Biodiversity Benchmarks in Space and Time: Polychaetes at a Single Location in Central California.

A Report Prepared for the Bodega Marine Reserve

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Introduction

Species lists are ubiquitous in the literature on biodiversity and anthopogenic impacts, including climate change and exotic species introduced via long range transport. Such lists need to be defined by area and time frame, if they are to be of value as benchmarks against which to track changes in species diversity due to natural and anthropogenic changes. Sources of uncertainty in such lists includes unrecognized synonyms, misidentified species, and the well known dependence of species number on sampling effort, typically measured as a collector's curve. We used an unusually large (over 150 reports) and long (1932 to present) set of lists available for the outer coast of central California (Bodega Head to Point Pinos, Monterey) to quantify sources of uncertainty in species richness, and the rate of change in the estimate of richness at this relatively well studied location. We focused on polychaetes, an important marine group that is typically abundant in benthic habitats, especially unconsolidated sediments from the intertidal to abyssal depths. Polychaetes are a key link from detritus to upper trophic levels in benthic habitats throughout the ocean. The lists came from a landmark thesis (Hartman 1936a), contract reports (Shepherd 1964, Standing *et al.* 1975, PMS 1977, Ristau *et al.* 1978), a set of field notes from 1956-57 (Smith, unpublished), and the extensive collection of undergraduate student reports at the Cadet Hand Library (CHL) at the University of California's Bodega Marine Laboratory (BML) at Bodega Bay (Finity 2006).

Methods.

Documents were assembled by winnowing from within broad searches within CHL, a library where student reports are filed on the shelf by year within course, while research reports are filed under a variety of headings, usually non-taxonomic. A wild card search (polych*) yielded 26 research documents and 74 student reports. The student report list was expanded with wild card searches by family (e.g., Nerie*) and by type of survey ('survey invertebrates' 'survey wharf' *etc*). The list was then winnowed to documents reporting polychaetes. The library shelf was then searched in three areas: polychaetes (QL391.A6 in the Library of Congress system), graduate theses by students at the lab, and professional reports issued by the lab.

All polychaete names from reports and from the BML synpotic collection of specimens were recorded in a spreadsheet. Synonyms were obtained by consulting a sequence of references in the following order: Light's Manual (Blake and Ruff 2007), Light's Manual (Blake 1975), Hartman (1968,1969), Hartman (1936a, 1936b), SCAMIT 2001, Salazar-Vallejo and Londono-Mesa 2004, Wolfowitz de Weiss 1995, Dean 2004). Online data bases were not used because they were for other areas (MARBEF, 2007) or produced reports (uBio 2007, Animal Diversity Web, Zipcode Zoo, Wikipedia) that were inconsistent with Hartman's monograph (1968, 1969) and Light's Manual (Blake 1975). The list of names was reduced to a list of species by assembling the evidence to reject a name in the following categories: synonyms, genus name only, corrected names (Blake and Ruff 2007), valid name found only in one student report, or name not valid for California coast (not found in any of the following: Hartman 1968, 1969, SCAMIT 2001, Shepherd 1964, Blake and Ruff 2007, or Kozloff and Price 1996). Note that SCAMIT (2001) lists species from south of the Bodega area, while Kozloff and Price (1996) list species from north of the area. An online tool (compare2.php, uBio 2006) was used to generate a

report on the validity (in the zoological sense), homonymy, and lexical form of the names in the list. The tool takes names and matches against Species 2000, ITIS, ERMS or other taxonomies indexed by uBio. The uBio report proved to be inconsistent with Hartman (1968, 1969) and Light's Manual (Blake 1975, Blake and Ruff 2007) and so was not used as evidence in the decision to reject a name.

Once the benchmark list was established, a collector's curve was constructed by tallying the cumulative number of species recorded, on the date of each report. The geographic distribution of reports became more restricted after 1964 so two curves were constructed. The first (1932-1964) was for the coast extending from Point Pinos, Monterey (36.6412°N, 121.9284° W) to Bodega Head and Horseshoe Cove (38.3171°N, 123.0698° W). The second (1932-present) was for the stretch of coast from Shell Beach (38.4173°N, 123.1056° W) southward to Bodega Head and Doran Beach, taken as extending to Pinnacle Rock (38.3068°N, 123.0187° W). A third curve was constructed for specimens at the Bodega Marine Laboratory, collected between Shell and Doran Beaches.

