

Appendix B. Three text sections and 12 figures providing details of sites, discussion of causes of local scale variation, results of surveys, oceanographic conditions, and ecological subsidies.

Text Section 1. Methods – Site names and details.

Three sites at Cape Foulweather (text Fig. 1) were Fogarty Creek (FC), Boiler Bay (BB), and Manipulation Bay (MB), spread along ~ 1 km of shoreline. FC and BB have been under continuous study since 1995 and 1983, respectively. Three sites at the next southward region, Cape Perpetua (CP), were Yachats Beach (YB), Strawberry Hill (SH), and Tokatee Klootchman (TK), spread over ~10 km of shore. SH is another long-term study site, with observations beginning in 1985, and YB and TK have been studied since ~1998. Four sites at the next southward location, Cape Blanco (CB), were Cape Blanco North (CBN), Cape Blanco South (CBS), Port Orford Heads (POH), and Rocky Point (RP), spread across ~10 km of shore. These sites have been under investigation since ~1996-97. Port Orford Head was added as a fourth site because prior observations suggested that pattern and dynamics at this site diverged from that at the sites to the north and south, and thus might provide an “exception to the rule” for Cape Blanco. The three most southerly sites on or just south of Cape Mendocino (CM), were Cape Mendocino North (CMN), Cape Mendocino South (CMS), and Kibesillah Hill (KH). The two CM sites are about 500 m apart, and KH is ~60 km further south. Although KH is still well within the oceanographic region most directly influenced by upwelling dynamics associated with Cape Mendocino, we recognize that it is also much more distant from the other two sites with which it is associated (in our analyses) and will address possible consequences in the Results section.

Text Section 2. Detailed results of community structure analysis.

To gain insight into whether the differences summarized in the analysis of total community structure were due primarily to sessile invertebrates or macrophytes, we analyzed the dominant constituent taxa within these groups (MANOVA, Appendix A Table A2B, C, Appendix B Figs. B2, B3). Results suggest that sessile invertebrates were the taxa most responsible for temporal (among-year) variability. Abundance of four barnacle species (*B. glandula*, *B. nubilus*, *C. dalli*, and *P. polymerus*) and mussels (*Mytilus* spp.) varied by both year and cape x year (Appendix A Table A2B, Appendix B Fig. B2, $p < 0.0001$). In contrast, abundance of the three most abundant taxa of macrophytes (*Saccharina sessilis*, *Phyllospadix scouleri*, and coralline algal turfs *Corallina* spp.) varied primarily at cape and site scales and less among years (Appendix A Table A2C, Appendix B Fig. B3). These results are consistent with our field observations that barnacle and mussel populations can vary substantially through time, both seasonally and among years, while abundances of macrophyte populations tend to vary less.

Text Section 3. Discussion of causes of local-scale variation

Sources of local-scale variation

Probing local-scale variation can suggest possible factors underlying among-site differences. Although sites within a few hundred meters of one another (e.g., FC and BB, CBS and CBN, CMN and CMS) can differ, they nonetheless tend to cluster together (e.g., Figs. 4, 5). Exceptions include: (1) sites at CF and CM, the most widely separated capes, are commingled with respect to community structure (Fig. 4a), and (2) environmentally, Cape Blanco sites POH and RP cluster with CB and CM sites, respectively. The commingling of CF and CM sites is interesting. Sites within both are macrophyte-dominated, with very low covers of sessile invertebrates (Appendix B Fig. B3). External inputs and conditions differ between these capes in

upwelling, temperature, nitrates + nitrites, and recruitment but are similar in having low phytoplankton abundance (Appendix B Figs. B5–B11).

The outlier status of environments POH and RP seem attributable to different factors. Both tend to have water temperatures (Appendix B Fig. B6) that are warmer than neighboring sites and overlap those at CP and CM. However, POH has higher and RP lower recruitment at levels more similar to those at CP and CM respectively. Higher recruitment at POH might explain why sessile invertebrates are relatively more abundant (due to higher settlement and growth; Fig. 3), while recruitment patterns at RP are most similar to those at CM sites (Appendix B Figs. B10, B11). Coastal topography may underlie the “outlier” status of these sites. POH is in the lee of Cape Blanco to the north (Fig. 1), where the California Current separates from the coast (Fig. 1 composite SST, Castelao and Barth 2005), and RP is in the lee of POH (Fig. 1). POH and RP are thus located in successive “upwelling shadows” which can influence retention and abundance of particles such as larvae and phytoplankton (e.g., Graham and Largier 1997). Further work would be needed to parse out the relative influence of these and other potential environmental differences (e.g., sand shifting) on these local communities.

LITERATURE CITED

- Castelao, R. M., and J. A. Barth. 2005. Coastal ocean response to summer upwelling favorable winds in a region of alongshore bottom topography variations off Oregon. *J. Geophys. Res.* **110**:C10S04, doi:10.1029/2004JC002409.
- Graham, W. M., and J. L. Largier. 1997. Upwelling shadows as nearshore retention sites: the example of northern Monterey Bay. *Continental Shelf Research* 17:509–532.
- Petraitis, P. S., A. E. Dunham, and P. H. Niewiarowski. 1996. Inferring multiple causality: the limitations of path analysis. *Functional Ecology* 10:421–431.

Wootton, J. T. 1994. Predicting direct and indirect effects: an integrated approach using experiments and path analysis. *Ecology* 75:151–165.

