

NPRB GOA-IERP Summary Page

Proposal Title: The role of cross-shelf and along-shelf transports as controlling mechanisms for nutrients, plankton and larval fish in the coastal Gulf of Alaska

GOA-IERP Component: Lower Trophic Level

Project Period: Start date: October, 2010

End date: January, 2015

Subaward Recipient(s):

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University of Alaska Fairbanks, 907-474-6446, gmgriscavage@alaska.edu

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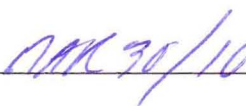
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Total Funding Requested From NPRB & Matching support:

	Requested	Other Support
University of Alaska Fairbanks	\$ 796,565	\$ 0
NOAA NMFS AFSC	\$ 628,000	\$ 859,033
University of Washington	\$ 620,602	\$ 0
NOAA PMEL	\$ 453,464	\$1,915,454
Western Washington University	\$ 494,933	\$ 0
....		
Total:	\$2,993,564	\$2,774,487

Legally Binding Authorization Signature and Affiliation:

Signature: 
 Dr. Russell Hopcroft, Lead Principal Investigator
 Associate Professor
 University of Alaska Fairbanks

Date: 

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Date: 03/31/10

Andrew Parkerson-Gray
 Director, Office of Sponsored Programs
 University of Alaska Fairbanks

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Signature: 
 William A. Karp, Ph.D.
 Deputy Director for Science and Research
 Alaska Fisheries Science Center

Date: March 31, 2010

NPRB Use Only	
Reference No 125	Date Submitted October 11, 2009
Date Received	
Project Title: The role of cross-shelf and along-shelf transports as controlling mechanisms for nutrients, plankton and larval fish in the coastal Gulf of Alaska	
Project Period: from October, 2010 to January, 2015	
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Research Priority: Lower Trophic Level	
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Total Other Support:	
Legally Binding Authorizing Signature and Affiliation:  03-29-10 	

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Executive Director
Office of Sponsored Programs

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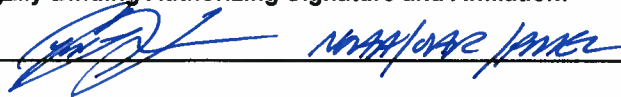
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Total Other Support:			
Legally Binding Authorizing Signature and Affiliation: 			

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B. Project Summary

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C. Project Design and Conceptual Approach

The coastal Gulf of Alaska (GOA) is a productive ecosystem, supporting some of the nation's largest fisheries and abundant populations of seabirds and protected marine mammals. The supply of nutrients to this system is somewhat enigmatic as riverine inputs are not rich in macronutrients and winds are predominantly downwelling. A large body of knowledge has been accumulated on the region (predominantly in western GOA) during recent decades by large programs such as GLOBEC (<http://www.sfos.uaf.edu/sewardline/> - see Weingartner *et al.* 2002), and FOCI (<http://www.pmel.noaa.gov/foci/>); nonetheless many aspects of the ecosystem productivity still remain poorly understood. Considerably less is known about south-eastern Alaska (EGOA). Strong cross-shelf patterns in the WGOA are obvious in phytoplankton (Strom *et al.* 2006), microzooplankton (Strom *et al.* 2007), meso/macro-zooplankton (Coyle & Pinchuk 2005; Pinchuk *et al.* 2008) and larval fish (Abookire *et al.* 2007; Bailey & Picquelle 2002), yet our understanding of how these assemblages are generated and maintained is poor.

Effective mechanisms of cross-shelf exchange **must** be operative to transport macronutrient-rich water from the basin onto the shelf (Hermann *et al.* 2009), which supports high primary production and its transformations of material from inorganic to organic forms. In addition, cross-shelf fluxes must transport oceanic zooplankton (e.g. Mackas & Coyle 2005) and larval fish from the shelf break to their nursery grounds (Bailey *et al.* 2008), while off-shelf flow can transport iron, zooplankton and larval fish into the basin. The design of previous programs has largely precluded our ability to understand the across-shelf and along-shelf processes. We propose to examine cross-shelf and along-shelf transport pathways of water, nutrients, plankton and the larvae of five groundfish taxa with diverse life history strategies: walleye pollock, Pacific cod, arrowtooth flounder, sablefish and rockfish.

Objectives and Hypotheses

Our overall goal of the proposed research is organized by a set of objectives and related hypotheses. These connect physical, chemical and biological cross-shelf and along-shelf processes to support the Upper Trophic Level (UTL) proposal (Moss *et al.*).

48 **O1: Compare and quantify the importance, timing and magnitude of the different cross-shelf and**
 49 **along-shelf transport mechanisms in the two regions.**

50 Many mechanisms transport macronutrients, zooplankton, fish eggs and larvae from one region to another
 51 in coastal GOA waters (Stabeno *et al.* 1996; Stabeno *et al.* 2004). These mechanisms include: (1) mean
 52 along-shelf flow, (2) large (100 km) eddies; (3) small mesoscale (20 km) eddies; (4) up canyon transport
 53 (5) strong downwelling favorable winds; (6) Ekman pumping; (7) strong offshore (gap winds) and
 54 alongshore (barrier jets) winds due to the coastal mountain range.

55 **O2: Compare and contrast how physical mechanisms influence the distribution, timing and**
 56 **magnitude of phytoplankton productivity in the two regions.**

57 The distribution and productivity of phytoplankton over the shelf is controlled by physical processes,
 58 nutrient availability and biological processes. While the first objective centered on the processes that
 59 control the transport of nutrients, phytoplankton, and grazers, this objective requires integration of the
 60 physics, chemistry, and biology to examine how they influence a single process, primary production.

61 **O3: Compare and contrast the mechanisms that control the distribution of the zooplankton prey**
 62 **for larval and juvenile fishes, and the structure of the food web between primary producers and**
 63 **these early life history stages of the target fish taxa in the two regions.**

64 The along-shelf and cross-shelf transport is only one factor that influences recruitment success. During
 65 the transport period, the fish larvae must feed, grow, and avoid predation. This objective ties together the
 66 different disciplines within the LTL component through bottom up processes. For this objective we ask
 67 how the physical processes influence the production and availability of food used by larval and juvenile
 68 fishes.

69 *H1: The mechanisms that promote along-shelf and cross-shelf transport of nutrients and plankton are*
 70 *identical between the two regions.*

71 *Alternative: Each area has a characteristic set of mechanisms that are important for that region and*
 72 *the rank order of importance of mechanisms is different in the two regions. The following*
 73 *mechanisms might be important transport mechanisms in one, but not both regions: mesoscale*
 74 *eddies, downwelling favorable winds, up-canyon flow, strong offshore and alongshore winds, Ekman*
 75 *pumping. For instance, the EGOA, with its narrow shelf, may be more influenced by short-lived*
 76 *mechanisms (e.g. upwelling) while the broader WGOA will be more influenced by topographic*
 77 *steering.*

78 *H2: The physical, chemical and biological mechanisms that control primary production in the two*
 79 *regions are identical.*

80 *Alternative: Each region has a characteristic set of mechanisms that are important for controlling*
 81 *primary production in that region. For example, the narrow shelf of EGOA, which is much closer to*
 82 *the basin high nutrient – low chlorophyll (HNLC) region, may experience fewer or shorter periods of*
 83 *macronutrient limitation, while the wider western shelf may experience longer or more frequent*
 84 *episodes of macronutrient limitation. Similarly, ocean-atmosphere interactions in one region may*
 85 *favor more extensive cloud cover than in the other leading to a higher prevalence of light limitation.*

86 *H3: The food webs leading to larval and juvenile fish in the two regions are identical.*

87 *Alternative: The food webs leading to larval and juvenile fish are not identical during the same*
 88 *seasons. The food webs have strong and demonstrable differences in their function and form and are,*
 89 *at least in part, a function of the separation of basin, shelf, and neritic species. Thus over the*
 90 *narrower EGOA shelf where all three communities are in close proximity, there may be a single food*
 91 *web which responds to local biophysical forcing, whereas over the wider shelf in the WGOA there*
 92 *are multiple food webs that mix and interact as a function of physical forcing.*

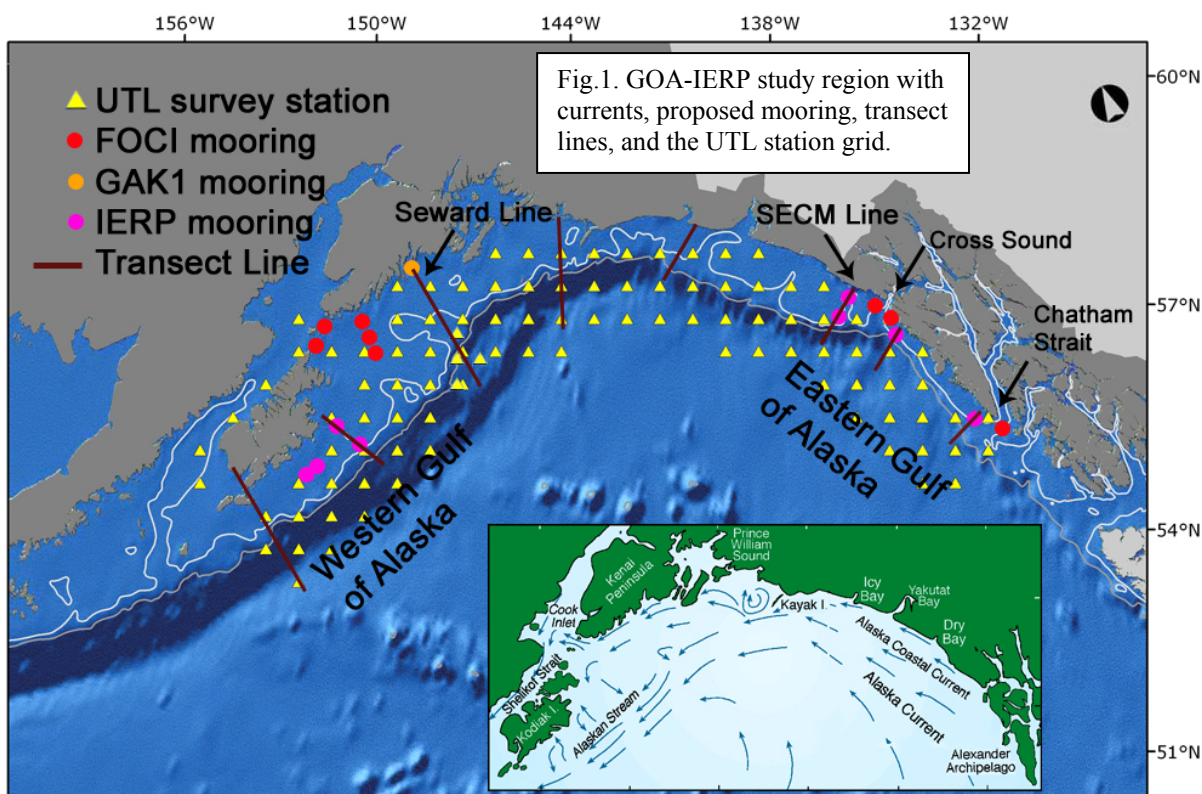
93 **Background**94 **Physics**

95 The Gulf of Alaska shelf consists of three dynamically distinct zones extending from the coast to the
 96 continental slope. The inner shelf consists of the swift, westward-flowing Alaska Coastal Current (ACC),
 97 that is forced by coastal freshwater runoff and downwelling favorable winds, and extends from 10-40 km
 98 offshore. The ACC originates on the British Columbian shelf and flows around the entire GOA coast,
 99 with a portion flowing through Prince William Sound. The coastal flow in the EGOA has not been
 100 measured, although moorings have shown a strong northward flow through Chatham Strait that exits
 101 through Cross Sound (Fig. 1). The inner shelf stratification is controlled primarily by salinity, whereas the
 102 outer shelf domain primarily stratifies through thermal variations controlled by wind mixing and surface
 103 heating (Weingartner *et al.* 2002). As a consequence, stratification and the spring bloom begin earlier on
 104 the inner shelf than over the remainder of the shelf. The EGOA is likely to be structured differently due to
 105 its narrow shelf and the northward flow in Chatham Strait.

106 In the WGOA, there is a middle shelf domain between the ACC front and the shelfbreak front. Flow
 107 within this region is weakly westward, but highly variable (Stabeno *et al.* 2004) due to eddies spun off the
 108 ACC by capes and meanders, and eddies formed at the shelfbreak (Ladd *et al.* 2007). Consequently, the
 109 mid-shelf domain contains a mixture of waters derived from the ACC and from along the continental
 110 slope. Mid-shelf water mass properties vary considerably from year-to-year, depending upon the extent of
 111 cross-shelf mixing (Royer 2005).

112 The outer shelf consists of the shelfbreak front and waters flowing westward as part of the Alaska
 113 Current-Alaskan Stream. These current systems transport waters formed in the northwest Pacific Ocean
 114 and subsequently modified during transit across the sub-arctic Pacific through exchanges with the
 115 atmosphere, lateral mixing, and upwelling in the GOA basin. These three distinct shelf regimes support
 116 different phytoplankton and zooplankton communities (Weingartner *et al.* 2002; Strom *et al.* 2006), and
 117 are utilized by a variety of commercially harvested species including all 5 of the focal taxa for this study.

118 While much is known from drifter trajectories and current meter moorings about the continuity,
 119 seasonal variability and mean flow of the ACC from the Kenai Peninsula westward, very little is known



120 in the region east and south of Kayak Island (Fig.1). The ACC exists along the Alaska coast from the
121 Alexander Archipelago to Unimak Pass (165° W), and is modified by broad-scale, cross-shelf Ekman
122 transport and episodic entrainment events, as well as by topographic steering (e.g., at Kayak Island).
123 Alongshore transport can exceed $3.0 \times 10^6 \text{ m}^3 \text{ s}^{-1}$ (Stabeno *et al.* 1995; Stabeno & Hermann, 1996) and
124 speeds $\geq 80 \text{ cm s}^{-1}$ were measured near Icy Bay during February 1975 (Holbrook & Halpern, 1977;
125 Muench & Schumacher, 1979; Royer *et al.* 1979).

126 Flow at the shelf-break is dominated by the northwestward flowing Alaska Current in EGOA and by
127 the southwestward flowing Alaska Stream along Kodiak Island and the Aleutian Islands (Fig. 1). Large
128 (~200 km) eddies play a significant role in cross-shelf exchange over the entire GOA shelf (Ladd *et al.*
129 2007; Okkonen *et al.* 2003). Float-tracking studies using regional model output (Hermann, per. comm.)
130 also indicate strong cross-shelf Ekman flux in the surface layer, associated with downwelling-favorable
131 winds. On monthly time scales, downwelling-favorable winds dominate from September through April
132 with neutral (neither strongly up- nor downwelling) wind conditions persisting over the rest of the year.
133 On weekly time scales, however, periods of upwelling occur during spring and summer (Ladd *et al.* 2005;
134 Stabeno *et al.* 2007; Hermann *et al.* 2009). Together, the Ekman and eddy fluxes interact with the mean
135 currents and bathymetry and seem to favor certain areas as loci of cross-shelf exchange.

136 The dynamics of flow along the coast of the EGOA has received very little attention (cf. Weingartner
137 *et al.* 2009). Very little historical information exists regarding mean flows, seasonal patterns in flow, or
138 the influence of mesoscale features and episodic events. It is expected that the narrow outer shelf supports
139 a northward flowing coastal current, but it is not known how much flow occurs in the inside passage
140 (Chatham Strait to Cross Sound). The continuity of any shelf flow at Cross Sound is unlikely. Any water
141 that flows through the inside passage will be greatly modified by runoff in that region and by the strong
142 tidal mixing that occurs over banks and in the narrow passages. There is evidence that the flow exiting
143 Cross Sound can turn northward onto the shelf or exit the shelf into the basin.

144 While addressing climate change is not an immediate objective of this proposal, recent years have
145 witnessed net melting of glaciers in the region surrounding the GOA. It remains unclear whether this is a
146 manifestation of global warming or decadal-scale climate variability (Hodge *et al.* 1998; Adalgeirsdottir
147 *et al.* 1998; Bitz & Battisti, 1999). The past decade has seen a general warming trend of water at the
148 GAK1 station (Royer & Grosch 2006), the location for which we have the most complete data and where
149 a long-term mooring is maintained (<http://www.ims.uaf.edu/gak1/>). Long-term observations at GAK1,
150 the Seward Line and the SECM Line off Icy Point provide the important context in which to place the
151 observations obtained in this study. A fuller understanding of inter-annual variation, and their forcing
152 mechanisms, will require a separate multi-year sampling program, such as NPRB has maintained along
153 the Seward Line to present.

