Northeastern U.S. and Atlantic Canada. The geographic region extends from Cape Hatteras, North Carolina to the Strait of Belle Isle, Newfoundland with a diversity of habitats and oceanographic influences from the Arctic and the equator. Within these boundaries are known invaders such as the predaceous Rapa whelk (*Rapana venosa*) found only in the Chesapeake Bay area that could be transported to new areas. One species, the aggressive compound tunicate (*Didemnum* sp.) is present in ports and estuaries from Connecticut to Maine and is also present in the highly productive Georges Bank scallop and groundfishing areas. Although several best ballast water management practices are suggested in the July 2004 regulation, such as to avoid taking on ballast where there are known invaders, there is no enforcement to ensure vessels avoid areas of known invaders or avoid discharging in protected areas. None of the Northeastern states have enforceable regulations to address this issue, nor are they likely to pass regulations. Some factors that limit individual states and provinces from taking action are competition among ports for commerce, a lack of concordance between political boundaries and biogeographic boundaries, and insufficient data on invaders and the risks of exchange to support political action. For the Northern Atlantic region, coastal traffic from the north carries goods to southern ports and returns with ballast that is discharged in port or along the route.

Is there a problem in the Northeast? Based on the reporting forms and the general pattern of traffic and ballast discharge available on the web, which is limited to 2004, (http://invasions.si.edu/nbic/search.html), there is minimal release of ballast in the northeastern U.S. states, but greater volumes, many of which originate in ports from Cape Hatteras and north, are discharged in Canada (Carver and Mallett 2002). It is a misconception to assume that smaller volumes of ballast release do not introduce new species. It is also difficult to identify specific regions where there are few or no introduced or invasive species as many invasive tunicates and crustaceans are found throughout the northeast region (Pederson et al. 2005). The issue of addressing coastal traffic ballast water management emerged as a high priority for the region and one that could be addressed regionally prior to international or national regulations.

In October 2003, a jointly sponsored MIT Sea Grant and Transport Canada workshop on the Feasibility of Ballast Water Exchange Zones in the Northeast was convened to identify scientific, shipping, and regulatory perspectives on ballast water exchange options. The workshop reviewed (1) our knowledge of the physical and biological oceanography of the Gulf of Maine and regions to the north on the Atlantic side of Newfoundland and south to Cape Hatteras, (2) what is known about ballast water exchange in the region and from the U.S. and Canadian shipping community perspective, and (3) risk assessment approaches. In addition, the group was charged with developing consensus on the feasibility of potential alternate ballast water exchange zones for vessels traveling within the coastal waters for each of the three regions that incorporated the best scientific information. The consensus statement reflected all perspectives, but scientific understanding served to provide guidance on minimizing risk.

Since the workshop was held, several important actions have been initiated. The International Maritime Organization formalized its Ballast Water Treaty in 2004 that includes a depth (200 m) and distance (either 200 NM or if that is not feasible, to no less than 50 NM) guidelines for ballast discharge (IMO 2004). In addition, standards for alternative technologies that would treat ballast water were identified, although these are not yet adopted globally. The U.S. Coast Guard is preparing an Environmental Impact Statement that assesses the impact of ballast water discharge and addresses a process for verifying alternative ballast water treatment technologies including the standards that must be met by the technologies. In 2004, Canada convened a National Peer Review to assess the scientific data in working papers on alternative ballast water exchange zones on the East Coast, West Coast and Laurentian Channel (Paradis 2005). A comparison of proposed ballast water exchange zones within the Gulf of Maine will be discussed in the context of scientific recommendations.

Questions and Answers:

Q1**:** Given that the exchange zones in the presentation were relatively small and narrow, do you recommend vessels to exchange exclusively within these zones, which would require that vessels remain stationary within the zones until exchanges are completed? Consequently, how would longer transit times affect the shipping industry?

A1: The shipping industry calculated that 24 hour shipping diversions cost $ 25,000. This daily cost can accumulate very quickly and negatively impact the shipping industry. Despite this extra cost, shipping industries from Cape Hatteras, NC to Georges Bank, ME agree that ballast water has caused coastal problems that should be addressed. Within the Gulf of Maine, ballast mediated invasions are less of a concern because vessels are smaller and therefore have less ballast to exchange. In addition, given their short voyages, vessels traversing the Gulf of Maine often cannot and are not encouraged to exchange ballast.

Q2: Regarding the exchange zones discussed in this presentation, how many vessels currently use these zones?

A2: We have three shipping industry representatives that cumulatively employ 20–30 vessels. But because north east states depend heavily on petroleum imports, these vessels make many trips and create high vessel traffic. For example, ports in Boston, MA, Portland, ME, and New York, NY receive 680, 900, and 5000 vessels per year.

> ***Q2 follow-up:*** Do vessels have forms that enable them to report where and when they use ABWEA’s?
>
> ***A2 follow-up:*** No, but this question raises an important issue that we have not followed up on, and vessels currently fail to report where they exchange ballast.

Q3: In this presentation, it was considered unpractical to create a list of species of concern for all east coast ports and then use this list to guide where ballast exchanges should and should not be conducted; will you elaborate on why such a list is a poor solution?

A3: Because every east coast port has a species from at least one of the three major non-native taxonomic categories (i.e., tunicate, crab, and algae) and because these species can survive in a vessel’s ballast, a non-native species list would guide vessels to exchange nowhere. In contrast, a better approach would be to determine a certain distance beyond shore where vessels may exchange ballast without introducing or taking on non-native species; this distance has yet to be determined.

Q4: Have you investigated whether commercial fishermen helped introduce and spread invasive species?

A4: It's unclear whether fishermen helped introduce a particular invasive species like the invasive tunicate (*Didemnum* sp.). But if fishermen did not help introduce this invasive tunicate, fishermen certainly helped spread this species by trawling and disturbing the bottom seafloor. Fishermen, however, believe that bottom trawling will disturb and eliminate this invasive tunicate. But this tunicate reproduces sexually and asexually. As a result, if any part of this tunicate is left on the side of a disturbed rock, it will quickly grow back.

Commercial fishermen can also help manage invasive species. For example, Lobster fishermen in Cape Cod Bay currently report that *Didemnum sp.* is not settling on their offshore traps. As a result, we know that the tunicate's current distribution is restricted to Cape Cod Bay's shallow waters (45-60 m).

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3. Ballast Water and Shipping in Puget Sound, Considerations for Citing Alternative Ballast Water Exchange Zones

Kevin Anderson. Puget Sound Action Team. Olympia, WA.

Abstract: This presentation will provide basic information on the number of port arrivals and volume of unexchanged ballast water discharged to Washington ports, and recommends against alternative exchanges zones off the north coast of Washington and in internal waters of the Strait of Juan de Fuca and Puget Sound based on operational, biological, oceanographic and institutional considerations.

More than 4,300 vessels called on Washington ports both in Puget Sound and the Columbia River between July 2004 and June 2005. About 40 percent arrived from Pacific Rim countries and therefore were regulated under the U.S. Coast Guard ballast water management program. Another 40 percent arrived from California, Oregon, and Alaskan ports. About 600 vessels arrived at Puget Sound ports from California.

In 2005, these vessels discharged about 45,000 and 90,000 cubic meters of high-risk unexchanged ballast water to Puget Sound and Columbia River ports, respectively. More than 95 percent of this volume originated from California ports.

Potential alternative exchange zones were assessed against various factors such as vessel safety, proximity to trade routes and shipping lanes, time required to complete an exchange, proximity to sensitive biological areas, and circulation patterns

Questions and Answers:

Q1: How would your model results change if, instead of going directly into the Strait of Juan de Fuca, the ballast water sank to the bottom?

A1: As ballast particles sink to 50 meters or deeper, their transport directions change and these particles would be transported directly into the Strait of Juan de Fuca.

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4. 2003 West Coast Coastal Exchange Workshop Summary

Karen McDowell, San Francisco Estuary Project, Oakland, California.

Abstract: California, Washington, and Oregon had all passed mandatory ballast water management programs, by December 2001. These programs were fairly uniform with regards to transoceanic traffic. All three states also implemented regulations on domestic and/or foreign (Canada and Mexico) coastal traffic (traffic which travels within 200 nautical miles of the shoreline). With shorter transit times on coastal voyages (which lead to a lower mortality in the tank), the states were concerned that isolated populations of invasive species would be spread by coastal traffic. Washington and Oregon were particularly concerned with receiving ballast water from the San Francisco Bay-Delta, known as one of the most invaded aquatic systems in the world. Ballast water treatment will be the long term solution for coastal traffic, but until technologies are developed and approved, conducting an exchange within the 200 nautical mile zone is the only potential stop-gap measure. Unfortunately, the initial coastal traffic programs implemented by the West Coast states differed significantly. In 2001, the project advisory committee suggested that the California Sea Grant Extension Program's West Coast Ballast Outreach Project (WCBOP) should focus on coordinating efforts coastal ballast water exchange, so that programs would be more uniform West Coast.

The WCBOP worked together with many partners to sponsor two workshops on coastal ballast water exchange. The first workshop "Physical Oceanography: Implications for Coastal Ballast Water Exchange" was held in March of 2002, and cosponsored by the WCBOP, the Pacific Ballast Water Group, the Pacific States Marine Fisheries Commission, and Portland State University. The goal of the workshop was to compile the current information on coastal processes on the West Coast to enable informed decisions on how best to manage ballast water in coastal shipping to minimize the risk on establishment of aquatic nuisance species. The workshop was attended by the project sponsors and three prominent physical oceanographers: Barbara Hickey, University of Washington; Jack Barth, Oregon State University; and Curtis Collins, Naval Postgraduate School, Monterey, California. The primary product of this workshop was a draft report: "West Coast Oceanography: Implications for Coastal Ballast Water Exchange." The primary recommendations in the report were: 1) the retention zones identified in the report should be considered as possible exclusion zones for ballast water exchange (from the shoreline to 50 nautical miles offshore); 2) Along all other areas of the coast, any ballast water discharged outside the 1000 m isobath has a relatively low probability of reaching the shoreline; and 3) seasonal fluctuations should also be considered when determining "when and where" to exchange ballast water.

The second workshop sponsored by the WCBOP, “The West Coast Coastal Exchange Workshop,” was held on January 6-7, 2003. This workshop was attended by 50 participants that were already familiar with the ballast water issue. The active participation by the maritime industry (20 participants), regulatory agencies (20 participants), researchers (8 participants), and environmental groups (2 participants) played a vital role in the success of the workshop. The primary goal of the workshop was to review the physical oceanography report and outline some potential regional plans for coastal ballast water exchange. Three draft regional plans were developed in the workshop (two were almost identical). All three plans incorporated two tiered system for coastal ballast exchange, with some vessels and/or regions having a 15-25 nautical miles offshore requirement and other vessels and/or locations having a 50 nautical mile offshore requirement. The biologist noted that even though the vulnerability of the open coastline to invasion is unknown, that it is important to exchange on coastal voyages to reduce the risk of invasion since direct estuary to estuary transport of ballast water is high risk. The participants noted that there was additional existing data/information that was not accessible at the workshop that should be used to modify and improve the regional plan.

In April 2004, the California State Lands Commission (CSLC) held a meeting to discuss setting regulations for coastal traffic in California. Reports from the two workshops were used as a starting point. In addition, CSLC used the IMO Ballast Water Convention passed in February of 2004, to make sure that the state program was compatible with federal and international programs. In 2006, CSLC implemented regulations requiring vessels discharging ballast water from coastal voyages to exchange the ballast water 50 nautical miles offshore and in water greater that 200 m in depth. These regulations are very similar to regulations for coastal traffic in Oregon and Washington.

In summary, since conflicting regulations for coastal traffic were being set along the west coast, a group of partners worked to pull together current knowledge and come up with the best possible solution on a short time-line. The work that was completed for this project can be used as a starting point for looking at Alternative Ballast Water Exchange Areas (ABWEA’s) on the west coast. Although many of the concepts are similar, it is important to note the difference between setting requirements for coastal traffic and selecting ABWEA’s. Many assumptions and decisions were made for the coastal traffic based specific details and circumstances. It is important to reexamine the original data and use the parameters specific for ABWEA’s before decisions are made.

Questions and Answers:

Q1: When vessels travel along the California coast, how far offshore do they prefer to travel?

A1: The preferred travel distance offshore depends on the vessel’s size. For example, large tankers usually travel 50 nm offshore and smaller vessels travel 12-15 nm offshore. A new California regulation, however, mandates that all vessels exchange ballast 50 nm beyond shore. Currently, vessels are also required to collect operational cost data. These data will be used by California to quantify how much exchanging ballast beyond 50 nm increases a voyage’s cost.

Q2: You presented a map of retention zones where ballast should not be exchanged, and an area from Cape Blanco to Cape Mendocino was excluded from this recommendation. Did you consciously decide to exclude the area between Cape Blanco and Cape Mendocino? Alternatively, was this area excluded because data necessary for any recommendations fail to exist?

A2: We recommended that ballast should not be exchanged in areas that are known to retain organisms. An unmarked area such as that lying between Cape Blanco and Cape Mendocino should not be interpreted as areas where vessels can safely exchange ballast close to shore (< 50 nm). Rather, these unmarked areas should guide where future biological and oceanographic research should be conducted.

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5. State of California – ABWEA Perspectives

Maurya Falkner, California State Lands Commission, Sacramento, California.

Abstract: In October 1999, California enacted the first statewide mandatory ballast water management law designed to prevent or reduce the introduction and spread of nonindigenous aquatic species (NAS) via ship's ballast into California state waters. The California law required that vessels arriving from places outside of the United States Exclusive Economic Zone (U.S. EEZ) manage ballast water to reduce the discharge of nonindigenous organisms in California waters. However, there were no ballast management requirements for vessels that arrive to California ports from places within the U.S. EEZ, even though research has shown that there is a significant threat for such voyages to facilitate the establishment and spread of NAS throughout a region.

A preliminary analysis of data compiled by the California Department of Fish and Game in 2002 revealed notable differences in introduced (non-native) species between the port zones of concern (Table 1). Between 66 and 142 introduced species can be found in the Los Angeles/Long Beach port zones and not in the San Diego Harbor area, and between 203 and 315 introduced species found in the San Francisco Bay area have not yet been observed in the Eureka port zone area.

Species found in:	LA/LB* not SD	SD not LA/LB	SF not Eureka	Eureka not SF
Introduced	66	10	203	30
Cryptogenic (Likely Introduced)	76	7	112	35

*LA/LB = Los Angeles/Long Beach Port Zones, SD = San Diego Port Zone, SF = San Francisco Port Zone

Table 1: Introduced species between California Port Zones.

While the State Law's initial focus was on foreign ballast water management, the law was reauthorized during the 2003 Legislative session as the Marine Invasive Species Act (MISA), expanding the state's ballast program to one that more comprehensively pursues the prevention of NAS via the commercial shipping vector. The California State Lands Commission (Commission) was charged with several expanded responsibilities. Key among them and

specific to this paper, the Commission was required to develop and adopt regulations governing the ballast water management for vessels operating within the Pacific Coast Region (Figure 1).

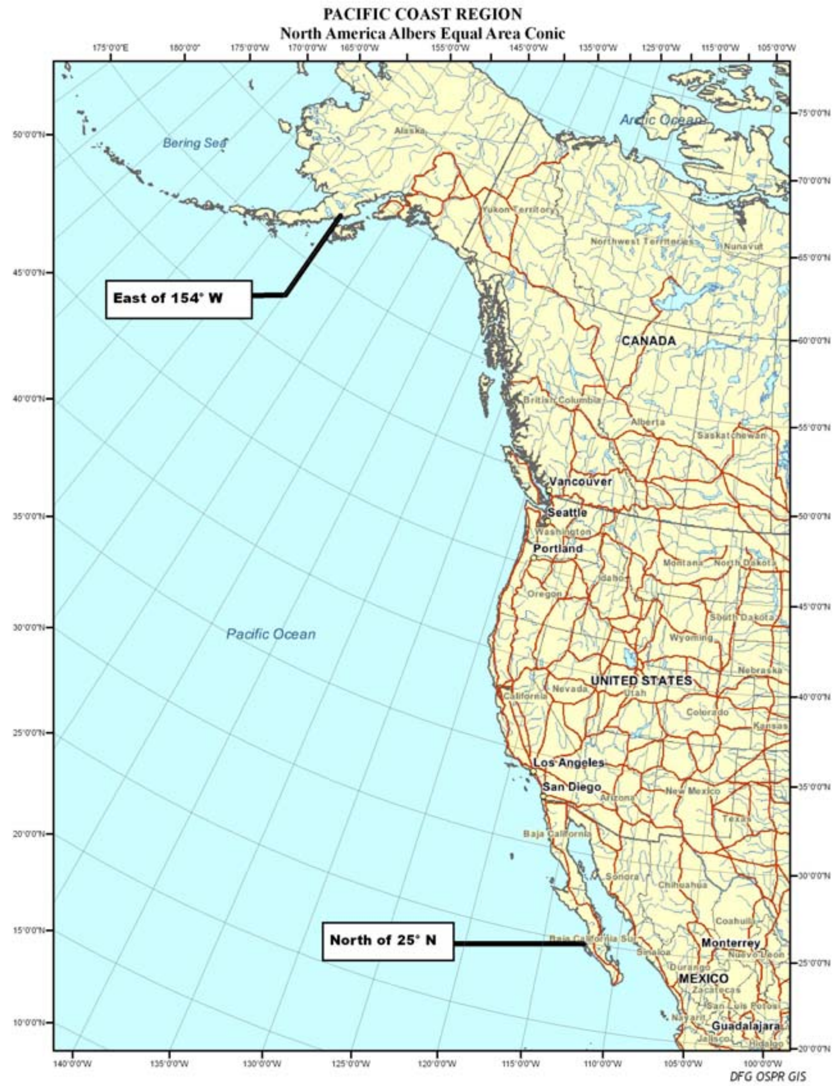


Figure 1: Pacific Coast Region are coastal waters east of 154 degrees west and North of 25 degrees North.

Prior to the passage of the 2003 Legislation, Commission Staff, the regulated community, and interested parties had begun considering potential controls on ballast water transported within the Pacific Coast Region. In preparation for anticipated regulations, a workshop hosted by the West Coast Ballast Outreach Project and Portland State University took place in March 2002 to gather information on the physical oceanography of the West Coast and its implications for ballast water management. A draft workshop report was produced outlining recommendations for coastal ballast water management based on the known oceanographic patterns in the region.

In January 2003, the Commission's Marine Invasive Species Program (MISP) and the West Coast Ballast Outreach Project formed a Technical Advisory Group (TAG) to solicit input regarding the implementation of the provisions of Public Resources Code (P.R.C.) Section 71201.7, the portion of the act that specifically directed the development of ballast water management within the Pacific Coast Region. The TAG represented a wide cross section of the marine transportation, terminalling, and oil industries together with representatives from maritime shipping associations, state and local harbor organizations, port authorities, state and federal regulators, environmental organizations, and academicians. Following adoption of the new Marine Invasive Species Act and P.R.C. 71204.5, the TAG members extensively discussed and reviewed the draft report on physical oceanography and regulations. Proposed changes were incorporated into final regulations that were adopted in September 2005, and were effective in March 2006.

The regulations require that vessels operating within the Pacific Coast Region exchange their ballast water in "near-coastal waters" (waters at least 50 nautical miles (nm) from shore, and at least 200 meter deep) before discharging that water in State waters. The 50 nm limit incorporates several key issues discussed during the aforementioned workshops and meetings. Although ballast water exchange at distances more than 200 nm offshore is considered the most biologically prudent to prevent NIS discharge in port, such a requirement could divert vessels traveling within the Pacific Coast Region more than 100 nm offshore from their normal route. For most voyages, the 50 nm distance would require no course deviation for some vessels and a minor deviation for many. Exchange at 50 nm avoids ballast discharge in coastal "retention zones" and at the mouths of estuaries, where currents and tides can carry organisms to shore or sweep them into bays and estuaries. The limit also lies beyond the boundaries of sensitive protected areas, such as Marine Sanctuaries. Further, the maritime industry requested that California's regulation be consistent with other U.S. state, federal and international regulations, in order to avoid confusion that would occur should vessels encounter a patchwork of varying regulations as they traveled across jurisdictions. The 50 nm limit also addressed this request, as Washington, and the International Maritime Organization require that ballast water exchange be conducted 50 nm offshore. Additionally, Oregon passed legislation that adopted the 50 nm offshore ballast water exchange requirement in January 2006, three months following the adoption of the California regulation.

The adoption of regulations governing the ballast water management practices of vessels operating within the Pacific Coast Region addressed an obvious gap in the State's attempts to minimize NAS introduction and spread, however vessels arriving from Southern Mexican ports and ports in Central and South America continue to be problematic. For example, in 2004, 17% of vessel calls reported the discharge ballast water while in California waters (Figure 2), totaling 7.8 million metric tons of ballast water. Four percent of the total volume discharged did not comply with the mid-ocean exchange requirements, and the vast majority of this volume came from the Mexican and Central American region (Figure 3)

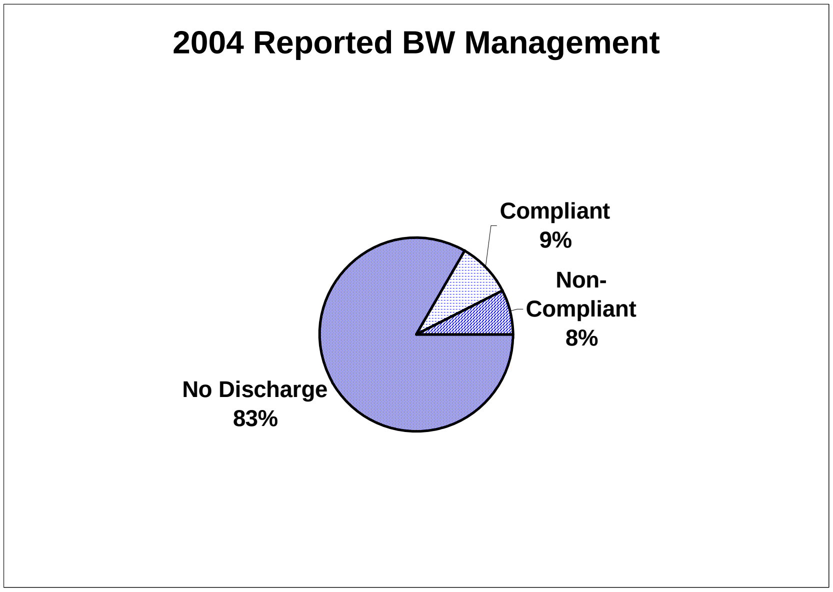


Figure 2 – Number of vessel voyages retaining versus discharging ballast water (Based on 10074 Reporting Forms submitted).

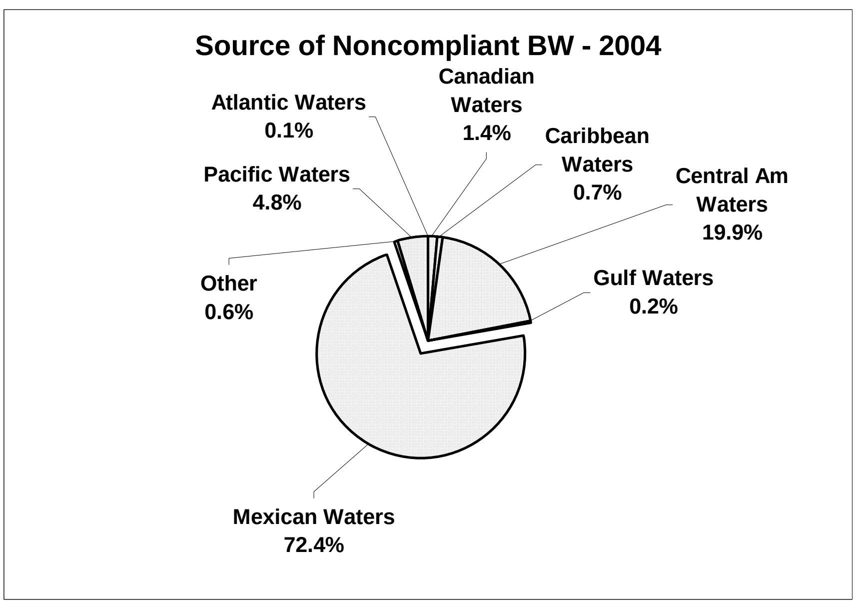


Figure 3 – Source of unexchanged or incompletely exchanged ballast water by volume, discharged in 2004.