Figures

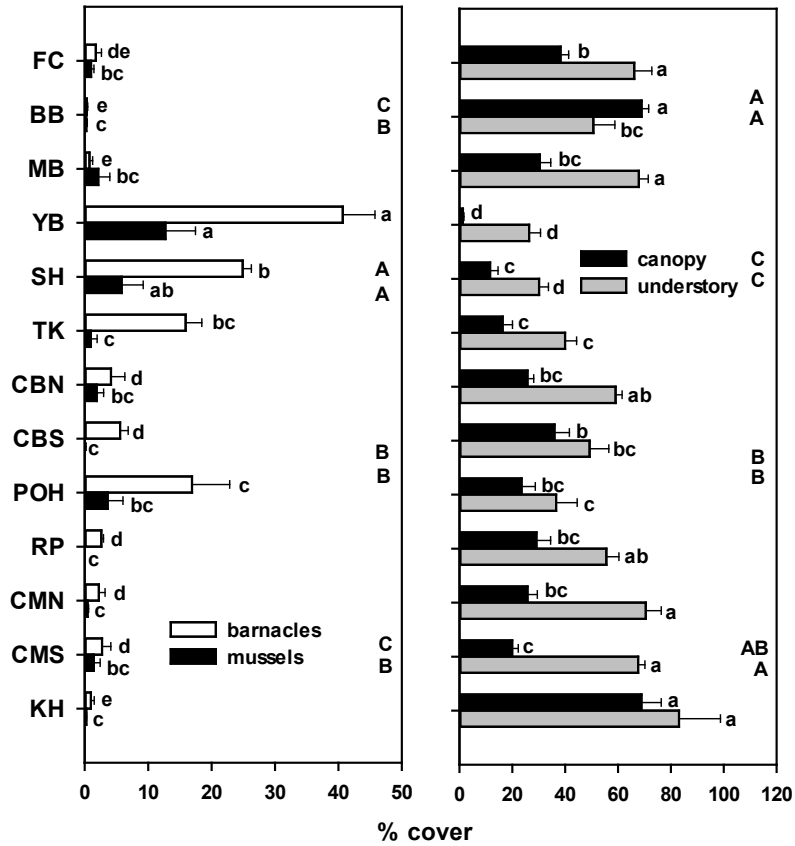


FIG. B1. Average abundances (% cover) of dominant sessile invertebrates (barnacles and mussels, left panel) and macrophytes (canopy and understory, right panel) at 13 study sites, shown from north to south from top to bottom. Differences among sites (lower-case letters) or capes (upper-case letters) are shown for each taxon, with abundances having different letters being different at $p < 0.05$ (as determined using linear contrasts after analysis of variance). Such comparisons were made for each taxon among sites or capes, not between taxa. See text and Appendix A Table A2 for results of multivariate analysis of variance testing total cover each of barnacles, mussels, canopy, and understory across years.

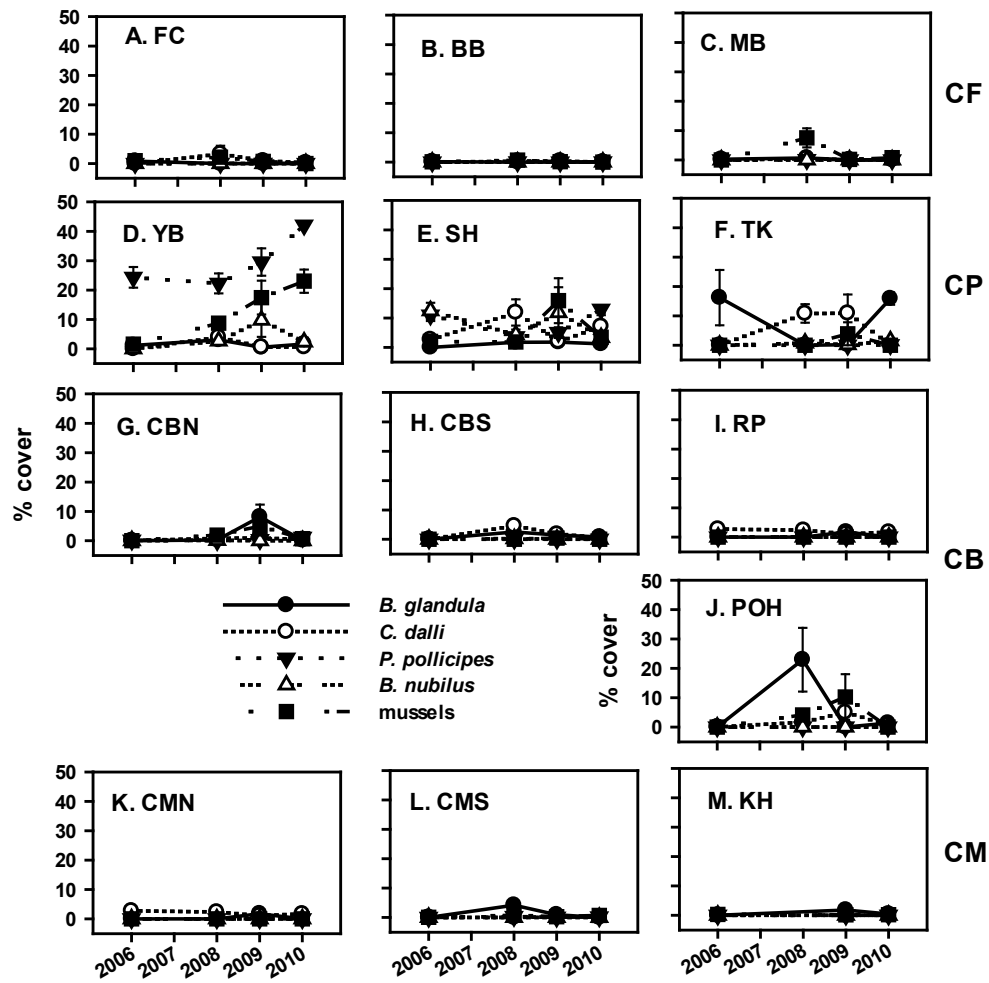


FIG. B2. Time series from 2006 to 2010 of abundance (mean % cover) of major sessile animal taxa at 3-4 sites nested within 4 capes, arranged from north to south from top to bottom and from left to right within each cape.