154 ***Nutrients and primary production***

155 Like most of the dominant physical processes in the coastal GOA, primary production varies on
156 seasonal and inter-annual time scales, and exhibits pronounced cross-shelf and along-shelf gradients
157 (Brickley & Thomas 2004). Nutrient re-supply to deep shelf waters occurs during summer relaxation of
158 downwelling winds, and re-supply to surface waters occurs primarily during winter mixing (Childers *et al.*
159 2005; Hermann *et al.* 2009). Spring bloom onset is closely tied to increases in water column stability
160 (Henson 2007) and solar irradiance (Dagg *et al.* in prep). Duration and intensity of the shelf spring bloom
161 may be related to variations in bloom timing, with earlier blooms supporting higher chlorophyll
162 concentrations (Henson 2007). Eslinger *et al.* (2001) proposed an analogous model for Prince William
163 Sound, and concluded that production during later, weaker, more persistent blooms was transferred with
164 higher efficiency to the zooplankton community. The alternate fate of diatom bloom production is sinking
165 to the benthos. Therefore bloom timing and magnitude can affect not only pelagic production at higher
166 trophic levels, but also the efficiency of pelagic-benthic coupling.

167 Macronutrient (N, Si) limitation of phytoplankton growth and production is evident during the latter
168 part of the spring bloom as soon as biomass peaks (May), and continues throughout the summer months
169 (Strom *et al.* 2006; Whitney *et al.* 2005). Episodic mixing due to tides and winds can stimulate summer

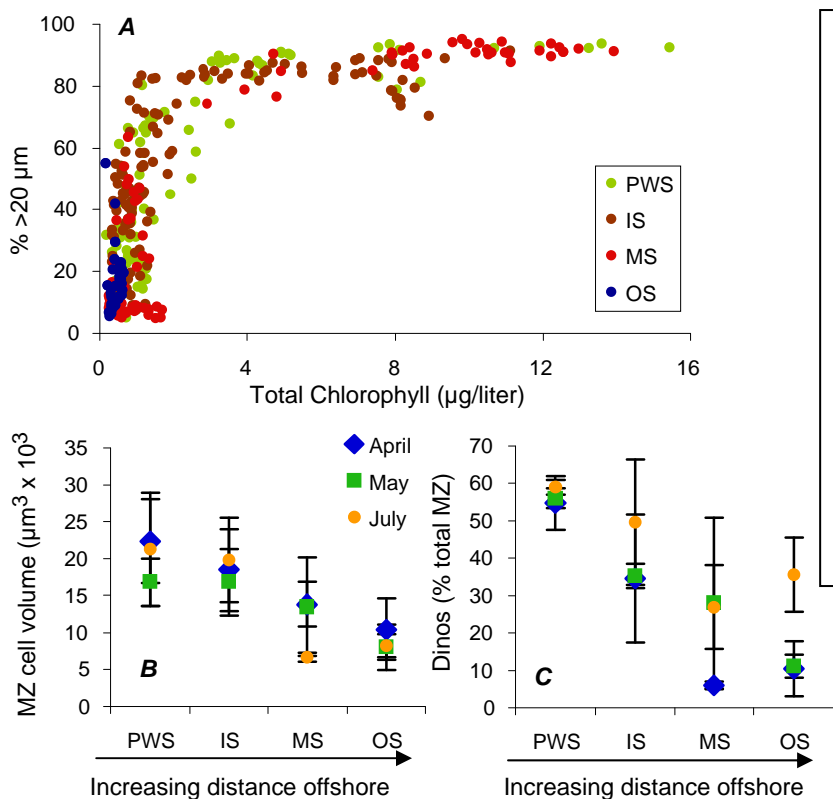


Fig. 2. Pronounced cross-shelf gradients in planktonic community structure and biomass are characteristic of the northern coastal GOA. A) When total chlorophyll levels are high, the community is dominated by large (>20 µm) phytoplankton cells. Note chronically low chlorophyll levels in the outer shelf/slope region (dark blue). B) Average cell size of microzooplankton and C) % of microzooplankton biomass consisting of heterotrophic dinoflagellates (from Strom *et al.* 2007). Both decrease in the offshore direction.

170 production by delivering nutrients to surface waters, and primary production “hot spots” in the coastal
 171 Gulf are typically associated with tidal mixing over banks and through channels (Stabeno *et al.* 2004,
 172 Hermann *et al.* 2009, Cheng *et al.*, submitted). Study of the WGOA during the U.S. GLOBEC program
 173 revealed strong cross-shelf gradients in plankton community composition (Fig. 2), growth rates, and
 174 macronutrient distributions. These gradients are consistent with the hypothesis that iron may limit
 175 production at times on the mid and outer shelf (Strom *et al.* 2006). This is supported by dissolved Fe
 176 measurements from the same region (Wu *et al.* 2009) which show sharply decreasing surface Fe levels
 177 from the inner to mid- and outer shelf, and a strong depth gradient on the outer shelf. Although Fe
 178 limitation of phytoplankton production in the open subarctic is well established (e.g. Boyd *et al.* 2004;
 179 Martin *et al.* 1989), the extent to which Fe limitation occurs in shelf waters is unknown. Main sources of
 180 iron and macronutrients to the shelf are probably deep water and freshwater runoff, with riverine inputs
 181 high in Fe and potentially, Si, and deep water enriched in N, Fe, and Si (Stabeno *et al.* 2004; Whitney *et al.*
 182 *et al.* 2005). Since only diatoms require Si, and many diatom species have high Fe requirements, the
 183 pathways delivering macro- and micronutrients to shelf surface waters will have major effects on the type
 184 and quantity of primary production, and may distinguish production between the EGOA and WGOA.

185 Light limitation clearly plays a role in spring bloom timing and magnitude (Napp *et al.* 1996), and
 186 light is sometimes considered the key limiting resource for this high-latitude ecosystem (Gargett 1997;
 187 but see discussion of nutrients, above). Our recent studies (Strom *et al.* submitted) revealed that light
 188 limitation can also influence summer production levels on the WGOA shelf. Two main factors
 189 contributed to light limitation. The first was the episodically heavy cloud cover which can reduce
 190 irradiance to subsaturating levels (Fig. 3). The second was the photophysiology of the phytoplankton
 191 community. We found that summer phytoplankton communities in the WGOA were high-light
 192 acclimated, probably due to episodic exposure to cloud-free days (intense sunlight can damage low-light
 193 acclimated phytoplankton). Due to their low photosynthetic efficiencies, even surface phytoplankton
 194 communities would have experienced light limited photosynthesis rates on the cloudiest days (Fig. 3).

195 Processes that affect the amount of primary production are intimately tied to its fate in the food web.
 196 High phytoplankton chlorophyll levels are associated with large phytoplankton cells – typically chain

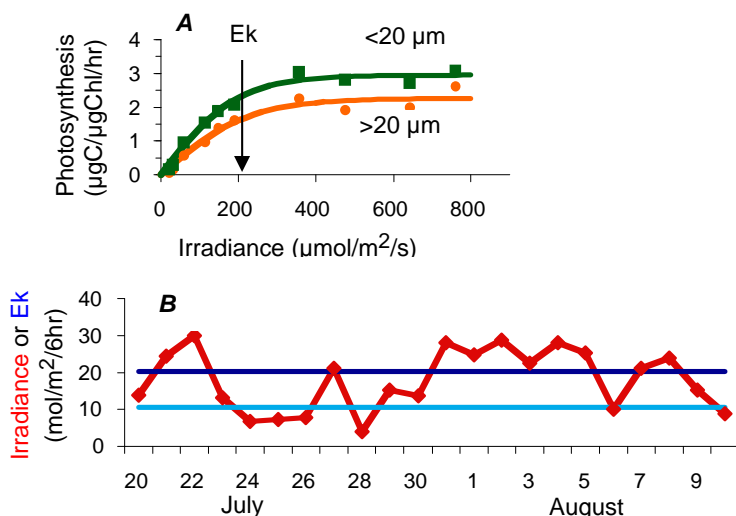


Fig. 3. Evidence for episodic light limitation summer northern coastal GOA phytoplankton in summer. A) Example of P-E data and curve fits for outer shelf phytoplankton in two size fractions (Seward Line, July 2003). Ek is the irradiance below which light limits photosynthesis rates. B) Sea surface irradiance (red) compared with Ek for mixed layer phytoplankton community (study average: light blue; study maximum: dark blue). When irradiance is less than Ek (e.g. July 24-26), even near-surface phytoplankton will experience light limitation (Data from Strom *et al.* submitted)

197 diatoms - in the WGOA, while communities with lower chlorophyll levels are usually dominated by small
 198 cells (Fig. 2; Strom *et al.* 2006). Diatom blooms often support high abundances of large
 199 microzooplankton (Sherr & Sherr 2007); both of these groups are important prey species for crustacean
 200 zooplankton, which feed far less effectively on small cells (Dagg *et al.* 2009; Liu *et al.* 2005). It is the
 201 large size fraction of microplankton (>20 µm) that is most closely associated with the production of prey
 202 for larval fish in the WGOA (Napp *et al.* in prep.). Note that the total grazing impact of the micro- plus
 203 mesozooplankton is insufficient to consume more than a modest fraction of bloom production, much of
 204 which is exported to the benthos. In contrast, microzooplankton effectively consume all of the production
 205 of small phytoplankton in this region (Strom *et al.* 2007), retaining that production in the upper water
 206 column, but adding additional trophic transfers to the food web linking phytoplankton to fish. The
 207 structure of the food web at the lowest trophic levels fundamentally influences the efficiencies and
 208 pathways of transfer to higher trophic-levels (benthic and pelagic species). Contrasting environmental
 209 conditions in the EGOA and WGOA may result in different lower trophic level structure.

210 **Zooplankton:**

211 Zooplankton on the GOA shelf are a mixture of two major species complexes, composed of neritic
 212 and oceanic taxa. During May and early June, the oceanic complex, consisting primarily of *Neocalanus*
 213 *flemingeri/plumchrus*, *N. cristatus* and *Eucalanus bungii*, dominates the biomass. Abundances are
 214 dominated by smaller copepods, *Pseudocalanus* spp. and *Oithona similis*, with population peaks in July
 215 or August. The above copepods are major vectors moving energy from primary producers to both middle
 216 and upper trophic levels (including fish). Conditions which enhance or depress these populations may
 217 thus impact the survival and year-class strength of fish stocks on the shelf. Organisms of secondary
 218 importance in terms of abundance and biomass include the euphausiids (four *Thysanoessa* species plus
 219 *Euphausia pacifica*), the pteropod *Limacina helicina* and larvaceans (*Oikopleura* spp.). All of these taxa
 220 contribute to the diets of various fishes during their early life-histories (see references below).

221 Prior to the GLOBEC program, little information was available on interannual variations in
 222 zooplankton stocks and the physical mechanisms influencing those variations. Post-GLOBEC sampling
 223 has continued along the Seward Line during 2005-2009 through NPRB funding, although confined to
 224 May and early September only. This sampling has revealed significant interannual differences in
 225 abundance, biomass and cross-shelf distribution of zooplankton over the past 12 years. For example,
 226 during May of 1998, 2002, 2006 and 2007, populations of *Neocalanus flemingeri* were two to five times
 227 higher than populations during other years (Fig. 4). These years coincided with years of high Pink salmon
 228 survival (Fig. 4). *Pseudocalanus* abundances in July 1998 and 2004 were about five times higher than in
 229 other years. Zooplankton abundance and biomass have been negatively correlated to salinity on the shelf,
 230 particularly in the region between the outer boundary of the Alaska Coastal Current (ACC) and the shelf

231 break (Coyle & Pinchuk 2005). Examination of
 232 cross-shelf salinity-temperature profiles has further
 233 revealed that zooplankton abundance and biomass
 234 were depressed when oceanic water was pushed
 235 across the shelf, confining the mixing zone to a
 236 narrow band along the outer boundary of the ACC.
 237 High zooplankton abundance was observed when
 238 physical conditions created a middle shelf domain
 239 that extended from the outer boundary of the ACC to
 240 the shelf break. Interannual differences in
 241 zooplankton abundance and biomass within the ACC
 242 were much less pronounced. Thus, the abundance,
 243 biomass and productivity of zooplankton on the shelf
 244 is not simply the magnitude of cross-shelf transport
 245 of dominant species such as *Neocalanus* and
 246 euphausiids, but the degree to which they are mixed
 247 with shelf waters during along-shelf transport.

248 The exact cause of enhanced zooplankton
 249 abundance and biomass in the middle shelf mixing
 250 zone is uncertain, but preliminary measurements of
 251 iron concentration (Wu *et al.* 2009) suggest iron
 252 limitation of primary production in those regions
 253 where oceanic water occupies the shelf. Elevated
 254 iron concentrations in ACC waters suggest extended
 255 periods of high phytoplankton production in those
 256 regions where low-nutrient high-iron ACC waters mix with high-nutrient low-iron oceanic waters. We
 257 hypothesize that any condition strengthening the intensity, or lengthening the duration, of mixing between
 258 ACC and oceanic waters will result in elevated production of phytoplankton and consequently increased
 259 zooplankton. Ongoing work has demonstrated strong relationships between chlorophyll concentration,
 260 growth and egg production in many of the zooplankton species (e.g. Hopcroft *et al.* 2005; Napp *et al.*
 261 2005, Liu & Hopcroft 2006a, b, 2007, 2008; Napp *et al.* in prep.). Interannual differences in the extent
 262 and duration of the mixing zone, and the magnitude of primary production, result in significant
 263 interannual differences in zooplankton concentrations on the shelf between the outer boundary of the
 264 ACC and the shelf break. Thus, cross-shelf mixing and exchanges strongly influence the biomass of the
 265 zooplankton, and the underlying composition of these communities (Mackas & Coyle 2005).

266 Significant variation has also been observed in the composition of the zooplankton community.
 267 Notable has been the presence of “southern” species in warm years. During the 1997/98 El Niño the
 268 copepods *Mesocalanus tenuicornis* and *Calanus pacificus* became more abundant (Coyle & Pinchuk
 269 2003). During the warmer summer of 2003 the southern small copepod *Paracalanus parvus* began to
 270 appear in samples and it became unusually common during fall of 2005, persisted into 2006, concurrent
 271 with increases in *C. pacificus* – then disappeared from 2007 to present. All of these southern species are
 272 smaller than corresponding resident species, and therefore replace larger prey items that may be more
 273 nutritious per individual for larval fish.

274 An unexpected revelation from the GLOBEC study was the importance of larvaceans and thecosome
 275 (shelled) pteropods in the diets of pink salmon, challenging the traditional view that *Neocalanus* and
 276 euphausiid species are the key dietary elements (Armstrong *et al.* 2005; Cross *et al.* 2005). Years when
 277 juvenile pinks had high percentages of these species in the diet correlate with year classes of higher pink
 278 salmon growth and survival, albeit over a short (4 year) time frame (Halderson, unpublished). The role of
 279 these under-studied taxa in the diets of the larval fish in this proposal may hold similar surprises.

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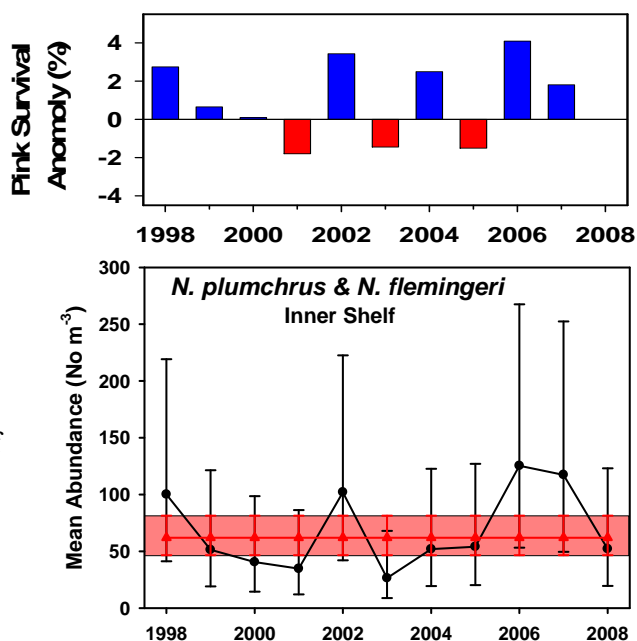


Fig. 4. Survival anomaly for Prince William Sound hatchery-released pink salmon tracks the abundance of *Neocalanus* copepods observed along the inner domain of the Seward Line. Red-band indicated long-term mean and 95% confidence interval.