The 2007 Bodega benchmark (Shell Beach to Doran Beach) was then compared to lists of introduced species (CDFG 2002, Maloney *et al.* 2006, Ruiz *et al*. 2000, Blake and Ruff 2007). The benchmark was also compared to voucher specimens collected in San Francisco Bay, known to have a high number of invasive species (Carlton 1979).

Results

The online catalogue search at the BML library resulted in approximately 150 undergraduate reports (Finity 2006) and relevant research documents (Gradek 1991, McHugh 1993). A search of the shelves, together with discussion with people having a long association with the lab (J. Carlton, P. Connors) yielded four contract reports, one of which (Standing *et al.* 1975) compiled the results of several previous reports.

For the period 1932-2007, 449 polychaete names were recorded. Appendix 1 lists each name, with synonyms and ITIS taxonomic serial numbers (if assigned). Of these 449 names from central California (Table 1), 331 appear in the 4th edition of Light's Manual (Blake and Ruff 2007), and 314 were recognized by the International Taxonomic Information Service (ITIS 2007). The larger number of names in the document based list was due for the most part to the larger number of synonyms (Appendix 1) than in Light's Manual or the ITIS report. The rate of synonymy was 31% for the list based on documents, 21% for Light's Manual (Blake and Ruff 2007), and only 8% for ITIS, which as a policy does not accept synonyms. Based on evidence in 6 categories (Appendix 1) names were rejected (shown in red in Appendix 1) to produce a central California species list (in black in Appendix 1). Nearly 40% of the 449 names were rejected, leaving a list of 449-173 = 276 species (Table 1). Approximately 30% of the names were rejected as synonyms, the next largest sources of rejection were invalid (4%) or corrected names (2%). Only three names were listed only to genus and of these, one was a monospecific genus within the area of interest (*Bispira* sp). If a different criterion for rejection is used (found only in Light's Manual 2007 edition), the central California species list drops by 10%, from 276 to 253 species. The document based species list was used because Light's Manual explicitly states that it is not a comprehensive list. When the uBio (2007) check of validity was run on the 449 central California names, the result was a list of 289 species (Table 1). While this is close in magnitude to the document based list of 276 species, the uBio list was generated by substantial rates of false positives and negatives (Table 1).

Of the 276 species of polychaete on the central California list, 205 were recorded for the vicinity of Bodega Head and the Bodega Marine Reserve (Shell Beach to Doran Beach), for the period 1932-2007 (Figure 1, Appendix 2). Of the 276 species, 138 were recorded from Dillon Beach and Tomales Bay (Appendix 2), which are located a little over 10 km further south along the coast. The Tomales number is based on a small number of reports (7) for a shorter period (1936-1984) in an area assumed to be similar in extent and known to be similar in diversity of habitat.

The collector's curve for the Bodega list of 205 species differed from the collector's curve for the central California list of 276 species (Figure 1). The two curves began with a report from Horseshoe Cove (Raeder 1932), rise at the same rate until 1942, then diverge due to slow growth in the Bodega area from 1942 to 1960. The increase in the larger scale curve after 1960 is due to the 1964 compilation for Tomales Bay (Shepherd 1964) and the monograph by Hartman (1968, 1969). The latter listed 170 species as estuarine or intertidal in quadrangles 16, 20, and 23, which cover the coast from Monterey to about 30 km north of Bodega Head. The smaller scale curve for the Bodega vicinity (Figure 1) accelerates after 1970 due to the influence of contract funded activity (Standing *et al.* 1975, PMS 1977, Ristau *et al.* 1978), then levels off at just over 200 species (Figure 1). The specimen collection at BML grew in the early 1970s, with little activity afterwards (Figure 1).

The large number of reports made it possible to examine whether the rate of synonymy declined over time, as would be expected if taxonomy were stabilizing. The rate of synonymy decreased in a stepwise fashion (Figure 2). The graph shows two levels of synonymy, one before and one after the monograph by Hartman (1968, 1969). The level after Hartman reflects the 20% rate (Table 1) in Light's Manual (Blake and Ruff 2007), which was used to reassign species in lists prior to 2007.

Absence from Light's Manual (Blake and Ruff 2007) was by itself not a criterion for rejection and so of the 449 names, 23 that do not appear in the Manual were retained. Of these (Table 2), three are dubious in that they appear only in Hartman (1968, 1969) and not more recent sources (Kozloff and Price 1996, SCAMIT 2001, Blake and Ruff 2007). One is dubious in that it appears in PMS (1977) but not in a later publication by the same author (Blake and Ruff 2007). In 17 cases a species not found in Light's Manual (Blake andRuff 2007) is listed by Kozloff and Price (1996), SCAMIT (2001), or both; in all of these cases there were few central California reports, suggesting that the species is transient, rare, or perhaps overlooked because it does not appear in Light's Manual.