It is suspected that this pattern results from vessels that hug the Mexican and Central American coast as they travel northwest towards California. Ballast water in vessels on such a route often originates from outside of the U.S. EEZ, and it must be exchanged 200 nm from shore before it is discharged in California. However, such a route does not routinely take a vessel 200 nm from shore without a significant route deviation. This pattern highlights the need for targeted compliance monitoring and enforcement action, and also argues for the development of alternative exchange zones for vessels arriving from outside U.S. EEZ that do not normally travel 200 nm from shore.

Several multidisciplinary factors should be considered as alternative exchange zones are established for vessels arriving from outside the U.S. EEZ. Clearly, physical and biological oceanography and the associated "biological protectiveness" of proposed zones should be of utmost importance. However, policymakers need to also examine numerous non-scientific issues such as the existing voyage patterns of the industry, the need to establish alternative zones, the criteria vessel owners/operators must meet to in order to be granted the use of alternative zones, and the specific conditions (routes, voyages, timeframes, etc.) under which vessels will be allowed to use such zones. In addition, federal policymakers should consult with State resource managers to ensure policies do not conflict with existing State rules.

Currently, alternatives to ballast water exchange are extremely limited. Until effective treatment technologies are developed and installed fleetwide, ballast water exchange will remain the primary method used to minimize NAS introductions via ballast water. While many vessel voyages originating from outside the U.S. EEZ on the West Coast of North America are able to utilize mid-ocean exchange, this management practice is not practical for all vessel types and routes. To most effectively protect the environment while accommodating the complexity of commercial shipping alternative exchange zones will be an important step in ballast water management.

Questions and Answers:

Q1: Do know when state or federal legislatures will pass legislation concerning performance standards for shipping vessels?

A1: At both the federal and state levels, legislation pertaining to performance standards is being considered, but I am unsure whether and when such legislation will be passed. In California, the shipping industry's opposing argument to a performance standard bill comprises that the California State Lands Commission (CSLC), who must adopt regulations, has no mechanism of can subsequently changing any adopted regulations if shipping technology fails to meet the regulation's performance standard.

Q2: Do technologies exist that can be used to help enforce a performance standard regulation?

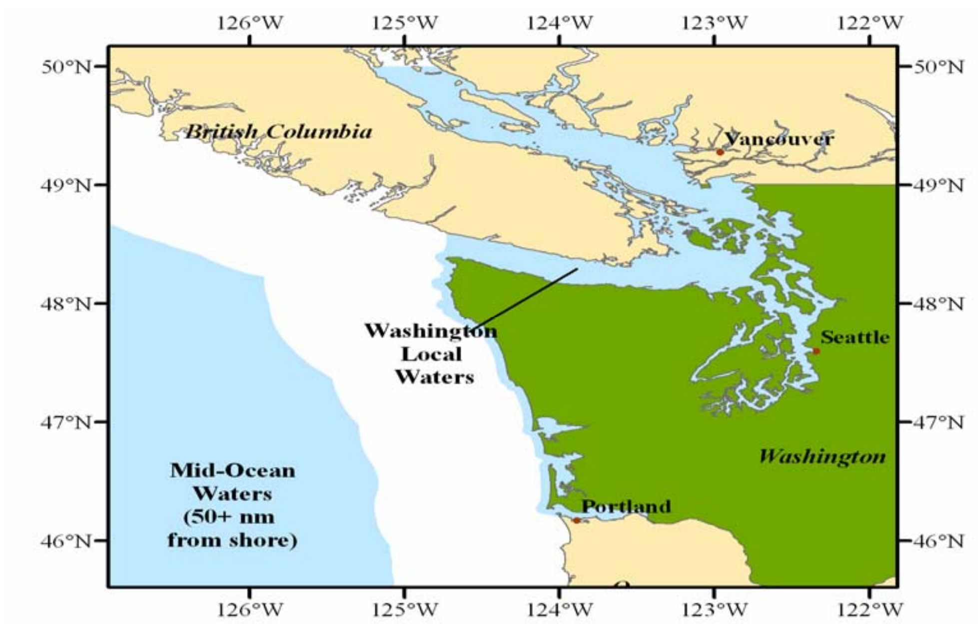
A2: Currently, experimental technology looks promising but this technology has yet to be approved. This technological gap, however, fails to justify the argument that a performance standard regulation should not be adopted. Because in the absence of a performance standard, the shipping industry will fail to strive for benchmark and our ballast water problems will not be addressed. As a best-case scenario, a performance standard regulation will pass this year mandating that vessels will comply by 2012. Regarding technology, performance standards, and ABWEA's, this best-case scenario would leave us with 6 years during which ABWEA's could be used to manage ballast mediated invasions.

6. State of Washington – ABWEA Perspectives

Scott Smith, Washington Department of Fish and Wildlife, OLYMPIA, WASHINGTON.

Abstract: Washington State was the first jurisdiction in the world to establish an alternative exchange zone for vessels engaged in coastal trade. Oceanographers advised WDFW that ballast exchanged 50 nautical miles from the Pacific coast would have a low probability of reaching shore. Pacific coast currents are highly variable, but 50 nautical miles was considered to provide a reasonable margin of safety. Washington law requires vessels traveling from outside the EEZ to exchange ballast a minimum of 200 nautical miles from shore and coastal trade vessels to exchange a minimum of 50 nautical miles from shore. Vessel operators may discharge ballast that is taken from "Local Waters" without conducting a ballast exchange (see map below). Washington State does not have a depth requirement in addition to the 50 nautical mile requirement. The water depth, 50 nautical miles from shore, is generally greater than 200 meters along the Pacific Coast, except of outside of the Straight of Juan De Fuca, which would require approximately 75 miles to achieve the 200 meters. The decision to require coastal exchange at 50 miles was made in cooperation with representatives of the maritime industry. Many vessels were already required to transit 50 miles from shore due to other regulatory requirements. Compliance with this law is high.

Potential alternative exchange zones on the pacific coast closer than 50 miles from shore are considered to have a high-risk of spreading aquatic invasive species and should not be considered for implementation. Vessel operators engaged in voyages from outside the EEZ may request to exchange their ballast between 200 and 50 nautical miles from shore, if weather or other unusual circumstances would not permit a normal exchange outside of 200 miles. The existing law is a good balance between minimizing risk and being practical for vessel operators to comply.



Questions and Answers: None.

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7. Ecological and Oceanographic Criteria for Alternate Ballast Water Exchange Zones in the Pacific Region

Robin Brown, Department of Fisheries and Ocean, Sidney, British Columbia.

Abstract: Canada is considering new regulations and practices for the management of ballast water. As in other jurisdictions, ballast water is recognized as a significant vector for Aquatic Invasive Species (AIS). The Canadian regulator (Transport Canada) has issued draft ballast water exchange regulations, modelled on those proposed by the IMO. This draft provides for Alternate Ballast Water Exchange Areas in regions at least 50 nautical miles from shore and in waters greater than 200 metres depth. Fisheries and Oceans Canada has been asked to provide comments on this draft regulation.

The comments are summarized as:

- The historical ballast water exchange zones in the Strait of Juan de Fuca (along the north portion of the Strait, between Race Rocks and Port San Juan) are not appropriate. Organisms released in these areas, particularly those that migrate vertically, can be carried into the Georgia Basin (Strait of Georgia/Puget Sound) through estuarine circulation. (Larson et al, 2003).
- In general, the continental shelf off the BC coast is quite narrow, so that the 50 nautical mile regulation would mostly place ABWEA's in deep water (mostly greater than 1000 metres).

- Deep canyons in the continental shelf provide areas where deeper ocean waters are carried inshore and up onto the shelf. These areas should be avoided as ballast water exchange areas.
- There are important concentrations of commercial bottom fish stocks seaward of the 200 metre contour (between 200m and 500m). Thus we recommend that all ballast water exchanges occur in waters deeper than 500 metres.
- In the Queen Charlotte Sound area, we recommend that the 50 nautical mile limit be measured from a baseline drawn between the north end of Vancouver Island and the south end of the Queen Charlotte Islands. This would prevent ballast water entrainment in shoreward circulation features of surface waters and deep canyons in the continental shelf.
- Ballast water exchange should be excluded from the area around Bowie Seamount. This is a unique habitat and a proposed Marine Protected Area.

Questions and Answers:

Q1: Regarding the model used to produce the circulation maps, the model runs were based on summer averages. Given that oceanography changes seasonally and that averages fail to account for fluctuating or extreme conditions, do you have a feel for how the model and predicted water movements would be affected by winter and fluctuating or extreme conditions (rather than averages)?

A1: Because the Strait of Juan de Fuca's net winter flow goes out of the Strait, incorporating winter averages into the model is less problematic. Strong weather systems, however, can quickly change surface flows and these flows will contrast the model's predictions. In the winter (i.e., net flow out), for example, strong weather systems create time periods of up to a week when surface waters flow into the Strait of Juan de Fuca, instead of out.

Discussion Panel Involving Presenters Falkner, McDowell, Brown, Pederson, and Smith

Q1: Regarding State legislation, how difficult would a regulation change from 50 nm to 75 nm be?

A1(a): The answer depends on how the shipping industry regards such a change and on the amount and quality of data used to argue for such a change. In state of Washington, for example, a ballast water work group formed and this group included the shipping industry. This work group will draft a consensus recommendation and will report this recommendation to legislature in December of 2006. Based on this recommendation, the legislature could decide to amend the State's law. This work group's recommendation would benefit from the conclusions of this ABWEA workshop.

A1(b): For California, the 50 nm exchange limit is a regulation, not legislation. The California State Lands Commission (CSLC) was granted authority to adopt a regulation for coastal traffic and to base this regulation on the best available data. The CSLC's key objective is to protect natural resources and then to think about how a regulation will impact the shipping industry. In the end, CSLC has the authority to make a regulatory change (e.g., 50 to 75 nm exchange limit) if new data indicate that such a change will benefit California natural resources.

Q2: Have the North Atlantic states drafted or approved any legislation to address ballast water exchange practices (e.g., 50 nm exclusion zone)?

A2: Rhode Island has a regulation working its way through the legislative process. Because New York's Hudson River is part of the Great Lakes, New York has some ballast exchange legislation. Maine has also considered regulations. While each of these states are thinking about regulations, they all realize that individual state regulations will inadequately solve the regional problem since the states share common waters. As a result, the North Atlantic states desire these a regional policy or regulation.

Q3: The Pacific and North Atlantic coast states seem to differ in how they approach ballast water problems. More specifically, North Atlantic states have a more complicated oceanography and more invasive species, and these states have considered locating ABWEA's within 50 nm of shore; yet oceanographic research suggests that such zones will fail to prevent the shoreward transport of ballast water. In contrast, Pacific coast states have less complex oceanography and less invasive species, and these states agree that exchanges and ABWEA's should not occur within 50 nm? Is this assessment of Pacific versus North Atlantic states correct and why?

A3(a): This summary is correct, and California will not allow ABWEA's within 50 nm.

A3(b): In the North Atlantic, the only proposed areas lying within 50 nm are the Laurentian Channel and the Gulf of Maine. In addition, these two locations are just recommendations, not regulations. Nonetheless, because the shipping industry cannot afford to conduct exchanges beyond 50 nm, if we fail to identify some place where exchanges are more acceptable then vessels will continue exchanging ballast everywhere.

A3(c): Despite the same shipping industry occurring in both the North Atlantic and Pacific states, the industry's attitude changes regionally. For example, vessels transiting from southern to northern California comply with state regulation by exchanging beyond 50 nm.

A3(d): Historically, California's environmental regulations have always been stricter than other regions. This stronger environmental ethic most likely stems from powerful environmental non-profit organizations that have raised the public's expectations regarding environmental standards.

Q4: For the west coast, we have observed that species distributions end and begin abruptly. We also know that these changing species distributions overlap with certain oceanographic and landmass features (e.g., Capes). Consequently, we all agree that waters, and therefore species, from different regions should not be exchanged via ballast water. Have North Atlantic states quantified similar species and oceanographic patterns? In other words, if Boston and Bay of Fundy waters mix back and forth, does it matter whether a vessel traveling from Boston to the Bay of Fundy exchanges its ballast before entering the Bay?

A4: At this time, drifter data suggests that Boston Harbor and Bay of Fundy waters do not mix. As a result, vessels originating from Boston should not exchange ballast within the Bay of Fundy. But these drifter data indicate how passive particles will move in surface waters, and these movements will likely differ from that of migrating larvae. One way to obtain more robust data may be to use natural tracers such as frequently occurring red tides. Because red tides begin offshore and move shoreward over time, red tide may provide regulators with biological trajectories that may better illustrate how and where ballast exchanged in certain offshore areas will be transported.

Q5: Thus far, this workshop has discussed where exchanges should occur with respect to distance offshore. But certain oceanographic circulation scenarios likely occur that make exchanging ballast 20 nm offshore a better option than exchanging ballast 50 nm offshore. When formulating exchange regulations, have these 20 nm scenarios? An exchange zone that is closer to shore and that more effectively inhibits ballast being transported to shore would benefit California's natural resources and the shipping industry.

A5(a): When California examined its coastal traffic with respect to exchange zones, the state realized that vessels exchange ballast throughout their voyages. The 50 nm regulation allows vessels to continue exchanging ballast all throughout their voyages as long as they do so 50 nm offshore. Patchily distributed nearshore zones, however, would require vessels to remain stationary while exchanging. As a result, patchily distributed zones would lengthen a vessel's transit time and therefore costs. These additional costs and difficulty involved in finding these patchy zones would combine to make complying very difficult.

A5(b): While California and the shipping industry would both love such exchange zones, we currently lack data indicating where such places exist.

A5(c): In the state of Washington, we found that educating the shipping industry about the state's 50 nm regulation took four years. Because compliance with this relatively simple regulation occurred four years after the regulation took affect, we recommend keeping regulations simple (exchange beyond 50 nm) instead of complex (patchy, nearshore zones). The more complex the regulation, the less the industry will comply.

Q6: Regarding non-native species, who pays for ballast water research?

A6: Depends on the state. In California, each vessel entering a state port pays a fee and these vessel fees pay for ballast water research.

Q7: Currently, many Coastal Oceanographic Observing Systems (COOS) are being built or are already operating. Can COOS research be integrated with management needs or questions? For example, COOS utilize CODAR that can produce real time data concerning where surface waters move. Perhaps these data could help answer ballast exchange and ABWEZA questions?

A7(a): For answering regulator questions, COOS data do seem promising. While the California State Lands Commission (CSLC) has been invited to help guide and use COOS research, the CSLC has yet to do so.

A7(b): COOS research may help create dynamic solutions that include changing where a port suggests vessels exchange ballast and basing such changes on seasonal or real time weather conditions. But dynamic solutions worry regulators and will likely not be implemented even though dynamic solutions may be more appropriate.

Q8: Common or shared water scenarios are a pressing problem that this workshop has yet discussed. For example, a Vancouver vessel that travels to the state of Washington may be required to travel 50 nm outside the Strait of Juan de Fuca to exchange ballast before entering Washington, even though the water and species in the Vancouver ballast equals are equal to that in Washington.

A8(a): Instead of Vancouver or 'shared water vessels' traveling 50 nm offshore to exchange ballast, the state of Washington developed a compromise where vessels originating from east of the 50 degrees latitude to the Columbia River do not have to exchange prior to entering Washington ports.

A8(b): In contrast, California lacks any shared waters and therefore needs intrastate exchanges. For example, the California Department of Fish and Game surveyed non-natives species in all California estuaries and found that the number and identify of non-native species differ throughout all California ports. Exceptions include Long Beach/LA and San Francisco Bay/Delta regions, which are close together and share common water as well as species.

SECTION 2: Physical Oceanography

1. Ocean Circulation Along the U.S. West Coast: Big, Little, and In-Between

Kipp Shearman, Oregon State University, Corvallis, Oregon.

Abstract: The discharge of ship's ballast water in coastal regions may lead to infestations of coastlines and estuaries by aquatic invasive species. Understanding the coastal circulation patterns is important to understanding the ultimate risk of contamination. Circulation along the U.S. west coast is part of the large scale clockwise circulation of the north Pacific, an eastern boundary current, known as the California Current System (CCS). Prominent large scale features of the CCS include the equatorward-flowing California Current, the wintertime-poleward-flowing Davidson Current over the shelf, and the deeper poleward-flowing California Undercurrent over the continental slope. Flow in the CCS, particularly over the shelf, is dominated by seasonal changes in wind forcing – roughly southward in summer and northward in winter -that generally divide the west coast into three regions; from Vancouver Island to Cape Blanco, where winds reverse direction seasonal (northward in winter and southward in summer); from Cape Blanco to Point Conception, where winds are intensely southward weakening somewhat during winter; and the Southern California Bight, where winds are generally weak with complex structure. In summer, surface circulation from Point Conception on north is generally offshore and south. The southward winds, which occur during the spring and summer, drive an offshore surface Ekman transport with speeds of 5-10 km/day. As a consequence, near the coast, cold, nutrient-rich water is upwelled from depth. A current jet flows along the upwelling front, the sharp boundary between cold, nutrient-rich water inshore and warm, low nutrient water offshore with speeds of 50-100 km/day. In winter, surface Ekman transport is onshore (5-10 km/day) due to northward winds, and over the shelf the northward along-shelf flow (the Davidson Current) is strong (50-100 km/day). In the Southern California Bight, seasonal variations are generally weaker and more spatially complex. Another seasonal feature of the CCS is the evolution of mesoscale fronts, jets and eddies (10-100 km size) that reach their peak strength during the summer and fall, creating complex circulation patterns. Finally, a few spots were discussed in greater detail: Cape Blanco, because it is a site of strong offshore flow and a transition between regions; Heceta Bank, because interactions between the currents and complex topography can lead to retention of organisms; and the Columbia River, because low salinity water from the plume impacts large regions of the CCS during summer upwelling. In light of the strong seasonal variability, high spatial variability and strong along-shelf flow, designating alternative ballast water exchange zones over any part of the shelf (water depths less than 200m) along the U.S. west coast, would likely see that ballast water come in contact with the coast.

Questions and Answers:

Q1: What is a Kelvin wave and how does a Kelvin wave affect the onset of El Nino?

A1: A Kelvin wave is considered a coastal trap wave because the coast line helps guide the wave's trajectory. More specifically, El Nino conditions create a large scale wave that propagates across the equator and then piles up water against the east coast of the Pacific. This piled up water then propagates up the coast, which is how El Nino's warm waters reach northern Pacific states. But this warm El Nino water is not transported from the equator. Instead, the piled up water displaces the thermocline so that cold nutrient rich water resides deeper in the water column than in non El Nino years. As a result, seasonal upwelling continues, but upwelling winds bring warm, nutrient poor water to the surface instead of cold, nutrient rich water.

Q2: Can we assume that the mesoscale eddies mentioned in this presentation meander unpredictably and lack a consistent temporal or spatial structure?

A2: Yes. The chaotic nature of mesoscale circulations and eddies suggests that predicting particle transport trajectories is impossible. But predicting intensity of eddy activity and a range of particle trajectories may be possible.

Q3: The blue line on the right graph illustrates the time it takes for surface drifters to be transported on and offshore. What time scale do these data represent?

A3: Because the drogue was released in August 1995 and returned to shore in March of 1996, the data points represent weeks.

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2. Ocean-Coast Exchange Processes and Sesonde Mapping

P. *Michael Kosro, Oregon State University, Corvallis, Oregon.*

Abstract: A central issue in selecting safe exchange zones for ballast water is determining the probability that released exotic species can be transported alive from the exchange zone to a nearshore zone where they can become established. We therefore discuss the exchange processes between the open ocean, the slope and the shelf along the west coast, their time and space scales, and the means that we have to *detect and predict them.*

At the largest scales, upper-layer water from the deep ocean is transported toward the coast by the basin gyre circulation in the West Wind Drift [e.g. Kirwan, et al., 1978]. This flow divides as it turns nears North America, part flowing north in the Alaska Current and part flowing south in the California Current. The latitude of this split and the division of transport varies seasonally and interannually.

At medium scales on the west coast, cross-shelf transport is largely driven by the direct and indirect effects of the wind.

Direct steady wind forcing results in Ekman flows -- surface transport in the upper layer at 90º to the right of the wind, and currents at the very surface at about 45º to the right of the wind -- so that equatorward (poleward) alongshore winds drive surface-layer flows away from (toward) the coast. These cross-shore flows diverge (converge) near the coast, resulting in upwelling (downwelling), which in turn is fed by onshore (offshore) flows below the surface layer. The strength of these flows depend on the strength of the wind forcing and depth of the upper layer,

but offshore surface flows of 5-10 cm/s (5-10 km/day) are common for moderate upwelling off Oregon. The winds vary seasonally, with upwelling (downwelling) dominating in the summer (winter). Episodes of winter upwelling and summer downwelling also occur during most years, but tend to be short-lived [*Bane, et al.*, 2005].

Indirect effects of wind forcing result from the actions of upwelling and downwelling in tilting the ocean stratification, producing geostrophic alongshore currents which can be several times stronger than the directly forced cross-shore Ekman flows. These strong alongshore currents over time can meander into cross-shore currents, both through instability processes and through interactions with the underlying topography. If the meanders become strong enough, free-standing eddies can pinch off; these can exhibit water properties and species ratios that differ from surrounding waters. [*Nishimoto and Washburn*, 2002]. Concentrated offshore flows, where the coastal jet travels from the shelf into deep water, develop in summer along the northern and central west coast, particularly in association with flows around Heceta Bank, past Cape Blanco, Cape Mendocino, Point Arena, and other coastal headlands. Concentrated onshore flows are less regularly, but are known. Through January 2003, a month-long concentrated onshore flow was observed just north of the Oregon/California border, associated with a quasi-stationary mesoscale eddy. It is important to understand the probability and intensity of strong onshore flows to assess potential alternate ballast-water release zones.

Real-time assessment of risks may be possible in the mid-term future through observations combined with models. Regional coastal ocean observing systems have been developed on an ad-hoc basis, and there is a national movement to incorporate and expand their elements into a coastal component of the Integrated and Sustained Ocean Observing System (IOOS). In the Pacific Northwest, daily maps of measured ocean surface circulation along the entire Oregon and southern Washington coast are available from HF surface current mappers (http://bragg.coas.oregonstate.edu), and California is well along in building a similar system for their waters (http://www.cocmp.org) [*Paduan, et al.*, 2004]. Farther from shore, satellite altimeters are providing measurements of the large-scale and some of the mesoscale circulation. In addition, ocean modelers have developed coastal models capable of assimilating surface-current data to produce “nowcast” estimates of surface circulation and dynamically consistent estimates of subsurface circulation [*Oke, et al.*, 2002; *Paduan and Shulman*, 2004]. Research is ongoing for expanding these modeling techniques out to the slope and deep-ocean environments, and matching them up with basin scale models. These tools should lend themselves to probabilistic estimates of trajectories which could be used to assess the impact alternate ballast water release zones both on-average and for a proposed real-time release.