281 **Larval Fish**

282 The ichthyoplankton of the Gulf of Alaska is a rich assemblage of temperate and subarctic taxa
 283 containing commercial species, ecologically significant species, and other non target species (Matarese *et al.*
 284 *et al.* 2003; <http://access.afsc.noaa.gov/ichthyo/index.cfm>). NOAA/AFSC-supported investigations by
 285 the Recruitment Processes Program (a.k.a. FOCI) have identified the dominant taxa and multispecies
 286 assemblages in the ichthyoplankton of the western Gulf of Alaska. Studies have been published on the
 287 taxonomy, variability in the occurrence, abundance, and fisheries oceanography of many individual
 288 species that are numerically dominant (e.g., *Theragra chalcogramma*, walleye pollock, Brodeur *et al.*
 289 1995; *Hippoglossoides elassodon*, flathead sole, Porter 2005; *Atheresthes stomias*, arrowtooth flounder,
 290 Blood *et al.* 2007) and ecologically important (e.g., *Mallotus villosus*, capelin, Doyle *et al.* 2002a and
 291 other flatfishes, Abookire & Bailey 2007). Seasonal multispecies ichthyoplankton assemblages been have
 292 identified and described in both the Gulf of Alaska and Bering Sea. Our data show that assemblage
 293 structure is strongly related to depth (Doyle *et al.* 2002b), temperature (Duffy-Anderson *et al.* 2006),
 294 topography (Lanksbury *et al.* 2005), and presence of eddies (Atwood *et al.*, in review). Other studies have
 295 investigated the along-shelf transport of ichthyoplankton and show that larvae in the western Gulf of
 296 Alaska are entrained in downstream currents (e.g. Hermann *et al.* 1996; Bailey *et al.* 1999), in eddies that
 297 propagate along-shore (Bailey *et al.* 1995; Bailey *et al.* 1997), and in currents influenced by along-shore
 298 winds (Cooper *et al.*, in review). The larvae of certain shelf/slope spawning fish species can be used as
 299 tracers of cross-shelf exchange and indicators of changes regional ocean conditions (e.g., Bailey &
 300 Picquelle 2002; Bailey *et al.* 2005a; Atwood *et al.* in review). The Program has also provided descriptions
 301 of their horizontal distribution patterns, and related these patterns to the regional and local oceanographic
 302 and atmospheric forcing, demonstrating that larvae are influenced by both local-and basin-scale
 303 atmospheric and hydrographic forcing parameters (Doyle *et al.* 2009). Most of our knowledge about
 304 larval fish distributions comes from the WGOA; the EGOA has had relatively little sampling for larvae
 305 (*c.f.* Wing *et al.* 1997; Johnson *et al.* 2003).

306 Current information on
 307 recruitment processes among the
 308 GOA-IERP target species is most
 309 robust for walleye pollock (Brodeur
 310 *et al.* 1995; Kendall *et al.* 1996,
 311 Bailey *et al.* 2000, 2003, 2005b;
 312 Wilson *et al.* 2005; Wilson *et al.*
 313 2006; Logerwell *et al.* in press),
 314 limited for Pacific cod and
 315 arrowtooth flounder (Blood *et al.*
 316 2007; Ormseth & Norcross 2008;
 317 Doyle *et al.* 2009), and poor for
 318 sablefish (Fig. 5, *c.f.* Sigler *et al.*
 319 2001) and Pacific ocean perch
 320 (Matarese *et al.* 2003). Critical gaps
 321 in our knowledge of the early life
 322 history recruitment processes among
 323 the latter species can be filled
 324 initially by retrospective analysis of
 325 existing data sets from the WGOA.
 326 These analyses will then generate
 327 new hypotheses and
 328 recommendations for targeted
 329 sampling during the field program
 330 supported by GOA IERP. The

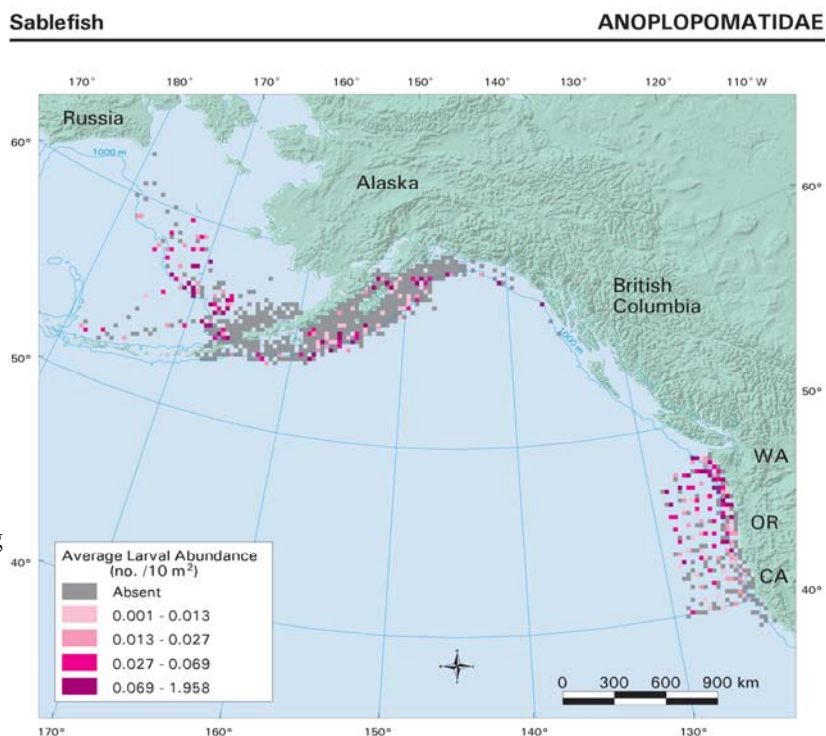


Fig. 5. Distribution of larval sablefish in the northeastern Pacific Ocean based on NMFS surveys.

331 hypothesis to be addressed is that variability in environmental forcing during early life history regulates
332 the initial production and survival to the juvenile stage of these species. Variability in the oceanographic
333 environment affects the productivity of the target taxa through bottom up effects on larval abundance and
334 along-shelf and on-shelf transport to nursery areas.

335 The Gulf of Alaska and eastern Bering Sea (and other LMEs) are experiencing basin wide changes in
336 response to climate that may affect the main flow patterns along and across the shelf edge during each
337 season (e.g. Schumacher *et al.* 2003; Stabeno *et al.* 2006). Differential patterns of transport and flow
338 affect dispersal pathways and survival of economic and ecological species, including the target taxa of
339 this project. Although this project (with only two field years) cannot address secular changes in physical
340 forcing, the proposed work is critical to: (1) get baseline measurements for the EGOA and (2) learn if
341 climate-sensitive mechanisms are responsible for the along and cross-shelf transport of fish species. There
342 are many examples of larval transport case histories that link climate and transport. For example, in the
343 Bering Sea, Wilderbuer *et al.* (2002) showed that above-average flatfish recruitment coincided with
344 decadal-scale changes in wind-driven advection of larvae to juvenile nursery grounds. Lanksbury *et al.*
345 (2007) used a depth-discrete model (NEP-ROMS) to demonstrate that differences in larval depth
346 distribution (affected by light, prey concentrations, and temperature) affect dispersal trajectories of
347 northern rock sole in the same region. Parada *et al.* (submitted) used modeling as a tool to examine how
348 physical forcing affects the connectivity between spawning and nursery areas for pollock in the WGOA.
349 These studies suggest that broad-scale shifts in climatological forcing factors and their associated changes
350 in oceanographic processes could affect the production, abundance, distribution, and dispersal of fishes.
351 Slope-spawning species (e.g., arrowtooth flounder, Pacific halibut and sablefish) may be particularly
352 vulnerable because their larvae must be advected from the slope, where they are spawned, to nursery
353 areas on the inner shelf. Thus, a more complete understanding of these dispersal pathways is critical to
354 appreciating how variations in physical forcing (including climate) will alter fish distribution and
355 recruitment in the GOA.

356 The diet of the target taxa during their pelagic early life history is generally comprised of crustacean
357 zooplankton with the size of the prey increasing as the fish grow. For example, walleye pollock begin
358 feeding on invertebrate eggs and copepod nauplii as yolk sac larvae, add copepodites when they are larger
359 and more competent, and graduate to euphausiids during the age-0 stage at about 50 – 60 mm (e.g. Clarke
360 1984; Grover 1990; Kendall & Nakatani 1991; Napp *et al.* 1996; Wilson *et al.* 2006). Pacific cod
361 presumably eat similar items when they are in the water column; however the young of the year begin to
362 settle in bays around the Gulf of Alaska in July. At first the diets of the smaller YOY (40 – 60 mm) are
363 predominantly small copepods, but as they mature, more benthic and epibenthic prey items such as
364 gammarid amphipods, mysids and isopods are added (Abookire *et al.* 2007). Sablefish start feeding on
365 copepod nauplii and gradually add larger copepodites to the diet as they grow (Grover & Olla 1986).
366 During their first summer, YOY sablefish (90 – 200 mm FL) diet consisted mainly of euphausiids, salps,
367 and pteropods (Sigler *et al.* 2001). Rockfish larvae follow the same pattern of eating predominantly
368 crustacean zooplankton (copepods) early in the lives and eventually shifting to include larger prey items
369 such as euphausiids (Love *et al.* 2002).

370 **Approach**

371 This is an integrated, collaborative, multi-disciplinary study designed to examine many of the
372 physical processes related to cross- and along-shelf transport and their impacts on bottom up forcing of a
373 coastal marine ecosystem. We will account for seasonal variability of atmospheric forcing and distributed
374 runoff in the coastal GOA and a continuous causal link from the atmospheric forcing to local ecosystem
375 productivity. Specifically, we will address the previously stated hypotheses and objectives using a
376 combination of retrospective analysis, oceanographic research cruises, moored instruments, satellite-
377 tracked drifters, satellite observations, and chemical and biological analyses. A primary objective is to
378 determine the mechanisms that control along-shelf and cross-shelf transport in the study area –
379 particularly the impact of topographic steering, eddies, cross shelf wind stress curl, downwelling,

380 estuarine forcing and episodic upwelling – and how these ultimately influence the recruitment success of
381 5 groundfish taxa from the GOA.

382 **Retrospective analysis**

383 The availability of historical information in the GOA varies greatly between the disciplines within
384 this proposal. Physical oceanographic data for the region is archived by NODC and freely available.
385 Additional datasets exist from efforts such as Auke Bay's OCC program, with hydrography recently
386 completed in and around Cross Sound by Stabeno. In 2010, a series of moorings will be deployed in Icy
387 Strait and Cross Sound. These data will also be made available to investigators. Retrospective analysis
388 of these data together with Argo data is planned for winter of 2011. Several biological data are publicly
389 available, while others still need to be recovered from reports. The plankton data from OCSEAP (e.g.
390 Damkaer, 1977) is all available through NMFS (<http://www.st.nmfs.noaa.gov/plankton/>). The
391 zooplankton data collected by FOCI (Shelikof Strait) and GLOBEC/SewardLine are also available
392 digitally, as is the data from the Southeast Coastal Monitoring Program conducted by the NOAA lab in
393 Juneau. We will seek-out and rescue any additional relevant data sets to more fully appreciate the scales
394 of inter-annual and longer-term variability for the coastal GOA.

395 Retrospective analysis of ichthyoplankton time-series will be undertaken as part of this proposal.
396 Existing data collected by the Alaska Fisheries Science Center will allow detailed examination of egg and
397 larval distribution, and the abundance patterns of the target taxa in relation to topographic features and
398 local physical oceanography. Horizontal and vertical distribution patterns of eggs, and larvae in different
399 length categories will be examined to infer ontogenetic drift patterns among the species of interest.
400 Particular focus will be given to years when collections of winter (Jan-March) and early spring (April-
401 May) data can be compared to the time-series of late spring (mid-May/June) ichthyoplankton data
402 collected annually since 1981. For these years, the sequential sampling will allow a comparison of
403 distribution patterns of newly hatched larvae with those of later larvae from the same spawning
404 population. This analysis will be important for understanding potential onshore larval drift pathways of
405 the deep-water spawners: arrowtooth flounder and sablefish. Where possible, relationships between larval
406 abundance trends and selected physical variables will be explored using Generalized Additive Modeling
407 (GAM; Doyle *et al.* 2009). Mean abundance levels of species will be calculated for sampling areas and
408 times having the most consistent sampling across years. A late spring time-series of larval abundance is
409 already available for many species (Doyle *et al.* 2009), and a winter and early spring time series will be
410 developed from historical data. Environmental variables and climate indices will be compiled to represent
411 variation in climate-ocean conditions in the Northeast Pacific basin, as well as at the species early life
412 history habitat level in the western GOA (Doyle *et al.* 2009). GAM is a form of non-parametric multiple
413 regression that models a response variable (e.g. larval abundance) as a function of one or several predictor
414 variables (Hastie & Tibshirani 1990; Wood 2004, 2006). When using GAM, it is unnecessary to specify
415 the type of relationship between the forcing and response variables *a priori*, because these are determined
416 from the data. Significant environmental forcing variables for each species will be determined through
417 variable selection yielding the best-fit GAM by minimizing the generalized cross validation (GCV), a
418 measure of the mean predictive square error (Green & Silverman 1994). Variables used in Doyle *et al.*,
419 (2009) included 5 basin scale climate indices (EP-NP, AO, NP, PDO, MEI) and alongshore winds,
420 freshwater input, SST, alongshore flow, mixing, retention. Results from the GAM analyses are expected
421 to illuminate potential mechanisms of environmental forcing, in particular cross-shelf transport, on early
422 life history survival among the target taxa.

423 **Atmospheric Forcing**

424 To examine wind forcing of the coastal ocean, we will take advantage of multiple data products.
425 QuikSCAT satellite winds are available from 1999 to 2009 on daily timescales and 0.25 degree spatial
426 resolution. This dataset allows analysis of higher spatial resolution closer to the coast than other wind
427 products. Unfortunately, the QuikSCAT mission ended in November 2009. The European ASCAT
428 satellite winds may be available from the end of the QuikSCAT mission until present to provide
429 scatterometer winds coincident with field data collections. However, these data are currently in

430 “preview” status and are meant for operational and experimental use only. The NCEP/NCAR reanalysis
 431 (Kalnay *et al.* 1996) 6 hourly winds from 1948 until present provides a longer time series and can be
 432 downloaded from <http://www.cdc.noaa.gov/data/gridded/data.ncep.reanalysis.html>. These winds are
 433 on a relatively sparse Gaussian grid (~1.9 degree grid spacing). They are well correlated with in situ wind
 434 data from moorings in the GOA. However, the influence of topography very near the coast is not well
 435 resolved by the reanalysis assimilation/model system (Ladd & Bond 2002). The coastal Upwelling Index
 436 can be downloaded from NOAA’s Environmental Research Division
 437 (<http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/upwelling.html>). This is
 438 an index of the intensity of large-scale, wind-induced coastal upwelling derived from 6 hourly sea level
 439 pressure gridded fields for 15 standard locations along the west coast of North America. As a complement
 440 to these large-scale gridded fields, Synthetic Aperture Radar (SAR) imagery will be accessed from the
 441 Alaska Satellite Facility (http://wind.asf.alaska.edu/windspeed/sar_web/). SAR detects capillary
 442 waves on the surface of the ocean. The backscatter from these waves can be related to wind speed at the
 443 surface. SAR wind mapping provides subkilometer resolution over a swath of mesoscale width (~500
 444 km). Unfortunately, SAR imagery is limited temporally. Any given location on the Alaska coast is
 445 imaged approximately once every 3 days (Loescher *et al.* 2006).

446 Retrospective analysis of solar irradiance (amount and timing of PAR) in the two study regions will
 447 leverage U.S. GLOBEC pan-regional synthesis funds. That program shares the goal of looking at spatial
 448 coherence (or lack thereof) in coastal WGOA irradiance fields. We will work with Dr. A Thomas (U
 449 Maine) to extract PAR data from SeaWiFS (Frouin *et al.* 2001), as we have done for a two-year period in
 450 the Seward Line region (Dagg *et al.* in prep). Irradiance variations will also be indirectly assessed through
 451 cloud cover. Sky cover conditions are assessed multiple times per hour at AWOS stations maintained by
 452 the FAA throughout Alaska, including in and near the EGOA and WGOA regions. These data will
 453 provide an important context for comparison of potential light limitation of primary production between
 454 regions.