The Bodega benchmark of 205 species was then used to evaluate northward shifts in range, as would be expected from global warming (Barry *et al.* 1995). The evidence for a northward shift during the period of record was at best weak. In six cases where the species does not appear in Light's Manual (Table 2) the species was reported to the north (Kozloff and Price1996) but not the south (SCAMIT 2001). Four species were reported from the south but not the north. In two of the six northward cases (*Nereis zonata, Chone infundibuliformis)* records occur entirely before 1980, which points at northward retreat and disappearance from central California. One species that appears in Light's Manual (Blake and Ruff 2007) and Kozloff and Price (1996), *Ophiodromus pugettensis*, appeared in 18 reports up until 1978, but none afterwards.

The Bodega benchmark was then compared to available lists of introduced polychaetes for all of California (Blake and Ruff 2007, CDFG 2002, Maloney *et al.* 2006) and for San Francisco Bay (Ruiz *et al.* 2000). Table 3 shows the 21 species that were listed as introduced in at least

one of these reports, and for which there was at least one report of presence from central California (Appendix 1). The number of species differed considerably, ranging from 12 (WEMAP, Table 3) to 21 (Blake and Ruff 2007) to 39 (CDFG 2002) in three reports with similar geographic ranges. The CDFG (2002) list, as updated by Maloney *et al.* (2006) contained inconsistencies and several false positives due to synonymy. CDFG (2002) listed four cryptogenic and one introduced caprellid as annelids. *Polydora cornuta* is listed twice, once as cryptogenic (Table 3) and once as introduced (under its synonym *P. ligni*). Five species in Table 3 occur in Hartman (1936a) and are listed as recently discovered introductions: *Laonice cirrata* listed as discovered in 1959, *Scolelepis squamata* (*Nerinides acuta* in Hartman) listed as discovered in 1960, *Serpula vermicularis* (*S. columbiana* in Hartman) listed as discovered in 1992, *Spiochaetopterus pottsi* (*S. costarum* in CDFG 2002) listed as discovered in 1990, and *Circeis spirillum* (*Spirorbis spirillum* in Hartman) with no discovery date listed. The rate of false positives due to synonymy in the CDFG list in Table 3 was 5/14 = 36%. The number of introduced species listed by CDFG (2002) and found on the central California list drops from 14 to 9 (Table 3), comparable to the numbers of Ruiz et al (2000) and Blake and Ruff (2007). When the five false positives are removed, the number of introduced polychaete species for which there are records in the Bodega vicinity drops from 14 to 9, or 9/205 = 4.4% of the list. The number of introduced species drops to 5/205 = 2.4% relative to the San Francisco Bay list of Ruiz *et al.* (2000) and 4/205 = 2% relative to the list of Blake and Ruff (2007).

The Bodega benchmark was compared to a species list supported by the voucher specimens from San Francisco Bay (California Academy of Science 2005), an ecosystem known to have a high rate of invasive species (Carlton 1979). The two species lists differed substantially. Out of 244 polychaete names on the San Francisco Bay list, 111 were present in the list of 449 names assembled from documents outside San Francisco Bay (Appendix 1), while 133 names were not present (Table 4). The criteria in Table 1 were then applied to the San Francisco Bay name list to produce a species list. Within the list of 111 species there was one invalid species (Blake and Ruff 2007) and 14 duplicates due to synonymies, resulting in 96 species. From this acceptance rate (96/111 = 86%), the number of San Francisco Bay species not on the central California list was estimated at 115 out of 133 names. The estimated number of species in the San Francisco Bay name list was 96+115 = 211 species. The Bodega species list was cross-tabulated with the San Francisco Bay list, within the 276 valid species from the central California list (Table 4). For this tabulation only 7 species at Bodega were not in the San Francisco Bay list. This contrasts with the 113 species not on the Bodega list (Table 4). This cross tabulation does not include the estimated 115 species absent from the central California list. When the 115 species unique to San Francisco Bay are add to the central California list, the count rose from 276 to 276+115 = 391. Of these, 23% occur in both Bodega and San Francisco Bay, while around 30% occur in one or the other location (Table 4). When the San Francisco voucher collection list is included, the number of species found in the central California list but not yet reported at the northern limit (Bodega Bay) rises from 276-205 = 71 species to 391-205 = 186 species.

