Comparison of Methods for Obtaining Group Biomass Measurements of Trawl-caught Fishes

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For the past 25 years, the major publicly-owned treatment works (POTWs) and the Southern California Coastal Water Research Project (SCCWRP) have monitored and studied the impacts of wastewater discharge on demersal fish and invertebrate assemblages. These assemblages have been characterized using abundance, biomass, and length (i.e. size-class) data. Although most of the emphasis has been on abundance and length-frequency analyses, biomass provides another important measure of a population. Fish and invertebrate species collected at a station are typically sorted according to species and weighed in the field using spring scales. However, field conditions may affect the accuracy of these measurements. For instance, biomass, which is recorded as a bulk weight per species, may be affected by accumulated fish slime in the measuring containers (i.e. tare buckets) or unstable conditions due to the motion of the boat. Both of these factors would affect scale readings, and the latter would have a greater effect in rough sea conditions. Although bulk biomass per species has been measured for many years, it is not known whether field conditions significantly affect these measurements.

The procedure used for obtaining biomasses in the field may not only be inadequate, but may also be particularly stressful on the fish being measured (Arnason and Mills 1987). Typically fish are identified and sorted by species and then measured individually on a measuring board to obtain size-class data. Finally, individuals are piled into a bucket where a bulk weight is obtained; depending on the number of individuals being measured, some may be in the bucket for several minutes, and it is not uncommon for a large portion of the trawl catch to die. The combination of these procedures results in a time-consuming and costly process which leads to high mortality of specimens (Arnason and Mills 1987, Dunning *et al.* 1989). Depending on the frequency of sampling and the level of mortality, this may have a detrimental effect on the sampled populations (Quinn *et al.* 1990). Size-class measurements alone require minimal handling, and provide useful information on fish populations; therefore, they may be used to calculate biomass per species if the mean biomass per size-class of a species were known within acceptable error limits. Biomasses calculated from lenth-frequency distribution may reduce measurement error due to field conditions and additionally decrease handling time and mortality of fish.

The objectives of this study are 1) to calculate bulk biomasses based on size-class data, and 2) to determine the accuracy of three different methods used to obtain biomass measurements (field bulk weights, laboratory bulk weights, and weights calculated based on size-class data), relative to actual weights.

MATERIALS AND METHODS

Specimens were collected from six stations between Santa Monica and Dana Point, California. Sampling was conducted by four organizations (SCCWRP; City of Los Angeles, Environmental Monitoring Division; County Sanitation Districts of Los Angeles; and MEC Analytical Systems, Inc.) in June-November, 1995. Sampling procedures followed those outlined in SCBPP, FCT (1994). We used a 7.6 m (head rope) semiballoon otter trawl with a 3.8 cm body mesh and 1.3 cm cod-end mesh to collect individuals. Tow times ranged from 10-15 min at depths of 18 to 305 m (Table 1).

For each trawl, fish were identified and sorted into groups according to species (hereafter referred to as groups). Individuals in each group were measured to centimeter size-class which extended from 0.1 to 1.0 cm, 1.1 to 2.0 cm, etc., and then a bulk weight was recorded for that group. Field bulk weights (FBWs) were measured to the nearest 0.1 kg using a 5.0 kg spring scale and 0.80 kg bucket as a tare. Groups were then stored in plastic bags, placed on ice, and eventually frozen at -19°C at the SCCWRP laboratory. In the laboratory, the individuals were thawed, measured to the nearest millimeter, and weighed to the nearest 0.01 g using a Sartorius L-310 electronic platform scale. A summed group weight (SGW) was determined by summing the actual weights of the individuals in the group, and lab bulk weights (LBWs) were determined using the same equipment and procedure used to determine the FBWs.

The weights (i.e. individual weights from the Sartorius scale) for a particular size-class of a species were pooled for all trawls and then a mean weight was calculated. Calcu-

TABLE 1. Station locations and numbers of fish species and individuals collected between Santa Monica and Dana Point, California in June-November 1995 for biomass measurement study.