455 **Field Program**

456 We propose two intensive oceanographic field years (2011 and 2013) each entailing two mooring
 457 cruises and five hydrographic cruises (Table 1). Details of the primary along-shore flow and the
 458 secondary cross-shelf flow will be quantified from the coast out to beyond the continental slope. The

459 Table 1. Observational Framework for Physical Oceanography and Lower Trophic Levels. Institutions listed are
 460 responsible for the analysis of data. ♦ Indicates when a different institution is responsible for collecting the samples
 461 on a particular cruise

Month / Season	February	April /May	May	May/June ¹	Summer	October	October
CRUISES							
Ship	NOAA Vessel	<i>R/V Thompson</i>	<i>M/V Tiglax</i>	<i>FSV Oscar Dyson</i>	<i>F/V Ocean Storm</i>	<i>FSV Oscar Dyson</i>	NOAA Vessel
Purpose & Location	Deploy Moorings WGPA + EGOA	Hydrography EGOA	Hydrography Seward Line	Hydrography WGOA	Hydrography WGOA + EGOA	Hydrography WGOA + EGOA	Recover Moorings
SAMPLES							
CTD	PMEL	PMEL	UAF	PMEL	PMEL♦	PMEL	PMEL
Oxygen	PMEL	PMEL	UAF	PMEL	PMEL♦	PMEL	PMEL
Nutrients	UW	UW	UAF	UW	UAF	UW	UW
Chlorophyll (size fractions)		UW	UAF	UW	UAF	UW	
Primary Productivity		WWU		WWU		WWU	
DISTRIBUTIONS							
Microzooplankton		WWU		WWU	WWU♦	WWU	
Zooplankton		UAF♦	UAF	UAF♦	UAF	UAF	
Ichthyoplankton		AFSC	AFSC♦	AFSC	AFSC♦		

462 ¹The May/June cruise will only sample the southwest Kodiak region in 2013. It is too late to request addition of the
 463 4 days needed to cover this area in 2011 (Year 1).

464 horizontal mixing of relatively high-nutrient water from offshore with relatively high-iron shelf water in
465 the presence of a buoyancy front will be examined. We will delineate the degree to which this mixing
466 arises from wind-driven effects, hydrodynamic instability, and/or topographic effects, and we will
467 investigate the role of this mixing on the coastal ecosystem.

468 This program will require significant hydrographic sea time in both regions. To optimize our time
469 at sea, we propose to use different ships in each region while leveraging a large amount of ship time
470 from NOAA-funded programs (Table 1). Mooring cruises in spring and fall will occur on NOAA
471 vessels during seasonal transits through the GOA. The spring hydrographic cruise on a UNOLS
472 vessel (e.g. R/V *Thompson*) will occur in the EGOA and use ~20 days of ship time provided by
473 NOAA. On this cruise, most of the EGOA UTL grid stations will be sampled plus several more
474 intense hydrographic sections needed to delineate oceanographic fronts, determine geostrophy,
475 examine cross-shelf transport, and examine bottom-up forcing on plankton distribution and
476 production. The M/V *Tiglax* will be chartered for a 12 day spring hydrographic cruise in the WGOA
477 for intense sampling along the Seward Line, as well as UTL grid stations toward Kodiak. The Kodiak
478 region of the WGOA will be sampled from the *Tiglax* in 2011 and from the NOAA ship *Oscar Dyson*
479 in 2013 as part of a proposed 4-day piggy back on the EcoFOCI late larval cruise. The remaining
480 summer and fall cruises comprise the UTL field component, and we will jointly participate on those
481 cruises.

482 *Biophysical moorings*

483 Moorings will be deployed in February and be recovered the following October. The proposed study
484 will employ a total of 16 moorings; 7 (4 funded by this proposal and 3 as part of EcoFOCI) moorings in
485 the EGOA and 9 (4 by this proposal, and 5 as part of EcoFOCI) moorings in the WGOA (tentative
486 locations in Fig. 1). The moored arrays are designed to sample the mesoscale structures in the two
487 regions. The combination of the moored array and the mesoscale mapping will be used to derive estimates
488 of dynamically important quantities (horizontal and vertical current shear, stratification, mixed layer
489 depth). We will combine the physical, chemical and bio-optical data from both the moorings and
490 hydrography to make estimates of along- and cross-shelf transport.

491 In the WGOA, EcoFOCI moorings will be deployed at Kennedy and Stevenson Entrances, plus three
492 moorings across the ACC at Gore Point, all equipped with bottom mounted ADCPs to measure currents
493 and an additional instrument to measure near-bottom temperature and salinity. These moorings will allow
494 estimates of ACC transport along the Kenai Peninsula, permitting us to determine the fractions of flow
495 down Shelikof Strait and along the south side of Kodiak Island. A similar mooring array has previously
496 measured these transports (Stabeno *et al.* 1995). The strength of the flow to the south of Kodiak Island is
497 a determining factor on the position of frontal structure that exists there. This front influences the
498 distribution of juvenile pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*) south of the
499 island (Logerwell *et al.* 2007). GOA-IERP moorings (two each) will be deployed in both Chiniak Canyon
500 and Barnabus Canyon south of Kodiak Island to provide information on the influence of canyons on
501 cross-shelf flow. These four moorings will also support instruments that measure temperature, salinity,
502 oxygen, and fluorescence in addition to currents. In the EGOA, two EcoFOCI moorings in Cross Sound
503 and one in Chatham Strait will consist of bottom-mounted 75 kHz ADCPs to measure transport currents
504 and an instrument to measure near-bottom salinity and temperature. Two GOA-IERP moorings will be
505 deployed on the narrow outer shelf south of Cross Sound (one just north of Chatham Strait and one just
506 south of Cross Sound), while two others will be deployed across the wider shelf north of Cross Sound. In
507 addition to currents, these latter 4 moorings will have instruments that measure temperature, salinity,
508 oxygen, and fluorescence. On one GOA-IERP moorings in each region), an optical nitrate meter (ISUS)
509 will be deployed next to the fluorometer to measure the seasonal dynamics of upper-layer nitrate. The
510 ISUS technology, based on UV spectra, provides chemical-free measurements of *in situ* nitrate and has
511 been field tested on drifting buoys, towed vehicles, moorings and CTD profilers (Johnson & Coletti
512 2002). The instrument is solid state and reliable, with no moving parts, a sensitivity of 0.25 μM and a 1%
513 accuracy with post-processed CTD temperature corrections.

514 To complement the mooring data, drifters will be deployed to map mean currents and continuity of
515 flow in the coastal currents and the ACC, resolve mesoscale features on the shelf and shelf break, and
516 identify preferred sites of cross-shelf fluxes. Satellite-tracked drifters have been successfully used to track
517 patches of larvae or zooplankton, defining mean flow and have been used often in examining eddies (e.g.,
518 Ladd et al. 2009; Stabeno et al. 1996; Stabeno & Reed, 1994). The exact location at which they will be
519 deployed will be decided during the cruises.

520 We will also utilize data from the global array of profiling drifters (Argo), which measure
521 temperature and salinity in the upper 2000 m of the water column. Data from approximately a dozen
522 Argo drifters that are typically found in the Gulf of Alaska will be utilized to characterize the temperature
523 and salinity along the slope of the GOA in our proposed study area. Data are freely available on web
524 sites, and will allow us to relate the temperature and salinity observed on the shelf with measurements in
525 the basin and along the slope.

526 *Hydrography and nutrients*

527 The funded UTL program proposes to sample a fixed grid of stations in the two regions. However, to
528 understand cross- and along-shelf transport mechanisms, it is necessary to sample transects with higher
529 spatial resolution. In addition to the grid of stations of the UTL proposal, we propose to sample along
530 three transects in each region (Fig. 1). On the hydrographic surveys, each cast will include high-resolution
531 vertical profiling of water properties (including temperature, salinity, chlorophyll fluorescence, PAR, O₂)
532 to within 4 m of the bottom using a Seabird 911*Plus* CTD with dual temperature, conductivity and
533 oxygen sensors. Dissolved inorganic nutrients (phosphate, silicic acid, nitrate, nitrite, ammonium) will be
534 collected from rosette bottles that will sample at 10 m depths in the upper 50 m, and at irregularly spaced
535 depths to the bottom. Oxygen and salinity samples will be collected from rosette bottles for calibration of
536 high-resolution sensors. Nutrient samples will be analyzed on board the spring cruise in EGOA and fall
537 UTL cruise. The remaining nutrient samples (and all chlorophyll samples) will be collected, frozen, and
538 transported to laboratories at UAF or Seattle for analysis (Table 1). Nutrients and oxygen will be
539 measured according to specifications set forth in the World Ocean Circulation Experiment WOCE
540 (Gordon *et al.* 1994). A limited number of hydrocasts (temperature, conductivity, nitrate, oxygen) will
541 also be conducted on the mooring cruises for in-situ calibration of moored instruments.

542 Nutrient measurements from hydrographic transects and moorings will be used to: 1) ascertain up-
543 canyon flux of nutrients (by measuring the salt flux and deep nitrate-salinity relationship, e.g. Mordy *et*
544 *al.* 2005), 2) compare how the nutrient flux varies on a narrow vs. wide shelf in response to Ekman
545 forcing (to be accomplished through a combination of LTL data and the IERP modeling component, e.g.
546 Hermann *et al.* 2009) and downwelling (or relaxation of downwelling) (Ladd *et al.* 2005), and 3) quantify
547 the entrainment of coastal water and the resulting cross shelf flux in meso-scale eddies (if present, Ladd *et*
548 *al.* 2007). Together, these measurements account for much of the cross shelf nutrient flux in the GOA,
549 and the seasonal measurements should allow for reasonable estimates of the nitrate drawdown and
550 primary production in each region (Hermann *et al.* 2009). These mechanisms were well studied in the
551 WGOA during GLOBEC, and this proposal extends those measurements to the EGOA.

552 Dissolved inorganic nutrients will be analyzed on samples collected from the seven different cruises
553 during the primary field year. The autoanalyzers used at PMEL and UAF are continuous flow analyzers
554 with segmented flow and colorimetric detection. These instruments conform to the specifications
555 established for the WOCE (now CLIVAR) (Gordon *et al.* 1994, [http://chemoc.coas.oregonstate.edu:
556 16080/~lgordon/cfamanual/whpmanual.pdf](http://chemoc.coas.oregonstate.edu:16080/~lgordon/cfamanual/whpmanual.pdf)), and have been successfully used to collect high-precision
557 nutrient data for WOCE, CLIVAR, GLOBEC, and FOCI. Prior to the field program, the two systems (and
558 standards) will be inter-calibrated.

559 Although we recognize that iron is of key importance in understanding the nutrient dynamics of the
560 Gulf of Alaska, implementation costs of an iron component are estimated at approximately ~\$250K, and
561 insufficient funds are available to undertake such research. Additionally, for various logistical reasons,
562 trace-metal clean sampling will only be possible from the oceanographic vessels proposed for the spring

563 and fall cruises. We plan to submit a proposal to NSF to fund such activities in August 2010, and are
 564 exploring if NPRB can find funds for such measurements in their fall 2010 RFP.

565 *Chlorophyll, photosynthesis and primary production*

566 *Chlorophyll a* concentrations will be measured at all stations as a measure of phytoplankton biomass
 567 and as a means to calibrate *in vivo* fluorescence sensors on CTD packages. We will coordinate sampling
 568 depths with water column chemistry measurements (i.e. at 10 m depths in the upper 50 m). Samples will
 569 be collected with the rosette on up-casts, filtered at low pressure onto GF/F filters, and stored frozen for
 570 post-cruise fluorometric analysis (Parsons *et al.* 1984). At selected stations chlorophyll will be size-
 571 fractionated through 20 μm pore-size polycarbonate filters to estimate biomass partitioning into ≥ 20 and
 572 < 20 μm size classes. Previous work has shown that these two size classes respond to different sets of
 573 environmental conditions and have different fates in the marine food web.

574 *Photosynthesis rates* will be measured using a photosynthesis – irradiance (P-E) approach on vessels
 575 where radioisotope (^{14}C) use is permitted. If an iron component to GOA IERP is funded through NPRB or
 576 other sources, we will collaborate with those investigators to ensure that measured rates are not affected
 577 by iron contamination. This will include trace-metal clean water collection and subsampling procedures
 578 such as use of Kevlar line and plastic block, as well as trace-metal clean subsampling of Go-Flos in a
 579 filtered air environment. All incubation bottles and other materials (tubing) will be cleaned to trace metal
 580 standards in any case. A photosynthetron will be used to generate the range of light intensities for 2-hr
 581 incubations (e.g. Platt & Jassby 1976; Shields & Smith 2009). Mixed layer phytoplankton communities
 582 will be targeted as this depth zone represents the bulk of water column production. P-E experiments will
 583 yield estimates of maximum photosynthetic rate, photosynthetic efficiency, and light saturation parameter
 584 (E_k) for < 20 and ≥ 20 μm size fractions of the phytoplankton community. P-E data are necessary for
 585 parameterizing plankton dynamic models; models of the coastal Gulf of Alaska currently suffer from a
 586 nearly complete lack of regional data, and model performance is highly sensitive to choice of P-E
 587 parameters (Coyle *et al.* in prep). These experiments will also allow us to determine whether
 588 photosynthetic performance varies with time (season) and location (cross-shelf, WGOA versus EGOA),
 589 as necessary to test hypothesis 2. Finally, P-E parameters will be used with concurrent irradiance and
 590 chlorophyll data to estimate *integrated water column production* (Yoshikawa & Furuya 2008).
 591 Occasional “standard” water column productivity estimates will also be made for comparison, using water
 592 collected from multiple depths and incubated under simulated *in situ* conditions for 24 hr (Welschmeyer
 593 *et al.* 1993). Where ^{14}C use is not permitted, we will make daily measurements of water column
 594 productivity using 24-hr simulated *in situ* incubations and the stable isotope ^{13}C as the tracer (Mousseau
 595 *et al.* 1995). Stable isotope methods lack the sensitivity required to determine P-E parameters from
 596 necessarily short-term P-E experiments, and we would lose the predictive ability that is afforded by
 597 estimation of maximum photosynthetic rate and photosynthetic efficiency (the P-E parameters). However,
 598 stable isotope-based measurements will still yield estimates of daily integrated primary production for
 599 comparison among seasons and locations. We will conduct a minimum of one productivity experiment of
 600 either type per day on spring and fall cruises (Table 1).

601 *Phytoplankton and Microzooplankton abundance, biomass and community composition*

602 Determination of phyto- and microzooplankton composition and biomass provides information on the
 603 functioning of the ecosystem, and will be an important element in contrasting WGOA and EGOA
 604 responses to environmental forcing. Knowledge of phytoplankton composition will allow us to relate
 605 physical processes (mixing, light availability) and nutrient supplies to the nature of the production
 606 response. As described above, large chain diatoms may be particularly important in connecting pelagic
 607 production with the benthos. Large heterotrophic dinoflagellates can respond strongly to diatom blooms;
 608 their biomass will indicate potential grazing impact of microzooplankton on diatom blooms, a major
 609 trophic transfer pathway in coastal GOA waters sampled so far (Strom *et al.* 2001; Strom *et al.* 2007).
 610 Large microzooplankters are also important prey for the crustacean zooplankton that support larvae of
 611 target fish taxa (Liu *et al.* 2005; Napp *et al.* in prep). In general, knowledge of phyto- and microzoo-

612 plankton composition and biomass is essential for evaluating the food web structure of the two regions
613 (Hypothesis 3).

614 To assess phytoplankton community composition, two types of samples will be collected on spring
615 and fall cruises (Table 1): formalin-fixed samples for inverted light microscopy (diatom and
616 dinoflagellate identification); and glutaraldehyde-fixed samples for epifluorescence microscopy (nano-
617 and picophytoplankton identification and enumeration). Epifluorescence samples will also yield the
618 abundance, biomass, and composition of the $<20\ \mu\text{m}$ microzooplankton community (Sherr & Sherr 1993;
619 Strom & Fredrickson 2008). For microzooplankton, acid Lugol's fixation and inverted light microscopy
620 will be used to identify, count and size all microzooplankton $\geq 20\ \mu\text{m}$ in size using a semi-automated
621 digitizing system (Strom *et al.* 2007). The data product will be abundance, biomass and composition of
622 the $\geq 20\ \mu\text{m}$ microzooplankton, the crucial size class for direct consumption by mesozooplankton. We
623 propose to collect compositional samples at a subset of grid stations (e.g. 20-30 stations per cruise for
624 phytoplankton, focused on significant environmental gradients such as cross-shelf transects, ~ 60 samples
625 per cruise for microzooplankton). Highest priority for sampling will be surface mixed layer samples; we
626 will collect occasional vertical profiles from stations showing vertical structure in hydrography and
627 chlorophyll (fluorescence) distribution.