Discussion

The 2007 biodiversity benchmark for the vicinity of the Bodega Marine Reserve (Shell Beach to Pinnacle Rock) was 205 species of polychaete. The potential number was 276 species, based on species reported along the outer coast to the south of Bodega. This rises to 391 species when San Francisco Bay voucher specimens are included. When species to the north and south are

included the potential number rises to around 420 species, based on Light's Manual 4th edition (414 species), plus records not in the Manual (Table 2). While the potential species number is on the order of 300-400, little increase beyond 205 is expected at Bodega, given the fairly flat collector's curve (Figure 1), which includes a substantial effort (PMS 1977) with good taxonomic resolution throughout an entire year. A recent PhD thesis with a substantial field collection effort (Larson 2007) added 3 species, for an increase of 3/202 = 1.5%. The large pool of introduced species in San Francisco Bay has evidently not expanded northward, given the stable numbers at Bodega (asumptotic collector's curve) and the disparity in faunal composition between Bodega and San Francisco Bay (Table 4). This is consistent with the limited opportunities for expansion of infaunal species along an exposed coast with few areas of sheltered shallow water sediment north of San Francisco Bay. The opportunities for introduction are low for infaunal species, except those such as *Leitoscoloplos pugettensis*, an infaunal species found in fouling assemblages carried by marine vessels.

Searching a large number of documents yield 205 species, far more than the 59 species in Standing *et al*. (1975) or the 119 species in PMS (1977). The differences are due to several factors. The benchmark number (205 species) contains many rare or uncommon species, species that would be under-reported by Standing (1977), given the reconnaissance goals of the surveys on which this document is based. The benchmark covers a wider variety of habitats than the infaunal plots surveyed repeatedly by PMS (1977). The utility of such lists depends on the context. In general a variety of lists are more useful than a single list. Thus for the Bodega vicinity (Shell Beach to Pinnacle Rock) the number of polychaete species that can potentially occur is on the order of 300 species, the number known to occur is 205 species, the number encountered in a one year study is 119 species, and the number of commonly encountered species is on the order of 60.

At the outset of the study, the largest source of uncertainty was expected to be identification to no lower than the genus level, with less uncertainty due to synonymy or limited collection effort in this well studied location. The Bodega collector's curve corroborated the expectation with respect to uncertainty due to effort. The low rate of assignment only to the genus level was a surprise, as was the taxonomic flux and consequent rate of synonymy.

Another surprise was the rate of uncertainty that currently attends online indexing of taxonomically organized biological knowledge. Table 1 shows the uncertainty from the Compare2.php taxonomic tool (uBio 2007). Out of the list of 449 names, the tool recognized 311 as valid species in the ITIS data, a number well above the benchmark number for Bodega or the number of valid species in the central California list. This overestimate is consistent with the prevalence of false positives (over 30%, across several categories) compared to false negatives (12%) in the uBio report (Table 1). These rates are relative to the older literature (*e.g.* Light's Manual 1975 or Hartman 1968, 1969). They are likely the result of a combination of factors, including high rates of taxonomic flux in polychaetes, low rates of reporting of synonymy, and too little information to include geographic restrictions on validation checks. The rates in Table 1 illustrate the sensitivity of online catalogues to high rates of taxonomic flux and absence of information from monographs. Evidence based benchmarks for known periods and time and defined areas are a step toward putting web based species catalogues on a sound biogeographic basis. Better assimilation of monographs (*e.g.* Hartman 1968, 1969) and older synonymies are also needed.

The evidence based benchmark developed for Bodega could be implemented with a computer

assisted algorithm, for which pseudocode is shown in Box 1.

Box 1. Procedure to establish an evidence based biodiversity benchmark.

1. Define taxonomic group and geographic extent for benchmark.
2. Assemble documents that list names for the group in the area.
3. Assemble species names for the group and area.
4. Establish synonyms from primary sources (monographs, etc).
5. Distinguish monospecific genera from polyspecific genera.
6. For each name rejected, list evidence (a reason with source).
7. Assign names based on synonyms and monospecific genera.
8. Arrange documents in order of date to construct a collector's curve.
9. Quantify sources of uncertainty and evaluate benchmark.