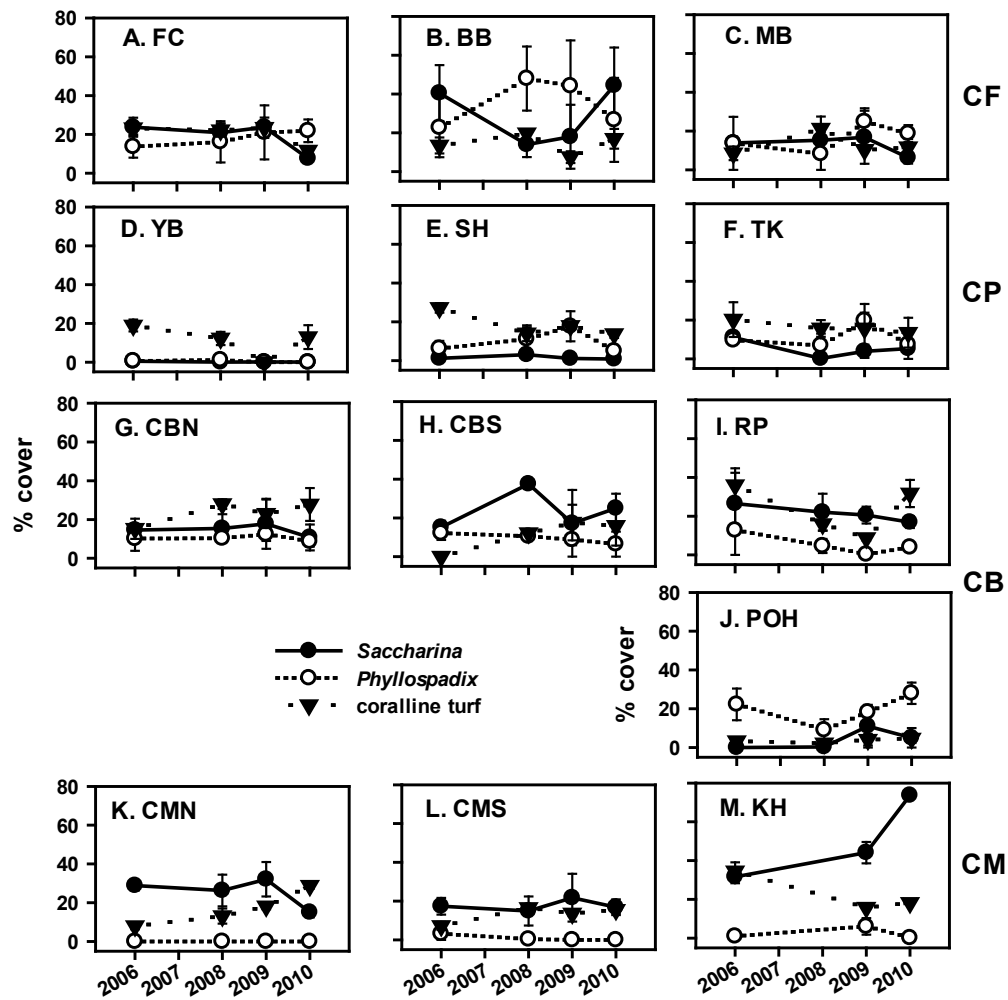


FIG. B3. Time series from 2006 to 2010 of abundance (mean % cover) of major macrophyte taxa at 3–4 sites nested within 4 capes, arranged from north to south from top to bottom and from left to right within each cape.

