Abstract.–Biological interactions among species can play a dominant role in structuring marine fish communities. Specifically, predation may represent a significant source of mortality for larval and juvenile fishes. Analysis of predator diet requires accurate information on the identity as well as the sizes of prey consumed. In examinations of stomach contents of piscivorous fishes, the condition of recovered prey items varies substantially not only in the large range of digestive states encountered but also in the occurrence of partially consumed fishes. To estimate the original sizes of well-digested and partially consumed prey fishes we constructed a series of predictive equations relating total length, fork length, and weight of fish to seven morphometric measurements including dorsoventral body depth, eye diameter, caudal peduncle depth, pectoral-fin length, opercle length, cleithrum length, and dentary length for ten common prey fishes in the Northwest Atlantic. All relationships were highly significant, with coefficients of determination typically exceeding 0.90 and mean percent prediction errors less than 10%, indicating that reliable original size estimates are obtainable from incomplete fish remains. To aid in field-based identification of prey fishes, we extracted and examined opercles, cleithra, and dentaries from each fish. Careful examination of bones revealed prominent diagnostic characteristics with clear differences among family taxa, demonstrating their potential utility as identification tools. Used collectively, the predictive equations and the diagnostic features of the bones should allow for inclusion in diet analyses of prey items previously designated as unidentifiable or unmeasurable, and thus increase the amount of dietary information obtainable from stomach contents analyses of Northwest Atlantic piscivores.

Enhancing diet analyses of piscivorous fishes in the Northwest Atlantic through identification and reconstruction of original prey sizes from ingested remains

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Biological interactions among species can significantly affect the dynamics of marine fish populations (Overholtz et al., 1991; Rothschild, 1991). Specifically, predation by piscivorous fishes is recognized as an important mechanism in structuring fish communities (Hackney, 1979; Lyons and Magnuson, 1987; Tonn et al., 1992), particularly in the role it plays to potentially regulate natural mortality rates and recruitment of larval and juvenile fishes (Sissenwine, 1984; Houde, 1987; Bailey and Houde, 1989). In order to estimate consumption rates of key predators, details are needed on the types and sizes of prey fishes consumed across spatial and temporal scales. However, because of the substantial variability in the condition of recovered prey items, the collection of stomach contents data in the field is often limited to only those items that are readily identified and measured, resulting in the loss of potentially important diet information.

Identification of piscine prey ingested by fish, avian, and mammalian predators has frequently involved the use of diagnostic bones including vertebrae (Pikhu and Pikhu, 1970; Feltham and Marquiss, 1989; Carss and Elston, 1996), pharyngeal arches (McIntyre and Ward, 1986; Raven, 1986), opercular bones (Newsome, 1977), the axial skeleton

and hypurals (Trippel and Beamish, 1987), and cleithra and dentaries (Hansel et al., 1988). Measurements of the dimensions of diagnostic bones have often then been used to estimate original prey size (Trippel and Beamish, 1987; Hansel et al., 1988; Carss and Elston, 1996). Previous studies on the food habits of piscivores have used fish otoliths as an aid in prey identification and original prey size estimation (Jobling and Breiby, 1986). However, acidic preservatives, such as formaldehyde, can dissolve otoliths, resulting in unreliable otolith length and fish length relationships (McMahon and Tash, 1979). In addition to bones, external morphological measurements, such as eye diameter and caudal peduncle depth, have been used successfully to reconstruct prey body size for recently consumed prey fishes (Crane et al., 1987; Scharf et al., 1997). However, the majority of fish feeding studies employing such techniques have been directed at freshwater piscivores, whereas researchers examining the diets of marine fishes have utilized these techniques much less frequently (Crane et al., 1987; Scharf et al., 1997). Moreover, no such techniques are currently available to enhance diet analyses and more completely define the role of piscivorous fishes in structuring fish communities in the Northwest Atlantic.[1]

Here, we generate a series of predictive regression equations to estimate prey fish total length, fork length, and weight for ten fish species. Original fish size is estimated from four external morphometric measurements including maximum body depth, eye diameter, caudal peduncle depth, and pectoral-fin length, as well as from length measurements of three diagnostic bones: the opercle, the cleithrum, and the

dentary. The prey species used here include several of commercial and recreational importance and commonly occur in the diets of marine piscivores in the Northwest Atlantic, representing approximately 52% of the total fish prey consumed by piscivorous fishes during 1973–90 (Grosslein et al., 1980; Langton and Bowman, 1981).[2] We also identify and describe the unique characteristics of the three diagnostic bones for each fish species and assess their potential value as tools for field identification of prey fishes recovered from predator stomachs.