The details of application will differ among groups. For groups with stable taxonomy (*e.g.*, birds) little effort is needed to assemble synonyms, unlike groups such as polychaetes. The procedure can be applied to rigorous surveys, in which equal units of effort are sampled within a defined frame of potential samples. Equal units of effort are possible within any one study, but will not be possible when assembling lists from different sources. Student reports are similar in effort because of the time constraints of course deadlines, but the effort per report is small compared to a contract report. The collector's curve (Figure 1) reflects the highly episodic growth in biodiversity information in groups such as polychaetes, where there are few specialists and research activity tends to be intermittent.

In using the student reports we took into account their uneven quality, ranging from thorough (*e.g.*, Pettibone 1941, Pitelka and Paulson 1942, Feder 1948, Gaffney 1972, Grebmeier 1976) to casual. We rejected polychaete names that occurred in only one student report, unless there was strong evidence to retain the record, such as a detailed drawing that included a key trait and was not a copy from a contemporary text or guide (*e.g.*, Siddiqui 1958). We note that with birds the standards for adding a species to a benchmark list is a photograph where a key distinguishing trait is clearly visible. We recommend a similar approach with invertebrate groups such as polychaetes. Thus the next step for the Bodega benchmark would be assembling a set of photographs of each species, showing the trait used to assign the species name to the animal. Figure 3 shows an example for *Platynereis bicanaliculata*. The procedure in Figure 3 relies on a web based tool, Polikey (Glasby and Fauchald 2003) to identify a specimen to family. Polikey is an interactive key that uses an expert system to combine multiple characteristics to exclude families and reach an endpoint of one family (Dallwitz, Paine & Zurcher 1995). Within a defined geographic area, the number of species per family will be small, which makes a visual key practical. The same logic used it identify the family (a sequence of traits) can be extended to species within a family, using key traits marked on photographic records of specimens, as in Figure 3.

From our experience in constructing the Bodega benchmark we make several recommendations.

(1) Benchmarks similar to that at Bodega be constructed at other locations along the California coast to evaluate, in conjunction with surveys (Maloney *et al* 2006), whether or not species

introduced into San Francisco Bay are expanding beyond that bay.

(2) The intensive study (PMS 1977) in Bodega Harbor be repeated to test whether introduced species known from San Francisco Bay have expanded northward.

(3) A photographic record (with key traits as in Figure 3) be assembled in conjunction with the synoptic specimen collection at BML. This could be done as a class project, assuming adequate camera equipment and photographic experience by BMR staff. Based on Ristau (1978) and Standing *et al*. (1975), photographs of roughly 50 species would serve to identify the most commonly encountered polychaetes.

(4) A visual key be produced for the Bodega Head vicinity, to improve the student educational experience at this marine lab and to facilitate polychaete identification in the context of introduced species and climate change.

(5) A software package be developed to implement biodiversity benchmarks, defined as an evidence based list of species in a stated area for a stated time period.

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Table 1. Sources of uncertainty in species list of polychaetes from Central California, 1932 to present, Monterey to Bodega Bay. List assembled from documents in the BML Cadet Hand Library (Finity 2006). Of the 414 species listed by Blake and Ruff (2007), 253 occur in the list of 276 species from documents.

	ITIS May 2007	Blake and Ruff 2007	From Documents	
names	314	331	449	
synonyms (syn)	-25	-68	-137	-30.5%
polyspecific genera (unsp)			-2	-0.4%
corrected (corr)		-9	-10	-2.2%
single student report (st)			-6	-1.3%
not valid (nv)			-17	-3.8%
monospecific genera removed (mono)			-1	-0.2%
eliminated	-25	-77	-173	-38.5%
species	289	253	276	61.5%
% synonyms	8.0%	20.5%	30.5%	

Validation (uBio 2007) based on Integrated Taxonomic Information System (ITIS).

Fails to reject invalid species	8	2%	false positive
Valid name not recognized	57	13%	false negative
Accepted name, no synonym	57	13%	false positive
Recognizes synonym as valid species	49	11%	false positive
Reports incorrect synonym	15	3%	false positive
Not eastern Pacific	22	5%	false positive
Sum	200	45%	
Cases	449	100%	

Table 2. Species not in Blake and Ruff (2007) or with unusual distributions in the sequence of reports, 1932 to present, in Central California (Monterey to Bodega).
San Francisco region (Q16) and Monterey region (Q23) as shown in Hartman (1968,1969).
Range = south if SCAMIT (2001) and not Kozloff and Price (1996). Range = north if vice versa.