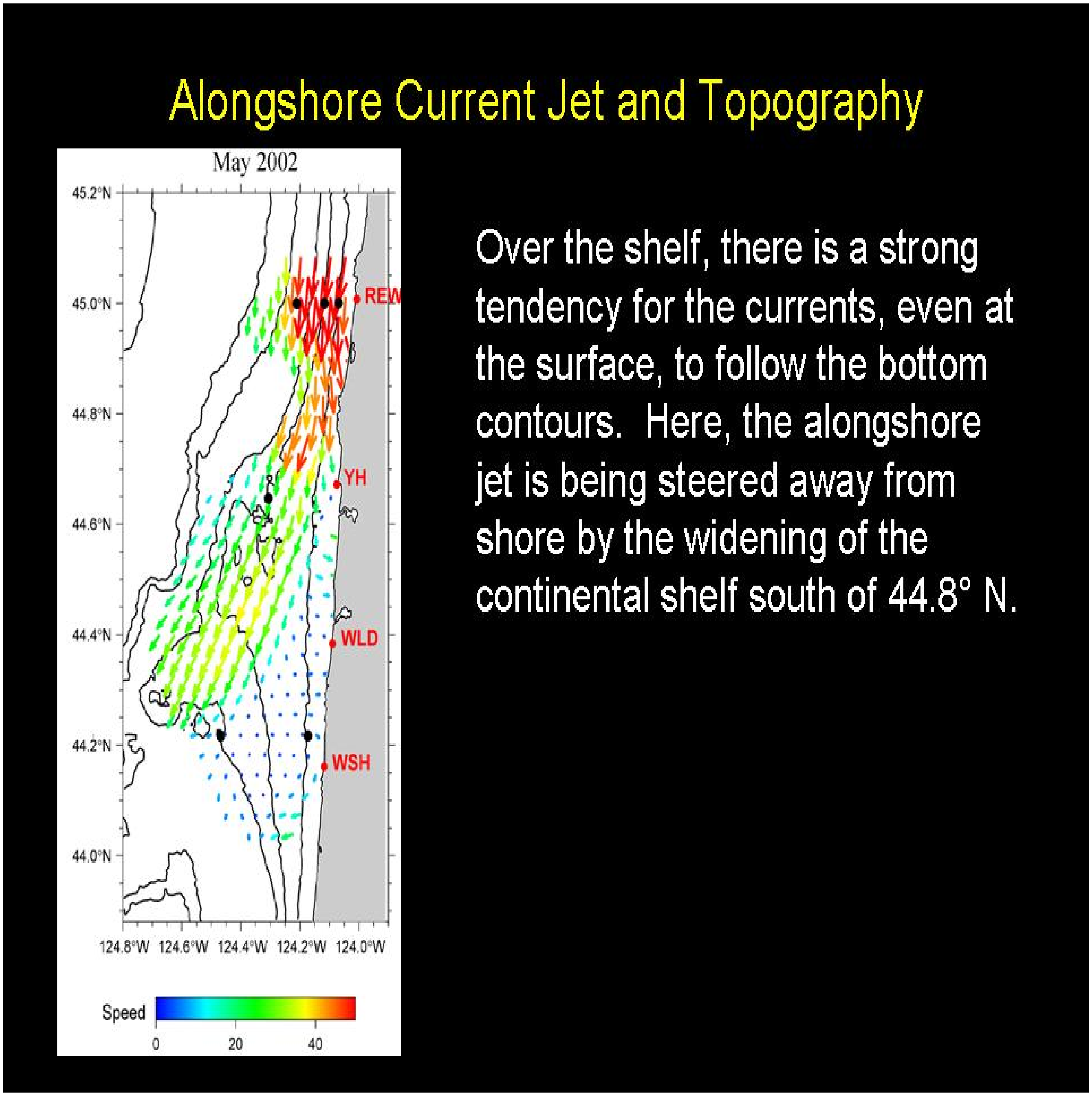

Figure 1 – Average surface currents off Newport, May 2002, from HF surface current mapping system [*Kosro*, 2005]. Dominated by alongshore current jet, but the jet core is steered offshore by the underlying bottom topography of Heceta Bank. Jet currents are much stronger than the average of the directly-forced cross-shore Ekman currents.

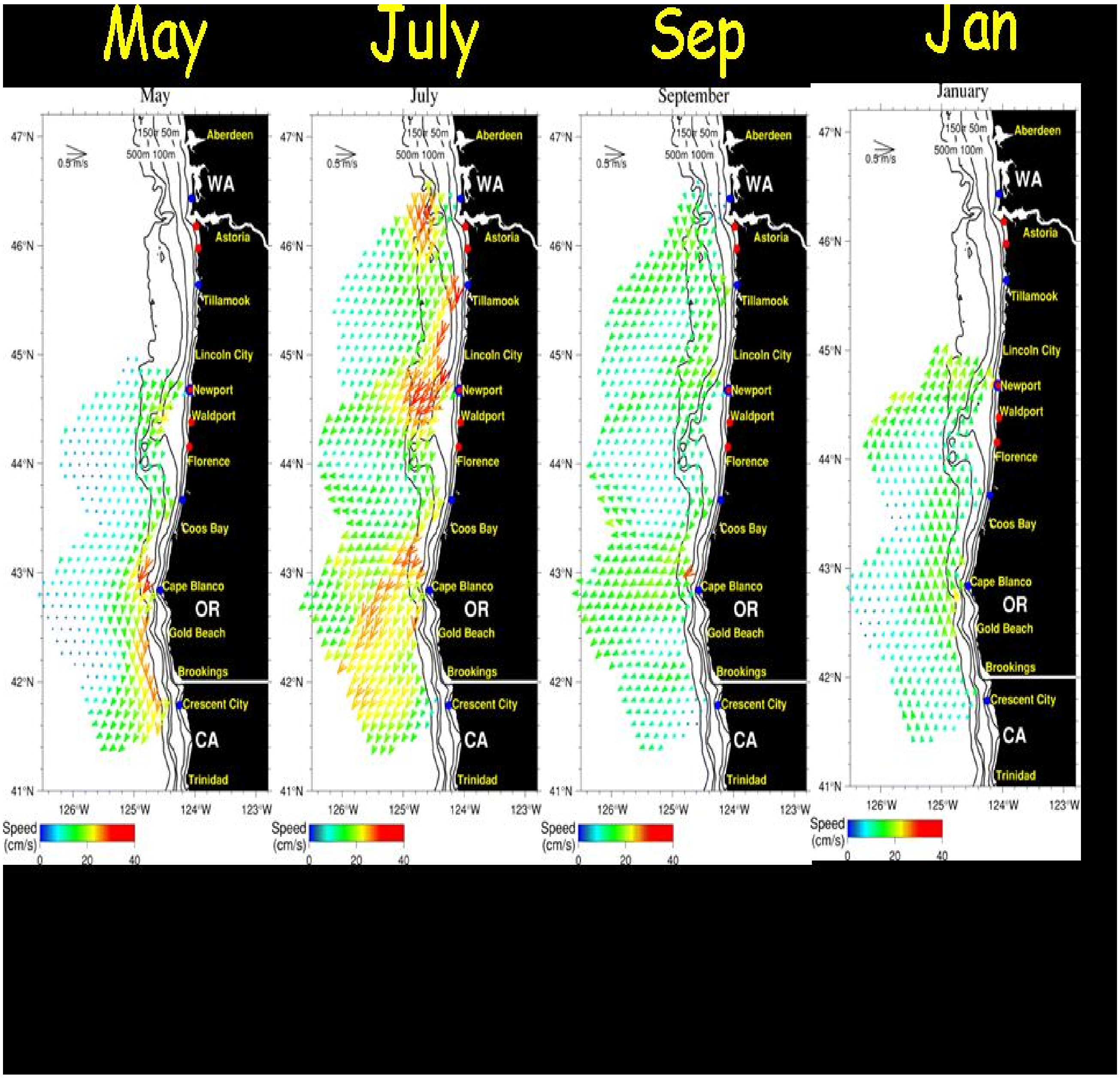

Figure 2 – Larger scale picture of monthly-average surface currents from long-range HF current mappers. Spin-up of alongshore jet near the coast in spring (May) develops substantial cross-shore components in summer (July). By early fall, these weaken but still extend far offshore. During winter (Dec) currents generally are poleward, shoreward, and strongest near the coast. [*Kosro*, in prep].

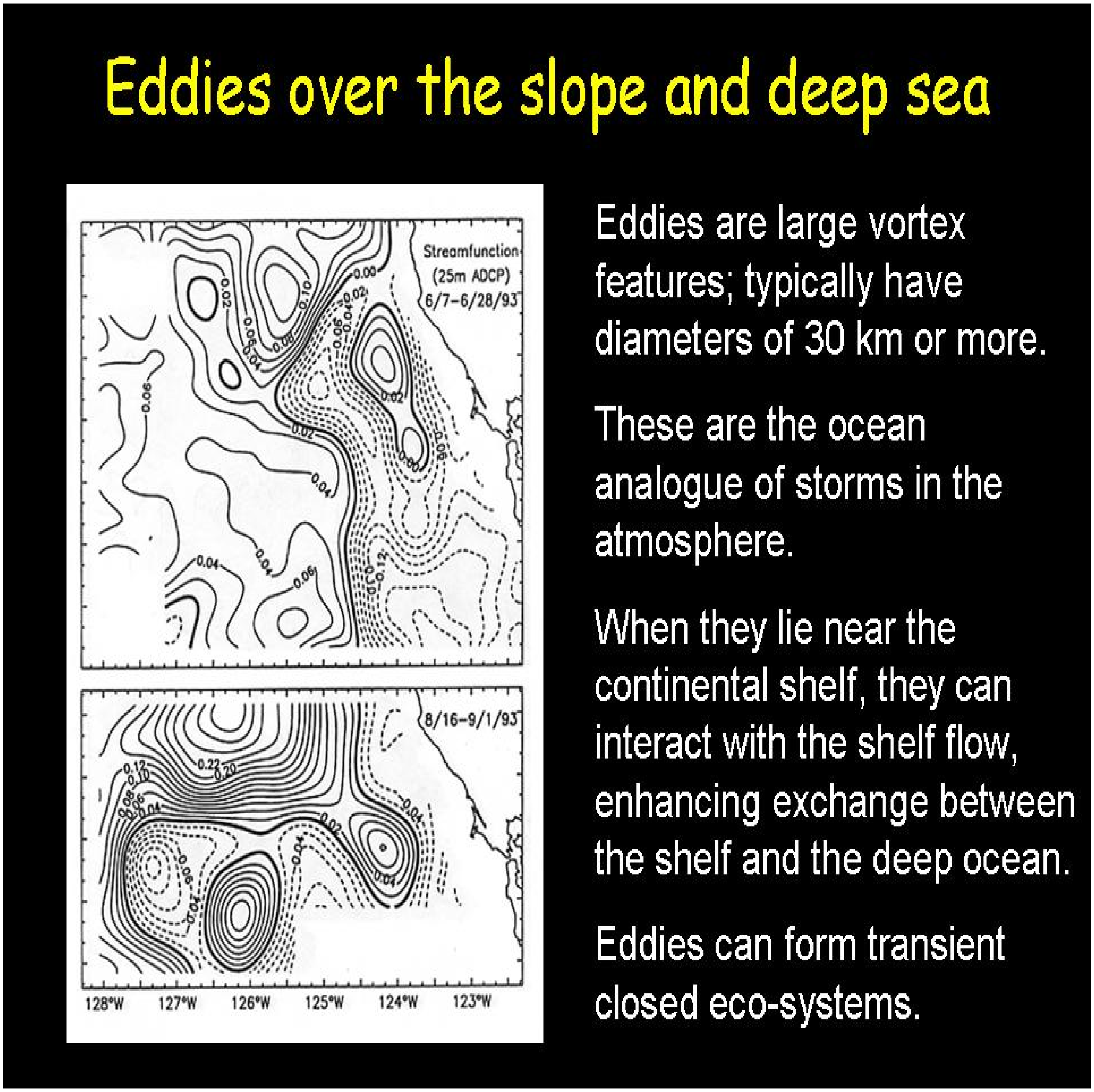

Figure 3 – Mesoscale surface-layer flows off California show strong cross-shelf components linking shelf and offshore, including numerous eddies.

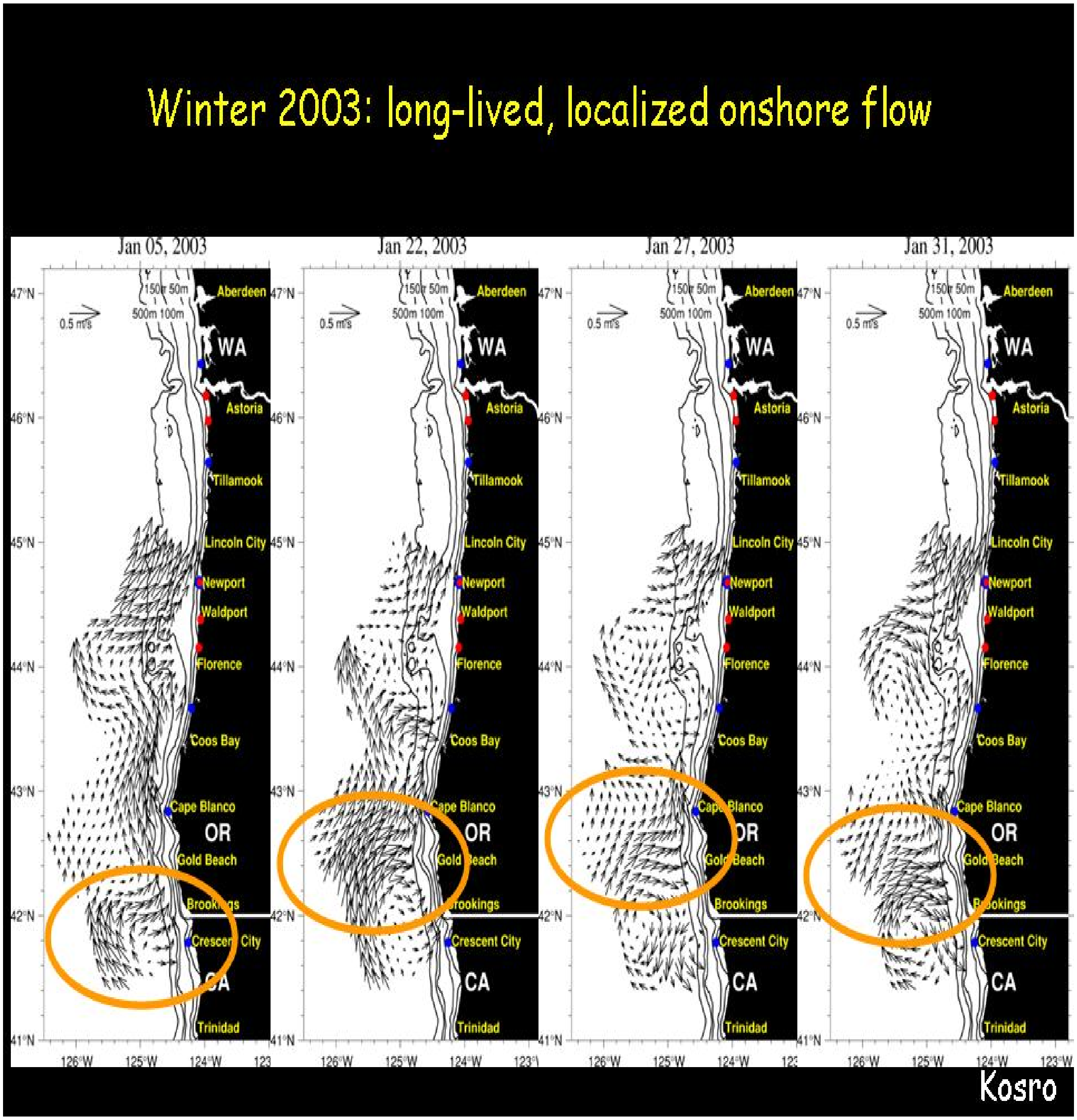

Figure 4 – A long-lived strong onshore flow feature during Jan 2003.

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Questions and Answers:

Q1: In upwelling regions, does the surface current have a general depth?

A1: For systems shown in this presentation, the surface current's depth was 1-2 meters. By combining oceanographic measurements into new data assimilation models, we can now use surface current data to predict current, temperature, and salinity patterns deeper in the water column.

Q2: If a vessel exchanged ballast 40-50 feet below the surface layer, could these new models enable us to predict whether the ballast would mix with the surface layer?

A2: Your question addresses a very active area of research. With surface layer measurements and the data assimilation models, we could predict the trajectory of exchanged ballast water over the continental shelf. But we could not predict the trajectory of exchanged ballast water over the deep ocean.

3. Wind-Driven Shelf Dynamics and Their Influences on River Plumes: Implications for Surface Parcel Transport

Ed Dever, Oregon State University, Corvallis, Oregon.

Abstract: This short review focuses on locally wind-driven shelf dynamics and their impacts on surface parcel transport by river plumes. The influence of wind-driven shelf dynamics on river plumes focuses on the example of the Columbia River plume but is applicable to river plumes elsewhere.

The Ekman Transport

Wind forcing enters the ocean through the wind stress. The direct influence of wind stress on the ocean is confined to the oceanic surface boundary layer (Figure 1). On time scales comparable to or longer than the local inertial time scale set by the Coriolis parameter, the dominant balance in the surface boundary layer will be between the surface wind stress and the Coriolis acceleration. The influence of the Coriolis acceleration leads to a surface velocity that is to the right of the wind direction in the northern hemisphere, and the transport integrated through the oceanic surface boundary layer is 90° to the right of the wind stress direction. The magnitude of this transport (called the Ekman transport) is given by $\tau/\rho f$ where τ is the wind stress, ρ is the ocean density and f is the Coriolis parameter. The observed surface boundary layer transport has been shown to be similar in magnitude to the Ekman transport predicted by wind stress for a number of coastal upwelling regions (Lentz, 1992).

Along the west coast of the North American continent, wind-forced variations in the surface Ekman layer transport are crucial to shelf dynamics. The surface Ekman transport occurs within the oceanic surface boundary layer. For many intents and purposes, the Ekman transport distribution can be considered slab-like within this boundary layer. That is, the velocities due to the Ekman balance are evenly distributed within the surface boundary layer, and may be estimated roughly as the Ekman transport divided by the surface boundary layer depth. Both the wind forcing and the surface boundary layer depth vary as a function of latitude along the west coast, and this has important implications for surface velocities due to the Ekman transport. For example, a wind forcing of 0.1 Pa would suggest near surface velocities due to Ekman transport of about 0.05 m/s, 0.1 m/s, and 0.20 m/s for surface boundary layer depths of 20, 10 and 5 m respectively.

Coastal upwelling and downwelling

In the presence of a coastal boundary, the blocking of wind driven transport by that boundary will give rise to upwelling or downwelling (Figure 2). On the west coast, an equatorward wind stress will force an offshore surface Ekman transport. The blocking of this transport by the coastal boundary will then cause a divergence at the coast. In order to maintain conservation of volume, a volume of water will be upwelled that equals the offshore Ekman transport. The converse situation holds true for a poleward wind stress. A poleward wind stress forces an onshore surface Ekman transport and convergence near the coastal boundary with resulting downwelling.

Upwelling and downwelling favorable winds also affect the along-shelf transport. As upwelling occurs, the coastal sea level is lowered. For geostrophic flow, the onshore-offshore pressure gradient will be balanced by the Coriolis force. For upwelling, drop in coastal sea level means the pressure gradient will be onshore. A pressure gradient in the onshore direction implies equatorward transport on the west coast. The reverse situation is true for downwelling. Onshore Ekman transport piles water up at the coast raising coastal sea level and leading to a poleward transport. Upwelling and downwelling favorable winds affect coastal sea level even if the water column is not stratified. In the presence of stratification, upwelling will bring isopycnals to the surface in an upwelling front. The pressure gradient caused by coastal sea level drop will also be influenced by the horizontal gradient in density associated with the upwelling front. Variations in this pressure gradient lead to geostrophically balanced horizontal and vertical variations in the along-shelf velocity (Figure 3). Downwelling causes analogous pressure gradients as warmer, lighter water is transported onshore by the Ekman transport. Geostrophic along-shelf velocities forced by upwelling and downwelling are typically much larger (on the order of 0.5 m/s) than the near surface velocities associated with the Ekman transport that started the upwelling or downwelling process (Huyer, 1990; Dever *et al.*, 2006).

River plumes in the absence of wind forcing

In the absence of wind forcing, small river plumes will be advected along with whatever ambient flow exists outside the river mouth. Larger river plumes will be influenced by the Coriolis force. The fresher water within a river plume is lighter than the ambient sea water. The horizontal pressure gradient caused by density differences between the river plume and ambient ocean sea water lead to poleward transport in river plumes on the west coast.

The influence of upwelling and downwelling on river plumes

Upwelling and downwelling favorable winds strongly influence river plumes. Because the river plumes are shallow, even moderate winds can force relatively large near surface velocities to and from the coast. Upwelling favorable winds move the plume offshore (Figure 4). Equatorward velocities associated with coastal upwelling advect the plume southwards as well. Downwelling favorable winds move the plume onshore (Figure 5) and reinforce the tendency of the plume to flow northwards (on the west coast).

Fluctuating wind fields cause alternate equatorward and poleward advection of the plume during upwelling and downwelling events respectively (Hickey *et al.*, 2005). The alternation of wind stress sign breaks the plume into discrete pieces along the coast (Figure 6). Remnants of the upwelling plume can be found both north and south of the river mouth.

<u>Questions and Answers:</u>

Q1: During upwelling, surface waters are transported offshore at 5 cm/second. This surface water is then replaced by upwelled water that must move across a thicker slab of water than the slab that the surface water must move across. As a result, at what rate does upwelled water replace the surface layer water?

A1: In upwelling regions, the vertical structure of the onshore return flow is actively being researched. From some data, including that of this presentation, the onshore return flow lacks a strong vertical structure. But, using simple theory, we would predict that after several upwelling days the onshore flow would occur in a bottom boundary layer. More recent data, however, suggest that the onshore return flow may occur beneath the surface boundary layer. If return flow does occur beneath the surface boundary layer, then this will directly affect where exchanged ballast water, nutrients, and plankton are transported in the coastal zone.

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Q1 follow up: When upwelled water is transported back onto the continental shelf, what depth does this water come from?

A1 follow up: During the winter and based on temperature as well as salinity signals, the waters comprising the newly upwelled water originated from 100-150 meters. During the summer time, the newly upwelled water originates from shallower water of 70 – 80 meters.

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4. California Current System From a Langrangian Perspective

Carter Ohlman, University of California, Santa Barbara.

Abstract: To understand the transport of potentially dumped ballast water, probability density functions giving the probability that a water parcel beginning at a given location (proposed dump site) ends up at other locations, must be determined (Figure 1). This is best accomplished with ocean circulation information from repeated trajectory observations with drifting buoys, enhanced where possible by satellite altimetry data, high frequency (HF) radar observations, and ocean circulation model results. As an example, the climatological mean circulation and associated eddy energy for the California Current system from a combined drifter – satellite altimetry product is presented.

SVP drifter data from 1992-2004, AVISO sea level anomalies, and NCEP reanalysis winds are used to assemble a time mean distribution of the surface (15 m depth) velocity in the California Current System (CCS) seaward of ~50 km from the coast. Ekman currents are first subtracted from the drifter measurements. Resulting geostrophic velocities from drifters are then used to correct the energy given in AVISO data, and AVISO data are used to eliminate the temporal bias in drifter observations. The resulting product from a combination of platforms gives the best estimate of the mean flow field and its associated variance or "diffusivity", products necessary for computing transport trajectories from Eulerian fields.

The CCS flows southward with four permanent meanders that can have seaward extensions more than 2000 km offshore. Mean velocities are near 5 to 10 cm s^{-1} in magnitude with a significant cross-shore component in 100 to 200 km bands with alternating (onshore and offshore) direction (Figure 2). Eddy kinetic energy values are mostly between 10 and 20 cm s^{-1}, many times larger than the mean energy (Figure 3). Thus, water parcels are not expected to exactly follow the mean CCS. Rather, motions are dominated by a variety of eddies, jets, and squirts on various scales (Figure 4).

The observed time mean circulation and its associated eddy energy are compared to those produced by various high resolutions ocean general circulation model solutions: ROMS (5 km), POP (1/10º), HYCOM (1/12º) and NLOM (1/16º). Simulations in closest agreement with observations come from ROMS. The ROMS output shows four meanders and eddy energy within 50% of observed values. The time mean ageostropic velocity in ROMS is strongest within the cyclonic part of the meanders and appears similar to the ageostrophic velocity produced by non-linear interaction of Ekman currents with the near surface vorticity field. Other models may give a qualitatively plausible mean structure, but eddy energy values are only a small fraction of those observed. Ocean circulation models used to help understand how potentially spilled ballast water is transported must thus be selected with care.