628 *Bio-optical measurements and remote sensing*

629 Bio-optical measurements will also be obtained on selected cruises to evaluate the accuracy of
630 satellite ocean color measurements from SeaWiFS and MODIS (terra and aqua). Ocean color
631 measurements provide excellent information about the distribution of materials and will be used in this
632 program to assess temporal and spatial variability within the study site on days with good satellite
633 observation conditions. Once the ocean color data quality has been confirmed, we will use MODIS (terra
634 and aqua) and SeaWiFS data to evaluate the spatial and temporal changes phytoplankton standing stocks,
635 sediment loading (based on backscattering to chlorophyll ratios), and CDOM absorption.

636 *Net Sampling for Meso/Macrozooplankton and Ichthyoplankton:*

637 Net sampling will employ 4 or 5 different samplers to maximize comparison to previous studies in the
638 GOA and to address our hypotheses (H1 & H3). On all cruises, mesozooplankton will be collected with
639 paired 20 or 25 cm diameter nets 0.15 mm mesh and equipped with GO flowmeters that will target the
640 small, primarily early copepodid stages of copepods to 100 m depth (Incze *et al.* 1997; Coyle & Pinchuk
641 2003). A larger, 60 cm diameter, 0.5 mm mesh MARMAP Bongo net equipped with GO flowmeters and
642 a Seacat CTD will be used to assess larger meso- and macrozooplankton, and larval fish as is standard in
643 most programs targeting these components (e.g. CalCOFI, FOCI, MARMAP). Bongo collections will be
644 made from just above the bottom or 300 m depth consistent with FOCI methods. Spring and summer
645 cruises will also include neuston samples (Sameoto net with 0.500 mm mesh; Jump *et al.* 2008) for
646 sablefish which are in the neuston during the latter part of their larval period (Doyle *et al.* 1995).
647 Vertically stratified samples for zoo- and ichthyoplankton are highly desirable, but increase the number of
648 samples requiring processing. Stratified samples will be taken on the Seward and the Icy Point Lines.
649 After that, stratified samples will be taken at a few selected "hot spots" where there are high
650 concentrations of targeted fish larvae. The stratified samples will be obtained with either a 0.25-m²
651 Hydrobios Multinet system or with a 1-m² MOCNESS. Both will have 0.5 mm mesh nets. Prey for larval
652 fish (H3) will be collected with vertically integrated tows of 20 or 25 cm diameter nets with 0.053 mm
653 mesh and also equipped with GO flowmeters.

654 All zooplankton samples will be preserved in 10% Formalin and stained with Rose Bengal for later
655 analysis. During the spring cruises, samples from the 0.5 mm bongo zooplankton net will be rapidly
656 sorted on a light table prior to preservation to remove larval rockfish for genetic analysis by the UTL
657 project. We will work with the MTL team to access the composition, abundance and biomass of the
658 macro-zooplankton captured by their trawl nets, especially the scyphozoan jellies, euphausiids and
659 shrimps. Acoustics would be a desirable addition to the program to assess these components; the
660 inclusion is possible when one of the instrumented NOAA ships is in use, but is prohibited when a
661 UNOLS or fishing charter is used. Processing of the hydroacoustic records for euphausiids would require

662 additional financial resources for the MTL program.

663 *Meso/Macrozooplankton*

664 Budget limitations preclude complete taxonomic enumeration of all samples. We propose to use
 665 image analysis to classify samples to major taxonomic and size categories (i.e. copepods, euphausiids,
 666 chaetognaths). This approach completes sample processing in less than 1/4th the time required for
 667 traditional analysis. A scanning approach has been recently applied in other sample intensive studies
 668 (Zarauz *et al.* 2007, 2008; Irigoien *et al.* 2009; Manriquez *et al.* 2009), including nearby Prince William
 669 Sound (Bell & Hopcroft 2008, in prep.). Samples for automated image analysis will have the larger
 670 organisms removed (for separate scanning), then will be split to yield samples of 500-2000 biological
 671 particles. Fractionated samples are poured onto a flatbed scanner (see Bell & Hopcroft 2008) and
 672 arranged to reduce the number of particles touching each other or the edges of the containment frame.
 673 ZooImage then scans and calculates abundance (ind. m⁻³) and biomass (mg m⁻³) of plankton categories
 674 using the size determined by ZooImage with tax specific conversions based on published length-weight
 675 relationships for local zooplankton taxa (Bell & Hopcroft, in prep). Insights gained during our previous
 676 work with ZooImage should further improve the discriminative ability of the system. We will validate our
 677 approach by comparison to traditional taxonomic analysis conducted on all Seward Line samples.

678 Along the Seward Line samples will be processed to the lowest taxonomic category possible as per
 679 our laboratory protocol for GLOBEC to determine composition, abundance and wet-weight biomass
 680 (Coyle & Pinchuk 2003, 2005). The samples of small-sized larval prey (0.053 mm mesh), will be
 681 enumerated for basic categories of prey items as traditionally used for larval pollock research (Incze &
 682 Ainaire 1994, Napp *et al.* 1996). All data are uploaded to a Microsoft Access database for sorting and
 683 analysis. Multidimensional scaling of Bray-Curtis similarities between samples has proven an effective
 684 method of revealing cross-shelf zooplankton patterns (Coyle & Pinchuk 2005; Hopcroft *et al.* in press).

685 Rates of secondary production of prey available to MTL and UTL organisms will be calculated by
 686 applying growth and reproductive rates for copepods (Napp *et al.* 2005; Hopcroft *et al.* 2005; Liu *et al.*
 687 2006a,b, 2007, 2008; Hopcroft unpublished) and euphausiids (Pinchuk & Hopcroft 2006, 2007)
 688 determined for the GOA region during the GLOBEC program. Such relationships generally account for
 689 the influence of temperature, food availability and body size. Several such relationships are already
 690 incorporated into the coupled bio-physical models for the GOA. Literature values will be employed for
 691 other groups for which locally determined values are unavailable. Estimates of biomass and production
 692 can then be used not only to quantify the prey fields for larval fish and both MTL and UTL, but to
 693 evaluate the performance of the biophysical models developed within the GOA-IERP.

694 *Ichthyoplankton*

695 Ichthyoplankton samples from the 0.5 mm bongo will be immediately preserved in 5% buffered
 696 formalin upon collection as described above from the two spring and two summer cruises (Table 1) using
 697 the hybrid station plan previously presented (i.e. cross shelf transects added to the UTL station grid). Fish
 698 eggs and larvae will be sorted and identified at the Plankton Sorting and Identification Center in Szczecin,
 699 Poland to the lowest taxonomic level possible using the AFSC protocol. All identifications will be
 700 verified in Seattle (Matarese *et al.* 1989) and the data archived in our relational database (IchBase). Data
 701 and syntheses will be delivered to the other GOA IERP components for their use (e.g. in model – data
 702 comparisons).

703 The proposed research will first and foremost address the need to “quantify [the] distribution of larval
 704 stages of the focal species in the eastern GOA ...” This is considered a requirement of the LTL
 705 Component. Second, we will provide spatial and temporal data to parameterize the IBM transport models
 706 which must “simulate transport of early life history stages to quantify spatial match between simulated
 707 transport and suitable habitat.” Third, we will couple our physical and biological measurements to provide
 708 insights on transport and survival mechanisms that are operative in the two regions. Fourth we will
 709 provide new data on the ichthyoplankton assemblages of southeastern Alaska where there are very few
 710 data about focal species, in particular, and the ichthyoplankton assemblages in general. Fifth, this work
 711 continues the strong involvement the EcoFOCI Program has had addressing recruitment processes

712 research in the Gulf of Alaska. This project, if funded, will help us to better understand the operative
 713 recruitment processes of Groundfish in Alaskan waters by giving us access to data from the central and
 714 southeastern portions of the Gulf. These data, when combined with EcoFOCI's historical studies in
 715 Shelikof Strait and our newer NOAA and NPRB –supported studies in the eastern Bering Sea, will greatly
 716 enhance our understanding of strategies that control recruitment success.

717 Our strategy is to use the temporal and spatial (horizontal and vertical) distributions of the larvae and
 718 their prey to provide clues to the operative biophysical mechanisms that increase or decrease mortality
 719 during the early life history stages through transport to favorable or unfavorable nursery grounds
 720 [Hypothesis 1]. The data collected will provide clues, and when used as groundtruth or initial condition
 721 data for the simulation modeling, will provide much more insight into the operative physical processes
 722 that are most important. Also noteworthy is that Pacific ocean perch larvae cannot be visually
 723 distinguished from other rockfish larvae, making exact construction of species-specific distribution
 724 patterns of this taxa impossible (Gray *et al.* 2006). The UTL component will attempt to approximate the
 725 horizontal and vertical distributions of POP by assaying a small proportion of rockfish larvae from the
 726 region and applying a conversion factor to our ichthyoplankton counts of total rockfish larvae. While this
 727 is a tractable approach, it also results in a large amount of uncertainty in the derived distribution. Since
 728 larval fish often have “patchy” distributions, a better approach would be to develop the ability to visually
 729 identify the larvae of POP. If additional funds are available, we are willing and ready to collaborate with
 730 a molecular geneticist to attempt to develop morphometric, meristic, and pigment characters to visually
 731 distinguish POP from other rockfish larvae. We have been successful doing this in the eastern Bering
 732 Sea for arrowtooth and Kamchatka flounder.

733 **Significance of Research**

734 This proposal will elucidate and quantify key mechanisms responsible for the seemingly enigmatic
 735 high productivity of the coastal GOA and the fisheries, seabirds and marine mammals it supports. By
 736 employing a spatial comparison approach, this research will effectively connect atmospheric and
 737 oceanographic processes to the survival and recruitment of key groundfish species in this ecosystem,
 738 helping form a complete and vertically integrated view of this ecosystem. Improved understanding of
 739 these connections – in conjunction with longer-term observations from programs such as FOCI and
 740 GLOBEC/Seward Line – should not only lead to improved management of resources in the GOA that are
 741 driven by inter-annual variation, but provide valuable insights into how this ecosystem may respond to
 742 various longer-term climate change scenarios. In the broadest sense, the proposed research addresses
 743 important questions that will improve our general understanding of shelf transport mechanisms in
 744 buoyancy-dominated shelf regions here and elsewhere in the world (e.g., Norway, South Atlantic Bight).

745 **Connection to other GOA-IERP components (UTL, MTL, modeling)**

746 The GOA-IERP consists of 4 inter-dependent modules. As evidenced by Table 3 of the UTL
 747 proposal, the work specified in this proposal is critical to the success of the overall integration of the
 748 GOA-IERP. Our results will enable the other three GOA IERP components to test their hypotheses and
 749 accomplish their objectives. The LTL component outlined here, focuses on describing the patterns and
 750 defining the mechanisms that control the primary and secondary production in the food-web on which
 751 MTL and UTL organisms depend directly or indirectly. Furthermore, this component provides critical
 752 information on the earliest life stages of UTL target species. Finally, this component supplies essential
 753 information on variables required for seeding, evaluating and refining the performance of the coupled
 754 biophysical models (e.g. Coyle *et al.* in prep) to be employed by the modeling component.

755 Recent studies in the Gulf of Alaska (Bailey *et al.* 2005a, 2005b, Duffy-Anderson *et al.* 2005),
 756 demonstrate that fish early life histories and larval capabilities are factors that strongly influence
 757 population structure, connectivity, and recruitment success. In the WGOA spring ichthyoplankton
 758 abundance of particular species with shared early life history characteristics is synchronous with both
 759 regional and local physical forcing (Doyle *et al.* 2009). Clearly, the effectiveness of any marine fish
 760 population response model will depend on a comprehensive understanding of the early life history
 761 ecology and physical transport. For example, the success or failure of the individual-based models to

762 correctly simulate population response to physical and biological forcing will depend on the quality and
 763 amount of information we provide about the operative physical transport mechanisms, the distributions of
 764 the target taxa (horizontal and vertical) and the prey and predator fields that co-occur with the larvae.

765 **Relationship to previous work by Principal Investigators**

766 This proposal is a logical progression of research activities currently underway by the PIs and builds
 767 upon their long-term involvement in Gulf of Alaska research. This proposal will simultaneously evaluate
 768 the cross-shelf and along-shelf mechanisms that were not resolved by GLOBEC due to that program's
 769 emphasis on the single cross-shelf transect of the Seward Line. Although GLOBEC examined mesoscale
 770 patterns along the shelf in 2003, those surveys were localized and their confinement to physics, nutrients
 771 and optics prohibited them from making direct connections to zooplankton and fish. The wide geographic
 772 scale of the GOA-IERP will finally allow an evaluation of the coupled biophysical models whose
 773 development began under GLOBEC program across a large region of the coastal GOA. For the Federal
 774 (NOAA) investigators, the research proposed extends beyond what the EcoFOCI program would attempt
 775 as part of its annual operations. For example, the EGOA is a region that is not normally sampled by
 776 EcoFOCI. Working in that region at the same time as continuing operations in the WGOA requires new
 777 resources. Similarly the program does not normally sample the WGOA with the sample density and effort
 778 needed to simultaneously cover the along-shelf and cross-shelf transport of salt, heat, nutrients, fish and
 779 zooplankton. The effort proposed for this project, sampling along- and cross-shelf transport in the WGOA
 780 and EGOA in the same year(s) extends well beyond our normal annual operations and resources. See
 781 *Project Management/ PI Responsibilities* and CVs for further details.

782 **D. Project Responsiveness.**

783 In the RFP, the North Pacific Research Board stipulates that Lower Trophic Level (LTL) proposals
 784 must include: 1) a planning year, 2) two-three intensive field years, 3) an analysis or synthesis year, 4)
 785 ship time for LTL and the Middle Trophic Level (MTL) component (UNOLS vessels are not adequate for
 786 MTL sampling), and 5) annual travel to PI meetings. It is also stipulated that the LTL proposals respond
 787 to sampling requirements set forth in the Upper Trophic Level (UTL) program. Those requirements
 788 include: 1) a dedicated spring survey covering both regions in each year to obtain concurrent
 789 measurements of temperature and salinity profiles, nutrient levels, phytoplankton biomass and size
 790 structure, primary productivity, microzooplankton abundance and production, zooplankton abundance,
 791 biomass and community structure (Multi-net), sampling for the target fish larvae (following the methods
 792 described in Matarese *et al.* 2003) to identify the initial spatial distribution (time-zero) of this stage for
 793 each groundfish species, 2) in addition to sampling widely spaced survey grid points, provide
 794 measurements on scales sufficient to determine location of oceanic fronts and cross-shelf transport, 3)
 795 contribute to the summer and fall sampling surveys with all samples collected concurrently at each grid
 796 station. All sampling requests made by the RFP and the funded UTL proposal by Moss *et al.* are fully
 797 addressed given the expanded budget made available for LTL (~\$3M), and this proposal reflects
 798 numerous discussions at meetings with the UTL, MTL and modeling components anticipated to be
 799 funded under this program.

800 **E. Program Management, Timeline and Milestones**

801 *Project Management / PI Responsibilities*

802 **Hopcroft:** Russ Hopcroft will oversee the sampling program, act as Chief Scientist on the *Tiglux* cruise,
 803 and be responsible for synthesis and preparation of the Final report to NPRB. Within the disciplines,
 804 Hopcroft will be responsible for the zooplankton sampling, plus oversee associated zooplankton sample
 805 processing on shore. Hopcroft has more than 25 years of research experience. He has been lead PI and
 806 overseen sampling along the Seward Line for the past 5 years, and was a GLOBEC participant for the 4
 807 years prior. He (like most co-PIs) has significant experience in managing large projects, and working
 808 closely with several of this proposal's co-PIs. This project builds on knowledge and infrastructure

809 developed along the Seward Line, and significant interaction is expected with GLOBEC and other LTOPs
810 ongoing around the Pacific.