Materials and methods

Over 700 fish representing ten species in five families ranging in size from 52 to 340 millimeters (mm) total length (TL) were measured and dissected (Table 1). Fish were collected as part of Food Chain Dynamics Investigation (FCDI) (NEFSC, NMFS) research cruises conducted on Georges Bank during June and August of 1995 and 1996. FCDI research cruises were sponsored through the National Oceanic and Atmospheric Administration Coastal Ocean Program-Georges Bank Predation Study. Fish were also collected from waters off the Northeast U.S. coast during September and October of 1996 as part of the NEFSC Fall bottom trawl surveys. Additional fish were collected by personnel from the Massachusetts Division of Marine Fisheries as part of a coastal trawling survey conducted in May and September of 1996. All fish were immediately frozen until they could be returned to the laboratory. In the laboratory, fish were thawed and weighed wet to the near-

[1] Rountree, R. A. 1997. Food Chain Dynamics Investigation (FCDI). Northeast Fisheries Science Center (NEFSC), National Marine Fisheries Service (NMFS), 166 Water St., Woods. Hole, MA 02543. Personal commun.

[2] Food Chain Dynamics Investigation (FCDI). Northeast Fisheries Science Center, NMFS, 166 Water St., Woods Hole, MA 02543. Unpublished data.

Table 1

Family, species, number (*n*), and size range (total length in millimeters) of prey fishes used to construct predictive equations.

Family	Species	Common name	n	Size range
Clupeidae	Alosa pseudoharengus	Alewife	137	73–282
	Alosa aestivalis	Blueback herring	38	83–134
	Clupea harengus	Atlantic herring	84	97–269
Scombridae	Scomber scombrus	Atlantic mackerel	56	158–330
Stromateidae	Peprilus triacanthus	Butterfish	108	54–193
Ammodytidae	Ammodytes dubius	Sand lance	75	109–209
Gadidae	Urophycis chuss	Red hake	45	108–340
	Merluccius bilinearis	Silver hake	95	75–300
	Melanogrammus aeglefinus	Haddock	47	79–202
	Gadus morhua	Atlantic cod	31	52–140

est 0.01 gram (g) before external measurements were completed to the nearest 0.01 mm with digital calipers. To remove diagnostic bones, fish were placed in boiling water for 30–90 seconds, depending on fish size. Bones were then extracted from the soft tissue and measured to the nearest 0.025 mm with an ocular micrometer (2.75×).

Least squares regression equations (StataCorp., 1995) were generated to predict original total length, fork length, and weight from measurements of body depth, eye diameter, caudal peduncle depth, pectoral-fin length, opercle length, cleithrum length, and dentary length. The left eye, left pectoral fin, and diagnostic bones from the left side of each fish were used consistently unless damaged. Body depth was measured as the maximum linear dorsoventral distance with fins depressed. Eye diameter was measured horizontally along the anteroposterior axis. Caudal peduncle depth was measured dorsoventrally. Pectoral-fin length was measured from the anterior most point of fin insertion to the tip of the longest fin ray. Opercle length was measured as the maximum linear dorsoventral distance, usually from the dorsal most point to the tip of the primary ray (Fig. 1). Cleithrum length was measured from the tip of the dorsal process to the tip of the ventral process (Fig. 2). Dentary length was defined as the maximum linear anteroposterior distance from the symphyseal margin located anteriorly between the left and right dentaries to the posterior tip of the dorsal or ventral process, whichever was longer (Fig. 3). A series of least squares regression equations to predict fish weight from total or fork length for each species was also generated. To further assess the strength of individual bivariate relationships, mean percent prediction errors (Smith, 1980) were determined for each regression by averaging the percent prediction error calculated for each observation as

$$[(Observed - Predicted) / Predicted] \times 100.$$

Forward and backward stepwise linear regressions (StataCorp., 1995) were performed in an attempt to identify the best set of predictor variables. To ensure that all variables in the stepwise model were individually significant, the value of the F-statistic used to determine variable inclusion was set at four (Draper and Smith, 1981).