Tracking the movement of water parcels throughout the CCS, from 100's of kilometers offshore to the near-shore region where invasive species will ultimately recruit, requires resolving many scales. Lagrangian observations a few times daily with 100 meter resolution are sufficient for the mostly geostrophic region of the CCS. Trajectories in the near-shore region must be resolved on 10 meter and 10 minute scales to ensure that a water parcel actually reaches suitable habitat for invasive species to recruit. A distance of a few meters can be the difference between recruitment and advection back out to sea.

Both drifter observations and ROMS model results show the near surface velocity within ~50km of the coast is neither in Ekman nor in geostrophic balance, reducing the utility of remotely sensed wind and altimetry data in observing the circulation within this region. Remotely sensed surface currents from HF radar can potentially be used with drifter observations to determine large quantities of accurate transport pathways over the continental shelf. In summary, a combination of technologies and techniques must be employed to determine the necessary ocean circulation information from which probability density functions that quantify water parcel connectivity from proposed alternative ballast water discharge locations can be computed. Connectivity should then be investigated prior to any formal designation of alternative ballast water discharge sites.

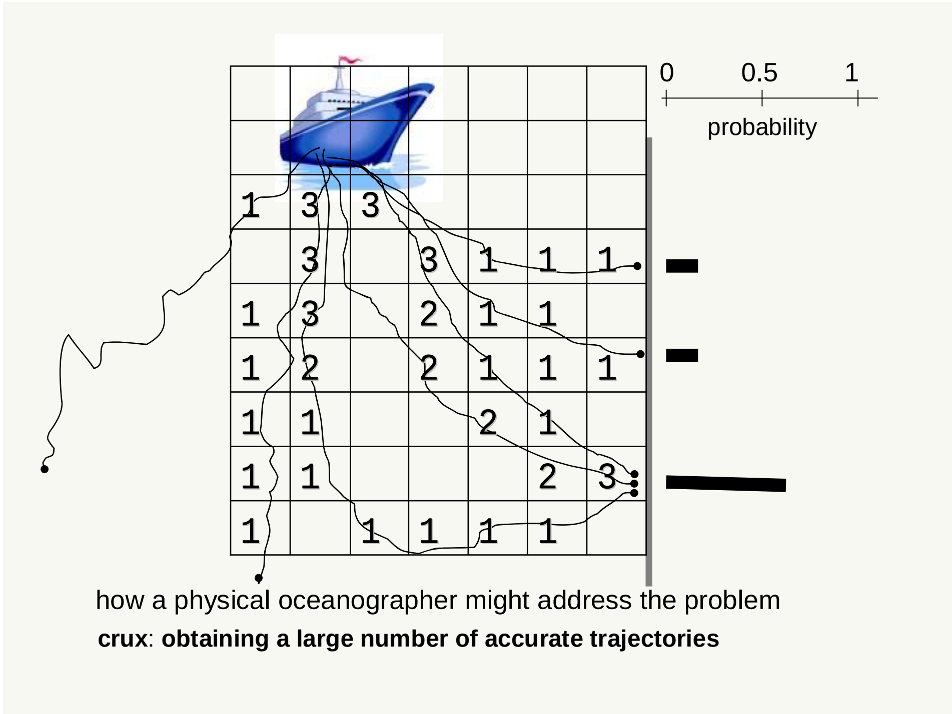

Figure 1 – Cartoon showing a strategy for addressing the ballast water transport problem. The matrix gives the number of "connections" between the location of ballast water discharge and other locations in the ocean. Connections to a hypothetical coastal region shown by the vertical grey line are given as probabilities (i.e. 3 of 5 tracks reaching the hypothetical coast do so in 1 specific region for a 60% probability). Upon selection of alternative ballast water discharge sites, connectivity can be examined with existing data or ocean circulation model results.

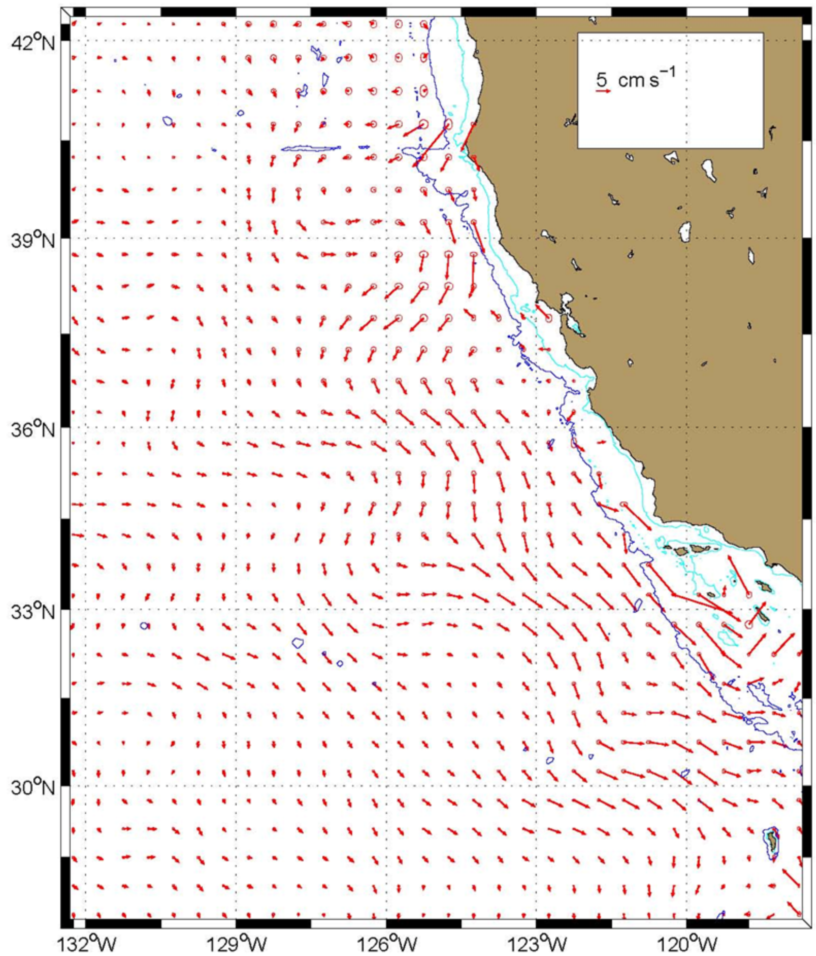

Figure 2 – Mean geostrophic surface (15 m depth) circulation for the California Current System from a combined analysis of drifter and satellite altimetry (AVISO) data collected from 1992 – 2004.

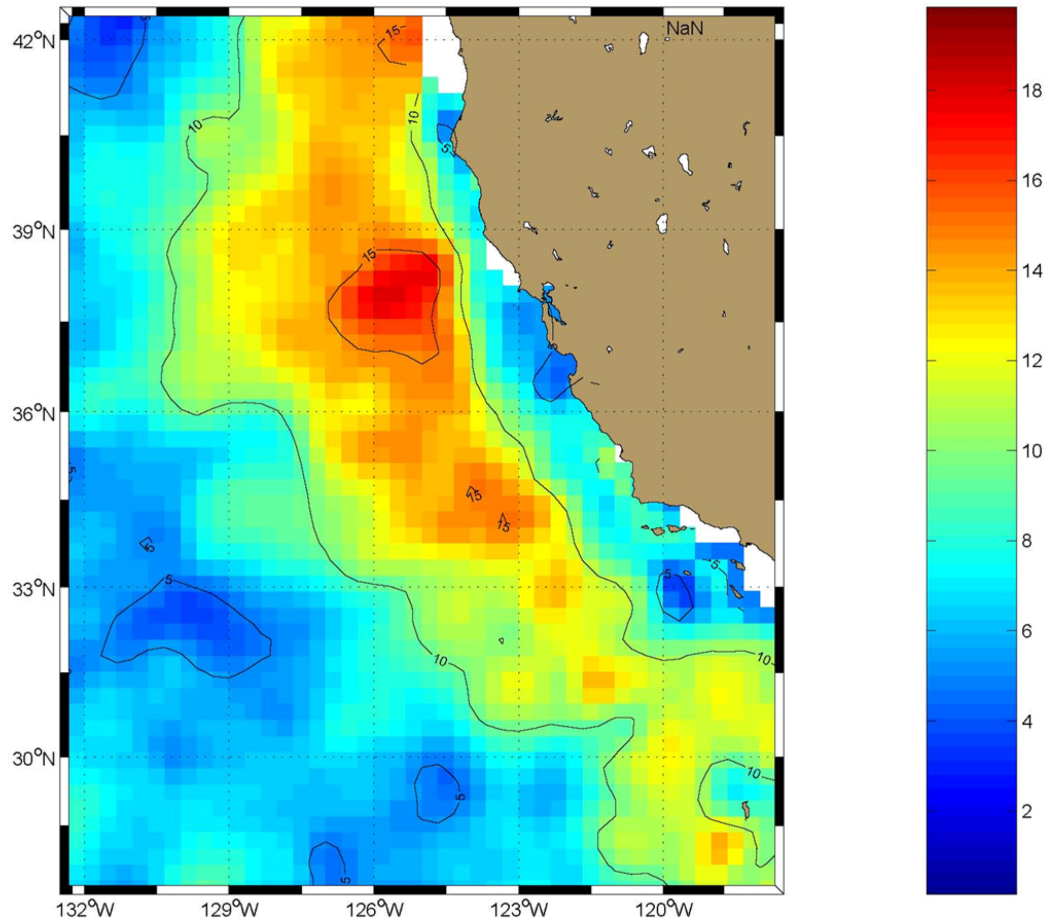

Figure 3 – Geostrophic eddy kinetic energy for the California Current System from a combined analysis of drifter and satellite altimetry (AVISO) data collected from 1992 – 2004. Energy is computed as $(0.5\,(<u'^2 + v'^2>))^{0.5}$ where *u* and *v* are horizontal velocity components, primes indicate deviations from the mean, and <·> denotes a mean quantity.

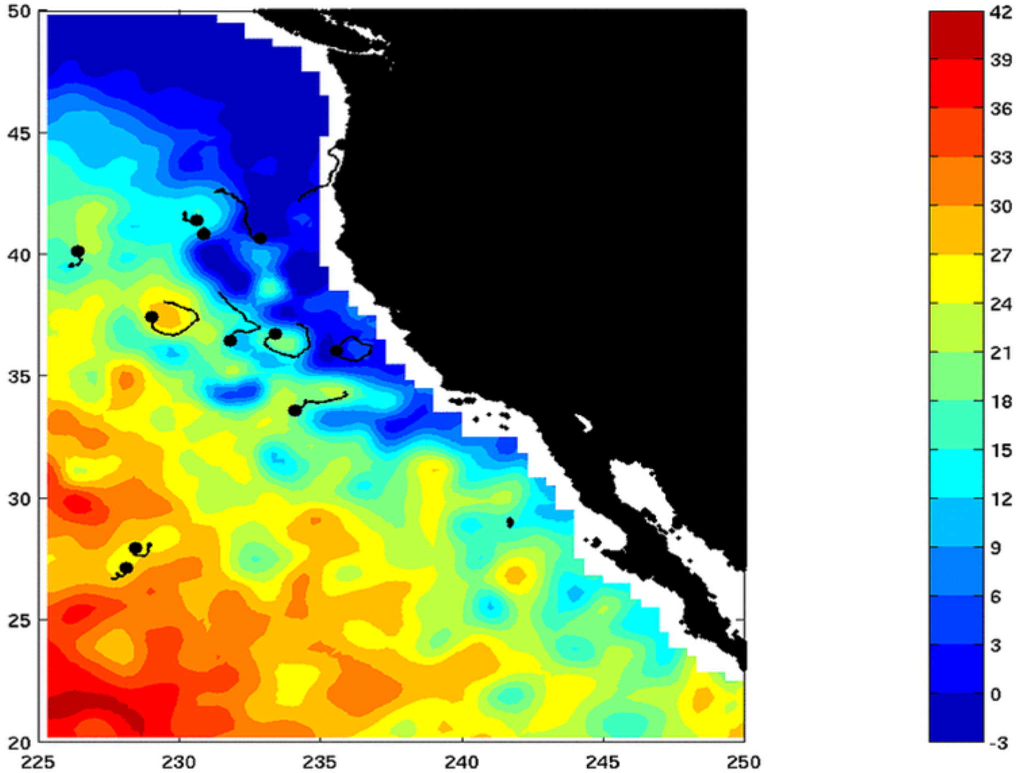

Figure 4 – Sea level anomaly from AVISO data and corresponding drifter tracks/locations for 30 December 2000 showing the role of eddies in the California current circulation. Drifter tails are 7 days long. Dots indicate the most recent positions.

Questions and Answers:

***Q1**:* How much do drogue drifters cost?

A1: A drogue drifter costs approximately $1500. The SVP drifter is deployed for 1-2 years and is less recoverable than smaller drifters, which use different technology.

Q2: Because vessels exchange ballast sometimes at the surface and sometimes at the vessel's bottom, can a drogue's depth be changed? Collecting data from different depths would allow us to analyze how exchanging ballast at the surface versus at depth affects shoreward transport of ballast.

A2: A drogue's depth can be changed within reason (e.g., 20-25 meters). Because waters at this depth mix quickly, the time scale of a depth-deployment would be very short. At 50 meters, a drogue will not perform well.

Q3: In your presentation, you talked about combining different observational technologies to remove discrepancies between different data concerning the California current system. But another option includes combining observational data with data assimilation models. In fact, research has shown that model errors decrease significantly when these models incorporate high quality observational data.

A3: You are correct, and I did not mean to denounce models in my presentation. Instead, my point was that you should not blindly pick up a model and expect that model to yield results that will be as accurate as someone else's who used the model for a different purpose.

Q4: In your presentation, you talked about using probabilities to predict when and where water will come onshore. But we are worried about non-native larvae coming onshore, and larvae do not necessarily follow water.

A4: When I showed my cartoon about constructing a model, I mentioned that you may want to include some biological behavior.

> **Q4 follow-up:** But, because larvae (especially crustaceans) will do things that completely rectify water movements, the biology (larval behavior) must be included in models from the very beginning.

Discussion Panel Involving Presenters Dever, Kosro, Ohlmann, and Shearman

Q1: If eddies are retentive and are distributed up and down the coastline, should vessels take advantage of this natural retention and exchange ballast directly into eddies? This question's assumption is that an eddy will retain ballast and thereby prevent any ballast from reaching shore.

A1(a): Even though eddies generally move offshore, eddies sometimes move onshore. This unpredictable eddy movement should prevent us from recommending that vessels exchange ballast in the middle of eddies.

A1(b): With regards to an eddy's retentive integrity and movement offshore, these generalities typically occur in offshore oceanographic regions that are beyond the focus of today's meeting. Instead, today's meeting focuses on oceanographic areas within 200 - 50 nm of shore, and eddy retentive integrity and movement becomes very different in this region.

Q2: Based on the content of today's presentations, could our unanswered questions concerning ABWEA's be addressed by your ongoing oceanographic research?

A2(a): From current HF daily observations collected over large scales, we could address ABWEA questions by conducting large scale and modern drift card experiments. These investigations would involve our using HF daily observations to create Langrangian particles that follow the observed flow trajectories. Identifying these large scale flow trajectories could help address ABWEA questions.

A2(b): Observational data is not the only means to address ABWEA questions. Currently, we have technology that can generate mean and variance field trajectories. With these fields in hand, we can conduct simulations through the mean and variance field trajectories to build large databases.

Q3: If Ekman transport in the mixed layer produces surface current speeds ranging from 20, 10, or 5 cm/second, then this water could move 50 nm in 4-5. 8-10, or 16-20 days, respectively. With regards to ABWEA's and the amount of time that larvae remain viable in ballast water, are these time scales of water movement acceptable?

A3(a): Because larval periods range from minutes to months, the answer depends on what species is in the ballast. In other words, some larval species would settle out of the ballast before the ballast made it onshore (e.g., 16 days). But other species would be just fine waiting 16 days to settle out at which time the ballast water and they would be onshore.

A3(b): The answer to Question 3 also depends on the relative speed of currents with respect to the rates of physical forcing changes. For example, at higher speeds, water will move far over the time scale of a weather system. But at a lower speed, water will move only a short distance before wind or another weather variable changes and therefore changes the water's trajectory and speed.

A3(c): The above current speed estimates concern cross-shore velocity transport. But water is also transported alongshore, so alongshore transport velocity is also important. Because eddies and onshore currents are long-lived and stronger than 20 cm/second, the above cross-shore speeds are optimistic. As a result, eddies and onshore currents could bring things in from 50 nm, which raises a red flag over Pacific States' current 50 nm exchange regulation.

Q4: How will global warming affect upwelling?

A4(a): A better question is how will global warming affect stratification? In response to global warming, the water column may stratify differently. An altered stratification could then change the depth scale of surface boundary layers and thereby affect Ekman and Geostrophic responses. Because global warming will also change nutrient concentrations, predicting an oceanographic response to global warming becomes complicated. A further complication concerns how oceanic temperatures will interact with atmospheric boundary layers. For example, upwelled water is usually cold and cools the coastal atmosphere, stabilizing the marine atmospheric boundary layer. A warmer ocean may destabalize the marine atmospheric boundary layer and in turn alter the coastal wind field. In the end, global warming will affect both upwelling response and the coastal wind field.

A4(b): In Science, Baukun (1990) argued that global warming has increases upwelling intensity by increasing wind intensity.

Q5: Because most of our coastal taxa occur in estuaries and embayments, what is the probability that water exchanged at 50 nm (and larvae within this ballast) will propagate towards and then get sucked into an estuary?

A5(a): Even if the probability is low, how many rare occurrences will it take before we should worry?

A5(b): There is a definite communication between estuaries and oceans, but we cannot give you probabilities of their communication.

A5(c): Although we cannot provide probabilities for all locations, we can identify the worst areas to exchange ballast. For example, the Columbia River plume is a horrible place to exchange ballast because upwelling event push the plume offshore. If vessels exchange ballast in the plume, then a down-welling event could push the plume and ballast against the coast and mouths of estuaries, creating a very high probability of transporting ballast and invasive species into estuaries.

A5(d): Because the Columbia River plume is so thin, this plume is pushed around rapidly by upwelling and down-welling events. In addition, if we get a probability density function of wind directions from buoy winds, then we will see that probability of upwelling and down-welling events throughout the year is high. Another factor making an area like the Columbia River plume a horrible place to exchange ballast is that even from limited drifter data around Point Conception, we saw some winter cases where drifters were advected 50-100 km offshore and then came back onshore within 40 days. So, if a larval period lasts 40 days, and if this larva is in ballast exchanged 50 nm offshore, then there is high probability that this larva will be advected onshore.

A5(e): When considering Question 5, we should also account for whether ballast and invasive species will be diluted before reaching shore. If ballast and organisms are diluted, some organisms will reproduce asexually and establish themselves once onshore. But many other sexually reproducing species will fail to establish if their numbers are diluted and they cannot find another member of their species. In other words, it's not enough just to get to shore. Instead, a species must get to shore with large enough numbers to reproduce.

Q6: ABWEA's are potential places where vessels could be directed to exchange if they were unable to exchange outside 200 or 50 nm. Within 200 nm, are there large areas (i.e., 100 Km) where net movement of water is offshore? How does this answer change as we increase our exchange distance from 50 to 200 nm offshore?

A6(a): To address these important questions, we should get a mean field and variance for the whole area and then use models to numerically put particles through this field. Repeating this process for 100s to 1000s of particles will allow us to develop a connectivity matrix for a particular ABWEA. We could then create matrices for additional ABWEA's. With many connectivity matrices, we could determine which ABWEA's contain a lower probability of having its water, and consequently is ballast, transported to a given location (e.g., San Francisco Bay).

A6(b): We have new knowledge about current patterns over large distances. These newer data are allowing researchers to ask questions similar to Question 6. While we have the data, the analyses, and therefore answers, are lacking.

Q7: Because the Pacific Ocean and its weather conditions are dynamic, should mariners be instructed to exchange in certain ABWEA's depending on upwelling/down-welling conditions? Because mariners monitor the weather, is such a dynamic solution possible?

A7(a): The more complicated and dynamic the solution, we find less mariner compliance.

A7(b): ABWEA's will mostly concern international industries. As the Puget Sound Action Team from Washington indicated, some mariners still fail to understand Washington's 50 nm regulation even after 4 years of public education and outreach. So, implementing a dynamic solution among international industries will likely be even more difficult and find less compliance.

Q8: Are demands for ABWEA's higher in a particular season (e.g., winter)?

A8: Winter storms may slightly increase demand for ABWEA's. But out of 14,000 voyages into California, only a handful asked for ABWEA's. Other than passenger vessels, we have not received a high demand for ABWEA's.

Q9: To make informed decisions regarding ABWEA's, we may need to know the probability that ballast exchanged in a certain area will get into the mouth of the Strait of Juan de Fuca. To address this question, we could spend money on modeling research that may suggest the probability for this year is low. But the presentations today illustrated that weather and flow conditions change annually. So, is a model study worth its required expense since a model's prediction may be right for one year and then wrong during the next year.

A9(a): From the Ocean Observing System, we have a system of observations in the ocean to produce data that can be assimilated into a models. By assimilating these data, we can improve a model's accuracy and predictability.

A9(b): Because ABWEA answers are needed now, we cannot wait 10-20 years for data that can improve models.

A9(c): Because we already have 10 years of drifter, altimetry, SST, hydrographic profiles, and HF radar data, we do not have to wait 10-20 years. Rather, these data should be integrated into models to produce statistics. With these statistics, we can then go forward to answer ABWEA questions.

A9(d): Using models to predict the behavior of currents and the utility of ABWEA's seems analogous to predicting the weather: the further in time one predicts, the less accurate the prediction.

A9(e): But we know that summer weather will generally be warmer than winter weather. From a manager's perspective, and at this level of discreteness, we know that a zero risk of larvae and ballast reaching shorelines can never be achieved. But we can create alternative practices to lower the risk associated with exchanging ballast. While a certain ABWEA may not reduce the risk that much, ABWEA's will likely have a lower risk than exchanging ballast directly in an estuary. So the critical question concerning ABWEA's is where are the areas with the lowest risk?

A9(f): To address where ABWEA's should be located, we must first stratify by season since we can accurately predict that temperature and wind patterns will differ among seasons. But before complicating the answer, we could also argue that mariners may resist complex solutions and schemes when exchanging ballast. To help gauge how much complexity a solution can incorporate, perhaps we should ask mariners how much complexity they want to deal with. When faced with a simple but low risk solution of traveling more than 200 nm offshore to exchange ballast, perhaps mariners will accept more dynamic ballast exchange solutions.

SECTION 3: Biological Oceanography

1. Vertical Distribution and Migration of Zooplankton

Steven Bollens, Washington State University, Vancouver, Washington.

Abstract: Not submitted

Questions and Answers:

Q1: Regarding vertical migration, are there any generalizations that can help direct ballast exchange practices? For example, do estuarine or coastal species generally migrate more than shelf or oceanic species?

A1: One generalization is that in order to be retained or transported out of an estuary, estuarine migrations are adapted to day-night and tidal cycles. Another generalization concerns ocean depth. As ocean depth increases, the prevalence of vertical migration behavior becomes stronger. In contrast, the prevalence of vertical migration is much less in well-mixed, shallow water. So, vertical migration tends to occur most in the outer shelf, less in the middle shelf, and least inside the shelf. But, even in deep outer shelf waters, vertical migration prevalence varies across species and environments so that vertical migrations are not ubiquitous.

Q2: In a vessel's ballast, invertebrates will not experience day-night light cycles. As a result, will longer voyages disrupt invertebrate migrating behavior once the invertebrates are released during ballast exchange?