	Blake and Ruff 2007	Hartman 1968,69	Kozloff 1996	SCAMIT 2001	Central California Records Location	Source	Range	
Boccardia pugettensis	No	No	Yes	Yes	Bodega Harbor	Hartman 1936 as *B. natrix*		
Brania limbata	No	No	No	No	Bodega Harbor	PMS 1977		valid?
Ceratonereis mirabilis	No	Yes	No	Yes	Q23		south	
Chone infundibuliformis	No	Yes	Yes	No	Dillon Beach	Pettibone 1941 but not Shepherd 1964	north	shift?
					Bodega Harbor	Fjeld 1957b		
Eumida longicornuta	No	Yes	Yes	Yes	Q23			
Eunice biannulata	No	Yes	No	No	Moss Beach	Kemp 1939		valid?
					Dillon Beach	Hartman 1936 but not Shepherd 1964		
Eunoe barbata	No	Yes	No	No	Mason's Marina	BML Specimen		
Eusyllis blomstrandi,	No	Yes	Yes	No	Q16		north	
Goniada maculata	No	No	Yes	Yes	Tomales	Pitelka and Paulson 1942		
Idanthyrsus armatus	No	No	Yes	No	Bolinas	Siddiqui 1958	north	shift?
Leiochrides palidior	No	Yes	No	No	Q23	Hartman 1969		valid?
Lumbrinerides platypygos	No	No	No	Yes	Tomales	Shepherd 1984	south	
Lumbrineris bassi	No	Yes	No	No	Tomales	Shepherd 1984		
Nereis zonata	No	Yes	Yes	No	Bodega Harbor	Charwat (1972) and 3 previous reports	north	shift?
Nicomache personata	No	Yes	Yes	Yes	Tomales	Shepherd 1984		
Nothria geophiliformis	No	Yes	Yes	Yes	Moss Beach	Roberts 1950		
Onuphis eremita	No	Yes	No	Yes	Dillon Beach	Pettibone 1941 but not Shepherd 1964	south	
Ophelia limacina	No	Yes	Yes	Yes	Q16	Lights 1975		
					Monterey	Parker 1947		
					Bodega Harbor	Holton 1957, Lekach 1971		
Ophiodromus pugettensis	Yes	Yes	Yes	Yes	Bodega to	18 records, none after 1978		shift?

					Monterey			
Phyllodoce madierensis	No	Yes	Yes	No	Duxbury Reef	detailed description by Siddiqui 1958	north	shift?
Pista disjuncta	No	Yes	No	Yes	Tomales	Shepherd 1984	south	
Pista moorei	No	Yes	Yes	Yes	Tomales	Shepherd 1984		
Travisia granulata	No	Yes	No	No	Q23			valid?
Typosyllis fasciata	No	Yes	Yes	No	Mason's Marina	BML specimen	north	shift?
					Bodega Harbor	Holton 1957, Belman 1971		
					Q16			

Table 3. Species listed as introduced and that occur on central California list.
Lists from CDFG (2002) in Table 1 of Appendix D as updated by Maloney et al 2006, from Ruiz *et al* (2000), and from Light's Manual (Blake and Ruff 2007). I = Introduced, C=Cryptogenic (unknown origin).

		CDFG 2002 Appendix A.				SFB		Bodega
	1994	1998	1992-97	1999	2002	Ruiz	Light's	List
Species	SCBPP	BIGHT'98	BPTCP	WEMAP	CDFG	2000	2007	
Boccardia probosicidea						I		**Y**
Circeis spirillum					I			Y
Eulalia viridis							I	
Eumida sanguinea							I	Y
Ficopomatus enigmaticus			I		I	I	I	
Heteromastus filiformis		I	I		I	I		
Laonice cirrata	I	I		I	I			Y
Manayunkia speciiosa					I	I	I	
Melinna oculata	I	I	I	I	I			
Myxicola infundibulum	I				C	I		**Y**
Nephtys caeca					C		I	Y
Polydora cornuta		C	C	C	C		I	Y
Polydora limicola	I	I			I		I	
Pseudopolydora kempi			I	I	I			Y
Pseudopolydora paucibranchiata		I	I	I	I	I		**Y**
Sabaco elongatus						I	I	**Y**
Sabellaria spinulosa					I		I	
Scolelepis squamata		I		I	I			Y
Serpula vermicularis					I			Y
Spiochaetopterus pottsi	I	I	I	I	I			Y
Streblospio benedicti		I	I	I	I	I	I	**Y**
Introduced species in report	7	12	12	12	39	18	21	
Cumulative	7	15	21	23	50	54	62	
Species on central California list	5	8	7	7	14	8	10	14
Cumulative	5	10	12	12	17	19	21	