Station	Coordinates Lat N.	Long W.	Depth (m)	Date	Trawl Duration (min)	No. Fish Collected Species	Individuals
DP	33°27.53	117°44.04	37	6/6/95	15	9	118
T4	33°36.28	118°57.46	18	7/18/95	10	2	5
T5	33°42.39	118°19.13	23	8/29/95	10	1	79
T5	--	–	61	11/6/95	10	1	92
T0	33°48.39	118°24.87	23	8/29/95	10	1	49
T0	--	–	23	8/29/95	10	1	31
T0	--	–	137	8/29/95	10	1	107
T0	--	–	305	8/29/95	10	1	38
Z2	33°54.84	118°31.70	60	8/21/95	10	7	233
C6	33°56.35	118°32.07	60	8/21/95	10	6	88

--=Coordinates not recorded.

lated group bulk weights (CGWs) were determined for each group using the following equation:

$$CGW = \sum_{S=1}^{k} mean * n_S$$

where CGW=calculated group bulk weight, S=size-class within the group, k= the number of size-classes for that group, mean=the pooled mean weight for size-class S, and n= the number of individuals in size-class S.

Due to the nonnormality of the data, comparisons were made using a nonparametric Friedman Repeated Measures Analysis of Variance (ANOVA) (Jandel Scientific, SigmaStat for Windows, v.1.0), and a Student-Newman-Keuls (SNK) multicomparison test was conducted on the ranks to isolate any differences (Jandel Scientific, SigmaStat for Windows, v.1.0). For the SNK tests, a p-value smaller than 0.05 was determined as significant.

RESULTS

This study included a total of 840 individuals represented by 14 species (Table 2). The most abundant species were the speckled sanddab (*Citharichthys stigmaeus*), California tonguefish (*Symphurus atricauda*), and longfin sanddab (*Citharichthys xanthostigma*). Of the original 45 groups recorded, 37 were used, and the number of individuals making up a group ranged from 1-107 (mean = 23± 27 SD) (Table 3). The excluded groups consisted of five that did not have either field or laboratory bulk weight data, and three that had more than a 5% difference in the number of individuals comprising the laboratory and field data.

Although mean biomass per size-class was calculated for each of the 14 species, a good characterization of the size range was obtained for only eight species (speckled sanddab; longfin sanddab; slender sole, *Eopsetta exilis*; bigmouth sole, *Hippoglossina stomata*; bay goby, *Lepidogobius lepidus*; English sole, *Pleuronectes vetulus*; California tonguefish; and pink seaperch, *Zalembius rosaceus*) (Table 4).

The Friedman Repeated Measures ANOVA revealed significant differences among the four measurement methods (c2 = 44.9, df=3, p=0.00). SNK multicomparison tests (Table 5) indicated that the FBWs did not significantly differ from the LBWs (p>0.05); however, both differed significantly from the actual weights (SGW) (p<0.05 for both). The CGWs, which were calculated from size-class data, were the most accurate of the bulk weights and did not significantly differ from the SGWs (p>0.05).

DISCUSSION

Bulk weight data are used by fisheries agencies to determine biomass of catch at commercial landings (Lagler

TABLE 2. Numbers of fish per species collected from Santa Monica to Dana Point, California in June-November 1995 for biomass measurement study.

Scientific Name	Common Name	No. Individuals
Citharichthys stigmaeus	speckled sanddab	207
Symphurus atricauda	California tonguefish	195
Citharichthys xanthostigma	longfin sanddab	153
Eopsetta exilis	slender sole	145
Pleuronectes vetulus	English sole	42
Lepidogobius lepidus	bay goby	29
Zalembius rosaceus	pink seaperch	28
Hippoglossina stomata	bigmouth sole	20
Pleuronichthys verticalis	hornyhead turbot	6
Pleuronichthys ritteri	spotted turbot	4
Xystreurys liolepis	fantail sole	4
Microstomus pacificus	Dover sole	3
Synodus lucioceps	California lizardfish	3
Odontopyxis trispinosa	pygmy poacher	1
Total		840

TABLE 3. Comparison of group weights for trawl-caught fishes from Santa Monica to Dana Point, California in June-November 1995.