A2: Study results on this topic are mixed. Some species have endogenous migration rhythms that restart once invertebrates are re-exposed to day-night cycles. In contrast, other invertebrates that initially migrate fail to vertically migrate after experiencing no day-light cycles over several days.

Q3: Because predation pressure on adult and larval invertebrates may be higher during the evening, should we advocate that vessels exchange ballast during evening hours?

A3: If the main source of evening mortality comes from non-visual invertebrates, then evening exchanges may be help reduce the threat of invasive species in ballast water. But if visual predators mostly control invasive species released in ballast water, then evening darkness will lower this predation control.

2. Coastal Oceanography, Larval Behavior, and the Cross-Shelf Transport of Larvae

Alan Shanks, Oregon Institute of Marine Biology, Charleston, Oregon.

Abstract: What we are attempting to do is develop methods of preventing the arrival of propagules (hence forth just larvae), animal or plant, in ballast water and the subsequent establishment of self-sustaining populations of these organisms. By exchanging ballast water some distance offshore we think we can prevent the arrival of larvae to shore.

Ideally we don't want any individual of an invasive species to get to shore, but what we are really concerned with is the establishment of an invasive species, or the establishment of a self-sustaining population. To be self-sustaining the populations first must be able to reproduce. Larvae that arrive on shore, but do not settle near another conspecific will be unable to reproduce. In biology, this is known as the Allee effect. It is not enough that larvae get to shore, they have to get to shore with enough others of their kind that they can successfully reproduce. When ballast water contaminated with invasive species is dumped within an estuary the ship is generally right next to shore and there is a much better chance that larvae will settle near enough to conspecifics to solve the Allee effect problem. Larvae released offshore during a ballast water exchange must migrate to the coast to settle, but during this migration, if they become dispersed they will probably be scattered far enough apart on the shore to prevent reproduction. So we need to worry not just about shoreward advection of the larvae, but mechanisms of shoreward advection that also concentrate the larvae so that when they arrive at the shore they settle near conspecifics.

Another attribute of a self-sustaining population is that larvae released by the population return and settle within the population at high enough rates to keep the population going. The larval phase of organisms appears to be adapted to the local oceanographic conditions such that on average larvae do return to sustain a population. Nearly all ballast water comes from within estuaries so nearly all of the larvae with which we are concerned are species that can live in an estuary. Many of these species are estuarine dependent and their entire life cycle is completed within an estuary. Others are estuarine dependent as adults, but larval development takes place in coastal waters. Many common east coast species have this type of a life cycle (e.g., blue crabs and fiddler crabs). Estuarine water obtained near the mouth of an estuary where the salinity is higher may contain non-estuarine dependent coastal species the larvae of which will typically be released into the coastal waters. From an oceanographic perspective, we are dealing with larvae that have evolved to exploit the circulation within an estuary to sustain the adult population or that exploit the coastal oceanography. Estuarine circulation patterns are generally very similar everywhere. Coastal oceanography varies a fair amount from coast to coast (e.g., west coast vs. east coast) so it is possible that a species would not develop a self-sustaining population because the larvae are not adapted to the local oceanography. Apparently there are, however, enough similar attributes of coastal oceanography that species that evolved in a coastal setting can become established in coastal setting with very different oceanography. For example, the green crab and blue crab have been introduced into many different locations with oceanography very different from original home range.

So when we decide on sites where ballast water can or can't be exchanged we need to consider the oceanography from the perspective of invasive species establishing self-sustaining populations. Will the oceanography concentrate and transport larvae to shore? Is the oceanography similar enough to that within an estuary that a species with an entirely estuarine dependent life cycle can sustain its population? Can the larvae of species (estuarine dependent or not) that develop in the coastal ocean exploit the local oceanography to allow their return and settlement into a population? Our current idea is that we require ballast water to be exchanged offshore somewhere. In light of these questions, where should we require ballast water to be exchanged and are their places we should exclude exchanges.

Organisms that swim well (e.g., juvenile or adult fish) might swim to shore, but nearly all of the organisms with which we are concerned do not swim well enough to make a swim ashore migration – they have to be transported to shore by currents. The oceanography and currents that might cause onshore transport are very different over the continental shelf than seaward of the shelf.

Over the continental shelf, there are three mechanisms of shoreward larval transport that are both capable of transporting larvae considerable distances (km to perhaps 10's of km) and at least two of these mechanisms will also concentrate larvae. As the tide ebbs and flows across the continental shelf break, it generates the internal tide. This takes the form of large internal waves that travel shoreward across the shelf.

1) Currents over these waves can generate a convergence zone that propagates along with the wave. Larvae that reside at the surface can become concentrated in the convergence and, under the right conditions (large enough internal wave that the converging currents are as fast as the speed of the wave), are transported to shore; larvae are both concentrated and transported. For a number of species, both estuarine dependent (e.g., blue crabs) and coastal (lined shore crab), this appears to be the most important mechanism for their onshore transport.

2) These large tidally generated internal waves can break and form internal bores. These bores can transport water from the location over the shelf where they break shoreward. Broken internal waves, bores, are probably also capable of transporting larvae shoreward, but it is not clear if they will also concentrate the larvae.

3) During wind driven coastal upwelling, low-density surface waters are pushed away from the coast and replaced by denser upwelled waters. Where these two water masses meet we find a front, the upwelling front. When upwelling winds relax or reverse to downwelling favorable, the dense upwelled water sinks back to a stable position in the water column and the low-density water mass moves back toward shore as a density current. At the head of this density current a moving convergence is formed which is capable of both concentrating and transporting larvae shoreward.

Over the continental shelf, there are at least two, possibly three, mechanisms of shoreward larval transport that also concentrate larvae. These current patterns are essentially ubiquitous features of the waters over the continental shelves of the world; the internal tides are present on all shelves and upwelling and downwelling occurs whenever the winds blow in the correct direction. Along the west coast, larvae released over the shelf can be concentrated and transported to shore by these currents. Also, because these currents are present on all or nearly all shelves, it is likely that some of the animals released during ballast water exchange will be adapted to exploit these mechanisms of shoreward transport. Ballast water should not be exchanged anywhere over the continental shelf.

In the Southern California Bight, large internal waves are generated as tidal currents flow around the Channel Islands and the associated banks. These internal tidal waves travel shoreward from the islands across the intervening basins back to the coast. Here there appears to be an effective transport mechanism present not only over the continental shelf, but also from the waters around the Channel Islands to the coast. Ballast water should not be exchanged anywhere within the Southern California Bight.

There are at least four mechanisms that might transport larvae from the open ocean shoreward. In some cases, transport may only be from the open ocean to the shelf and in other cases it maybe from the open ocean all the way to shore.

1) In the areas of the world characterized by classic wind driven upwelling (e.g., west coast of North and South America), upwelling favorable winds are strong and sustained; the source of the upwelled waters can be off the continental shelf. These deeper open ocean waters are pulled onto the shelf during upwelling and can travel across the shelf into the coastal upwelling zone. Larvae released during ballast water exchange, if they vertically migrate to depth (several hundred meters probably), maybe carried onto the shelf via this mechanism. The transport should not also concentrate the larvae. Once on the shelf, they may be transported shoreward by the above described shelf dependent transport mechanisms.

2) Wind blowing across the ocean, via the generation of Langmuir circulation cells, pushes the very surface essentially in the downwind direction. Along the west coast, a sustaining onshore wind can push organisms or flotsam in the surface layer (the neuston) to shore. Thus, during winter storms we can find vast numbers of *Vellela vellela* washed up on the beach as well as occasional glass fishing floats.

3) Along the west coast, as upwelling season progresses, large perturbations develop in the California Current. These take the form of eddies and jets generally associated with large topographic features like capes and banks. These perturbations can direct water from over the shelf and adjacent to the shelf far out to sea. They can also take the form of eddies that impinge on the shelf, transporting water of oceanic origin onto the shelf. The former situation could transport organisms released during ballast water exchange away from shore, a beneficial result. In the latter situation, oceanic water containing organisms released during ballast water exchange could be transported onto the shelf where the more efficient transport mechanisms characteristic of the continental shelf might transport the larvae to shore. While this flow might transport larvae onto the shelf, it will probably seldom cause transport all the way to the coast and I don't think it will concentrate larvae. The location of the offshore and onshore flows are fairly predictable in space and the perturbations tend to occur during the later months of the upwelling season.

4) The Columbia River and San Francisco Bay both generate large estuarine plumes. During upwelling favorable winds, the plumes bend to the south and extend a good

distance seaward. Under these conditions, the Columbia River plume regularly extends off the shelf and the San Francisco Bay may at times be found extending off the shelf. During downwelling favorable winds, the plume is pushed right up against the shore and extends substantial distances northward of the estuary mouth. As winds shift from upwelling the downwelling favorable, a plume that extends well out to sea can be pushed by the winds and Ekman transport back to the coast. Larvae released during ballast water exchange into a plume that has been pushed offshore by upwelling winds maybe transported to shore when winds become downwelling favorable, this mode of transport maybe particularly effective for organisms that go through their larval development within an estuary. These organisms may respond to the plume as if they were in an estuary. For example, as the low-density plume waters mix with the surrounding ocean, they may swim up into the low salinity water so as to remain within the "estuary". When the plume has been pushed up against the shore by a downwelling wind it is in the ideal location for plume waters to be drawn into estuaries. This mechanism maybe capable of concentrating estuarine dependent larvae in a water mass far from shore and then transporting them not only back to the coast, but also into a setting where they perhaps stand a good chance of being transported into an estuary.

My recommendations for avoiding the shoreward transport of larvae released off from the continental are a bit more vague. The biology of larvae associated with these flow patterns has been little studied. To avoid shoreward transport of larvae in the deeper waters drawn onto the shelf during upwelling, I would avoid ballast water exchange over the continental slope. I have no idea where ballast water should be exchanged to avoid the successful onshore transport of larvae by an onshore wind. Obviously, the farther out to sea the water is released the better, but where "far enough" is located is unknown. Drift card studies maybe able to address this question. Because the location of offshore and onshore perturbations in the California Current are due to topography and, hence, are fairly predictable in space, I recommend that ballast water not be exchanged in areas where onshore eddies are common. Lastly, I would not exchange ballast water in any estuarine plume water. If ballast water was not exchanged over the shelf, then the only locations where estuarine plume water is present off the shelf is adjacent to the Columbia River and San Francisco Bay. If ballast water is exchanged over the continental shelf, then there are many locations where estuarine plumes are present particularly in the winter months when run off is so much larger. Ballast water should not be exchanged in estuarine plume water either off the shelf or over the shelf.

Questions and Answers:

Q1: When I think about non-native zooplankton being dropped 50 nm offshore during an ballast exchange, I think about the zooplankton having to pass through a wall of predation or other mortality sources before reaching shore. How does mortality affect the shoreward transport of these non-native zooplankton?

A1: The answer depends on transport mechanisms (oceanography) and larval behavior. If a larva is dumped 50 nm from the east coast of the U.S., this larva will be on the continental shelf. In this area, very effective shoreward transport mechanisms exist that could move this larvae onshore in a little over a day if the larva has evolved to take advantage of transport in internal wave convergences.

Q1 follow-up: But is there any mortality research indicating that, for example, half of the non-native zooplankton would be dead in a day?

A1 follow-up(a): The answer depends on which species and taxa we are talking about. For example, a copepod species that has a life span of 30 days may only loose 5% of its population. In contrast, a copepod species that has a longer life span may experience much higher loss of its population.

A1 follow-up(b): Regarding predation and other sources of mortality, certain non-native estuarine species are adapted to successfully transit across a continental shelf even if the particular shelf differs from the species' origin. In addition, estuarine species are adapted to a general suite of predators. So, yes, a non-native species will experience mortality as it crosses the continental shelf. But, if the question is re-phrased as, "will a non-native species experience relatively higher mortality crossing North America's continental shelf than when crossing their native continental shelf?", then the answer is not necessarily yes; the non-native species' population could survive just fine.

Q3: In the NE Pacific, is there a distance offshore where coastal meroplankton species fail to exist or occur in only small numbers?

A3: The answer varies tremendously across species. Many species' larvae remain very close to shore (100s of meters). At the same time, many other species' larvae concentrate ~ 5 Km offshore. Finally, some species' larvae (e.g., Dungeness crab) are just crazy because these larvae begin close to shore, migrate across the continental shelf into the open ocean, and then come back close to shore. To reach declining numbers of shelf-slope species, one must move 100 nm past the continental shelf.

Q4: In the last figure of your presentation, blue bubbles were placed around areas where ballast water should not be exchanged. If ballast water is not exchanged inside the blue bubbles, then more ballast will be exchanged outside the blue bubbles. But the areas outside the blue bubbles may not be bubbled only because we understand less about their physical and biological oceanography. This lack of knowledge occurs because these areas lack large human populations, ports, and marine laboratories. So, is it environmentally just to concentrate more exchanged in the non-bubbled areas simply because we know less about them? More specifically, the area between the Bodega Marine Laboratory and the Oregon Institute of Marine Biology contains no marine labs and, consequently, we fail to understand whether this area should have a blue bubble. But the folks in this area will argue that more ballast exchanges should not be conducted in their back yard.

A4: As a regular exchange practice, water should be exchanged beyond the continental shelf (power point contains a rank ordering of exchange options). When extreme situations arise that require an ABWEA, an alternate and third-rate exchange option may be required such as exchanging outside the blue bubbles.

Q5: In the presentation, do the blue bubbles surrounding estuaries represent the exact exclusion area and distance offshore?

A5: No, the blue bubble on this slide does not represent the exact exclusion area and distance offshore. The blue bubbles fail to encompass all of the appropriate area because the bubbles do not account for seasonality. For example, during the winter time, the Columbia River plume extends farther south than the bubble.

Q6: From yesterday's presentations, I understood that the season of most concern is winter time since southerly winds generally force the plume offshore; is this correct?

A6: No. Regarding the Columbia River plume, we should worry most about summer conditions. In the summer, upwelling conditions will push the plume and any ballast derived larvae southward along the coastline. After a two week upwelling event, down-welling events often occur for two to three weeks. If down-welling event occurs, then the plume and any ballast derived larvae in the plume will be pushed northward along the coast. At this point, the ballast derived larvae could enter many estuaries and river mouths.

> **Q6 follow-up:** What kind of dilution factors are involved?
>
> ***A6 follow-up:*** Unlike water, larval dilution factors cannot accurately be predicted. Inaccurate predictions occur because larvae can swim and maintain themselves in ideal salinity or temperature conditions. This larval behavior then counteracts the mixing process such that larvae remain more concentrated than simple diffusion would predict.

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3. Dispersal of Introduced Species in the Coastal Oceans

Ted Grosholz, University of California, Davis.

Abstract: One of the goals of developing effect ABWEA's is to minimize the likelihood of establishment and spread of introduced species. Therefore, understanding how far and how fast introduced species may spread from a potential introduction site represents an important key to this goal. We have a number of proxies such as genetic population structure and data on physical transport processes to estimate rates of spread. But in the absence of truly experimental data, it is informative to look at past events involving the spread of introduced species along coastlines. I use these examples to emphasize several important points including the importance of estimating rates of spread due to rare events rather than focusing on average annual rates. Beginning with studies of rare recruitment events involving sand crabs along the west coast in the 1930 and very detailed studies of the spread of introduced barnacles in the U.K. during the 1950's. These studies show a general pattern of generally modest dispersal (tens of kilometers per year) as long-term average, although these can be punctuated by rare events involving hundreds of kilometers. These records also support the pattern of a much longer along shore dispersal to establish "beachheads" with more localized dispersal from these sites. Another striking pattern that emerges in a distinct asymmetry in the rate of spread along coastlines. This could be produced by differences in physical transport as well as differential reporting or other human influences. A summary of data on the along shore spread of seven invasive species show greater spread in the direction of the primary movement of surface waters suggesting that physical transport may be responsible. Finally, analysis of the spread of green crabs in different

habitats show dramatically different rates of spread suggesting that predictions based on one invasion, even for the same species may not apply to another region. I suggest that more emphasis be placed on measuring rates of spread and monitoring protocols need to be put in place to enable this. The development of hierarchical models combining broad scale physical transport with small scale biological mechanisms are also needed to improve our capacity for predicting spread rates in future invasions.

Questions and Answers:

Q1: Could upwelling or down-welling circulation systems cause the asymmetrical spread of invasive species along coastlines?

A1: With regards the ranges of invasive species, there does not appear to be a general upwelling or down-welling pattern. But I must go back and analyze whether the degree of asymmetry correlates with upwelling and down-welling systems.

> ***Q1 follow-up:*** But downwelling could hold surface waters and invasive species near the coastline.
>
> ***A1 follow-up:*** Yes, green crabs do appear to be spreading northward with the downwelling current But I must look at other coastlines to see if this downwelling pattern is a general phenomena.

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4. Inferences for Biological Transport: Results From a West Coast Drift Card Study

Vanessa Howard, Portland State University, Portland, Oregon.

Abstract: Drift cards have been employed previously to model circulation patterns, guide the design of marine protected areas, and simulate the potential transport of floating pollutants like sewage effluent or oil spills. We investigated spatial and temporal patterns of along shore ocean transport by deploying buoyant wooden drift cards from three locations along the West coast – Humboldt and San Francisco bays in California, and Willapa Bay in Washington. The original objective of this study was to examine the potential transport of invasive cordgrass (*Spartina spp.)* propagules from these heavily infested estuaries. However, results from this study may also provide useful insights into the potential transport of marine organisms, including those potentially released during ballast water exchanges in near shore environments.

Drift card releases were conducted on a monthly basis between September 2004 and August 2005 with 7,200 cards released in total (200 cards per release, per site). Cards were coded with a number denoting release location and date as well as reporting instructions for beach-goers who recovered the cards as they washed ashore. In an effort to minimize the percentage of cards entrained in their bay of origin, all releases were conducted within two hours of the local high tide. Reporting rates were high, averaging 42% from Willapa Bay (WB), 26% from Humboldt Bay (HB) and 44% from San Francisco Bay (SF). SF recoveries showed nearly 30% of cards found within the bay itself; of those found along the coast, the frequency of recovery decreased

notably with distance. A somewhat similar pattern emerged for releases from HB and WB, although significantly fewer cards were found within the bay of release and the maximum distance of transport was considerable higher from these two sites. Seasonal pattern of direction, distance and velocity were also evident and generally followed known patterns of ocean currents.

Because this study only spanned one year, it does not account for inter-annual variability. Unique conditions in the Pacific Northwest during the study period may indicate the results underestimate typical southward transport. Drift cards are useful for estimating surface currents only and these data should be used with caution in regards to deep-water transport.

Questions and Answers:

Q1: In San Francisco Bay, approximately where were drift cards deployed?

A1: In San Francisco, drift cards were released from the Golden Gate's south base. While we would like to have used a boat to release the cards directly in the channel, we stood on the shore and released the cards by tossing them towards the channel.

Q2: Were drift cards transported among bays?

A2: Only a few Humboldt Bay cards were found in Willapa Bay and a few Willapa Bay cards were found in Grays Harbor. In addition, some Humboldt Bay cards were also found south in the Eel River. But these few cards represent the only among bay exchanges of drift cards.

> ***Q2 follow-up:*** Other than the few instances mentioned above, were a majority of the cards found in estuaries?
>
> ***A2 follow-up:*** No, most cards were found along the outer coast. My personal theory is that cards float in the surface waters. As a result, fresh water lenses flowing out of estuaries push these surface waters and cards away from estuaries and out onto the outer coast.

Q3: Were any hitchhikers (e.g., barnacles) found on the drift cards?

A3: Yes. In five cases, goose neck barnacles colonized the drift cards.

Q4: Because reporting drift card landings involves having people around to find them, have you examined whether finding cards (i.e., transport trajectories) correlates with human populations along the coast?

A4: For the purposes of this study, no. In a different study in Puget Sound, researchers failed to find any correlation between remoteness and the number of cards found. But the absence of a correlation may not hold along the outer coast where remoteness is much greater than in Puget Sound.

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5. Application of the GNOME Oil Spill Trajectory Model.

Glen Watabayashi., NOAA. Seattle, Washington.

Abstract: not submitted

Questions and Answers:

Q1: Will you describe the trajectory mathematic schemes involve in GNOME?

A1: GNOME does not generate current or wind data and acquires these data from external sources (e.g., The National Weather Service). The user will then provide GNOME with a contour map of the shoreline. With these data, GNOME will indicate how far and where a particle would move at a given location. The model has specific built-in properties for floating oil, and the user can turn these properties off.

> ***Q1 follow-up:*** Does GNOME contain any kind of eddy diffusivity?
>
> ***A1 follow-up:*** Yes, GNOME has a horizontal mixing parameter that is set by the user. In the 3-D version, GNOME has two different algorithms that estimate vertical spread.
>
> ***Q2 follow-up*:** For the 1-D surface model, could GNOME appease the biologists by focusing on one particular forcing field and incorporating a daily migration cycle? For example, could GNOME predict particle trajectories at the surface waters during the morning and then also predict the particles' trajectories 12 hours later when the particles are 10 meters deep?
>
> ***A2 follow-up:*** Yes, GNOME can force particles up and down in the water column. If the experts tell us how things go up and down in the water column, then we can simulate that movement when using GNOME. For example, we are currently incorporating vertical movements into GNOME to study harmful algal blooms in the Gulf of Mexico.

Discussion Panel Involving Presenters Bollens, Howard, Grosholz, Shanks, and Watabayashi

Comment 1: The ordering of this morning's presentations was fabulous. Fist, we heard how biological behavior may offset alongshore and cross-shore transport. Second, we were shown a cartoon depicting how water is transported onshore along the Pacific Coast, and consequently, a diagram of zones where ballast should not be exchanged. While these exclusion zones lack supporting data, they are good starting points or hypotheses. Fourth, we introduced to an inexpensive tool (drift cards) that can be used to collect transport data. Finally, we saw how a model can use current and wind data to predict trajectories. I commend the organization of talks in this morning's conference.

Q1: Will you address the inherent paradox that exists between today's and yesterday's talks. Yesterday, we talked about the speed at which alongshore and cross-shore transport can occur. Today, we talked about biological behaviors that can retain or move organisms onshore. In addition, other talks this morning demonstrated that drift cards and invasive species populations move much slower than transport processes predict. Given that an invasive species needs for whole populations to successfully recruit, rather than a few rogue individuals, what accounts for the difference?

A1(a): Dennis Crisp's published work concerning the spread of the barnacle *Elminius modestus* around England can help answer your question. In his study, Crisp had two types of information that answered two critical questions. First, where are larvae dispersing? Second, have population sizes onshore reached a critical mass that allows them to reproduce and add more larvae to the water column so that this species can continue its spread around England? So, things are generally moving more slowly than currents because a species' spread depends on these two factors. A more simple answer is that larvae do not behave like water, and creatures do many simple things to have them selves retained or exported. For instance, creatures can stay near the bottom where currents are much slower in order to be retained. In addition, creatures may vertically migrate to take advantage of shearing currents that may help them maintain their positions. Finally, creatures may ontogenetically differ in the vertical migration behavior. As a result, larvae of different species occupy differing parts of the water column that move in unique directions. A variety of west coast species are found over the continental shelf as adults and these adults spawn in winter and produce larvae with long larval periods spanning the Davidson current period, the Spring Transition, and the Upwelling period. This long larvae period then suggests that these larvae first go north with the Davidson current and then go south with the California current. In the end, these behaviors suggest that creatures are potentially exploiting the variability in the oceanography to limit alongshore dispersal.

A1(b): The drift card study was instructive because it suggested that entering estuaries may be more difficult that we think. But this drift card and many other studies are anecdotal. In El Nino years, we saw high recruitment of invasive species in central California estuaries. In contrast, we saw low invasive species recruitment in non El Nino years. As a result, we may conclude that El Nino years have more down-welling and onshore transport currents making it easier to for species to invade an estuary. While invasive species may have evolutionary behaviors that allow them to be transported to an estuary, their getting into an estuary is much more difficult. As a result, invasive species likely must rely on down-welling events that are much more common during El Niño's.