811 **Ladd:** Carol Ladd will be responsible for retrospective analysis of wind influence on shelf circulation.
812 Particular emphasis will be placed on the influence of gap and barrier winds on the coastal oceanography.
813 Ladd has more than 8 years experience in the physical oceanography of Alaskan waters. Her research
814 focuses on the influence of physical oceanography on ecosystems in the Bering Sea and GOA.

815 **Matarese:** Ann Matarese will contribute to the collection and identification of the early life history stages
816 of the target fish species and to the analysis of their distribution and abundance. She has over 30 years of
817 experience in the field of marine fish early life history, and she is an expert in the taxonomy and
818 systematics of the early life history stages of Northeast Pacific fishes. Her group in the Recruitment
819 Processes Program of the RACE division at AFSC is primarily responsible for studying the taxonomy and
820 ecology of the early life stages of fish species from the U.S. West coast, the Gulf of Alaska, Bering Sea
821 and the Arctic Ocean.

822 **Mordy:** Calvin Mordy will be responsible for the collection and processing of nutrient, oxygen and
823 chlorophyll data at the University of Washington, and for the moored nitrate measurements. He will
824 participate at annual PI meetings, participate on the spring cruise in the EGOA, and will be responsible
825 for presenting data in Year 5. He has 15 years research experience as a chemical oceanographer. Recent
826 research has focused on nutrient cycling in the Bering Sea, Gulf of Alaska, and Aleutian Passes using
827 underway, moored and hydrographic data. He has received grants for 1) developing nutrient budgets
828 (including seasonal, cross-shelf, and vertical) in the northern Gulf of Alaska by integrating hydrographic
829 and moored data sets with models, 2) deploying chemical and optical nitrate meters on several ships of
830 opportunity including the Alaska Ferry /Tustumena/ which frequently crosses the Alaska Coastal Current
831 in the Gulf of Alaska, and 3) deploying about 30 nitrate meters in the Gulf of Alaska, in the Aleutian
832 Passes and in the Bering Sea.

833 **Napp:** Jeffrey Napp will lead coordination of the cruises to sample fish eggs and larvae and will work
834 with Dr. Matarese to document and distribute data/analyses on the along- and cross-shelf distributions of
835 fish eggs and larvae relative to the local and regional physical and biological forcing. He has 20 years of
836 research experience in the field of lower trophic level dynamics in the Gulf of Alaska and eastern Bering
837 Sea. He currently is Program Manager for the Recruitment Processes Program at the Alaska Fisheries
838 Science Center and Co-leads NOAA's Ecosystems and Fisheries Oceanography Coordinated
839 Investigations Program with Dr. Phyllis Stabeno (NOAA/PMEL).

840 **Sonnerup:** Rolf Sonnerup will be responsible for communicating with NPRB regarding budgets and
841 reports from the University of Washington. He has the same role with NSF in the Bering Sea Ecosystem
842 Study that partners with NPRB. He is an expert in dissolved gasses, and in the use of tracers for
843 understanding the oceans role in climate change.

844 **Stabeno:** Phyllis Stabeno has lead responsibility in all aspects of the moorings (design, building,
845 deployment, recovery and processing of data) and the satellite-tracked drifters, and has lead responsibility
846 on the spring cruise in SEA (she or one of her colleagues at PMEL will be Chief Scientist on that cruise).
847 She also has the lead responsibility on collection and processing of hydrographic data on the spring cruise
848 in EGOA, the spring NOAA cruise and the fall cruise on the NOAA ship *Dyson*. She will ensure a timely
849 distribution of all these data to fellow investigators and delivery to the appropriate databases. She has
850 over 20 years experience in physical oceanographic and ecosystem research in the North Pacific and
851 Bering Sea. She co-leads NOAA's Ecosystems and Fisheries Oceanography Coordinated Investigations
852 Program with Dr. Jeff Napp (NOAA/AFSC).

853 **Strom:** Suzanne Strom will be responsible for measurement of primary productivity as well as
854 quantitative assessment of phytoplankton and microzooplankton abundance and community composition.
855 She has been involved in deciphering lower trophic level relationships in the Gulf of Alaska since Project

856 SUPER in the 1980s. Recently she conducted field studies on the factors regulating phytoplankton growth
857 rates and microzooplankton grazing in the CGOA as part of the U.S. GLOBEC program. She also
858 collaborated with other GLOBEC investigators to understand predation on phyto- and microzooplankton
859 by copepods of various species. Strom is currently involved in both regional and pan-regional GLOBEC
860 synthesis projects that seek to understand broad-scale relationships between climate, oceanographic
861 processes, and marine animal production. Progress made and questions raised during the above projects
862 inform the research proposed here. As we have grown to better understand heterogeneity in physical
863 processes and their direct consequences for production at all trophic levels, it has become clear that an
864 important next step in understanding this ecosystem will be a comparison of contrasting shelf regions.

865 **Research Platforms:**

866 Moorings will be deployed utilizing a NOAA ship of opportunity or a contract vessel, depending
867 upon shiptime schedules in 2013. Because of the significant time required to sail between the EGOA and
868 WGOA (~3 days), we have decided to utilize several ships in the spring. For the EGOA, we will request
869 ~20 days on a UNOLs oceanographic research vessel. For the WGOA we will request from NOAA in
870 2013 that four days be added to the annual EcoFOCI late larval cruise (<http://www.ecofoci.noaa.gov/>).
871 It is too late to make that request for 2011. One of the four days is necessary so that we can add sampling
872 to the existing sample grid (e.g. more CTD stations), and the other three days are necessary to extend the
873 grid to the southeastern side of Kodiak Island in 2012, which is part of the UTL sampling plan, but not
874 part of the EcoFOCI late larval cruise grid. The likely ship will be either the NOAA ship *Oscar Dyson* or
875 the NOAA ship *Miller Freeman*. Both ships have capability to do full oceanographic measurements
876 including fishing. The eastern portion of the WGOA (Kenai Peninsula) will be done on the *Tiglax* and the
877 *Tiglax* will also be responsible for the southeastern side of Kodiak in 2011 when the NOAA ship is not
878 available. During the summer, we will participate on the ship provided by the Upper Trophic Level
879 Program. Finally, the fall cruise will be done on the NOAA ship *Oscar Dyson*. The moorings will be
880 recovered on this cruise. Two other research platforms will be utilized – moorings and satellite-tracked
881 drifters (discussed in their sections above).

882 **Products**

883 The major products anticipated from this project are: (1) increased understanding of the role of along-
884 shelf vs cross-shelf exchange and productivity in shaping the quantity and distribution of planktonic
885 organisms and larval fish which will lead to improved management of resources in the GOA; (2) specific
886 knowledge of the physical forcing mechanisms, nutrient dynamics, phytoplankton production, and zoo-
887 and ichthyoplankton assemblages of southeastern Alaska; (3) the physical, chemical, and biological data
888 required by the UTL, MTL and modeling components of the GOA-IERP necessary to do a vertically
889 integrated examination of the ecosystem in the two regions (as outlined in this proposal); (4) presentation
890 of results at the Alaska Marine Science and other national/international meetings and (5) publication of
891 results in the peer-reviewed literature.
892

893 **Timeline and Milestones**

Task	2010				2011				2012				2013				2014			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PLANNING AND PREPARATION																				
RETROSPECTIVE ANALYSIS																				
FIELD WORK																				
Mooring Deployment Cruise, WGOA (NOAA)																				
Mooring Deployment Cruise, EGOA (NOAA)																				
LTL Cruise, EGOA (UNOLS)																				
LTL Cruise, Kenai Peninsula (Charter Vessel)																				
LTL Cruise Shumagins/Kodiak (NOAA)																				
Participate on UTL Fisheries Survey																				
UTL Survey/LTL/Mooring Recovery, EGOA+WGOA (NOAA)																				
DATA ANALYSIS																				
Process Spring Cruise Data Sets																				
Process Summer Cruise Data Sets																				
Process Mooring Data																				
COORDINATION WITH UTL																				
Program Planning and Cruise Planning																				
Collaborate with UTL Retrospective Analysis																				
Provide UTL a Biophysical Description of Spring Conditions																				
Provide UTL a Biophysical Description of Summer Conditions																				
Provide UTL Patterns of On-shelf and Cross-shelf Flow																				
MEASURABLE MILESTONES																				
Attend PI Meetings and Alaska Symposium																				
Mooring Deployments in EGOA and WGOA																				
LTL Spring Cruises in EGOA and WGOA																				
Participate on UTL Summer Fisheries Survey																				
LTL Fall Cruise in EGOA and WGOA																				
Deliver All Data to GOAIERP																				
Presentation of Data																				

894
895 **F. Data Management Plan**

896 Consistent with past participation in interdisciplinary research programs, data will be deposited in
897 whatever repository NPRB selects, as soon as they are available and no later than one year after collection
898 for all but the preserved-sample data which require 2 years. Hopcroft will be the data management point
899 of contact. We assume NPRB will provide data management services similar to those for BSIERP.

900 **G. Outreach and Education Plan**

901 Education and Outreach efforts for the overall GOAIERP will be developed under the supervision of
902 NPRB's Education and Outreach Coordinator once the overall program has been defined. Hopcroft will
903 make images of the GOA planktonic organisms available to NPRB upon request, and likely through
904 species information pages being implementation through the Seward Line website
905 (<http://www.sfos.uaf.edu/sewardline/>). Journalist or teacher-at-sea experiences have been supported
906 previously by PIs, and are possible if space permits. SFOS public relations office could periodically assist
907 in posting with news-worthy activities through the SFOS web-site. Funds for 3 years support of a
908 graduate student are included in this proposal, with additional graduates and/or undergraduates likely to
909 participate on cruises.

910 **H. Coordination Strategy**

911 All of the PIs have previously worked together within GLOBEC and other programs. In addition to
912 required GOA-IERP meetings, within project co-ordination will occur through e-mail, video or phone
913 conferences, and Skype or WebEx. Frequency of meetings will increase as needed during the cruise
914 planning and analysis phases of the project when at least monthly conferences are anticipated. If
915 necessary, additional face-to-face meeting will be held in Seattle where most PIs reside. Between-
916 component meetings are anticipated to occur through similar mechanisms with a subset of PIs from each
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OTHER SIGNIFICANT PUBLICATIONS:

- Hopcroft, R.R.**, B.A. Bluhm, & R.R. Gradinger. 2008. Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research (2nd edition). *North Pacific Research Board, Anchorage, Alaska.* 153 p
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Education

B. S. California State University, Sacramento, Finance, December 1986
M. S. University of Washington, Seattle, Physical Oceanography, June 1996
Ph. D. University of Washington, Seattle, Physical Oceanography, June 2000

Professional Experience

Oceanographer, NOAA/Pacific Marine Environmental Laboratory (PMEL), 2005-present
Oceanographer, Joint Institute for the Study of Atmosphere and Ocean, University of Washington
2002-2005.
Postdoctoral Research Associate, National Research Council, NOAA/PMEL, 2001-2002
Scientific Programmer, University of Washington, Seattle, 2000-2001
Research Assistant, University of Washington, Seattle, 1993-2000

Relevant Publications

Ladd, C., W. R. Crawford, C. E. Harpold, W. K. Johnson, N. B. Kachel, P. J. Stabeno, and F. Whitney (2009), A synoptic survey of young mesoscale eddies in the Eastern Gulf of Alaska, *Deep Sea Res. II*, doi:10.1016/j.dsr2.2009.02.007.

Ladd, C., C. W. Mordy, N. B. Kachel, and P. J. Stabeno (2007), Northern Gulf of Alaska eddies and associated anomalies, *Deep Sea Res. I*, 54, 487-509, doi:10.1016/j.dsr.2007.01.006.

Ladd, C. (2007), Interannual variability of the Gulf of Alaska eddy field, *Geophys. Res. Lett.*, 34, L11605, doi:10.1029/2007GL029478.

Ladd, C., P. Stabeno, and E. D. Cokelet (2005), A note on cross-shelf exchange in the northern Gulf of Alaska, *Deep Sea Res. II*, 52, 667-679.

Ladd, C., and N. A. Bond (2002), Evaluation of the NCEP-NCAR Reanalysis in the Northeast Pacific and the Bering Sea, *J. Geophys. Res. - Oceans*, 107, 3158, doi:10.1029/2001JC001157.

Other Publications

Ladd, C., and P. J. Stabeno (2009), Freshwater transport from the Pacific to the Bering Sea through Amukta Pass, *Geophys. Res. Lett.*, *36*, L14608, doi:10.1029/2009GL039095.

Ladd, C., N. B. Kachel, C. W. Mordy, and P. J. Stabeno (2005), Observations from a Yakutat eddy in the northern Gulf of Alaska, *J. Geophys. Res. - Oceans*, *110*, C03003, doi: 03010.01029/02004JC002710.

Ladd, C., G. L. Hunt, Jr., C. W. Mordy, S. A. Salo, and P. J. Stabeno (2005), Marine environment of the eastern and central Aleutian Islands, *Fish. Oceanogr.*, *14*, 22-38.

Ladd, C., J. Jahncke, G. L. Hunt, Jr., K. O. Coyle, and P. J. Stabeno (2005), Hydrographic features and seabird foraging in Aleutian Passes, *Fish. Oceanogr.*, *14*, 178-195.

Ladd, C., and L. Thompson (2002), Decadal variability of North Pacific central mode water, *J. Phys. Oceanogr.*, *32*, 2870-2881.

Synergistic Activities:

Mentor for undergraduate student intern, summer 2004.

Reviewer for several oceanography journals (*Deep Sea Research*, *Dynamics of Atmospheres and Oceans*, *Geophysical Research Letters*, *Journal of Geophysical Research – Oceans*, *Journal of Physical Oceanography*, *Progress in Oceanography*)

Collaborators in past 48 months

N.A. Bond, UW/JISAO; W. Cheng, UW/JISAO; E. Churchitser, Columbia/LDEO; E. Cokelet, NOAA/PMEL; K. Coyle, UAF; W. Crawford, IOS, Canada; E. Dobbins, UW/JISAO; A.J. Hermann, UW/JISAO; G.L. Hunt, UW; J. Jahncke, Point Reyes Bird Observatory; N.B. Kachel, UW/JISAO; F.J. Meuter, NOAA/NMFS; S. Moore, NOAA/NMML; C. Mordy, UW/JISAO; D. Musgrave, UAF; J. Napp, NOAA/NMFS; S. Salo, NOAA/PMEL; P.J. Stabeno, NOAA/PMEL; F. Whitney, IOS, Canada

Thesis Advisor: L. Thompson, University of Washington

ANN MATARESE KIERNAN

NOAA, NMFS, AFSC

7600 Sand Point Way N.E, Seattle, Washington 98115

Tel: 206-526-4111, e-mail: Ann.Matarese@noaa.gov**EDUCATION:**

1978 - B.S. Biology (with honors), Northeastern University, Boston, MA. (GPA = 3.5).

1990 - Ph.D. (Fisheries), University of Washington (GPA = 3.8).

EXPERIENCE:

1978 - 2008 – (Research Fish Biologist). Recruitment Process Program - Responsible for laboratory operations including identification of early life stages, systematic relationships of fishes based on their larvae, ontogeny and phylogeny, and oceanographic studies designed to investigate recruitment of Northeast Pacific fishes. Research also includes specialized studies on the development and phylogenetic relationships of fishes.

2008-present – (Supervisory Research Fish Biologist). Recruitment Process Program

PRESENT POSITION

Present Title – Supervisory Research Fish Biologist, Project Leader.

Description of Research - Project Leader and Supervisor in the Recruitment Processes Program.

Responsible for laboratory operations including the identification of ichthyoplankton in the northeast Pacific Ocean and Bering Sea. Responsible for assisting in the planning, designing, and implementation of studies to investigate the following: (1) determining spawning grounds and distribution of eggs and larvae for target species; (2) ascertaining abundance and horizontal distribution of eggs and larvae of major taxa occurring in the NE Pacific and Bering Sea ecosystems; and (4) investigating the factors involved in the stock/recruitment relationship (e.g., feeding, growth, predation, and transport). Research also includes specialized studies on the development and phylogenetic relationships of fishes.

Areas of Scientific Expertise: taxonomy and development of fishes; fish eggs; Gadidae and Pleuronectidae worldwide; biology, ecology of gadid and pleuronectid fishes; systematic relationships of Bathymasteridae, zoarceoids, and Cottidae; and identification and geographic distribution of marine fish eggs and larvae.