Opercles, cleithra, and dentaries were also carefully examined to identify distinguishing characteristics that may be potentially useful for identification of each fish species. Several features of each bone were examined for differences among species, including the general shape of each bone; the numbers and orientation of ridges on the opercle and the curva-

ture of opercle margins; the numbers, sizes, and shapes of cleithrum processes; and the presence or absence of teeth on the dentary, with attention given to overall tooth size, shape, and orientation, as well as the shapes and relative lengths of dentary processes.
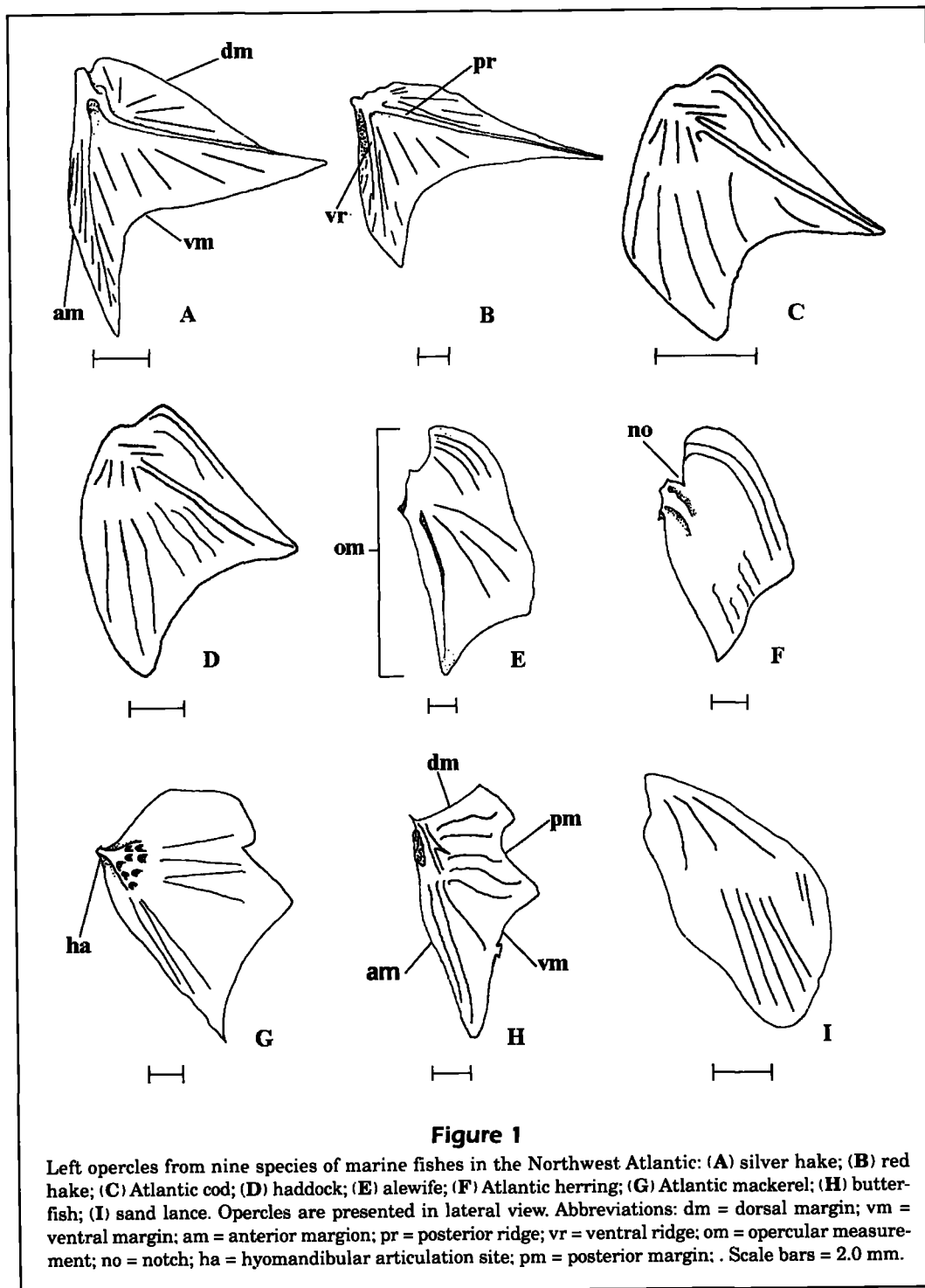
Results