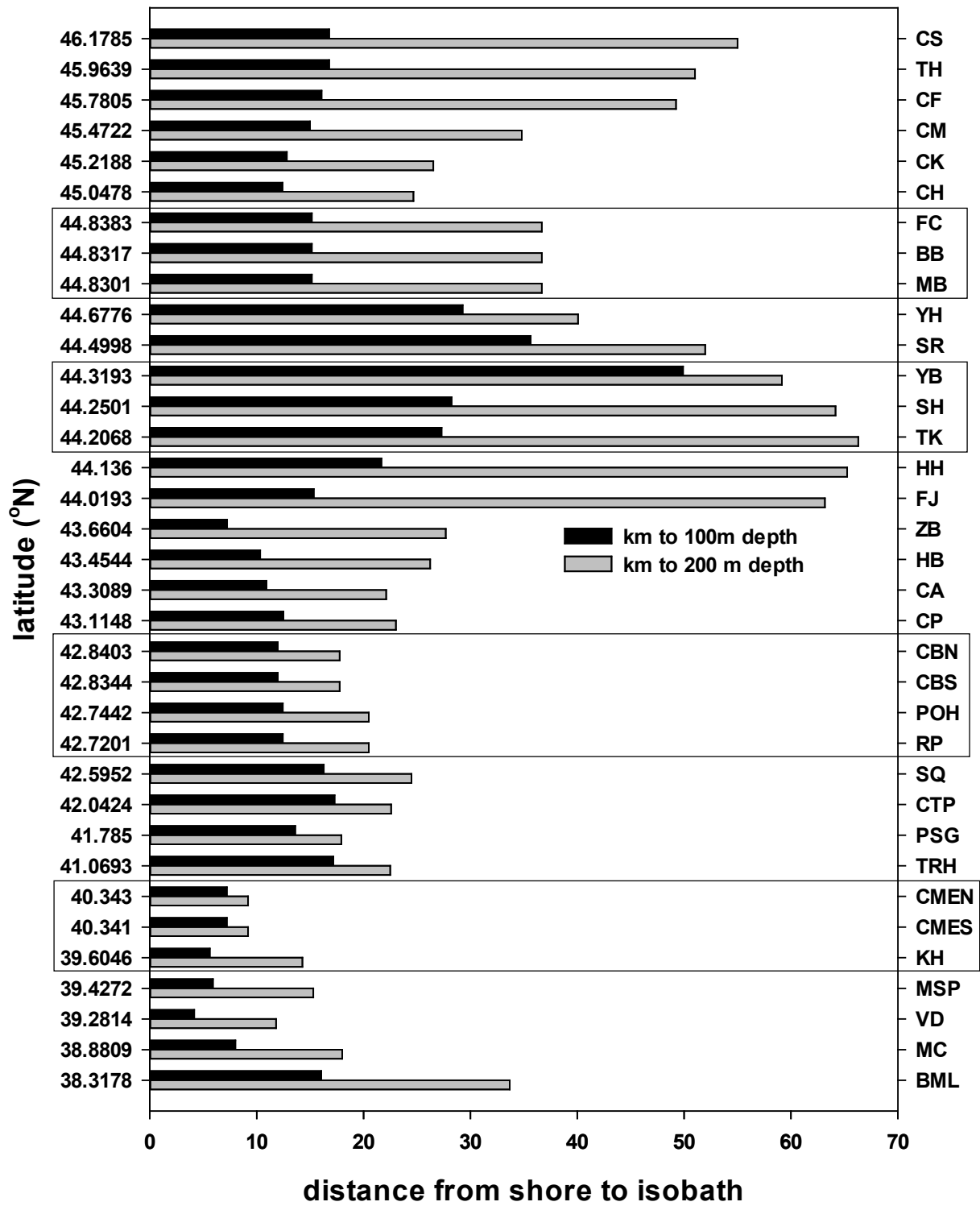


FIG. B4. Shelf width at 100m and 200m isobaths from northern Oregon to central California.

Sites within capes in the present study are in the four boxes (= Capes Foulweather, Perpetua, Blanco, and Mendocino) overlaid on the graph, arranged from north to south. Other sites are shown to present a higher resolution of shelf width along the overall study region. Site codes north of CF (top box) and successively between and south of the three cape regions studied are CS = Clatsop Spit, TH = Tillamook Head, CF = Cape Falcon, CM = Cape Meares, CK = Cape Kiwanda, CH = Cascade Head; YH = Yaquina Head, SR = Seal Rock; HH = Heceta Head, FJ = Florence Jetty, ZB = Zioulkouski Beach, HB = Horsfall Beach, CA = Cape Arago, BP = Blacklock Point, SQ = Sisters Quarry, CTP = Chetco Point, PSG = Point St. George, TRH = Trinidad Head; MSP = McKerricher State Park, VD = Van Damme State Park, MC = Moat Creek, and BML = Bodega Marine Lab. See Appendix A Table A1 for list of codes to study site names and full set of coordinates for each.

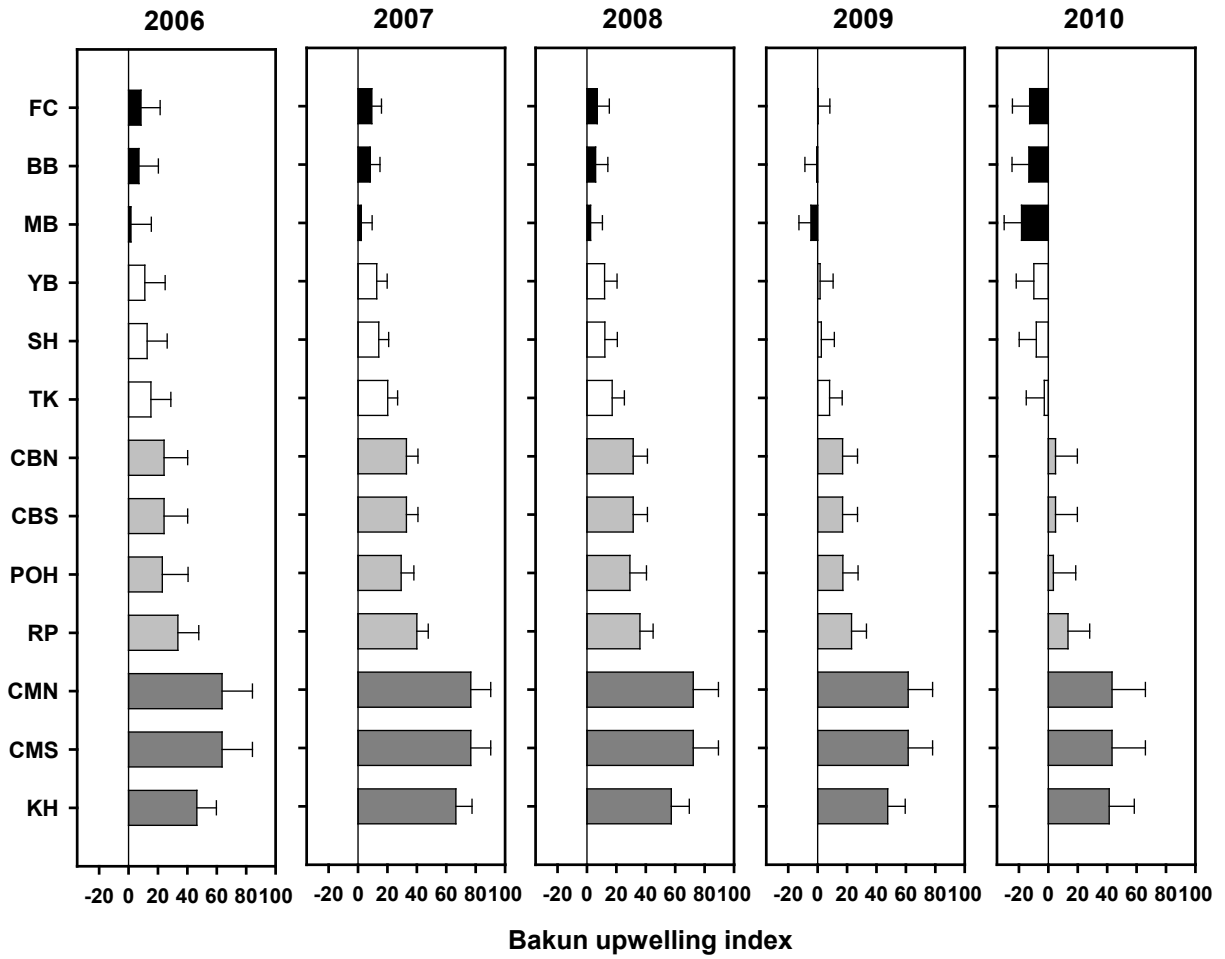


FIG. B5. Mean annual Bakun upwelling index by cape, site and year. Data are average monthly Bakun index and 1 SE.