				Biomass (kg)			
Species	Station	Rep	n	FBW	LBW	SGW	CGW
Citharichthys stigmaeus	T5	1	79	0.3	0.7	0.46169	0.44470
Citharichthys stigmaeus	T0	1	49	0.2	0.3	0.17502	0.19859
Citharichthys stigmaeus	C6	1	41	0.3	0.4	0.25983	0.27291
Citharichthys stigmaeus	T0	1	31	0.2	0.3	0.18316	0.16668
Citharichthys stigmaeus	DP	1	7	0.2	0.1	0.06380	0.06071
Citharichthys xanthostigma	DP	1	55	3.4	3.7	2.59374	2.64455
Citharichthys xanthostigma	Z2	2	46	1.1	1.3	1.04410	1.02644
Citharichthys xanthostigma	Z2	1	41	0.8	1.0	0.76440	0.77514
Citharichthys xanthostigma	C6	2	11	0.4	0.4	0.32510	0.34706
Eopsetta exilis	T0	1	107	1.8	2.2	1.66575	1.62904
Eopsetta exilis	T0	1	38	1.4	1.7	1.22964	1.26648
Hippoglossina stomata	C6	2	6	0.2	0.2	0.12400	0.12810
Hippoglossina stomata	Z2	2	5	0.4	0.5	0.35789	0.35100
Hippoglossina stomata	DP	1	4	0.3	0.3	0.21500	0.21929
Hippoglossina stomata	Z2	1	4	0.4	0.6	0.34160	0.34011
Hippoglossina stomata	C6	1	1	0.1	0.0	0.01471	0.01471
Lepidogobius lepidus	Z2	1	20	0.1	0.0	0.04036	0.03905
Lepidogobius lepidus	Z2	2	9	0.1	0.0	0.01475	0.01604
Microstomus pacificus	Z2	2	3	0.1	0.1	0.03190	0.03190
Odontopyxis trispinosa	C6	1	1	0.1	0.0	0.00082	0.00082
Pleuronectes vetulus	Z2	2	20	1.7	2.9	1.71640	1.73401
Pleuronectes vetulus	Z2	1	16	1.2	1.1	1.15150	1.13475
Pleuronectes vetulus	DP	1	4	0.2	0.2	0.17940	0.20493
Pleuronectes vetulus	C6	2	2	0.4	0.5	0.42460	0.39820
Pleuronichthys ritteri	T4	2	4	0.4	0.8	0.43650	0.43650
Pleuronichthys verticalis	DP	1	6	1.1	1.1	0.87550	0.87550
Symphurus atricauda	T5	1	92	1.8	2.5	1.67888	1.79412
Symphurus atricauda	Z2	1	38	1.1	1.2	0.98120	0.92806
Symphurus atricauda	Z2	2	30	0.9	1.2	0.82352	0.79485
Symphurus atricauda	C6	1	13	0.3	0.4	0.26271	0.25284
Symphurus atricauda	C6	2	13	0.3	0.4	0.29635	0.28393
Symphurus atricauda	DP	1	9	0.4	0.3	0.26870	0.21934
Synodus lucioceps	DP	1	2	0.7	0.8	0.63800	0.63800
Synodus lucioceps	T4	2	1	0.0	0.0	0.10950	0.10950
Xystreurys liolepis	DP	1	3	0.6	0.5	0.44250	0.44250
Xystreurys liolepis	Z2	1	1	0.2	0.2	0.14400	0.14400
Zalembius rosaceus	DP	1	28	0.5	0.4	0.37500	0.37500

Rep = replicate; n = number of individuals per group; FBW = field bulk weight;
LBW = lab bulk weight; SGW = summed group weight; CGW= calculated group weight.

TABLE 4. Mean biomass (g) per centimeter size class for 14 species of fish collected between Santa Monica and Dana Point in June-November 1995.