A1(c): As illustrated by the green crab invasion, green crab numbers were high in many central California estuaries. But, on a population level, these numbers were likely too low and too few larvae survived and returned to replace the adult populations. While this species comes from an upwelling regime and is probably doing the correct thing in the NE Pacific, its spread has likely been limited by failing to reach a critical mass inside estuaries.

Q2: To determine whether non-native species are moving from one particular estuary to other estuaries, can you take some data like Henry Lee's, which shows that estuaries contain different non-native species, and overlay these data with drift card results and current information?

A2(a): Because larvae naturally and unnaturally move among estuaries, your question would be difficult to answer. The current distribution of species is the result of both natural and unnatural events occurring over time. We do not have a good idea of what got where and when.

A2(b): Rephrasing part of Greg Ruiz's presentation, two patterns exist. First, many species fail to move among estuaries. Second, species that do move lack a dispersing larval stage that can be picked up in ballast. As a result, we expect species distributions to be a certain way, but the actual distributions differ because human mediated transported overwhelms physical and biological patterns.

A2(c): As Ted Grosholz is currently doing, investigating how new invasions spread is a more worth while approach that can answer your question. Such an approach allows one to see the when a species arrives and how quickly it spreads. Because these data are collected within the time of our observations, we can determine whether the species is jumping form estuary to estuary via shipping or natural dispersion.

Q3: If you look at the most abundant and frequent estuarine invader, most have direct or reduced developmental strategies. As a result, successful invaders having larval stages may be the exception instead of the rule. If so, then perhaps we should focus more attention on other transport mechanisms. For example, the drift card presentation suggests that seagrass and salt marsh rack may provide the means by which direct developing species are exported from one estuary to the next.

A3: Within the framework of ballast water and ABWEA's, ballast usually contains little seagrass or salt marsh wrack. But once a species establishes itself in an estuary, seagrass wrack may be a dominant vector by which direct developing species transport themselves among estuaries.

Q4: After listening to yesterday's and today's talks, I feel that we do not understand how to quantify a location's risk regarding it being an ABWEA and potentially spreading invasive species. Is my assessment incorrect? And, what critical pieces of information are needed to quantify a location's risk level?

A4: Yes, I cannot provide you with a probability that something released at various offshore locations will wind up onshore. But because we are looking for broad scale generalizations regarding where to exchange ballast, the situation is not as bad as you described. In addition, because ballast exchange practices are being managed now, we cannot wait to advise managers until we have collected more data and improved our understanding. Instead, we should provide managers with our current knowledge and advice. From a biological perspective, managers have made good conservative decisions by regulating that international vessels exchange beyond 200 nm offshore. As far as ABWEA's are concerned, I gave my best guess. Unfortunately, we will not know how locating an ABWEA's at various positions between 50 – 200 nm offshore will affect the probability of invasive species being transported onshore.

Q5: Regarding the relative risk issue, the emphasis should be on the level of resolution concerning the word 'relative'. In current Federal legislation, statutory language exempts ABWEA's from being designated if an ABWEA may create any adverse impacts. Because exchanging ballast in any location will pose some risk of an adverse impact, the decision boils down exchanging ballast somewhere offshore (between 50-200 nm) versus exchanging ballast at the berth in Coos or San Francisco Bay. If the legislation's statutory language goes away, then the decision of where to exchange becomes even more crucial. As I see more talks at this workshop, the more I think that a better decision must be to exchange ballast at some distance offshore, where the probability of something getting into an estuary from 30 nm is much lower than the 100% probability associated with exchanging ballast directly in an estuary.

A5(a): In a 1963 study conducted along the NE Pacific coast, multiple drift bottles were released at different distances offshore. Data showed that very few bottles returned to estuaries, especially from positions north of northern California. Beyond 40 nm, bottles failed to return at all. In southern California, returns still occurred up to 160 nm offshore.

A5(b): Getting back to Question 5, exchanging ballast away from the estuary is better than exchanging inside an estuary. But a vessel could carry invasive species that originated from a different continental shelf. If these species are emptied on our continental shelf, they may easily survive and establish them selves.

Q6: One assumption we face when deciding to discharge ballast and organisms offshore is that doing so lacks adverse impacts. While I accept that continuous coastal discharges of zooplankton and benthic organisms may create few problems, I wonder about the continually introducing protists and bacteria, which may impact autotroph communities. For example, we all agree that transporting soil and microorganisms from central California to another terrestrial system is a bad idea. Similarly, moving lots of coastal water and microorganisms around to different coastal regions is also likely a bad idea.

A6: Your comment raises two points. First, which and how many microorganisms are being spread around via ballast discharges represents a big black box, especially since one liter of water can have billions of microorganisms.

> ***Q6 follow-up:*** Building on Question 6, perhaps discharging ballast on the continental shelf may be better than exchanging ballast directly in an estuary since continental shelves have more diffusion and dilution processes than estuaries?
>
> ***A6 follow-up:*** No, the answer depends on what species are discharged. If a vessel takes on a species that prefers to not be in an estuary, then releasing this species on the continental shelf would facilitate its invasion. For example, when a Coos Bay vessel loads ballast, the vessel will take on many different species. Some species will be estuarine and some will be coastal. Because the vessel will take on ballast while being tied to a wharf, the vessel will also take on subtidal coastal species. So, in addition to worrying about invasive estuarine species entering our estuaries, we also need to worry about invasive coastal species settling on our continental shelf. The continental shelf on the east coast has an excellent, bad example of a coastal species invasion (i.e., Didemnum sp.).

Q7: When thinking about oil spills, the most frequently asked question is where should a vessel spill oil? In other words, is it better to spill offshore in port? From what I've heard, San Francisco Bay is already toast and the inner portions lack large currents. So, would it be better to spill oil or invasive species in SF Bay than to spill oil/invasive species offshore in a more pristine environment like the Farallon Islands?

A7(a): Because oil spills are easier to clean up than biological invasions, introducing invasive species does not equal spilling oil.

A7(b): If an oil spill occurs in SF Bay, commerce will shut down. But if an oil spill occurs along the Farallones, more time is available to clean up the spill before commerce will be affected. Despite more ecological damage occurring along the Farallones, conventional wisdom suggests that oil spills should be kept offshore to facilitate clean up efforts and to protect commerce. With invasive species, the same scenario applies and the decision will be based on the types of resources affected.

A7(c): The species that most vessels take on and then discharge via ballast will be estuarine. If our goal is to avoid exchanging ballast in high risk places, then discharging estuarine species into another estuary poses the highest risk. Therefore, preventing such discharges should be our first priority. Because plumes can help estuarine invasive species migrate into an estuary, exchanging ballast in plumes represents the next riskiest discharge option. Consequently, our second priority should be to exclude discharges from occurring around or near estuarine plumes. Because larger estuaries have larger plumes than smaller estuaries and because larger plumes can deliver more concentrated larvae back into an estuary than smaller plumes, preventing ballast exchanges near the largest estuaries should be our third goal. While acknowledging that exchanging ballast over the Continental Shelf poses some risk, I argue that our overall goal will be served well by establishing priority exclusion areas based on their level risk.

A7(d): The last comment suggests an exclusion hierarchy: avoid estuaries, then avoid estuarine plumes, then avoid the continental shelf/slope.

A7(e): Regarding the noting that exchanges in the open ocean pose relatively less risk than exchanging near estuaries, many open ocean plankton species are spread widely in ecological time and space. In British Columbia, some research also just showed that continental shelf eddies flush tremendous volumes of water off the shelf and up current into the open north Pacific. These waters then relax and release over a two year period,

A7(f): With respect to exchanging ballast in the across shore direction, we all agree that exchanging farther offshore is best. But more interesting and challenging will be deciding where to exchange ballast in the along shore direction. In today's discussion, many have strongly argued that exchanges near major estuaries and plumes should be avoided. If avoiding larger estuaries requires that more exchanges take place near smaller estuaries, we will have a hard time deciding which smaller estuaries should receive these ballast exchanges. In addition to public resistance (i.e., not in my back yard), most small estuaries occur in areas where we know less about community dynamics and retentions zones. As a result, we will lack research to guide us on choosing small estuaries with the lowest risk. So, choosing this spot over that one in the alongshore direction is much more challenging.

A7(g): While we all agree that ballast exchanges exist along a continuum of risk, we seem to disagree what level of risk along the continuum is acceptable. At least in Washington, we have drawn that risk level at 50 nm. As of 2007, unexchanged ballast cannot be exchanged inside estuaries. Washington has also asked the industry to design additional alternatives for managing ballast water such as not exchanging ballast or treating ballast water before exchanging.

A7(h): While Washington may have established a regulation that reflects the level of risk that it can accept, I doubt that Washington has actually calculated the risk probability associated with its regulation. When decision makers lack a common risk scale that can be used to compare different regulation options, deciding how to best reduce risk becomes more complicated and less transparent.

A7(i): We need to clarify that the 50 nm regulation is not an ABWEA. Rather, this state regulation requires that coastal vessels exchange ballast beyond 50 nm. Again, this workshop is focusing on finding ABWEA's where foreign vessels can exchange if for whatever reason they failed to do so before reaching 200 nm offshore the U.S. coast. In my opinion, the 50 nm regulation should apply to coastal vessels only.

A7(j): Returning to the original question posed (Question 7), San Francisco bay does not have every invasive species found on the Pacific coast. As a result, San Francisco bay should not receive everyone else's water. For my second point, we all agree that exchanging farther offshore is the best option and exchanging in ABWEA's is a third rate option for special situations. When developing the ABWEA regulation, we should carefully design how vessel operators can use ABWEA's. For instance, the regulation must prevent vessel operators from freely using the safety exemption and an ABWEA just because they do not want to conduct exchanges farther offshore.

A7(k): For California, there is no blanket regulation where vessels can freely exchange in an ABWEA. Instead, California has and will continue to regulate alternate ballast exchanges on a case-by-case basis. My fear is that a federal ABWEA regulation would allow more vessels to increase the number of times that they exchange ballast closer to or with 50 nm offshore.

Q7: Based on all of the information presented at this workshop, what will vessel operators prefer to do?

A7: Foreign vessels exchange ballast during transit. As a result, foreign vessels will likely not use ABWEA's because their use will increase transit time by idly exchanging ballast in one location. But during heavy weather, foreign vessels may see an ABWEA as advantageous. When weather becomes heavy, vessels will usually wait out the storm before beginning their voyage. In such a scenario, a foreign vessel will be idle anyway and could take this time to exchange ballast in an ABWEA.

> ***Q7 follow-up:*** Will coastal vessel operators use ABWEA's?
>
> ***A7 follow-up(a):*** For coastal vessels, Pacific states have only a few problem vessels that fail to comply with federal and state ballast exchange regulations. The majority of these problem vessels originate from Mexican and South American ports. As a result, I would like for this workshop to discuss how South American currents and bathymetry can influence the amount of invasive species that these problem vessels may upload in their ballast. While these Mexican and South American vessels are not fully complying with regulations, they are exchanging ballast in approximately 2000 m deep water. Therefore, these problem vessels are intending to comply with our regulations. Another group of problem vessels includes those operating within the passenger industry. Due to the legislation's language regarding safety exemptions and delays, passenger vessels are expected to remain a problem.
>
> ***A7 follow-up(b):*** Because a small number of transoceanic vessels request ballast exchange exemptions, ABWEA's will only affect a small number of ballast exchanges.

Our main ballast exchange problem, however, concerns a very large number of coastal vessels.

SECTION 4: Ballast Water Organisms and Threats to Habitat and Fisheries Resources in the EEZ

1. Off the Beaten Track: Invasion of "Minimally Exposed" Estuaries in the Pacific Northwest

Henry Lee, US EPA, Newport, Oregon.

Abstract: The larger estuaries on the Pacific Northwest coast of the United States such as the Columbia River and Coos Bay are heavily invaded, primarily through ballast water discharges, hull fouling, and aquaculture of exotic oysters. Much less is known about the extent of invasion in the smaller estuaries not directly exposed to these vectors. To assess the nature and extent of invasion in this type of estuary, we undertook a study of the soft-bottom communities in "minimally exposed" estuaries in the Columbian Biogeographic Province (Cape Mendocino, CA through the Strait Juan de Fuca, WA). "Minimally exposed" estuaries are defined as those that either have had no or only minor historical exposure to international shipping or to aquaculture of exotic oysters. In comparison, "exposed" estuaries are those that have international shipping ports and/or extensive oyster aquaculture. Data for this comparison were synthesized from the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) surveys in 1999, 2000, and 2001, from a survey of a suite of minimally exposed estuaries in 2002, and an intensive study of a single minimally exposed estuary (Siletz Estuary, OR) in 2003. In total, nine exposed estuaries and 22 minimally exposed estuaries were sampled.

Preliminary analysis identified at least 17 nonindigenous species in the minimally exposed estuaries. Two of these were freshwater/brackish species (*Corbicula fluminea* and *Potamopyrgus antipodarum*) while the other 15 nonindigenous species were marine/estuarine. Of the marine/estuarine invaders, the amphipod *Grandidierella japonica* and polychaete *Hobsonia florida* were both abundant and wide-spread among estuaries while the polychaete *Pseudopolydora kempi* and bivalve *Mya arenaria* were wide-spread and moderately abundant. All these marine/estuarine invaders were also among the most abundant/frequently occurring invaders in the exposed estuaries. Although approximately twice as many nonindigenous species (32 species) were collected in the exposed estuaries, the nonindigenous species constituted about 20% of the number of native species in both classes of estuaries. However, nonindigenous species were relatively more abundant in the exposed estuaries. Forty-four percent of the stations in the exposed estuaries were classified as moderately to highly invaded compared to only 20% of the stations in the minimally exposed estuaries. This preliminary analysis suggests that exposure to international shipping and/or oyster culture can increase the abundance and diversity of invaders but that at least some of the species introduced into the larger estuaries can disperse widely into other estuaries. As a result of this apparent regional dispersal of invaders from the exposed estuaries, even smaller "pristine" estuaries with no direct exposure to shipping or aquaculture are at substantial risk of invasion.

Questions and Answers:

Q1: To complete the database, what is your next step?

A1: In order to complete the database, we will need much more life history data on invasive species. Because we need information such as larval period lengths, collecting the life history data for all invasive species will be almost impossible. As a result, we will either guess a species' life history traits or we must extrapolate from the existing data we have on a few well known invasive species. To extrapolate, we must assume that our known invasive species represent a random subset of all invasive species. Once life history data is collected, we will combine these data with habitat type information. This goal will take at least one year to complete.

Q2: Because port-estuaries are large, data gathered from exposed or port-estuaries may be confounded by size or area. Using multivariate analyses, have you examined whether an estuary's area confounds your results?

A2: While we call these estuaries small, the distinction between large and small is not discrete. For example, an estuary like Netarts Bay, Oregon is relatively small but it contains oysters, which is a large estuarine characteristic. But because of its small size and consequent island biogeography effects, we can easily imagine that a small estuary will have fewer species than a larger estuary. As a result, percentage of invasive species in each estuary was normalized to the percentage of native species, where native species numbers represents an estuary's biotic potential. From these data, we found that exposed estuaries have ~ 17% invasive species and unexposed estuaries have ~12% invasive species. While exposed and unexposed estuaries differ in the percentage of invasive species, the difference is less than we expected. Because these results come from species-area curves, the data may be inaccurate. The accuracy of species-area curves depends on sample sizes, and one needs at least thirty samples before the ratio stabilizes.

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2. **Pacific Coast Groundfish Essential Fish Habitat (EFH) Interactive Mapper**

Van Hare, Pacific States Marine Fisheries Commission, Portland, Oregon.

Abstract: PSMFC hosts a number of projects that manage geo-referenced fisheries and aquatic habitat data. Using a common GIS infrastructure, these projects are able to publish their data through web-based, interactive mapping tools that allow users to view, query, and analyze spatial data without the need for GIS software or expertise. The Pacific Coast Groundfish Essential Fish Habitat (EFH) Mapper is an example of one such tool. Using a standard web browser, one can zoom to specific geographic areas of interest; display and query selected map layers related to Groundfish EFH, and create custom maps for printing.

The Groundfish EFH Mapper is available at http://marinehabitat.psmfc.org and provides access to map layers that may prove useful for identifying alternative areas for ballast water exchange, including:

- Areas designated as Essential Fish Habitat in the Final EIS
- Habitat Areas of Particular Concern (e.g. kelp, rocky reefs, corals, canyons)
- Ecologically Important Areas and the fishing closure types that apply to them
- Marine managed areas and conservation areas
- Exclusive Economic Zone and State jurisdictional boundaries

- Benthic substrate types (lithology, structure and habitat classification)
- Marine and terrestrial base maps (depth contours, latitude zones, roads, streams, etc.)

Future plans include the addition of NOAA nautical charts along with habitat suitability, fishing effort and fish catch data. The map viewer continues to evolve, serving the needs of policy makers, fisheries managers, scientists and the general public. Beyond publishing data related to the Groundfish EFH EIS, the overall project goal is to build a useful toolset for supporting ecosystem based approaches to fisheries and marine resource management.

Questions and Answers:

Q1: Does the Groundfish EEH Mapper contain a layer that can illustrate shipping lanes in the NE Pacific?

A1: At this point, no. But as part of an ecosystem tool to manage fisheries, we are adding NOAA nautical chart data. As a result, a future version of this Mapper will have shipping lane and buoy information. In addition, we will use nautical chart data to add base layers concerning open ocean marine environments. To add coastal zone base layers, we will use coastal TOPO maps based on USGS 24,000 scale Quad sheets.

Q2: Can you incorporate into the Mapper the data that has been shown and discussed throughout this workshop (e.g. 50 nm lines, shipping data, and oceanography)?

A2: While the Mapper described above focuses on groundfish, the Mapper's framework will allow us to add data including 50 nm lines, shipping lanes, recommendations, and other biological areas of concern.

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3. The Distribution and Abundance of Pelagic Fish Resources.

Robert Emmett, Northwest Fisheries Science Center (NMFS), Newport, Oregon.

Abstract: The distribution and abundance of pelagic fishery resources on the Pacific Northwest continental shelf is relatively well known. However, this is not true for pelagic fishery resources off the shelf (approximately 50 nm to 200 nm). Nevertheless, this offshore habitat is used by many species, some of which are commercially important. Offshore habitats are also an important spawning area for northern anchovy and Pacific sardine. Offshore areas have many species of small fish (e.g., Pacific saury, myctophids) which are prey for large predators, such as albacore tuna and sharks. Squids appear to play a very important role in the offshore environment, both as prey and predators. Migration, dielly, latitudinal, and longitudinal, plays an important role in determining the nekton species assemblages in this offshore habitat. The ballast water issues of primary concern in this habitat are the possible introduction of exotic diseases and parasites, and small plankton, especially in the Columbia River plume region.

Questions and Answers:

Q1: When examining essential fish habitat for salmon and other groundfish, have resource managers ever discussed the impacts of ballast exchanges?

A1: No.

Q2: Are Pacific sardines susceptible to the Australian sardine virus?

A2: While we are looking at some of the sardine's parasites and diseases, we are unaware of anyone specifically addressing how the Australian virus may affect Pacific sardines. Such research is needed.

Q3: Have any ROV surveys examined any offshore benthic habitats and quantified the presence or percent coverage of invasive species?

A3(a): Waldo Wakefield, who works at the Northwest Fisheries Science Center, has directed the ROV surveys in many benthic habitats. Waldo could answer your question.

A3(b): On board trawl and long-line vessels, we have observers who survey benthic sample baskets. In addition to recording all species within the basket, the observers will record the presence of invasive species.

> ***Q3 follow-up*:** where are these invasive species data?
>
> ***A3 follow-up(a):*** We have tons of invasive species data that you may look at.
>
> ***A3 follow-up(b):*** Like the recently discovered Humboldt Bay squid, fisherman will report any new invertebrate or fish to NMFS and the Oregon Fish and Wildlife. But the fisherman will most likely miss finding and therefore reporting smaller invasive microfauna.
>
> ***A3 follow-up(c):*** To understand whether ballast exchanges have introduced invasive species into offshore benthic habitats, we will need baseline ROV or other survey data indicating that prior to year X (or prior to receive ballast exchanges), a particular benthic location lacked an invasive species such as *Didemnum sp.* Without this baseline data, we cannot address how ballast exchanges are altering offshore benthic habitats. Therefore, offshore benthic surveys are desperately needed.

Workshop Attendees

Contact	Company	City	State
Kevin Anderson	Puget Sound Action Team	Olympia	WA
Susan Anderson	Pacific States Marine Fisheries Commission	Portland	OR
Michael L. Blanton	Pacific Northwest National Laboratory	Sequim	WA
Regan Blomshield	U.S. Coast Guard	Cleveland	OH
Stephen Bollens	Washington State University	Vancouver	WA
Robin M. Brown	Department of Fisheries & Oceans	Sidney	B.C.
Joan Cabreza	Environmental Protection Agency	Seattle	WA
Jeffery Cordell	University of Washington	Seattle	WA
Holly Crosson	University of California Sea Grant Extension	Davis	CA
Edward Dever	Oregon State University	Corvallis	OR
Nicole Dobroski	California Sea Grant Extension	Oakland	CA
Bob Emmett	NOAA/NMFS	Newport	OR
Richard A. Everett	U.S. Coast Guard	Washington	DC
Teresa Fairchild	Pacific States Marine Fisheries Commission	Portland	OR
Maurya Falkner	California State Lands Commission	Sacramento	CA
Blake Feist	NOAA Fisheries	Seattle	WA
Nissa C. Ferm	University of Washington	Seattle	WA
Randy Fisher	Pacific States Marine Fisheries Commission	Portland	OR
Edwin Grosholz	University of California, Davis	Davis	CA
Van Hare	Pacific States Marine Fisheries Commission	Portland	OR
Paul Heimowitz	U.S. Fish and Wildlife Service	Portland	OR
Russell P. Herwig	University of Washington	Seattle	WA
Vanessa Howard	Portland State University	Portland	OR
Pamela Jensen	NOAA/NMFS	Seattle	WA
David Kimbro	University of California, Davis	Bodega Bay	CA
Grant Kirby	Northwest Indian Fisheries Commission	Mt. Vernon	WA
Michael Kosro	Oregon State University	Corvallis	OR
Henry Lee	U.S. Environmental Protection Agency	Corvallis	OR
Vanessa Lowe	NOAA	Seattle	WA
Karen McDowell	San Francisco Estuary Project	Oakland	CA
Pamala Meacham	Washington Department of Fish and Wildlife	Olympia	WA
Michael Moore	Pacific Merchant Shipping Association	Seattle	WA
J. Frank Morado	NOAA NMFS	Seattle	WA
Carter Ohlmann	University of California, Santa Barbara	Santa Barbara	CA
Judith Pedersen	MIT Sea Grant College Program	Cambridge	MA
Sharon Perkins	Pacific States Marine Fisheries Commission	Portland	OR
Stephen Phillips	Pacific States Marine Fisheries Commission	Portland	OR
Russell Porter	Pacific States Marine Fisheries Commission	Portland	OR
Deborah A. Reusser	U.S. Geological Survey	Seal Rock	OR
Greg Ruiz	Smithsonian Environmental Research Center	Edgewater	MD
Alan Shanks	University Of Oregon	Charleston	OR
R. Kipp Shearman	Oregon State University	Corvallis	OR
Christina Simkanin	Portland State University	Portland	OR
Scott Smith	Washington Department of Fish and Wildlife	Olympia	WA
Keith Strieck	Washington Department of Fish and Wildlife	Olympia	WA
Martin K. Teachout	U.S. Coast Guard	Seattle	WA

John Veentjer	Pacific Merchant Shipping Association	Seattle	WA
Glen Watabayashi	NOAA	Seattle	WA
Chela Zabin	Smithsonian Environmental Research Center	Tiburon	CA
Bill Zook	Pacific States Marine Fisheries Commission	Shelton	WA

Recommendations and Summary of Discussion from the Alternative Ballast Water Exchange Area Workshop Working Group

Thursday, June 22, 2006
Seattle Washington

Prepared by Stephen Phillips, David Kimbro, and Dr. Edwin Grosholz

Participants:

Russ Herwig, University of Washington, Seattle, Washington
Scott Smith, Washington Department of Fish and Wildlife, Olympia
Pam Meacham, Washington Department of Fish and Wildlife, Olympia
Nissa Ferm, University of Washington, Seattle, Washington
Chela Zabin, Smithsonian Environmental Research Center, Tiburon, California
Regan Bloomshield, U.S. Coast Guard, Cleveland, Ohio
Stephen Bollens, Washington State University, Vancouver, Washington
Robin Brown, Department of Fisheries and Oceans, Sidney, British Columbia, Canada
Ed Dever, Oregon State University, Corvallis, Oregon
Robert Emmett, NMFS, Northwest, Fisheries Science Center, Newport, Oregon
Rich Everett, U. S. Coast Guard, Washington D. C.
Maurya Falkner, California State Lands Commission, Sacramento, California
Edwin Grosholz, University of California, Davis, California
Van Hare, Pacific States Marine Fisheries Commission, Portland, Oregon
Vanessa Howard, Portland State University, Portland, Oregon
David Kimbro, University of California, Davis, California
Michael Kosro, Oregon State University, Corvallis, Oregon
Henry Lee, U.S. EPA, Newport, Oregon
Carter Ohlmann, University of California, Santa Barbara, California
Judith Pederson, MIT Sea Grant College Program, Cambridge, Massachusetts
Stephen Phillips, Pacific States Marine Fisheries Commission, Portland, Oregon
Greg Ruiz, Smithsonian Environmental Research Center, Edgewater, Maryland
Alan Shanks, Oregon Institute of Marine Biology, Charleston, Oregon
R. Kipp Shearman, Oregon State University, Corvallis, Oregon
Susan Anderson, Pacific States Marine Fisheries Commission, Portland, Oregon

A. Introduction and Discussion

On June 22, 2006 a working group met to review information and make recommendations provided at the Alternative Ballast Water Exchange Area (ABWEA) Workshop (workshop) of June 20-21. The working group agreed that the purpose of the session was to summarize the findings of the workshop and to objectively discuss the issues influencing the designation of ABWEA's and to evaluate the potential areas possessing physical and biological characteristics that would prevent non-native species residing in ballast water from surviving or migrating to the U.S. coastline.