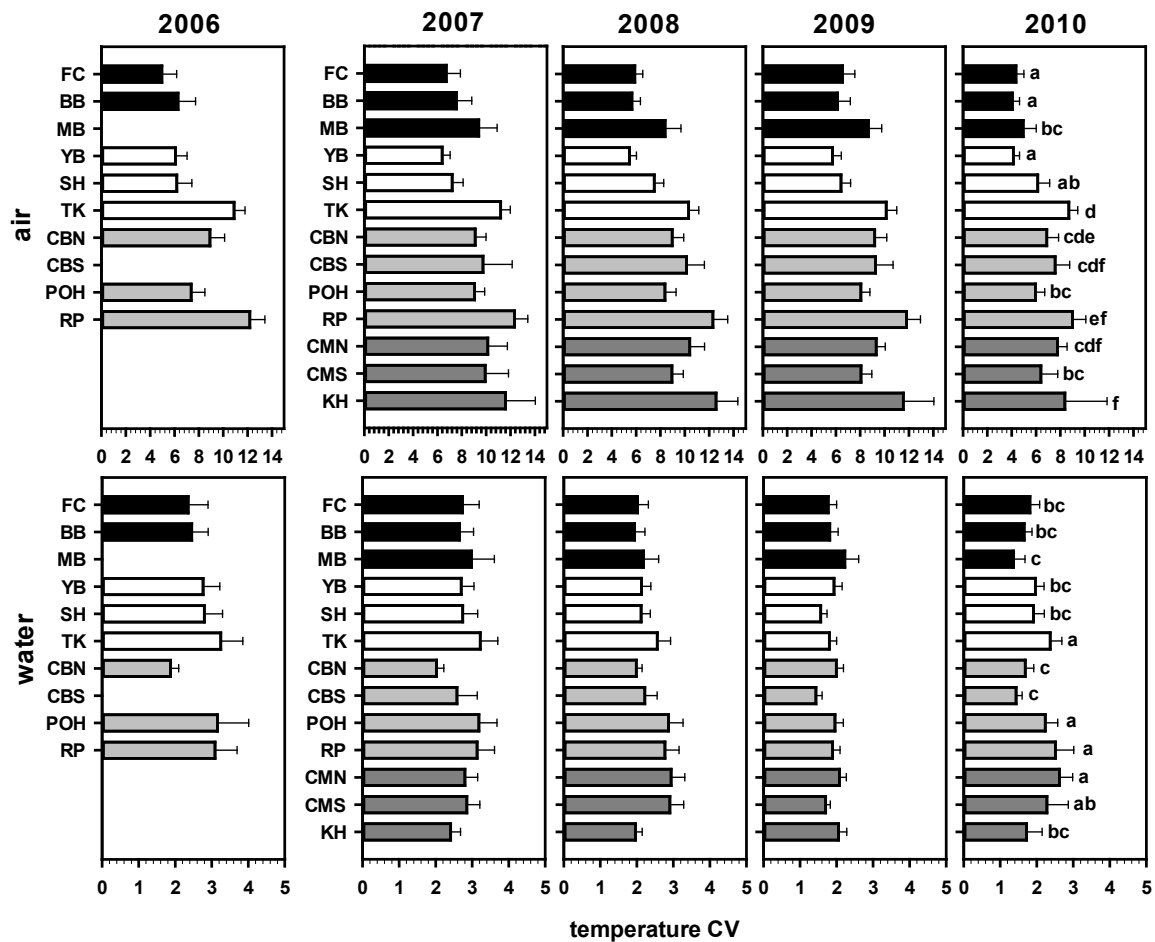


FIG. B6. Mean coefficient of variation (CV) of annual air and water temperature at 8-13 study sites from 2006 to 2010. Sites are shaded by cape, with black fill = Cape Foulweather (CF), white fill = Cape Perpetua (CP), gray fill = Cape Blanco (CB), and dark gray fill = Cape Mendocino (CM). Different letters to right of bars in 2010 panels indicate differences at $p < 0.05$ using linear contrasts.