SCBPP = Southern California Bight Pilot Project
Bight'98 = Southern California Bight 1998 Regional Marine Monitoring Survey
BPTCP = Bay Protection and Toxic Cleanup Program
WEMAP = Western Environmental Monitoring and Assessment Program

Table 4. Comparison of Bodega benchmark list to San Francisco Bay voucher specimens. Observed number of species in 112 voucher names used to estimate species in remaining names in list of voucher specimens

	Names	Species	Corrected Species	%non-synonyms
Voucher specimens	244	229	211	86% estimated from matches
Matches to document list	111	96	96	86% observed in matches
From documents	449	205	205	100% by definition
SF, not on list	133	133	115	86% estimated from matches
SF, on list		8	8	100% by definition
not SF, not Bodega		64	64	100% by definition

		SF		
		Yes	No	
Bodega	Yes	89	116	205
	No	7	64	71
		96	180	276

		SF		
		Yes	No	
Bodega	Yes	89	116	205
	No	122	64	186
		211	180	391

		SF		
		Yes	No	
Bodega	Yes	23%	30%	52%
	No	31%	16%	48%
		54%	46%	391

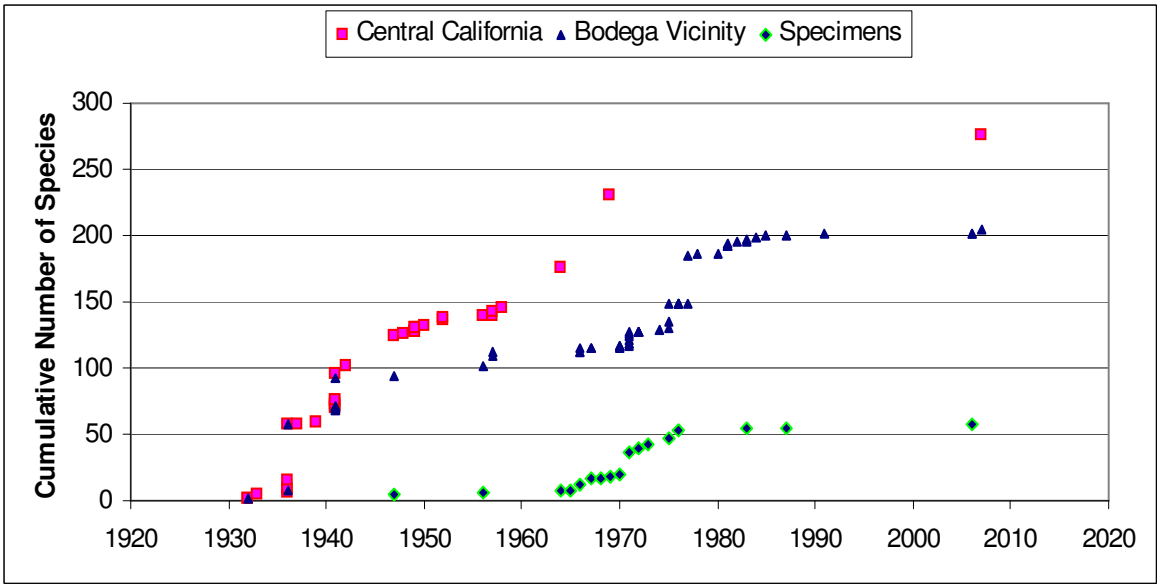

Figure 2. rate of accumulation of polychaete species at two spatial scales, central California and Bodega vicinity. Rate of accumulation of species in synoptic collection at Bodega marine Lab also shown.