	Size class[a]												
Species	4	5	6	7	8	9	10	11	12	13	14	15	16
Citharichthys stigmaeus													
mean biomass (g) /size class	0.76	1.34	2.53	4.13	6.91	10.01	14.31	23.72	26.02	-	-	-	-
n	7	22	57	60	19	20	15	5	2	-	-	-	-
Citharichthys xanthostigma													
mean biomass (g) /size class	-	-	3.85	5.55	9.50	13.19	17.20	22.69	31.91	40.77	50.40	65.84	76.10
n	-	-	2	4	2	17	44	17	22	12	11	11	8
Eopsetta exilis													
mean biomass (g) /size class	0.46	0.88	-	4.26	4.47	6.53	10.18	14.00	17.82	24.47	30.14	37.11	42.62
n	5	3	-	1	9	19	20	8	15	14	27	14	7
Hippoglossina stomata													
mean biomass (g) /size class	-	-	2.90	5.10	-	9.10	13.91	14.71	-	28.90	41.50	41.90	60.00
n	-	-	1	1	-	2	1	1	-	1	2	1	3
Lepidogobius lepidus													
mean biomass (g) /size class	-	1.16	1.90	2.85	-	-	-	-	-	-	-	-	-
n	-	9	13	7	-	-	-	-	-	-	-	-	-
Microstomus pacificus													
mean biomass (g) /size class	-	-	-	-	-	9.44	13.02	-	-	-	-	-	-
n	-	-	-	-	-	2	1	-	-	-	-	-	-
Odontopyxis trispinosa													
mean biomass (g) /size class	-	-	-	0.82	-	-	-	-	-	-	-	-	-
n	-	-	-	1	-	-	-	-	-	-	-	-	-
Pleuronectes vetulus													
mean biomass (g) /size class	-	-	-	4.30	8.90	-	-	21.70	27.20	34.20	53.67	53.36	63.70
n	-	-	-	1	1	-	-	1	1	1	3	8	7
Pleuronichthys ritteri													
mean biomass (g) /size class	-	-	-	-	-	-	-	-	-	-	-	93.03	-
n	-	-	-	-	-	-	-	-	-	-	-	3	-
Pleuronichthys verticalis													
mean biomass (g) /size class	-	-	-	-	-	-	-	-	-	-	-	95.20	110.35
n	-	-	-	-	-	-	-	-	-	-	-	1	2
Symphurus atricauda													
mean biomass (g) /size class	-	-	2.30	-	4.25	6.44	9.83	11.76	15.66	20.48	26.45	33.01	37.98
n	-	-	1	-	2	11	7	16	37	44	26	31	15
Synodus lucioceps													
mean biomass (g) /size class	-	-	-	-	-	-	-	-	-	-	-	-	-
n	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis													
mean biomass (g) /size class	-	-	-	-	-	-	-	-	-	-	63.50	-	-
n	-	-	-	-	-	-	-	-	-	-	1	-	-
Zalembius rosaceus													
mean biomass (g) /size class	-	-	5.54	7.30	-	18.06	24.40	31.20	-	-	-	-	-
n	-	-	8	7	-	7	5	1	-	-	-	-	-

[a]size classes extend from 0.1 to 1.0 cm, 1.1 to 2.0 cm, etc., with midpoints at 0.5 cm, 1.5 cm, etc.

1952), and the equations used are periodically modified to incorporate additional factors (Gunderson and Sample 1980). SCCWRP and other organizations that monitor fish populations use biomass data as one component in characterizing the status of fish and invertebrate populations or marine communities.

Although the procedure for collecting biomass data on a boat seems to incorporate added variances such as pitching and rolling of the vessel, movement of the spring scale, and accumulated debris in weighing containers, the data were not significantly affected by these additional factors as shown by the comparison between FBWs and LBWs (Table 5). Many of these factors, however, may be amplified during rough ocean conditions, and it should be noted that 34 of the 37 groups analyzed were sampled between the months of June and August (Table 1), which are considered outside of the normal storm season (SCBPP, FCT 1994). Bulk biomasses of small individuals of less abundant species may be more affected by field conditions than larger, more abundant species; however, this was not examined in this