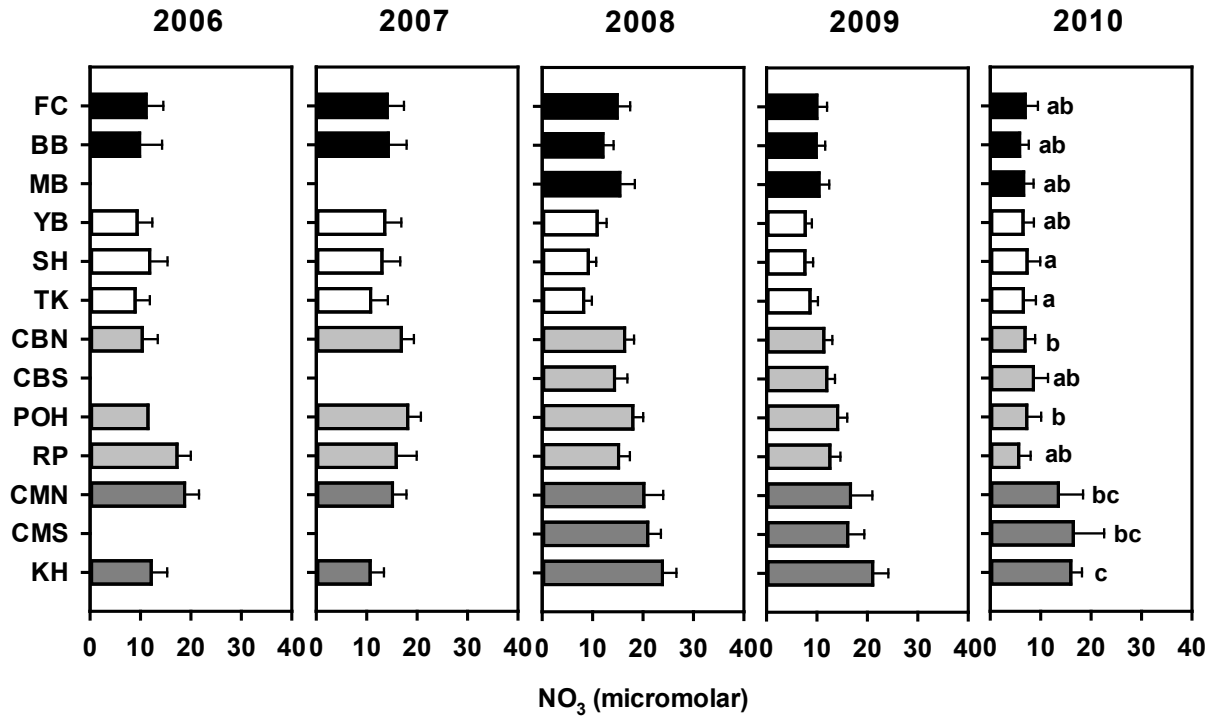


FIG. B7. Mean (+1SE) upwelling season nitrate (μM) at the 13 study sites from 2006 to 2010.

Bars are coded by cape as indicated in Fig. 1 caption. Replicate bottle samples were taken from shore at each site from April through September. Note that the number of sites increased in 2008 with the addition of MB, CBS, and CMS. Different letters to right of bars in 2010 panels indicate differences at $p < 0.05$ using linear contrasts.

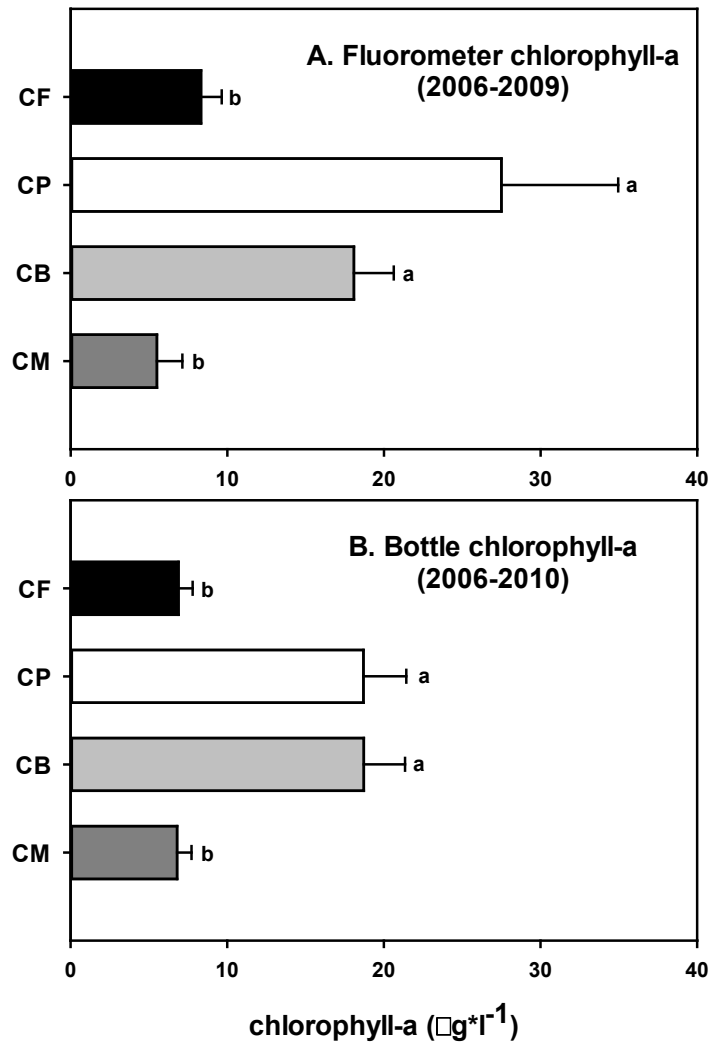


FIG. B8. Comparison between average phytoplankton abundance (µg/l of chlorophyll-a) estimated from A. continuous field fluorometry and B. point-in-time bottle samples by Cape. Chl-a fluorescence was linearly related to Chl-a measured from bottle samples ($y = 3.72x + 2.76$; $p < 0.0001$, $R^2 = 0.62$). Bars are coded by cape as indicated in Fig. 7 caption. Data were annual upwelling season averages. Bars with the same letters indicate cape means that were not different (linear contrasts, $p < 0.05$). See text for details.