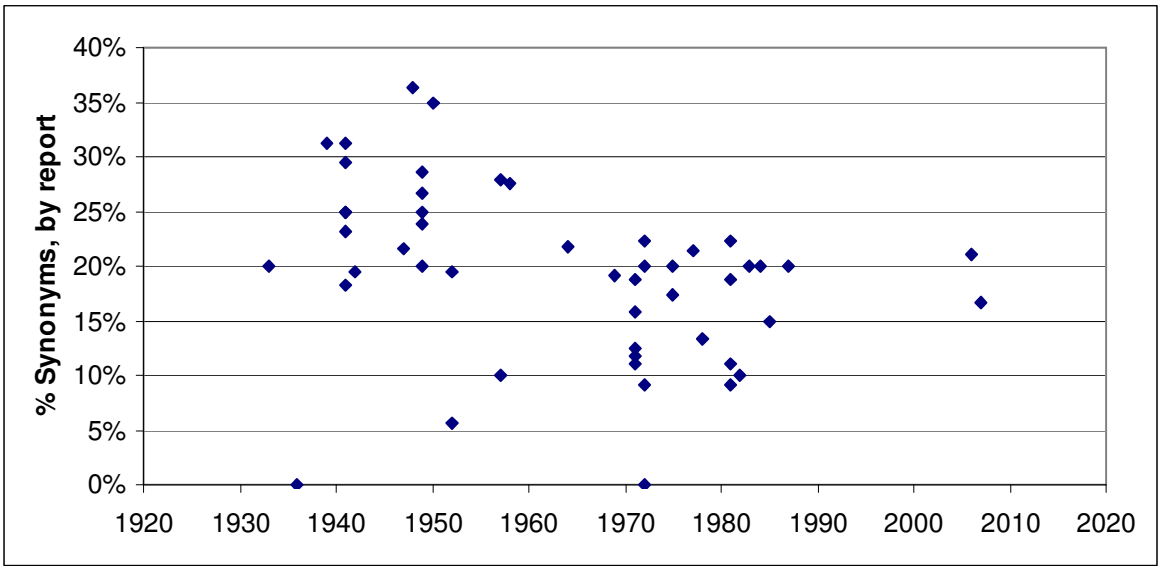

Figure 3. Synonyms, as a percentage of names, for documents shown in Figure 1. See Finity (2006) for list of documents and synonyms.

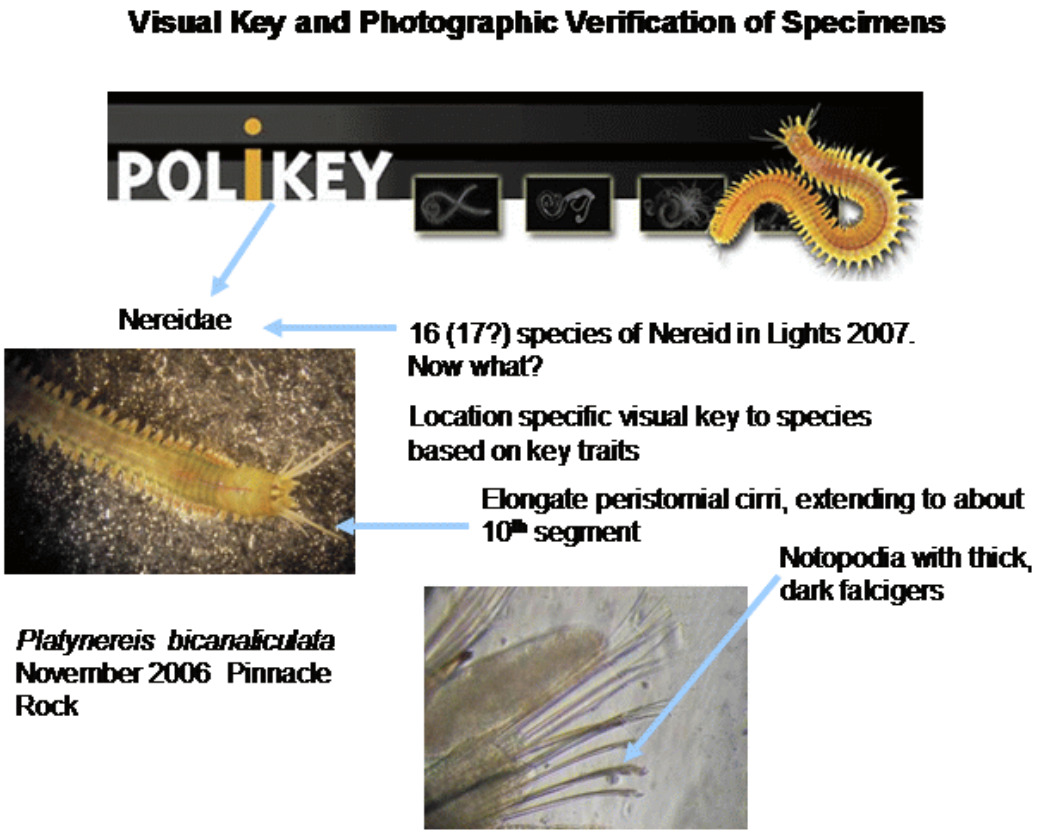

Figure 4 Structure of visual key to polychaetes, using computer assisted identification to family level, with key traits for local species.