Discussion began with the issue of state versus federal ballast water management authority. Dr. Grosholz and others emphasized that the ABWEA issue should be kept in the context of the separate state and federal authorities managing intracoastal and transoceanic traffic. Dr. Everett agreed, stating that these are two regulatory issues and need to be treated separately. Please refer to **Appendix 1** for a synopsis of Canadian, West Coast state and federal ballast law.

Dr. Everett summarized some key points relating to the ABWEA issue as follows:

1. While federal law (National Invasive Species Act) contains provisions for ABWEA's, there currently are no designated ABWEA's in the U.S. EEZ. However, there may be a need for ABWEA's because vessels originating outside the U.S. EEZ sometimes fail to exchange ballast in mid-ocean waters for safety and mechanical reasons.

2. The current federal ballast management statutes are very clear in giving regional authority to the USCG (through the Captain of the Port[1]) to designate areas within 200 nm from shore where vessels can and cannot discharge ballast water if they failed to conduct an open ocean exchange. As far as we know this authority has never been used, perhaps because guidance on alternative ballast water discharge sites is lacking.

3. There is the potential for adverse biological and ecological effects on receiving communities if ballast water is exchanged in an ABWEA.

4. Logistically, the designation of ABWEA's raises issues related to vessel traffic management (safety) and practicality (sufficient area). Several issues must be addressed from a regulatory perspective, including cost (to establish the regulation and to the public), regulation life-time (given that ballast water exchange is "expected" to be phased out over the next decade), and enforceability.

[1] The Captain of the Port (COPT) is designated by the Commandant to direct Coast Guard law enforcement activities within a designated area of responsibility. A COPT enforces regulations for the protection and security of vessels, harbors, and waterfront facilities; anchorages; bridges; safety and security zones; and ports and waterways. For the West Coast the COPT's are: Los Angeles-Long Beach, San Diego, San Francisco Bay, Puget Sound, Portland, SE Alaska, Western Alaska, and Prince William Sound.

There was a discussion on the historical frequency at which vessels originating outside the U.S. EEZ seek safety exemptions and exchange water between 50-200 nm of the U.S. shoreline. It was pointed out that only a small fraction of vessels originating outside the U.S. EEZ exchange water within the 200 nm exclusion zone (note: please refer to "B.2 Bilateral Coordination – Mexico" later in this document) discussion earlier in this document regarding vessels from Mexico and countries further south). Using the 2005 data for Oregon and Washington Columbia River ports, Christina Simkanin (Portland State University) determined that only two out of approximately 800 vessels originating outside the U.S. EEZ exchanged ballast between 50-200 nm (**See Appendix 4**).

Dr. Ruiz reminded the group that two preferred ballast water management strategies include on-board treatment of ballast (though this technology is in the early development stages) and retaining ballast water (i.e. no discharge). Exchanging ballast water in any area will always have some potential to introduce a non-native species, and that exchanging ballast water within 200 nm or within an ABWEA is a suboptimal strategy since the potential for an invasion always exists. While exchanging ballast water may reduce a vessel's density of non-native species by 90%, the vessel's remaining non-native species' densities (i.e., 10%) may still exceed a discharge standard deemed acceptable by the Pacific states[2].

There was general discussion that while the identification of ABWEA's within 50-200 nm zone is seen as a Federal process, selecting ABWEA's may help coastal states refine their rules regarding the management of ballast water for coastal vessel traffic. For example, important coastal/ocean habitat areas such as the Columbia River plume, offshore sea mounts, marine sanctuaries among others should be ballast water exchange exclusion areas. (Please refer to **Appendix 2**: "Essential Fish Habitat and Habitat Areas of Particular Concern.")

Maurya Falkner said that the West Coast states' ballast water management rules differ in origin. Washington's and Oregon's rules are outlined in legislation and require legislative action for any modification; whereas California's management requirements were established via regulations and can be modified by the responsible state agency

Ms. Falkner said that the National Marine Sanctuary Program (NMSP) is preparing joint draft Management Plans and Environmental Impact Statements for the Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries. This joint plan contains language prohibiting ballast water discharge within the sanctuary boundaries[3]. In addition, she said that California's 50 nm ballast water exchange boundary was developed to protect these ecologically important areas as they fall inside the 50 nm. If for physical and biological reasons, the exclusion areas should extend more than 50 nm offshore, then state agencies (e.g., California State Lands Commission) may use information such as presented at this workshop to modify a state's existing near-coastal exchange zone limit of 50 nm.

[2] For example, the State of California is proposing a ballast water discharge performance standard for California waters that will require, among other criteria, that the discharge contain no detectable living organisms that are greater than 50 micrometers in minimum dimension. For further information go to http://www.slc.ca.gov/Division_Pages/MFD/MFD_Home_Page.html.

[3] To see the draft plan, go to http://sanctuaries.noaa.gov/jointplan/

It was agreed that the Columbia River plume shown on the working draft map needed to be redrawn over a larger area outside of 50 nm and that further climatological research was needed to see how far that plume extends over time. It was recommended that the plume map found in Hickey et al. (2005) be used for reference (See **Figure 1**).

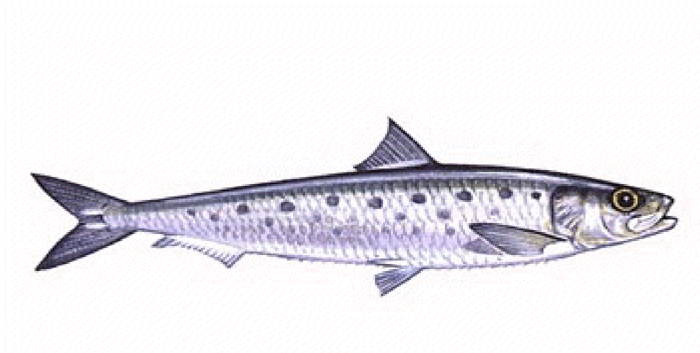
There was discussion on the risk posed by the movement of organisms that are picked up in the coastal zone between 50–200 miles and then transported along the coast and discharged in other ports or coastal areas. Dr. Alan Shanks did not think this was a problem on West Coast; but this was a more complex question for the East Coast. Dr. Shanks added that Cape Hatteras is a physical barrier that prevents movement of organisms and water between the North Atlantic Bight and South Atlantic Bight, so water moving from south to north has the possibility of moving organisms between biological provinces. In contrast, West Coast biological provinces (i.e., offshore oligotrophic waters versus the shelf eutrophic waters) have completely different biological communities, so transport across the shelf of a potential invasive species is less of an issue. In fact, Dr. Shanks added, this transport is a frequent natural occurrence during El Niño events.

Dr. Bollens suggested that exchanging ballast water during the daytime could reduce the number of species pumped into a vessel's ballast tanks. This is because many mesozooplankton species (size > 200 μm) migrate to the surface during the evening and to the bottom during the daytime.

There was discussion on the time of day that vessels conduct their ballast water exchange[4]. In response to Dr. Bollens' management suggestion, Dr. Everett and Ms. Falkner commented that many vessels exchange ballast water during the daytime and that California state law has good housekeeping (best management) practices that encourage industry to exchange during the day. The point was made that many vessels start their exchange and continue until finished, calling into question whether most exchanges occur during daylight hours. To verify that most vessels exchange ballast during the daytime, Dr. Everett referred to vessel logs submitted to the Port of Vancouver, British Columbia, by vessels transiting from Asia that showed very long distances between when a ballast exchange was started and when it ended. When industry was queried about why this might be, it was suggested that the Chief Engineer or Mate is usually in charge of conducting the exchange and they tend to work during the day.

Dr. Everett also commented that data entries in the Vancouver vessel logs have corresponding GPS positions. Federal and state agencies could enter this data into a GIS database and determine where exchanges took place. While discussing ballast water exchange best management practices and how agencies determine when and where exchanges typically occur, Dr. Everett cautioned that any best management practice recommendations developed here would diffuse the workshop's main goal, which is to investigate ABWEA's.

[4] Note: The time of day when ballast water exchange occurs is influenced by numerous variables such as time and distance of voyage (coastal versus transoceanic), type of ship (container, bulk), amount of ballast on board, and whether mechanical or safety problems arise.



Pacific sardine (*Sardinops sagax*)

B. Working Group Recommendations and Findings

*[Note: The recommendations below do **not** imply endorsement by the PSMFC, individuals, agencies, universities or other institutions that participated in the working group or workshop]*

B.1 ABWEA's: DEPTH AND DISTANCE FROM SHORE

In his presentation, Dr. Alan Shanks outlined four mechanisms by which water, and consequently non-native species, can be transported from the open ocean to the continental shelf or shore on the U.S. West Coast:

1. Classic wind-driven upwelling
2. Wind-driven surface currents (e.g., Langmuir Cells[5])
3. Upwelling jets and eddies
4. Movement of large estuarine plumes

Because the edge of the continental shelf on the West Coast is generally within 50 nm, a vessel that exchanges ballast water beyond 50 nm will usually pose a lower risk of introducing non-native species.

While the 50 nm limit can lower the risk of non-native species reaching the US West Coast, this distance limit may be an insufficient invasion barrier on its own. For example, a vessel that exchanges ballast water in areas outside of 50 nm offshore of Los Angeles, California would remain within waters shallower than 1000 feet (Southern California Bight). Dr. Shanks' presentation pointed out that throughout the Bight, there appears to be good mechanisms of

[5] Langmuir circulation forms in the surface layers of oceans, lakes and ponds when winds of moderate strength blow over them, and manifest as a parallel series of counter rotating vortices that more-or-less align with the wind. Since they act at the surface to concentrate flotsam, seaweed and air bubbles into streaks. Langmuir circulation is important because it acts like a giant mixing machine in the top layer of the ocean – the interface between the atmosphere and the deep ocean.

retention and cross-shelf shoreward larval transport, thus making the Southern California Bight a poor location for ballast water exchange.

***RECOMMENDATION I*:** **In general, ABWEA's should be established no closer than 50 nm from shore and in waters at least 1000 m in depth.**

> **Recommendation IA:** In order for vessels operating within Southern California to comply with Recommendation 1, their exchanges must occur approximately 50 nm offshore of the Channel Islands.
>
> **Recommendation IB:** For most of the Pacific Coast region depth increases rapidly beyond 50 nm offshore and the continental shelf. Consequently, extending the minimum depth requirement from 200 m to 1000 m would only marginally increase the distance offshore that vessels must travel to exchange ballast.

B.2 BILATERAL COORDINATION – MEXICO

According to Ms. Falkner, in 2004 ballast water discharges in California waters totaled 7,430,405 metric tons. Four percent of that total (349,606 metric tons) did not undergo any exchange or underwent exchange in areas other than 200 nautical miles from shore. In reviewing this data, most (92.3%) of the noncompliant ballast water discharged originated from Mexican or Central American waters. While most of this ballast water had undergone some form of an exchange, it was not a legal exchange because it was less than 200 nm from shore. The working group recognized that this workshop failed to consider the physical oceanography and shoreward transport mechanisms operating in Mexico. For example, Dr. Shanks said the oceanography of the Baja Peninsula is similar to southern California until about two-thirds to three-quarters of the way down the Baja Peninsula (North of La Paz). At that point, there is a sharp front where subtropical waters come up from the south.

***RECOMMENDATION II*:** The working group recommended that a workshop be convened that is modeled after this ABWEA workshop and includes Mexican officials as participants. The Proceedings from this workshop could be used to help establish recommendations and/or exclusion zones that reduce the number of non-native species introduced to both U.S. and Mexican waters.

B.3 LOCATING ABWEA's – CONSIDERATION OF ECOLOGICAL FEATURES

Along the Pacific coast, major estuaries and rivers create plumes that often extend more than 50 nm offshore (**see Figure 1**). The Columbia River plume is an important ecological feature and a key nursery area for juvenile salmon and other species. Because the salinity, temperature, and density of these plumes differ from that of the surrounding coastal water, the plumes remain as intact features in the open ocean.

As seasons and weather patterns change, plumes can vary their size and direction. Depending on their size and direction, plumes may connect and create very large areas. In addition, when the direction of wind stress changes, currents can transport these plumes and associated larvae back to their initial estuarine and river sources (see Dr. Dever's workshop presentation). As a result, if a vessel exchanges ballast in a river plume, then non-native larvae can be easily retained in the plume and potentially transported back into estuaries and rivers.

Seamounts are often associated with diverse marine species assemblages. Because some submarine features or seamounts are located beyond 50 nm and surface to less than 200 m (e.g., Bowie Seamount), seamounts can be exposed to ballast water containing non-native species that vertically migrate. Dr. Bollens stated that some of the large zooplankton species vertically migrate in the water column deeper than 200 m (see Dr. Bollens presentation), and that some organisms can migrate more than 500 meters. These organisms include larger crustaceans, shrimp, decapods, and small fish such as myctophids (lanternfishes). Therefore a depth limit of 200 meters is not a good cutoff number and rather, 500 meters makes a lot more sense. It was mentioned that larger organisms are less likely to get sucked into a ballast tank because they can avoid sheer gradients. Also, copepods are the most common organism in ballast water samples, and that amphipods and decapods are extremely rare.

The working group advised that exchanges should be prohibited near submarine features such as seamounts. Dr. Brown added that such an exclusionary process is being considered for the proposed Bowie Seamount Marine Protected Area in British Columbia (in which there is a seamount that comes within 40 meters of the surface). For locations of some of the Pacific Coast seamounts please refer to **Figure 2.**

In addition to prohibiting exchanges near certain physical features (e.g., plumes and sea mounts), the working group also discussed excluding exchanges near spawning or feeding grounds of important fisheries. One prominent U.S. fishery that was discussed was the Pacific sardine (*Sardinops sagax*). In complying with Recommendation 1 (50 nm and 1000 m), vessels could still introduce non-native species into sardine spawning habitat (**See Figure 3**), as sardines often aggregate more than 50 nm offshore**.** As discussed earlier, the herpes virus in the 1990s killed more Australian sardines over a larger area than any other previously reported pathogen. There is a concern is that Pacific sardine stocks could be infected by a similar virus introduced by ballast water from vessels originating outside the U.S. EEZ.

RECOMMENDATION III: **Establishment of ABWEA's should avoid major estuary and oceanic river plumes, subsurface physical features (e.g. seamounts), and known fishery habitats.**

> **Recommendation IIIA:** The working group concluded that exchange zones should not be established around oceanic plume areas.
>
> **Recommendation IIIB:** The working group advocated that seamounts which surface to relatively shallow depths be placed in a zone that excludes ballast exchanges.

Recommendation IIIC: Protecting important offshore benthic and coastal environments will require that vessels exchange ballast in water deeper than the depths to which zooplankton migrate; this depth was deemed by the working group to be 1000 m.
Recommendation IIID: Because of potential invasive species impacts such as disease transmission, Essential Fish Habitat (and Habitat Areas of Particular Concern) or other important natural resource areas should be avoided when locating AWBEA's.

B.4 ECONOMIC IMPACTS OF INVASIVE SPECIES

The movement of invasive/pathogenic organisms have adversely impacted economies by degrading marine habitats and important fisheries. Non-native species that have harmed subtidal marine populations and communities include a tunicate (*Didemnum* sp.) on Georges Bank off the Massachusetts coast, a herpes virus affecting sardines (*Sardinops sagax*) in Australia[6], and invasive algae (*Gracilaria salicornia* and *Kappaphycus alvarezii*) impacting Hawaiian coral reefs. Another concern was raised regarding the Viral Hemorrhagic Septicemia (VHS) virus, an extremely serious fish pathogen of fresh and saltwater fish. While it is wide-spread in the Pacific Ocean, a new and different strain has been found in the eastern Great Lakes. The U.S. Department of Agriculture implemented an emergency order in the Fall of 2006 to restrict the spread of this disease[7]. There is concern that ballast water is a possible fomite of this virus.

Dr. Chela Zabin discussed another invasive species -- the octocoral (*Carijoa riisei)* commonly called snowflake coral. It is a benthic invasive organism found in water deeper than approximately 70 meters, and it displaces and/or kills native benthic fauna, including the commercially valuable black coral (*Antipathes* spp.). It was likely introduced into Hawaii by ballast water. Dr. Bollens also pointed out other examples of ballast water-introduced species — copepods and other species such as the Asian or Amur River corbula clam (*Pomotaorcorbula amunrensis),* which have changed the San Francisco Estuary's lower food web dynamics and affected overall estuary productivity.

RECOMMENDATION IV: Invasive species can create significant ecological and economic impacts. Negative impacts associated with these invasions are important examples to convey to decision makers to underscore the importance of ballast water management programs when formulating policies on prevention and control.

[6] It is not known if the virus that caused the herpes outbreak was native to Australia or not, or if ballast water was the source of the virus.

[7] For further information on the emergency order go to http://www.aphis.usda.gov/vs/aqua/.

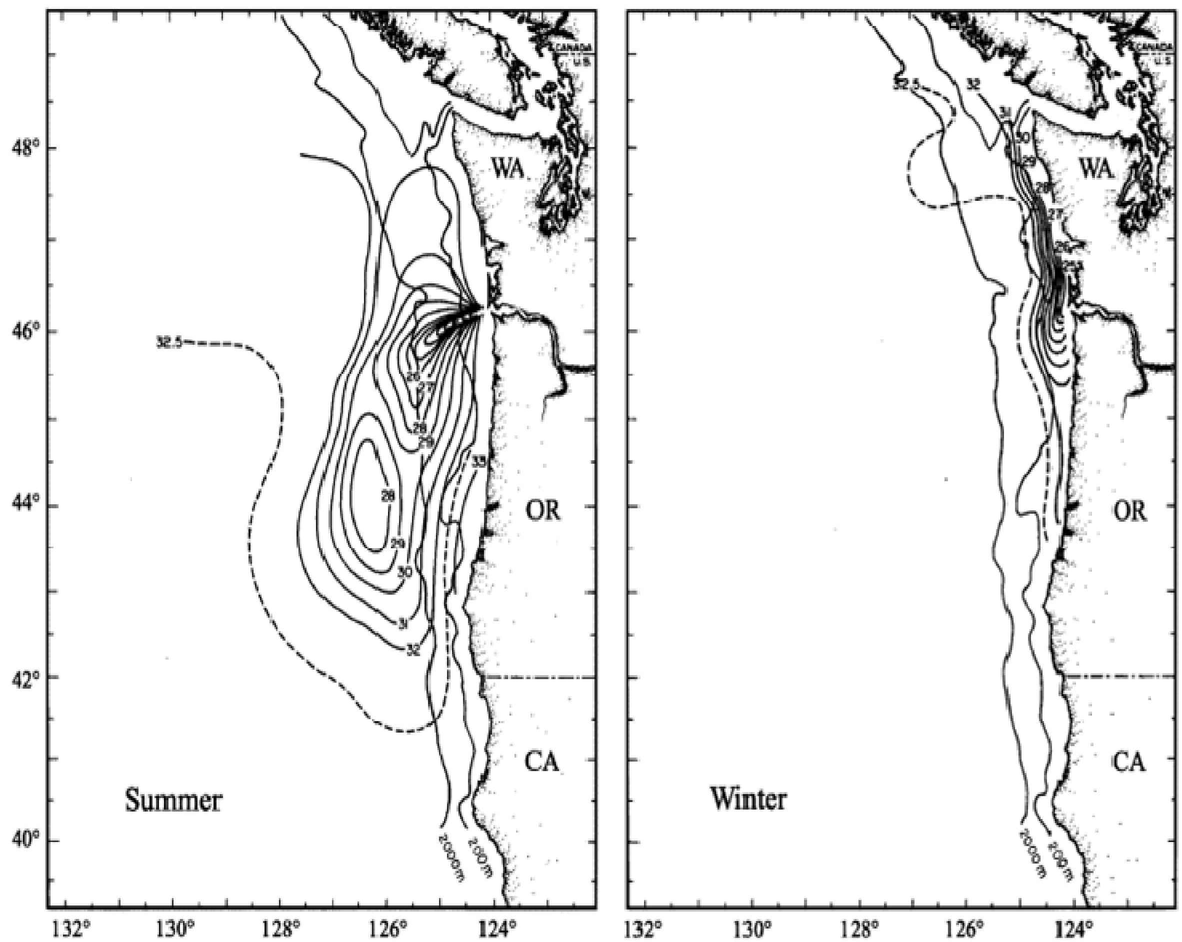


Figure 1: Traditional view of the seasonal location of the Columbia River plume: primarily southwest and seaward of the Oregon shelf in summer; primarily north along the Washington shelf in winter (Barnes et al., 1972). The plume is traced here in average surface salinity data (Source: Hickey et al., 2005).