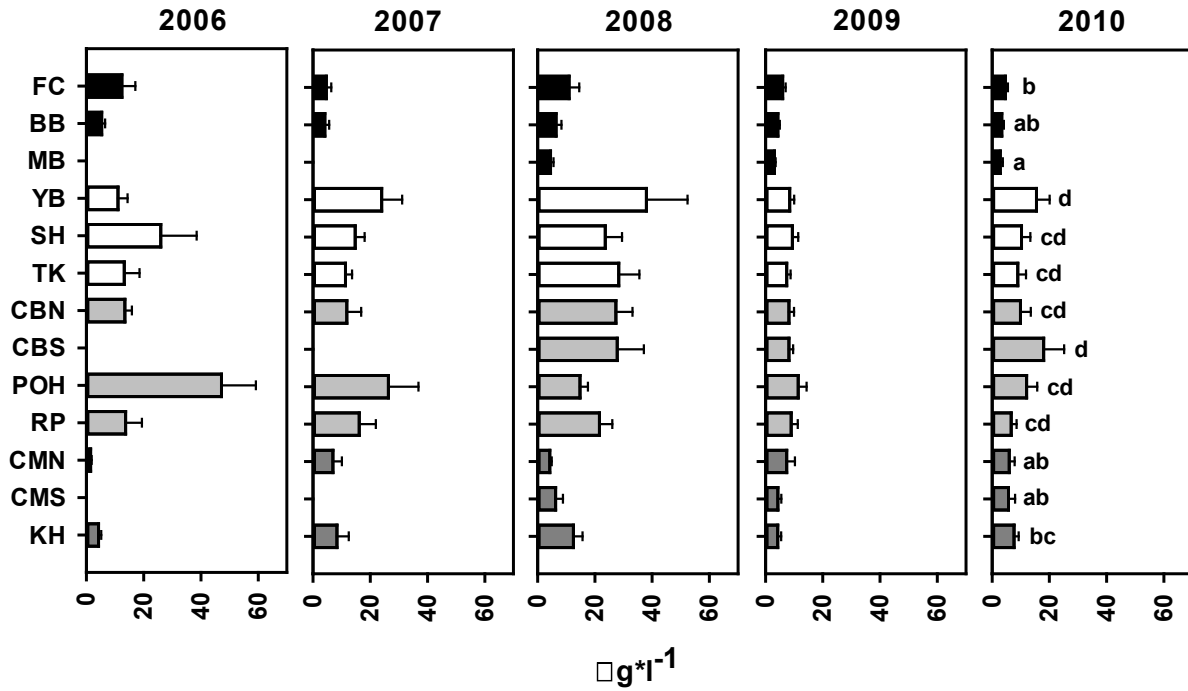


FIG. B9. Phytoplankton abundance from direct bottle sampling in the field, 2006-2010 at 10-13 study sites, ranging from north to south, from top to bottom of each panel. Bars are coded by cape as indicated in Fig. 7 caption. Data are from the upwelling season, April through September. Note that the number of sites increased in 2008 with the addition of MB, CBS, and CMES. Different letters to right of bars in 2010 panels indicate differences at $p < 0.05$ using linear contrasts.

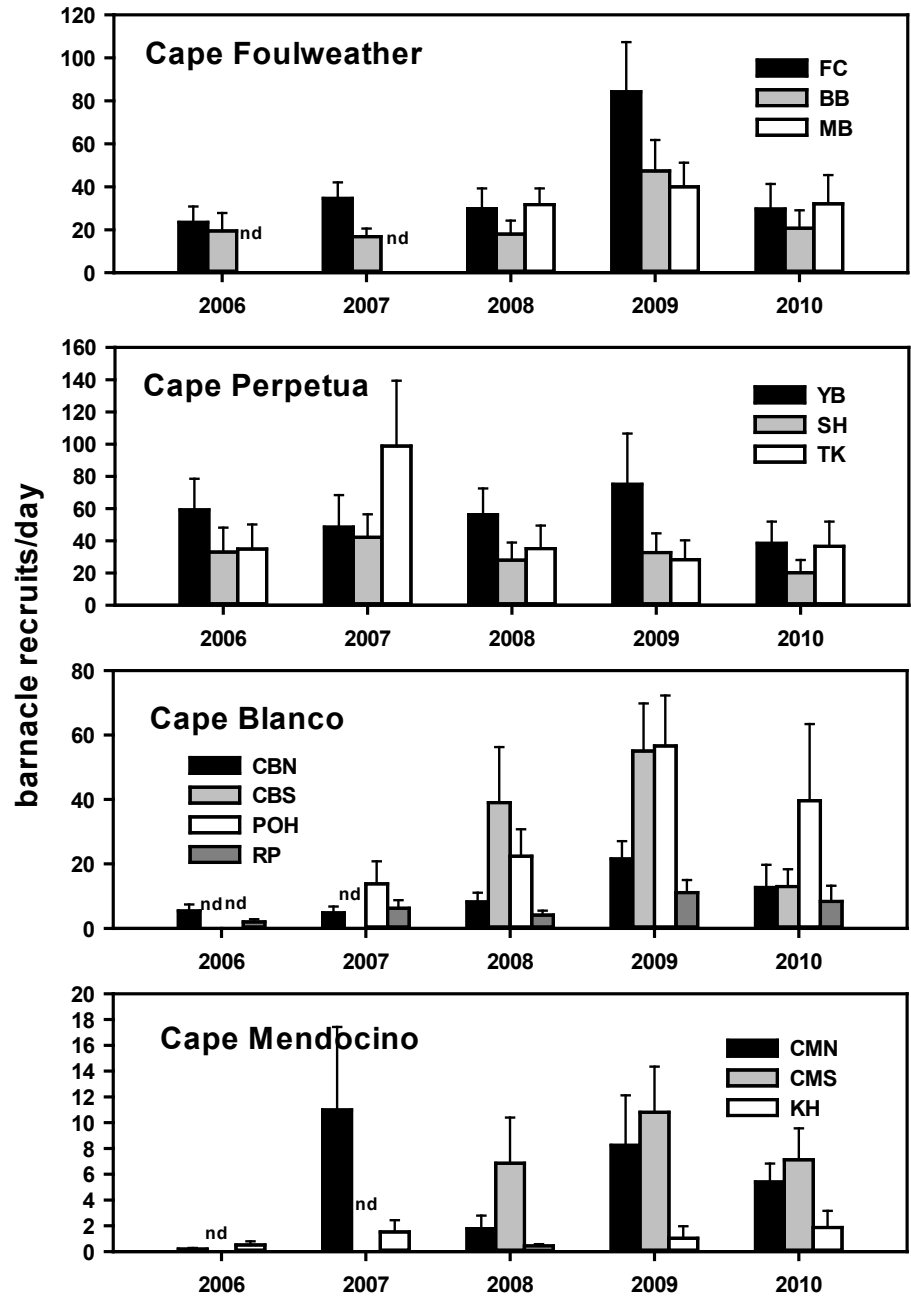


FIG. B10. Annual upwelling season recruitment of barnacles (mean + 1SE) at 13 sites nested within four capes, 2006-2010, arranged from north to south. Note that the ordinates are scaled differently, reflecting among-cape differences. See text for details.