17	18	19	20	21	22	23	28	34	Total
-	-	-	-	-	-	-	-	-	5.52
-	-	-	-	-	-	-	-	-	207
96.00	106.83	-	-	-	-	-	-	-	31.10
2	1	-	-	-	-	-	-	-	153
54.96	-	-	-	-	-	-	-	-	19.97
3	-	-	-	-	-	-	-	-	145
62.31	87.50	-	107.39	130.30	-	-	-	-	52.66
2	1	-	3	1	-	-	-	-	20
-	-	-	-	-	-	-	-	-	1.90
-	-	-	-	-	-	-	-	-	29
-	-	-	-	-	-	-	-	-	10.63
-	-	-	-	-	-	-	-	-	3
-	-	-	-	-	-	-	-	-	0.82
-	-	-	-	-	-	-	-	-	1
78.44	98.85	116.10	133.70	-	179.00	199.90	198.30	-	82.66
5	4	4	1	-	2	2	1	-	42
-	157.40	-	-	-	-	-	-	-	109.13
-	1	-	-	-	-	-	-	-	4
-	151.75	-	256.10	-	-	-	-	-	145.92
-	2	-	1	-	-	-	-	-	6
40.69	48.50	-	-	-	-	-	-	-	22.11
4	1	-	-	-	-	-	-	-	195
-	-	-	-	-	-	109.50	215.00	423.00	249.17
-	-	-	-	-	-	1	1	1	3
-	108.10	-	144.00	-	-	270.90	-	-	146.63
-	1	-	1	-	-	1	-	-	4
-	-	-	-	-	-	-	-	-	13.39
-	-	-	-	-	-	-	-	-	28

study. Although biomasses are commonly used, the data do not appear to be very accurate estimates as shown by the significant differences between bulk weights (FBWs and LBWs) and actual weights (SGWs) (Table 5).

A more accurate method for obtaining fish biomasses appears to be the use of CGWs, which are based on mean size-class weights for a single species (Tables 3 and 4). This method, unlike the other biomass estimates, did not differ significantly from the actual weights (Table 5). By eliminating the need to take bulk weights while out in the field, we not only obtain more accurate biomass estimates, but also may lower fish mortality and save costs by decreasing the time necessary for handling the fish (Arnason and Mills 1987).

Another benefit of calculating biomasses based on mean weights per size-class is the ability to report weights for small individuals of less abundant species. These individuals weigh less than the minimum scale reading of 0.1 kg, and therefore, their weights are recorded as zero. Three groups in this study had lab bulk weights less than 0.1 kg with two groups containing only one individual, and one group containing 20 individuals (Table 4). By calculating biomasses for small individuals of less abundant species, we may, therefore, obtain a more accurate biomass estimate.

This study was a preliminary effort in assessing current methods used in obtaining biomass data for characterizing biological assemblages, and the results suggest that the developing database used to obtain CGWs for this study may offer a more economical, accurate, and less imposing method. The mean weights per size-class for each species were preliminary and some were reported with as few as one representative in a size-class (Table 4). Clearly, the more individuals used in calculating these mean weights, the more accurate the biomass estimate. Additionally, although there was no significant difference between the FBWs and LBWs (Table 5), it is worth mentioning that the weights may be affected by transport and/or storage.

Finally, due to small sample sizes, we did not look at within-species variation. This is essential and needs to be examined since biomasses may vary within a size-class due to phenotypic (Chambers 1993), seasonal (Griffiths 1994), and nutritional differences among individuals.

CONCLUSIONS

This study showed that the method of recording bulk weights in the field was not significantly affected by factors outside of normal sampling error. It is suggested

TABLE 5. Results of Student-Newman-Keuls pairwise multiple comparison method comparing ranks of field bulk weights, lab bulk weights, summed group weights, and calculated group weights of trawl-caught fishes from Southern California in June-November 1995.[a]

	FBW	LBW	SGW
LBW	n.s.		
SGW	*	*	
CGW	*	*	ns

[a]Results of a nonparametric Friedman's Repeated Measures ANOVA showed significant differences among the four methods for measuring biomass (χ^2 = 44.9, df=3, p=0.00).

ns=not significant (p>0.05).
*=significant (p<0.05).
FBW = field bulk weight.
LBW = lab bulk weight.
SGW = summed group weight.
CGW = calculated group weight.

that future studies incorporate data recorded during storm periods since the movement of the boat and scale may be amplified. The data obtained from recording bulk weights (either in the field or the laboratory) were not accurate estimates of fish biomass, whereas biomass calculated from preliminary mean weights per size-class of a single species appeared to be more accurate and may lower field costs and fish mortality as well. In addition, by utilizing calculated biomasses we may preserve more of the populations being sampled. Future biomass studies may incorporate 1) species-specific weight-length regression equations, 2) conversions of length-frequency distributions to weight-frequency distributions to characterize and compare segments of the population (e.g. juveniles and adults), and 3) a more accurate mean-weight per size-class table.

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