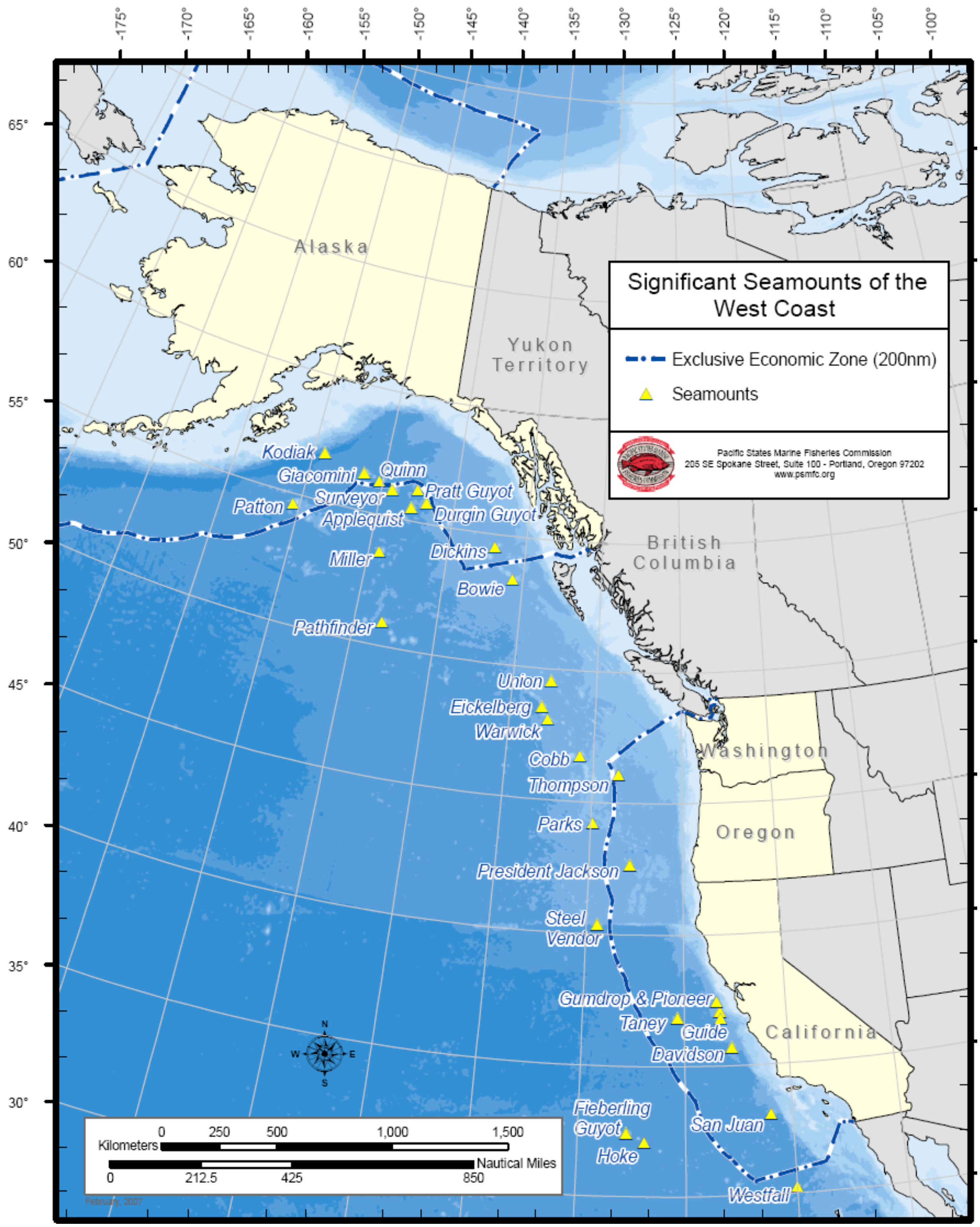


Figure 2: Significant seamounts of the West Coast/Northeast Pacific.

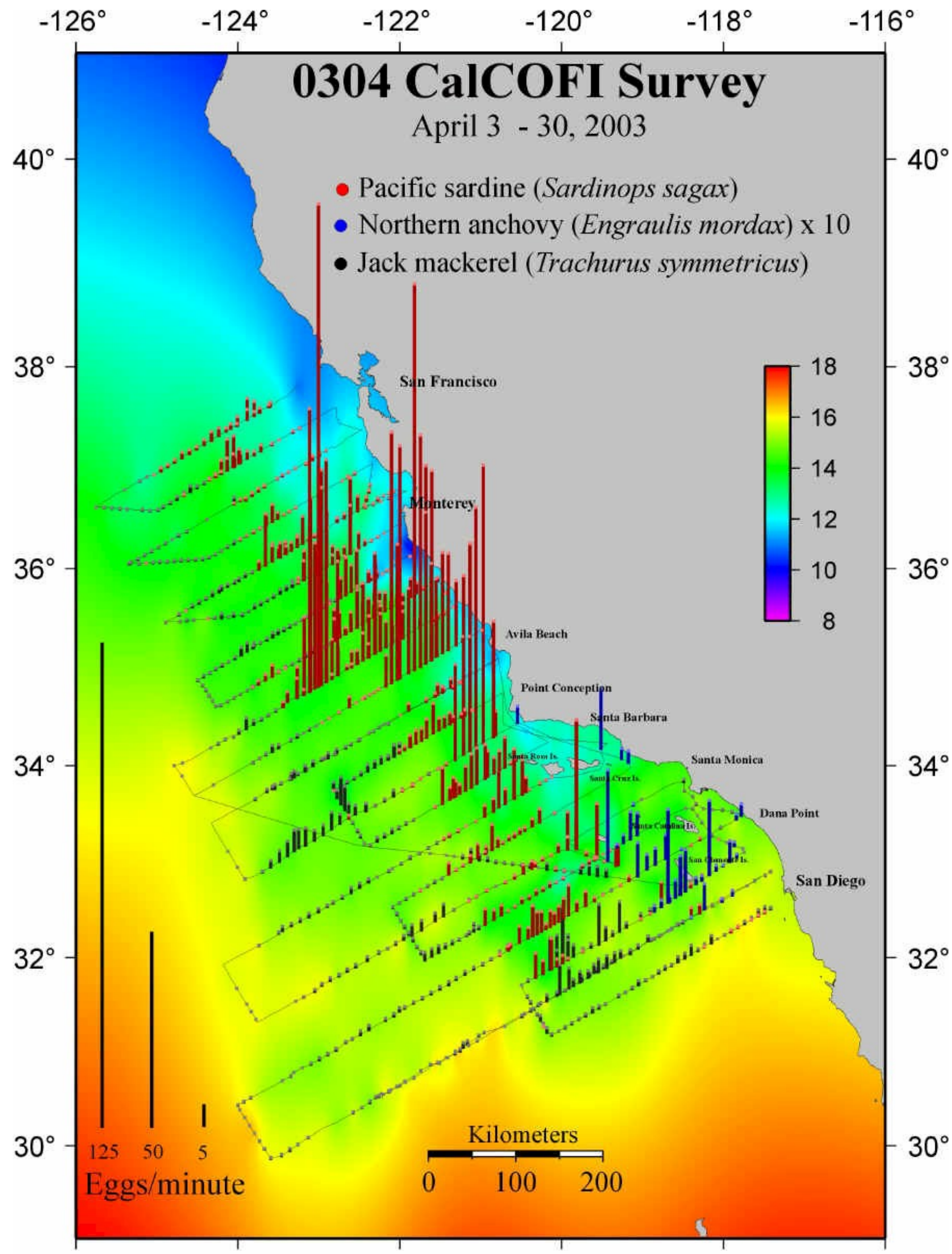


Figure 3: Sardine Egg Distribution Map from 2003. Annually, in April, the National Marine Fisheries Service's Fisheries Resources Division carries out an estimate of sardine biomass in U.S. waters using the Daily Egg Production Method (DEPM). The DEPM, used since 1996, employs a continuous underway fish egg sampler (CUFES), a device that continually collects fish eggs while the ship is underway, and also conventional vertical net tows (**Source: Fisheries Ecology Division (SWFSC/NMFS/NOAA).** http://swfsc.noaa.gov/textblock.aspx?Division=FRD&id=1121).

C. Summary Map, Additional Recommendations and Research Needs

1. **Figure 4** is a compilation of potential areas possessing physical and biological characteristics that are important to consider in identifying Pacific Coast ABWEA's from 50-200nm offshore. These include the Southern California Bight (Recommendation I); the Columbia River plume (Recommendation IIIA) and seamounts (see Recommendation IIIB). The Columbia River plume in Figure 4 is modeled after Hickey et al. (2005) and combines summer and winter locations. Hopefully the map will be of use in future ABWEA deliberations and should be seen as a work in progress.

Additional Recommendations and Discussion

2. Oregon, California and Washington State ballast water regulations require that ships on coastal shipping routes exchange water, which was taken up in a coastal port, at a point greater than 50 nm from shore to reduce the risk of port-to-port transfer of invasive species (**See Appendix 1**). Coastal ballast water exchange therefore occurs in areas identified in this workshop as areas to avoid – such as the Columbia River Plume. However, it is important to note that the 50 nm requirement for coastal exchange significantly reduces the risk of spread of invasive species between ports. No ballast exchange strategy completely eliminates the risk of transfer and establishment of invasive species and reduction in risk should be the goal of any ABWEA designation.

3. The working group concluded that the most significant non-native species risk is from coastal vessels moving ballast water up and down the coast. More specifically, a major problem may be the cruise ship industry.

4. Because the coastal shelves and open oceans of different regions can be physically similar, Dr. Brown and Dr. Shanks argued that vessels complying with Recommendation I could inadvertently increase open-ocean and coastal shelf introductions. For example, if a vessel originating outside the U.S. EEZ first exchanges ballast on Asia's continental shelf and, in compliance with Recommendation I (50 nm and 1000 m), subsequently exchanges ballast near North America's continental shelf (in an ABWEA), then well-adapted Asian species could invade North America's continental shelf. The issue of 'matching' open ocean exchanges, however, was considered by the working group to be a lower risk problem since potential invader densities decline in the open ocean and with depth. The working group recommended that transoceanic vessels should 'mis-match' their ballast exchanges. More specifically, ballast originating from a continental shelf or an estuary should subsequently be exchanged in the open ocean, rather than in another continental shelf or estuary.

5. Regarding the best management practice of 'mis-matching' exchanges, Dr. Ruiz questioned whether the working group should be concerned about a vessel that takes on ballast 150 nm offshore and then releases ballast when the vessel is nearshore or in port. In response, Dr. Shanks added that waters 150 nm offshore naturally and frequently mix with nearshore waters. Because these offshore and nearshore waters mix naturally, Dr.

Shanks contended that 'matching' 150 nm and nearshore exchanges poses a low risk for introducing non-native species into the nearshore.

6. Dr. Everett emphasized that the suggestions found in this workshop's proceedings would apply only to the Pacific coast. The Federal government would use the workshop's process and proceedings as a model that could be implemented by other regions in the U.S. to generate regional ABWEA recommendations.

7. If the federal government pursued establishing ABWEA's on the West Coast (and there is currently no indication that they will), additional data layers would be required to fully inform the process, such as Essential Fish Habitat for species such as Pacific sardine and coho and Chinook salmon. Also, any further work on ABWEA's on the West Coast must consider input from a broad range of interests, including all sectors of government, the maritime industry, environmental groups and the fishing industry. Integration of shipping lanes and transit times will also be critical in any ABWEA designation process. As an example, the 2003 ballast water exchange zone workshop held in Halifax, Nova Scotia integrated scientific information with issues and concerns from the shipping industry, environmental groups, and other stakeholders in the process of exploring potential alternate regions for ballast water exchange (Pederson 2004).

Research Needs

8. The working group expressed concern over establishing exclusion zones only around well-studied portions of the coast. For example, California coastal waters from Eureka to Pt. Arena are poorly studied and may contain seasonal plumes (which could be deemed ballast water exclusion zones). If vessels are prevented from exchanging in well-studied plume areas (e.g., Columbia River plume) and if these vessels subsequently exchange water more often in unstudied plume areas (e.g., Pt. Arena), then these exclusion zones may facilitate invasion in unstudied areas.

9. The working group also agreed that further climatologic and oceanographic research is needed to determine the extent of river plume areas.

10. In contrast to estuaries, the working group noted that relatively less is known about offshore benthic and pelagic invertebrates. Without taxonomic baselines, scientists and governments cannot detect whether species are invading offshore habitats. Mr. Jeff Cordell emphasized that there is not enough physical and biological information to set up ABWEA's. As a result, the working group recommended that further work be conducted offshore collecting biological samples which will be analyzed to generate an offshore species list.

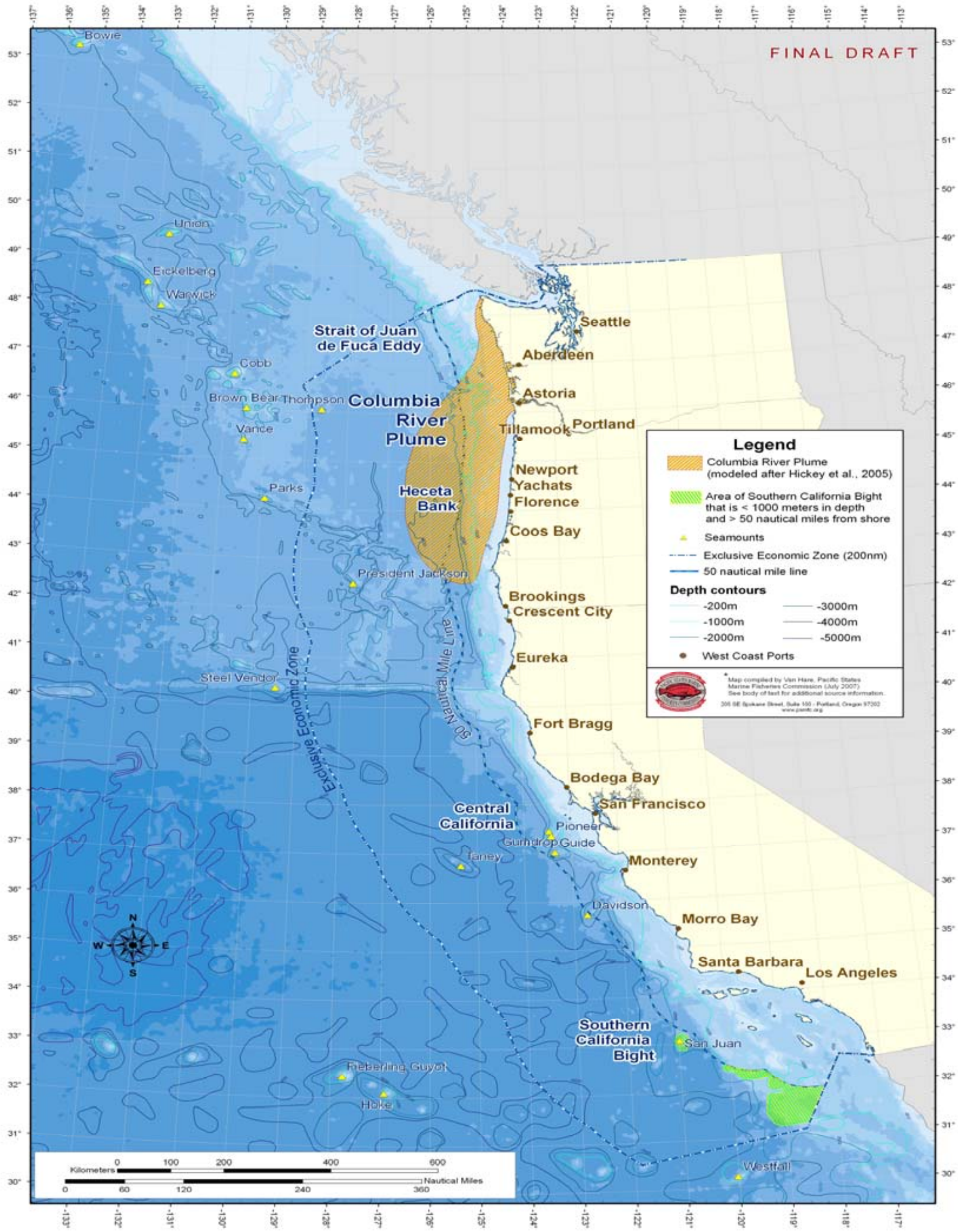


Figure 4: This map is a compilation of the potential areas possessing the physical and biological characteristics that are important to consider in identifying Pacific Coast ABWEA's from 50-200 nm offshore. These include the Southern California Bight (Recommendation I); the Columbia River Plume (Recommendation IIIA) and seamounts (see Recommendation IIIC). The Columbia River plume is modeled after Hickey et al. (2005) and combines summer and winter locations.

D. References

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2. Hickey, B., S. Geier, N. Kachel, and A. MacFadyen. 2005. A bi-directional river plume: The Columbia in summer. *Cont. Shelf Res.*, *25*, 1631–1656.

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4. PFMC (Pacific Fishery Management Council). 2000. Amendment 14 to the Pacific coast Salmon Plan (1997), Appendix A: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Portland, Oregon.

5. PFMC (Pacific Fishery Management Council). 2005. Amendment 18 (Bycatch Mitigation Program) Amendment 19 (Essential Fish Habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery. Portland, Oregon.

6. Simkanin, Christina. 2006. Ballast water exchange information for international vessels that arrived at Columbia River ports. Center for Lakes and Reservoirs, Portland State University. Portland, Oregon.

E. Appendices

Appendix 1: **Synopsis of state, federal and Canadian ballast water exchange regulations.** *[Note: Other ballast water management options besides exchange include retaining all ballast water on board the vessel or treating the ballast water with an approved shipboard or shore-based ballast water treatment system before discharging]*.

State of Oregon: Vessels of foreign origin are required to conduct exchange at least 200 nm offshore (or treat or retain). Vessels traveling within 200 nm of shore and entering Oregon from areas north of 50° N, or south of 40° N must conduct exchange at least 50 nm from shore in at least 200 m of water.
State of Washington: Vessels of foreign origin are required to conduct exchange at least 200 nm offshore. Coastally transiting vessels are required to conduct exchange at least 50 nm offshore, with the exception that exchange is not required if the ballast water is common to the state and has not been mixed with waters outside of the Columbia River system.
State of California: Vessels entering California from outside the EEZ are required to exchange ballast water 200 nm offshore or treat ballast water with an approved shipboard or shore-based treatment system. Vessels are required to exchange the ballast water in near-coastal waters (defined as more than 50nm from land and 200 meters in depth), before entering the waters of the state, if that ballast water has been taken on in a port or place within the Pacific coast region.
State of Alaska: No state mandated ballast water exchange requirements.
U.S. Federal: Exchange is required for vessels entering from outside the EEZ and is to be conducted more than 200 nm offshore. There is no federal management requirement for vessels traveling "coastally or wholly within the 200 nm EEZ.
Canada: Vessels arriving to Canadian ports with ballast originating from outside of Canadian waters must conduct exchange more than 200 nm from shore in at least 2000 m of water. Vessels transiting solely within 200 nm of land must conduct exchange at least 50 nm from shore at a minimum depth of 500 m. These requirements do not apply to vessels transiting exclusively within Canadian waters or the waters of the Great Lakes.

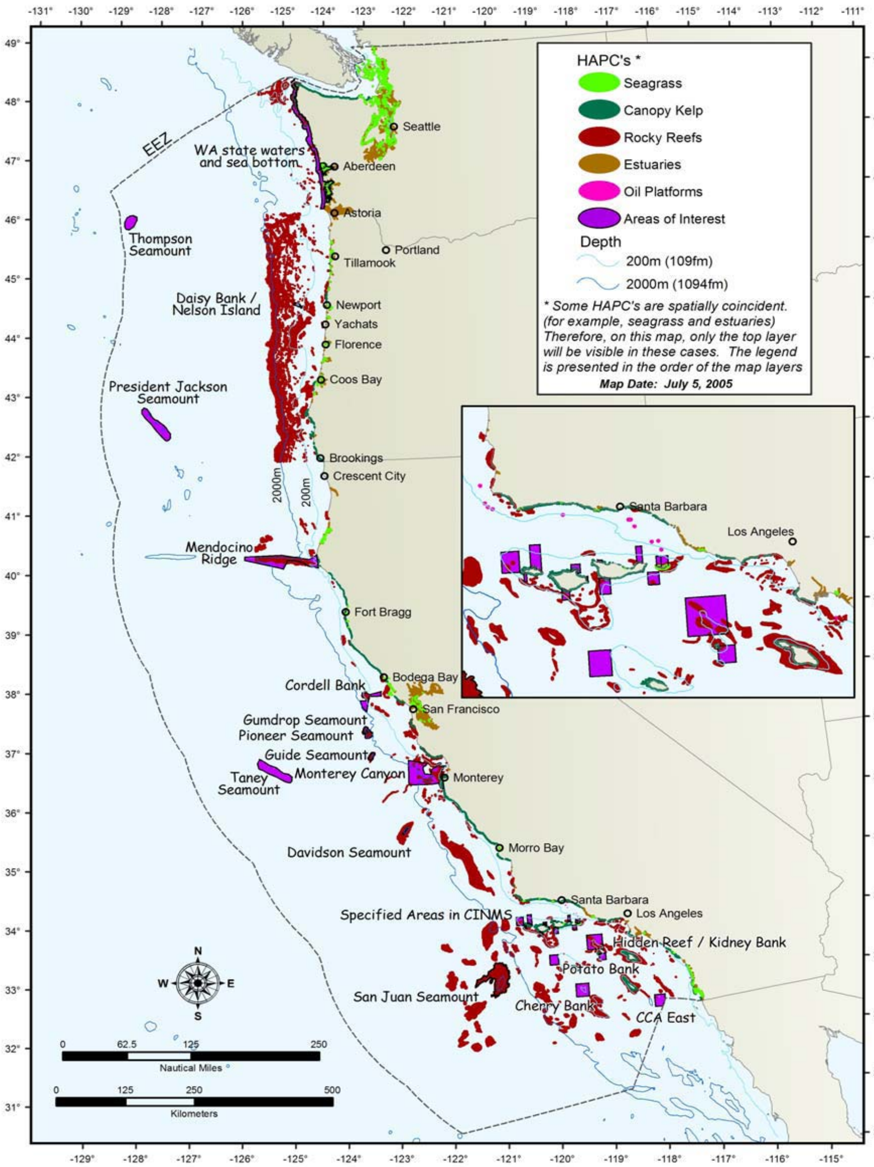
Appendix 2: Essential Fish Habitat and Habitat Areas of Particular Concern.

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) established a new mandate for the National Marine Fisheries Service, regional fishery management councils and other federal agencies to identify and protect important marine and anadromous fish habitat. This "Essential Fish Habitat" (EFH) can consist of both the water column and the underlying surface (e.g. seafloor) of a particular area. Areas designated as EFH contain habitat essential to the long-term survival and health of our nation's fisheries. Certain properties of the water column such as temperature, nutrients, or salinity are essential to various species. Some species may require certain bottom types such as sandy or rocky bottoms, vegetation such as seagrasses or kelp, or structurally complex coral or oyster reefs. EFH includes those habitats that support the different life stages of each managed species. A single species may use many different habitats throughout its life to support breeding, spawning, nursery, feeding, and protection functions. EFH encompasses those habitats necessary to ensure healthy fisheries now and in the future (source: OAA Fisheries Office of Habitat Conservation http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index_a.htm)

Habitat Areas of Particular Concern (HAPC) are discrete subsets of EFH that provide extremely important ecological functions or are especially vulnerable to degradation (For a HAPC map for groundfish, see **Appendix 3**). The regional fishery management councils may designate a specific habitat area as an HAPC based on one or more of the following reasons:

- Importance of the ecological function provided by the habitat
- Extent to which the habitat is sensitive to human-induced environmental degradation
- Whether, and to what extent, development activities are, or will be, stressing the habitat type
- Rarity of the habitat type

The HAPC designation does not confer additional protection or restrictions upon an area, but can help prioritize conservation efforts. Healthy populations of fish require not only the relatively small habitats identified as HAPC's, but also other areas that provide suitable habitat functions. The HAPC's alone will not suffice in supporting the larger numbers of fish needed to maintain sustainable fisheries and a healthy ecosystem (source: NOAA Fisheries Office of Habitat Conservation http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index_a.htm).



Appendix 3: Map showing Habitat Areas of Particular Concern for West Coast Groundfish (PFMC 2005).

Approx. distance from land	Arrival Date	VESSEL TYPE	Vessel Name	FLAG	Last Port List	Arrival Port	Exchange Date	Exchange Lat	Exchange Long
171 nm	09/23/05	Bulk Carrier	SOLAR OCEANA	LIBERIA	Nagoya Japan	Kalama	22-Sep-05	46º12' N	128º31' W
33 nm from the Channel Islands and 146 nm from the mainland	02/25/05	Bulk Carrier	TASMAN SEA	HONG KONG	Topolobampo Mexico	Portland	12-Feb-05	33-08.9N	120-20.2W

Appendix 4: 2005 ballast water exchange information for international vessels that arrived at Columbia River ports (OR and WA) and exchanged ballast water inside of 200 nm. Approximately 800 international vessels were surveyed for ballast water exchange locations. Only two vessels surveyed reported exchanges inside of 200 nm (Simkanin 2006).