Significant research accomplishments:

- Published comprehensive paper that elucidated identification of larval gadids in the NEP.
- Participated in 3-year OCSEAP study on the ichthyoplankton off Kodiak, Alaska- received Special Act/Service award.
- One of four authors who contributed seven or more papers to the Ahlstrom Memorial Volume - *Ontogeny and Systematics of Fishes* - received Special Act/Service award.
- First researcher to examine the family Bathymasteridae for revisional work.
- Senior author of the first comprehensive guide to early life history stages of North Pacific fishes (Matarese *et al.*, 1989)-received Special Act/Service award.
- Co-author of paper describing a new flatfish, *Lepidopsetta polyxystra* (Orr and Matarese, 2000)-received NMFS Publication award for best paper Fishery Bulletin
- Senior author of the first comprehensive atlas identifying the dominant NE Pacific taxa and their distributional and relative abundance patterns. (Matarese *et al.*, 2003) - received Special Act/Service Award.

Significant Publications Related to GOA IERP Proposal:

Matarese, A. C., S. L. Richardson, and J. R. Dunn.

1981. Larval development of Pacific tomcod, *Microgadus proximus*, in the Northeast Pacific Ocean with comparative notes on larvae of walleye pollock, *Theragra chalcogramma* and Pacific cod, *Gadus macrocephalus* (Gadidae). Fish. Bull., U.S. 78(4): 923-940.

Matarese, A. C., and E. M. Sandknop.

1984. Identification of fish eggs. In: H.G. Moser (editor-in-chief), Ontogeny and Systematics of Fishes, p. 27-30, Am. Soc. Ichthyol. Herpetol., Spec. Publ. 1, 760 p.

Kendall, A. W., Jr., and **A. C. Matarese**.

1987. Biology of eggs, larvae, and epipelagic juveniles of sablefish (*Anoplopoma fimbria*), in relation to their potential use in management. Mar. Fish. Rev., 49:1-13.

Matarese, A. C., A. W. Kendall, Jr., D. M. Blood, and B.V. Vinter.

1989. Laboratory guide to early life history stages of Northeast Pacific fishes. NOAA Tech. Rep. NMFS 80, Natl. Oceanic Atmos. Adm., Natl. Mar. Fish. Serv., Seattle, WA 98115, 652 p.

Blood, D.M., **A.C. Matarese**, and M.M. Yoklavich.

1994. Embryonic development of walleye pollock, *Theragra chalcogramma*, from Shelikof Strait, Gulf of Alaska. Fish Bull., U.S. 92:207-222.

Orr, J. W. and **A. C. Matarese**.

2000. Revision of the genus *Lepidopsetta* Gill, 1862, (Teleostei: Pleuronectidae) based on adult and larval morphology, with the description of a new species.

Doyle, M. J., Busby, M. S., Duffy-Anderson, J. T., Picquelle, S. J. and **Matarese, A. C.**

2002. Early life history of capelin (*Mallotus villosus*) in the Northeast Gulf of Alaska: A historical perspective based on larval collections 1977-79. ICES Journal of Marine Science.

Matarese, A. C., D. M. Blood, S. J. Picquelle, and J. L. Benson.

2003. Atlas of the abundance and distribution patterns of ichthyoplankton from the Northeast Pacific Ocean and Bering Sea based on research conducted by the ASFC (1971-1996). NOAA Professional Paper NMFS 1.

Blood, D.B., **A. C. Matarese**, and M. S. Busby.

2005. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the Gulf of Alaska. NOAA Professional Paper NMFS 7.

Synergistic Activities:

- Serves as member of the US delegation of the Advisory Committee for US/Poland Joint Studies Agreement and participates in Joint Studies.
- NOAA Bronze Medal Winner for 2007 for developing the Ichthyoplankton Information System, a web-based product that is the first decision support tool providing vital larval fish data to resource managers for ecosystem and climate impact assessments.
- Affiliate assistant professorship, currently advising UW student Dawn Roje on ATF genetics.

Collaborators and other Affiliations:

Co-PI NPRB Connectivity between Greenland halibut spawning and nursery areas in the Eastern Bering Sea: a paradigm for offshore spawning flatfish species. PIs: Cianelli (OSU), Duffy-Anderson, Matarese and Bailey. Collaborators: Stabeno (PMEL) and Widerbuer (RACE).

Co-PI BSIERP grant to NPRB Horizontal, vertical, and temporal distribution of larvae and juveniles of walleye pollock, and transport pathways between nursery areas. PIs: Hillgruber (UAF), Duffy-Anderson, Matarese, Napp and Eisner (Auke Bay). Collaborator: Ingrid Spies.

Graduate Advisors: Drs. Theodore Pietsch and Bruce Frost (UW), Dr. Arthur Kendall (NOAA).

Calvin W. Mordy

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PROFESSIONAL PREPARATION

Ph.D. Oregon State University, Chemical Oceanography, 1991
 M.S. University of Kansas, Bioorganic Chemistry, 1986
 B.S. Berry College, Chemistry, 1982

APPOINTMENTS AND AWARDS

Oceanographer, University of Washington, 1993-present
 Antarctic Service Medal of the United States, 1999
 International WOCE Hydrographic Programme Planning Committee, 1995-1996
 Postdoctoral Fellow, University of Southern California, 1991-1993
 Research Fellow, University of Kansas, 1984

RELEVANT ACTIVITIES

My research focuses on nutrient cycling in the Bering Sea, Gulf of Alaska, and Aleutian Passes using underway, moored and hydrographic data. I maintain a moored nitrate meter along the 70m isobath on the Bering Sea Shelf, and will be examining the distribution, utilization, and recycling of nutrients during the BEST cruise in spring 2007. In the Gulf of Alaska, nutrient budgets are being developed (including seasonal, cross-shelf, and vertical) by integrating hydrographic and moored data sets with models. I am a lead nutrient chemist for the U.S. CLIVAR hydrographic program (along with researchers at Scripps Institute of Oceanography and the Atlantic Oceanographic and Meteorological Laboratory), and the lead nutrient chemist for numerous programs in the Bering Sea.

PUBLICATIONS

Relevant Publications

- Hermann, A.J., S. Hinckley, E.L. Dobbins, D.B. Haidvogel, N.A. Bond, C.W. Mordy, N.B.Kachel and P. J. Stabeno (In Press). Quantifying cross-shelf and vertical nutrient flux in the Gulf of Alaska with a spatially nested, coupled biophysical model. *Deep Sea Research II*.
- Ladd, C., C.W. Mordy, N.B. Kachel, and P.J. Stabeno (2007): Northern Gulf of Alaska eddies and associated anomalies. *Deep-Sea Res.*, 54, 487–509.
- Strom, S.L., M.B. Olson, E.L. Macri, and C.W. Mordy (2006). Cross-shelf gradients in phytoplankton community structure, nutrient utilization, and growth rate in the coastal Gulf of Alaska. *Marine Ecology Progress Series*, 328:75-92.
- Ladd, C., N.B. Kachel, C.W. Mordy, and P.J. Stabeno (2005). Observations from a Yakutat Eddy in the Northern Gulf of Alaska. *Journal of Geophysical Research – Oceans* 110: C03003, doi: 10.1029/2004JC002710.
- Stabeno, P.J., N.A. Bond, A.J. Hermann, N.B. Kachel, C.W. Mordy, and J.E. Overland (2004). Meteorology and oceanography of the northern Gulf of Alaska. *Continental Shelf Research*, 24:859–897.

Other Publications

- Mordy, C.W., L. Eisner, P. Proctor, P.J. Stabeno, T. Whitledge, A. Devol, and D.H. Shull (Submitted): A breakdown in the marine nitrogen cycle: Accumulation of nitrite on the Bering Sea Shelf. *Mar. Chem.*
- Stabeno, P.J., J. Napp, C. Mordy, and T. Whitledge (Submitted), The influence of seasonal sea ice on the eastern Bering Sea shelf ecosystem: 2005. *Prog. Oceanogr.*
- Mordy, C.W., P.J. Stabeno, D. Righi, and F.A. Menzia (2008): Origins of the subsurface ammonium maximum in the southeast Bering Sea. *Deep-Sea Res. II*, 55(16–17), 1738-1744.
- Ladd, C., G.L. Hunt Jr., C.W. Mordy, S. Salo, and P.J. Stabeno (2005). Marine environment of the eastern and central Aleutian Islands. *Fish. Oceanogr.*, 14 (Suppl. 1):22-38.
- Mordy, C.W., P.J. Stabeno, C. Ladd, S. Zeeman, D.P. Wisegarver, S. Salo, and G. Hunt Jr. (2005). Nutrients and primary production along the eastern Aleutian Island Archipelago. *Fisheries Oceanography*, 14 (Suppl. 1):55-76.

COLLABORATORS

- | | |
|--|---|
| Nicholas A. Bond, University of Washington | Anne C. Sigleo, USEPA, Western Ecology |
| John Bullister, Pacific Marine Environmental Laboratory | Division, Newport, OR |
| Edward D. Cokelet, Pacific Marine Environmental Laboratory | Rolf Sonnerup, University of Washington |
| Richard Feely, Pacific Marine Environmental Laboratory | Phyllis J. Stabeno, Pacific Marine Environmental Laboratory |
| W. E. Frick, USEPA, Environmental Effects Laboratory, Athens, GA | Suzanne Strom, Western Washington University |
| Albert J. Hermann, University of Washington | R. Wanninkhof, Atlantic Oceanographic and Meteorological Laboratory |
| George Hunt, University of Washington | Frank Whitney, Institute of Ocean Sciences, Sidney, B.C |
| Gregory Johnson, Pacific Marine Environmental Laboratory | Terry E. Whitledge, University of Alaska Fairbanks |
| Nancy Kachel, University of Washington | David P. Wisegarver, Pacific Marine Environmental Laboratory |
| Robert Key, Princeton University | C. S. Wong, Institute of Ocean Sciences |
| A. Kozyr, Oak Ridge National Laboratory | Stephan I. Zeeman, University of New England |
| Carol Ladd, University of Washington | Jia-Zhong Zhang, Atlantic Oceanographic and Meteorological Laboratory |
| Kitack Lee, Pohang University, Republic of Korea | |
| Allen S. Macklin, Pacific Marine Environmental Laboratory | |
| F. Millero, University of Miami | |
| Jeffery Napp, Alaska Fisheries Science Center | |
| J. E. Overland, Pacific Marine Environmental Laboratory | |
| Scott Pegau, Alaska Fish and Game | |
| T.-H. Peng, Atlantic Oceanographic and Meteorological Laboratory | |
| Christopher Sabine, Pacific Marine Environmental Laboratory | |
| T. Saino, Nagoya University, Japan | |
| Sigrid A. Salo, Pacific Marine Environmental Laboratory | |

DR. JEFFREY MORTON NAPP**Personal Information**

NOAA, NMFS, Alaska Fisheries Science Center
 7600 Sand Point Way Northeast
 Seattle, WA 98115-6349
 (206) 526-4148; Jeff.Napp@.NOAA.gov

Academic credentials

(Degree and Date Conferred)	(Institution)
Ph.D. (Oceanography), November, 1986	University of California, San Diego
B.S. (Oceanography), <i>cum laude</i> , 1980	University of Washington
B.A. (Zoology), <i>cum laude</i> , 1980	University of Washington

Professional credentials

NOAA/NMFS, Recruitment Processes Program Leader, and Co-Leader of NOAA's Ecosystems & Fisheries Oceanography Coordinated Investigations (Eco-FOCI), 2001-Present.
 NOAA/NMFS, Oceanographer and Principal Investigator for FOCI, 1990-2001.
 University of Washington, School of Oceanography, Affiliate Associate Professor, 2003 - present.
 University of Washington, School of Oceanography, Affiliate Assistant Professor, 1991-2003.
 Executive Committee, Bering Sea FOCI. A NOAA Coastal Ocean Program sponsored research partnership between NOAA and Academia, 1993-1996
 University of Miami, Rosenstiel School of Marine and Atmospheric Science, Research Assistant Professor, 1989-1990.

Publications**5 most recent related to proposed project**

- Hinckley, S., J.M.Napp, A.J.Hermann, and C.Parada (2009). Simulation of physically-mediated variability in prey resources for larval fish: a three-dimensional NPZ model. *Fisheries Oceanography*, 18:201-223.
- Coyle, K.O., A.I. Pinchuk, L.B. Eisner, and J.M. Napp (2008). Zooplankton species composition, abundance and biomass on the eastern Bering Sea shelf during summer: the potential role of water column stability and nutrients in structuring the zooplankton community. *Deep-Sea Research II*, 55:1775-1791.
- Napp, J.M., R.R. Hopcroft, C.T. Baier, C. Clarke (2005). Distribution and species-specific egg production of *Pseudocalanus* in the Gulf of Alaska. *J. Plankton Research*, 27:415-428.
- Weingartner, T.J., K. Coyle, B. Finney, R. Hopcroft, T. Whitedge, R. Brodeur, M. Dagg, E. Farley, D. Haidvogel, L. Halderson, A. Hermann, S. Hinckley, J. Napp, P. Stabeno, T. Kline, C. Lee, E. Lessard, T. Royer, and S. Strom (2002). The Northeast Pacific GLOBEC Program: Coastal Gulf of Alaska. *Oceanography*, 15:48 - 63.
- Napp, J.M., L.S. Incze, P.B. Ortner, D.L.W. Siefert, and L. Britt (1996). The plankton of Shelikof Strait, Alaska: standing stock, production, mesoscale variability and their relevance to larval fish survival. *Fisheries Oceanography*, 5 (Suppl. 1):19-38.

5 other significant publications

- Holliday, D.V., P.L. Donaghay, C.F. Greenlaw, J.M. Napp, and J.M. Sullivan (2009). High-frequency acoustics and bio-optics in ecosystems research. *ICES Journal of Marine Research*, 66:974-980.

- Hunt, G.L., Jr., P.J. Stabeno, S. Strom, and J.M. Napp (2008). Patterns of spatial and temporal variation in the marine ecosystem of the southeastern Bering Sea, with special reference to the Pribilof Domain. *Deep-Sea Research. II*, 55:1919-1944.
- Stabeno, P.J., G.L. Hunt, Jr., J.M. Napp and J.D. Schumacher (2006). Physical forcing of ecosystem dynamics on the Bering Sea shelf. In: *The Sea*, Robinson, A.R. and Brink, K.H. (Eds.), Vol. 14:1177-1212.
- Napp, J.M., C.T. Baier, R.D. Brodeur, K.O. Coyle, N. Shiga, and K. Mier (2002). Interannual and decadal variability in zooplankton communities of the southeast Bering Sea shelf. *Deep Sea Research. II*, 49: 5991-6008.
- Napp, J.M. and G.L. Hunt, Jr. (2001). Anomalous conditions in the southeastern Bering Sea, 1997: Linkages among climate, weather, ocean, and biology. *Fisheries Oceanography*, 10:61-68.

Current Manuscripts

- Livingston, P.A., K.A., Aydin, J.L. Boldt, A.B. Hollowed, and J.M. Napp. Alaska marine fisheries management: advancements and linkages to ecosystem research. Book chapter
- Napp, J.M., C.T. Baier, S. Strom, and K. Fredrickson. Variability in copepod grazing and reproduction in the coastal subarctic northeast Pacific – the influence of climate. In progress.
- Stabeno, P.J., J.M. Napp, C. Mordy, and T.E. Whitledge. The influence of seasonal sea ice on the eastern Bering Sea shelf ecosystem. *Progress in Oceanography*, in revision.
- Stafford, K.M., S.E. Moore, P.J. Stabeno, D.V. Holliday, J.M. Napp and D.K. Mellinger. Biophysical ocean observation in the southeastern Bering Sea. *Geophysical Research Letters*, submitted.