Predictive equations

Regressions relating external morphological measurements to total and fork length were all highly significant ($P<0.0001$), with r^2 values ranging from 0.63 to 0.99 and mean percent prediction errors ranging from 2.68 to 10.83 (Table 2). Regressions from measurements of eye diameter to predict original fish length were typically more variable than those from other external measurements. This was likely due to measurement error associated with damage of the soft adipose tissue surrounding the eye incurred during the freezing and thawing processes. Regressions relating diagnostic bone measurements to total and fork length were also highly significant ($P<0.0001$), with r^2 values ranging from 0.81 to 0.99 and mean percent prediction errors ranging from 1.26 to 8.48 (Table 3). Compared with regressions from external morphological measurements, variation in diagnostic bone measurements typically explained more of the variation in original fish length (94% of r^2 values >0.90) and bones were generally more precise in predicting fish length (87% of mean %PEs < 5.00). Stepwise linear regressions indicated that cleithrum length was the most consistent predictor of original fish length and it was included in the best set of predictor variables for 8 of 10 species (Table 4). Pectoral-fin length was included in the best set of predictors for 6 species, whereas dentary length was included for 5 species. The remaining independent variables were included in the best set of predictors for either 3 or 4 species, respectively.

Regressions relating external morphological measurements and diagnostic bone measurements to fish weight were also each highly significant ($P<0.0001$), with r^2 values ranging from 0.71 to 0.99 (Table 5). Mean percent prediction errors for regressions predicting fish weight ranged from 5.97 to 39.17. These were typically higher compared with prediction errors for regressions predicting fish length, indicating that estimates of original fish length were more precise than estimates of original prey weight. Similar to length regressions, diagnostic bone measurements yielded higher r^2 values and lower mean percent prediction errors when regressed against fish weight compared with external morphological mea-

surements. Stepwise linear regressions indicated that body depth, caudal peduncle depth, and cleithrum length were the most consistent predictors of original fish weight and were included in the best set of predictor variables for 8, 9, and 8 species, respectively (Table 6). Pectoral-fin length was included in the best set of predictor variables for 5 species, whereas opercle length was included for 3 species. Dentary length and eye diameter appeared to be the least consistent predictors of fish weight and were included in the best set of predictor variables for 1 and 0 of the species, respectively. Lastly, measurements of total and fork length were significantly related to total weight for each species ($P<0.0001$) with

Figure 1

Left opercles from nine species of marine fishes in the Northwest Atlantic: (A) silver hake; (B) red hake; (C) Atlantic cod; (D) haddock; (E) alewife; (F) Atlantic herring; (G) Atlantic mackerel; (H) butterfish; (I) sand lance. Opercles are presented in lateral view. Abbreviations: dm = dorsal margin; vm = ventral margin; am = anterior margion; pr = posterior ridge; vr = ventral ridge; om = opercular measurement; no = notch; ha = hyomandibular articulation site; pm = posterior margin; . Scale bars = 2.0 mm.