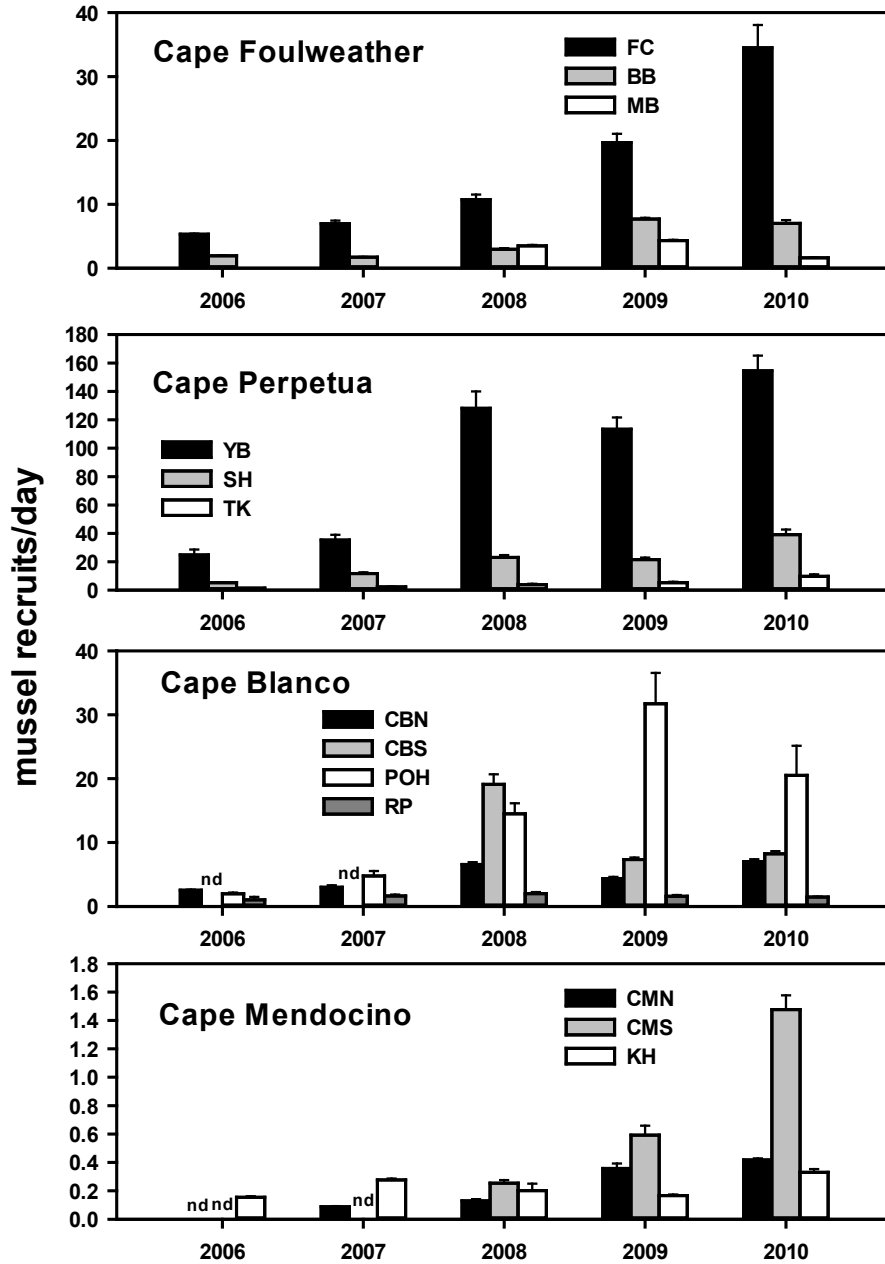


FIG. B11. Annual upwelling season recruitment of mussels (mean + 1SE) at 13 sites nested within four capes, 2006-2010, arranged from north to south. Note that the ordinates are scaled differently, reflecting among-cape differences. See text for details.

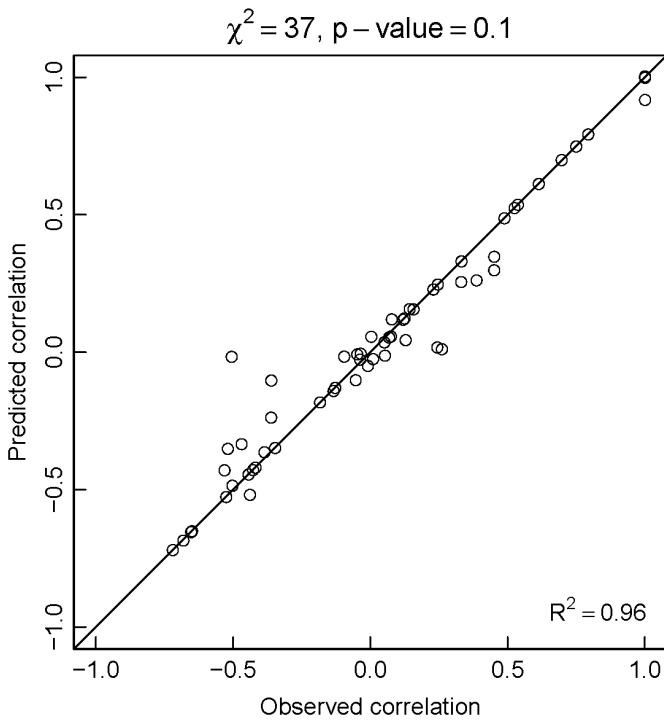


FIG. B12. Relationship between predicted and observed correlations in path analysis for the shelf width model (see Fig. 9, Appendix A Table A7).