Collaboration Past 4 years

K. Coyle, Univ. Alaska, Fairbanks	R. Hopcroft, Univ. Alaska, Fairbanks
E. Curchister, Rutgers Univ.	G. Hunt, Jr., Univ. Washington
M. Dagg, Louisiana Marine Consortium	G. Kruse, Univ. Alaska, Fairbanks
C. Greenlaw, BAE Systems, retired	E. Lessard, Univ. Washington
N. Hilgruber, Univ, Alaska, Fairbanks	P. Stabeno, NOAA, PMEL
S. Hinckley, NOAA - AFSC	S. Strom, Western Washington Univ.
D.V. Holliday, BAE Systems, retired	T. Whitledge, Univ. Alaska, Fairbanks

Graduate Advisor: M.M. Mullin, UCSD - SIO, deceased

Post-Graduate Advisor: P.B. Ortner, Univ. Miami

Thesis/Dissertation Advisees

Total Advisees – 2 Ph.D. / 2 M.Sc. / 1 B.S. / 4 NOAA Summer Interns

Biographical Sketch – Rolf E. Sonnerup

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 University of Washington
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 Seattle, WA 98105-5672
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 email rolf@u.washington.edu

Professional Preparation

Princeton University	Chemistry	B.A., 1987
University of Washington	Chemical Oceanography	Ph.D., 1999
Niels Bohr Institute for Geophysics	Postdoctoral Scholar	1999-2000
Joint Institute for Study of the Atmosphere and Ocean (JISAO)	Postdoctoral Scholar	2000-2001

Appointments

JISAO	Research Scientist	2002-
University of Washington	Affiliate research professor	2007-

Publications in last 3 years

- Sonnerup, R. E., J. L. Bullister, and M. J. Warner (2008) Improved estimates of ventilation rate changes and CO₂ uptake in the Pacific Ocean using chlorofluorocarbons and sulfur hexafluoride, *Journal of Geophysical Research*, **113**, C12007, doi: 10.1029/2008JC004864.
- Bullister, J. L., D. P. Wisegarver, and R. E. Sonnerup (2006) Sulfur Hexafluoride as a transient tracer in the North Pacific Ocean, *Geophysical Research Letters*, **33**, L18603, doi:10.1029/2006GL026514.
- Sonnerup, R. E., J. L. Bullister, S. Mecking (2007) Circulation rate changes in the eastern subtropical North Pacific based on chlorofluorocarbon ages, *Geophysical Research Letters*, **34**, L08605, doi:10.1029/2006GL028813.
- Sonnerup, R. E., A. P. McNichol, P. D. Quay, R. H. Gammon, J. L. Bullister, and R. D. Slater (2007) Anthropogenic $\delta^{13}\text{C}$ changes in the North Pacific Ocean reconstructed using a multiparameter mixing approach (MIX), *Tellus*, 59B, 303-317.
- Quay, P., R. Sonnerup, J. Stutsman, J. Maurer, A. Körtzinger, X. A. Padin, and C. Robinson (2007) Anthropogenic CO₂ accumulation rates in the North Atlantic Ocean from changes in the $^{13}\text{C}/^{12}\text{C}$ of dissolved organic carbon, *Global Biogeochemical Cycles*, **21**, GB1009, doi:10.1029/2006GB002761.

Other Relevant Publications

- Sonnerup, R. E. (2001) On the relations among CFC derived water mass ages, *Geophysical Research Letters* **28**, 9, 1739-1742.
- Sonnerup, R. E., P. D. Quay and J. L. Bullister (1999) Thermocline ventilation and oxygen utilization rates in the subtropical North Pacific based on CFC distributions during WOCE, *Deep Sea Research* **46**, 777-805.

Mecking, S., M. J. Warner, C. E. Greene, S. L. Hautala, and R. E. Sonnerup (2004)
Influence of mixing on CFC uptake and CFC ages in the North Pacific thermocline,
Journal of Geophysical Research, **109**, C07014, doi: 10.1029/2003JC001988.

Collaborators & Other Affiliations

i) Collaborators: C. Mordy, P. Quay, S. Mecking and M. Warner (U. Washington), J. Bullister, C. Sabine and R. Feely (NOAA-PMEL), W. J. Jenkins and A. P. McNichol (WHOI), R. Key and J. L. Sarmiento (Princeton).

ii) Graduate and Postdoctoral Advisors

Graduate Advisor: P. Quay (U. Washington)

Postdoctoral Sponsors: G. Shaffer (U. Copenhagen), J. Bullister (NOAA-PMEL)

Phyllis Jean Stabeno

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Education

B. S. University of Washington, Mathematics, June 1972
M. A. University of California, Berkeley, Mathematics, June, 1974
Ph. D. Oregon State University, Physical Oceanography, June, 1982

Professional Experience

Co-director of NPCREP ,	2004-present
Co-director of FOCI ,	1998-present
Oceanographer, NOAA/Pacific Marine Environmental Laboratory (PMEL),	1988-present
Oceanographer, Joint Institute for the Study of Atmos. and Ocean, U. of W.	1987-8.
Research Associate; Oregon State University, Corvallis OR,	1985-1987
Research Fellow; Univ. College Galway, Ireland,	1982-1984

PI or Co-PI on numerous research programs including:

2001-2005: Shelf Transport, NP GLOBEC (Stabeno *et al.*)
2001-2005: Modeling the GOA, NP GLOBEC (Haidvogel *et al.*)
2004-2005: Shelf-slope Exchange at Pribilof Islands, NSF (Hunt *et al.*)
2003-2005 Long-term observations on the Bering Sea shelf (2004-2005), NPRB (Stabeno *et al.*)
2005-2008 Synthesis: Bottom-up control of lower-trophic variability, GLOBEC (Bond *et al.*)
2008-2011 BEST: Hydrography of the Eastern Bering Sea shelf (Whitledge *et al.*)
2008-2012 Bering Sea Integrated Ecosystem Research Program (Sigler *et al.*)
2010-2013 MMS: Biophysical Moorings: Ecosystem Observations in the Chukchi Sea (Stabeno *et al.*)

Selected Publications (over 100 total publications)

5 recent publications relevant to proposed project

Stabeno, P.J., C. Ladd, and R.K. Reed (2008): Observations of the Aleutian North Slope Current, Bering Sea, 1996–2001. *J. Geophys. Res.* 2009.

Stabeno, P.J., N.A. Bond, and S.A. Salo (2007): On the recent warming of the southeastern Bering Sea Shelf. *Deep-Sea Res. II*, 54(23–26), 2599–2618..

Stabeno, P.J., D.G. Kachel, N.B. Kachel, and M.E. Sullivan (2005): Observations from moorings in the Aleutian Passes: Temperature, salinity, and transport. *Fish. Oceanogr.*, 14 (Suppl. 1), 39–54.

Stabeno, P.J., R.K. Reed, and J.M. Napp (2002): Transport through Unimak Pass, Alaska. *Deep-Sea Res. Pt. II*, 49(26), 5919–5930.

Stabeno, P.J., N.A. Bond, A.J. Hermann, N.B. Kachel, C.W. Mordy, and J.E. Overland (2004): Meteorology and oceanography of the northern Gulf of Alaska. *Cont. Shelf Res.*, 24, 859–897.

5 other significant publications

Stabeno, P.J., G.L. Hunt, Jr., J.M. Napp, and J.D. Schumacher (2005): Interdisciplinary ocean science of the Bering Sea Continental Shelf. In *The Sea*, Vol. 14—The Global Coastal Ocean: Interdisciplinary Regional Studies and Syntheses, John Wiley & Sons, Inc [in press]

Stabeno, P.J., J.D. Schumacher, and K. Ohtani (1999): The physical oceanography of the Bering Sea. In *Dynamics of the Bering Sea: A Summary of Physical, Chemical, and Biological Characteristics, and a Synopsis*

of *Research on the Bering Sea*, T.R. Loughlin and K. Ohtani (eds.), Univ. of Alaska Sea Grant, AK-SG-99-03, N. Pacific Marine Science Organization (PICES), 1–28.

Stabeno, P.J., N.B. Kachel, M. Sullivan, and T.E. Whitledge (2002): Variability of physical and chemical characteristics along the 70-m isobath of the southeast Bering Sea. *Deep-Sea Res. Pt. II*, 49(26), 5931–5943.

Stabeno, P.J., N.A. Bond, N.B. Kachel, S.A. Salo, and J.D. Schumacher (2001): On the temporal variability of the physical environment over the south-eastern Bering Sea. *Fish. Oceanogr.*, 10(1), 81–98.

Stabeno, P.J., and J.E. Overland (2001): The Bering Sea shifts toward an earlier spring transition. *Eos Trans. Am. Geophys. Union*, 82(29), 317, 321.

Synergistic Activities:

- 1998- present Co-director of Fisheries Oceanography Coordinated Investigations and NPCREP (since 2004), both interdisciplinary research programs that transfer information to Fisheries Management.
- 1995-present Collaborated on numerous hydrodynamic modeling efforts with A. Hermann, that have resulted in utilization of observations to ground truth models.
- 2001-2003 Together with G. L Hunt instigated Aleutian Islands Ecosystem Study, the first ecosystem study conducted in these islands.
- 2003-2005 Co-editor of special issue on the Aleutian Islands Ecosystem
- 2007-present Member of the Council of PIs for the Bering Sea Integrated Ecosystem Research Program
- 2008-2011 Member of Science Advisory Board for Bering Sea Study (2007-2010)

Collaborators in past 48 months

K.M. Bailey, NOAA/AFSC; N.A. Bond, UW/JISAO; R.D. Brodeur, NOAA/NWSC; E. Churchitser, Columbia/LDEO; E. Cokelet, NOAA/PMEL; K. Coyle, UAF; W. Crawford, IOS, Canada; J.J. Cullen, Dalhousie; R.F. Davis, Dalhousie; E. Dobbins, UW/JISAO; M. Flint, Moscow; M.G. Foreman, IOS, Canada; Gladyshev, Moscow; J. Goering, UAF; C. Grosch, ODU; D. Haidvogel, Rutgers; S. Henrichs, UAF; A. Hermann, UW/JISAO; B. M. Hickey, UW; A. Hollowed, NOAA/AFSC; R. Hopcroft, UAF; G. Hunt, UW; J. Johnson, NOAA/PMEL; N. Kachel, UW/JISAO; C. Ladd, NOAA/PMEL; R. Leben, U. Colorado; P. Livingston, NOAA/NMFS; E. Loggerwell, NOAA/NMFS; A. Macklin, NOAA/PMEL; L. McNutt, UJ. Meuter, NOAA/NMFS; S. Moore, NOAA/NMML; C. Mordy, UW/JISAO; D. Musgrave, UAF; J. Napp, NOAA/NMFS; S.R. Okkonen, UAF/SFOS; J. E. Overland, NOAA/PMEL; V.I. Radchenko, SakhNIRO; R. Reed, NOAA/PMEL Ret.; S. Riser, UW; T. Royer, Old Dominion; S. Saitoh, Hokkaido U., Japan; R. Sambrotto, Columbia/LDEO; G. Schmidt, SAIC, Maryland; J. Schumacher, Two Crow Con.; A. Sigleo, EPA/WED; E. Sinclair, NOAA/NMML; M. Spillane, UW/JISAO; R. Steed, UW; S. Strom, WWU; M. Sullivan, NOAA/PMEL; T. Whitledge, UAF; G. Walters, NOAA/NMFS Ret.; F. Whitney, IOS, Canada; C. Wilson, NOAA/NFSC; S. Zeeman, U. of New England

Students Advised and Postdoctoral Scholars Sponsored: P. van Meurs, (NRC post doc); Carol Ladd (NRC postdoc), Joint Institute for Study of Atmosphere and Ocean/ University of Washington.

Major Professor: P. P. Niiler, Scripps Institution of Oceanography

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PROFESSIONAL PREPARATION

University of Washington, Seattle, WA:	Ph.D., Biological Oceanography, 1990
Harvard University, Cambridge, MA:	M.A., Biology, 1983
Middlebury College, Middlebury, VT:	B.A., Biology, 1981 (magna cum laude)

APPOINTMENTS

2008-present	Senior Marine Scientist, Western Washington University
1995-2008	Marine Scientist, Western Washington University
1992-1995	Research associate, Western Washington University
1991-92	Postdoctoral research associate, University of Texas at Austin
1985-90	Research assistant, University of Washington
1983	Research assistant, Harvard University
1981-82	Research technician, Department of Nuclear Medicine, Children's Hospital, Boston, MA

RESEARCH INTERESTS

Planktonic food web interactions, including predator-prey relationships and chemical ecology
 Role of planktonic organisms in marine biogeochemistry
 Physiology, ecology and functional morphology of marine protozoa
 North Pacific, Gulf of Alaska and Bering Sea oceanography

5 PUBLICATIONS CLOSELY RELATED TO THIS PROJECT:

Strom, S.L., Macri, E.L., and K.A. Fredrickson. Light limitation of summer primary production in the coastal Gulf of Alaska: physiological and environmental causes. In review, *Marine Ecology Progress Series*.

Dagg, M., S. Strom, and H. Liu. 2009. High feeding rates on large particles by *Neocalanus flemingeri* and *N. plumchrus*, and consequences for phytoplankton community structure in the subarctic Pacific Ocean. *Deep-Sea Research I* 56: 716-726.

Strom, S.L., E.L. Macri and M.B. Olson. 2007. Microzooplankton grazing in the coastal Gulf of Alaska: variations in top-down control of phytoplankton. *Limnology and Oceanography* 52: 1480-1494.

Strom, S.L., M.B. Olson, E.L. Macri and C.W. Mordy. 2006. Cross-shelf gradients in phytoplankton community structure, nutrient utilization, and growth rate in the northern coastal Gulf of Alaska. *Marine Ecology Progress Series* 328: 75-92.

Strom, S.L. and K.A. Fredrickson. 2008. Intense stratification leads to phytoplankton nutrient limitation and reduced microzooplankton grazing in the southeastern Bering Sea. *Deep-Sea Research II* 55: 1761-1774.

5 OTHER PUBLICATIONS:

Graham, S.L. and S.L. Strom. Growth and grazing of microzooplankton in response to the harmful alga *Heterosigma akashiwo* in prey mixtures. In review, *Aquatic Microbial Ecology*.

- Fredrickson, K.A. and S.L. Strom. 2009. The algal osmolyte DMSP as a microzooplankton grazing deterrent in laboratory and field studies. *Journal of Plankton Research* 31: 135-152.
- Strom, S.L. and K.J. Bright. 2009. Inter-strain differences in nitrogen use by the coccolithophorid *Emiliania huxleyi*, and consequences for predation by a planktonic ciliate. *Harmful Algae* 8: 811-816.
- Hunt, G.L. Jr., P.J. Stabeno, S.L. Strom, and J.M. Napp. 2008. The Pribilof Domain: Patterns of spatial and temporal variation in the marine ecosystem of the southeastern Bering Sea. *Deep-Sea Research II* 55: 1919-1944.
- Strom, S.L. 2008. Microbial ecology of ocean biogeochemistry: a community perspective. *Science* 320: 1043-1045.

SYNERGISTIC ACTIVITIES

- Undergraduate and graduate teaching: teach graduate courses (Biological Oceanography, Coastal Ocean Processes), advise graduate and undergraduate research, including 1-2 students per yr in Shannon Point's Minorities in Marine Science Undergraduate Program (MIMSUP). Total undergraduate projects advised: >30.
- Organized 7 workshops for NEP GLOBEC process and synthesis groups (2002-2009), acted as chief scientist on 3 of 5 GLOBEC process cruises, served on regional and national GLOBEC science steering committees, and brought 7 students (including 2 REU-supported undergraduates) on research cruises to the Gulf of Alaska.
- Current committee service: Alaska Regional Research Vessel oversight committee; Journal of Plankton Research editorial board; PICES Working Group: Iron supply and its impact on biogeochemistry and ecosystems in the North Pacific Ocean.

COLLABORATORS AND OTHER AFFILIATIONS

i) Collaborators:

D. Ainley (H.T. Harvey & Associates), K. Aydin (AFSC), J. Bisagni (UMass Dartmouth), E. Hofmann (ODU), S. Bograd (SWFSC), B. Brahmsha (Scripps), R. Brodeur (NWFSC), J. Collie (URI), K. Coyle (UAF), M. Dagg (LLUMCON), K. Daly (Univ. South Florida), S. Gaichas (AFSC), D. Gifford (URI), R. Hopcroft (UAF), A. Hallowed (AFSC), G. Hunt (UW), S. Menden-Deuer (URI), C. Mordy (UW/PMEL), E. Murphy (British Antarctic Survey), J. Napp (AFSC/NOAA), B. Palenik (Scripps), F. Prahl (OSU), J. Ruzicka (NWFSC), T. Ryneerson (URI), E. Sherr (OSU), W. Smith (VIMS), P. Stabeno (PMEL/NOAA), J. Steele (WHOI), A. Thomas (Univ Maine), T. Whitledge (UAF), G. Wolfe (CSU Chico),

ii) Advisors:

Ph.D. advisor: Bruce W. Frost

Post-doctoral advisor: Edward J. Buskey

iii) Post-doctoral advisor for: Hans Jakobsen, Jude Apple

Thesis advisor (all M.S.) last 5 years for: Deborah Erenstone, Kerri Fredrickson, Tristan Wohlford, Brandon Jensen, Heidi Zimmer, Blair Paul, Sylvia Graham, Virginia Selz