r^2 values typically greater than 0.95 and mean percent prediction errors generally less than 10% (Table 7).
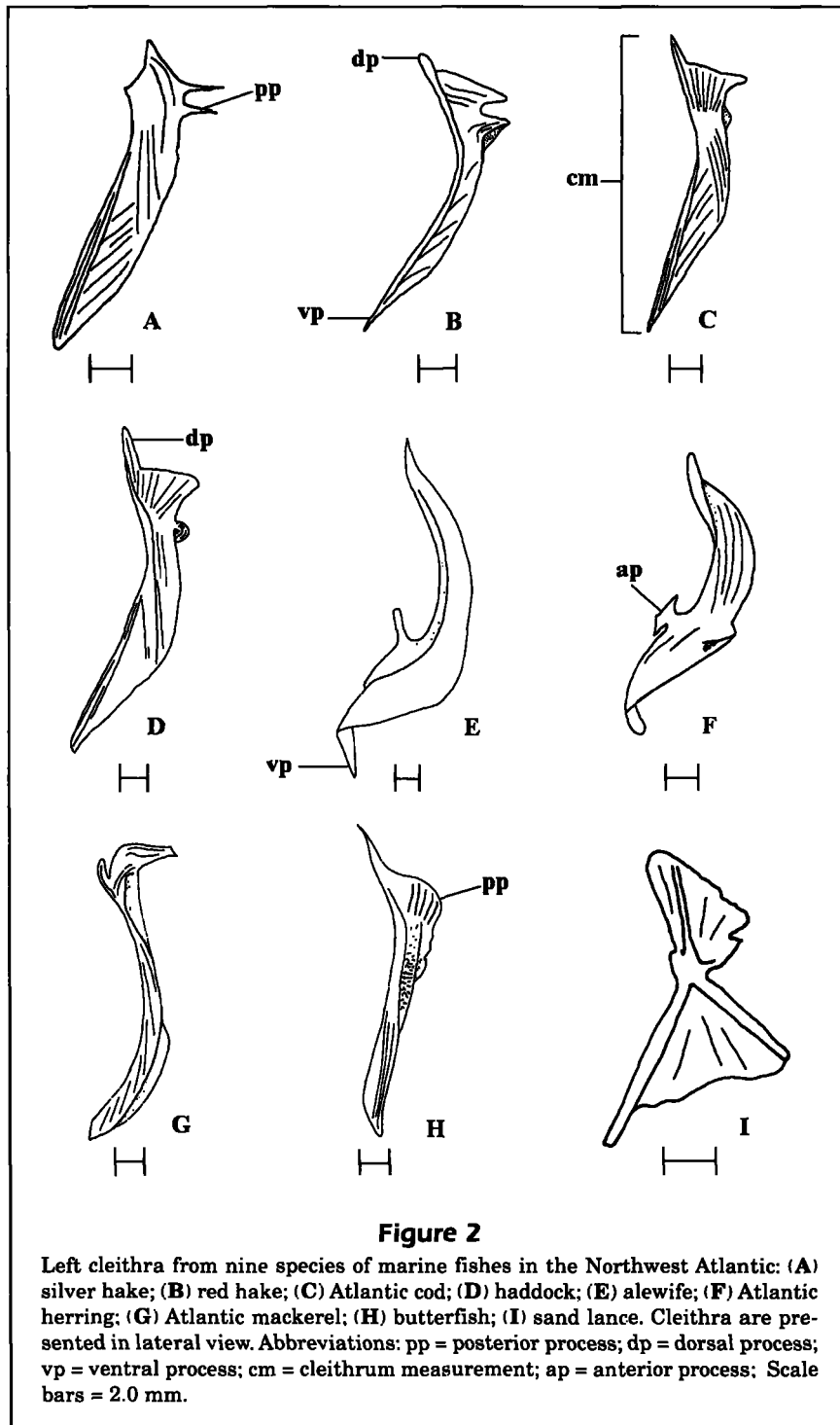
Diagnostic bones

For each of the bones examined here, clear differences in diagnostic features exist among family taxa. Distin-guishing bone characteristics were also evident among genera within the families Gadidae and Clupeidae. Differences between two species from the same genus (*Alosa*) were, however, difficult to discern from the three bones used here. Therefore, bone illustrations are presented for only nine species, with alewife, rather than blueback herring, representing the genus *Alosa*.

Opercles

The opercle is the largest and most dorsal bone in the opercular series, which consists of the opercle, the subopercle, and the interopercle. Together, these three bones provide the skeletal support for the muscular operculum, or gill cover in fishes. The opercle articulates with the opercular process of the hyomandibula. The articulation site is located in the anterodorsal region of the opercle, and represents a consistent morphological feature for orientation of the bone during examination. The opercles of the fishes examined here can be differentiated by two major diagnostic characteristics. First, the general shape of the opercle is clearly unique to several of the families examined. The opercles of some families share a general triangular shape with three well-defined margins, whereas others are not triangular and possess four definable margins. A second distinctive feature is the presence or absence of ridges originating at the site of hyomandibular articulation and extending ventrally or posteriorly along the margins of the opercle.

Of the taxa examined here, silver hake (*Merluccius bilinearis*) and red hake (*Urophycis chuss*) have opercles with the most pronounced triangular shape and three clearly defined margins (Fig. 1, A and B). The hake opercles are further distinguished by the presence of two prominent ridges originating at the site of hyomandibular articulation and extending ventrally and posteriorly along the anterior and dorsal margins, respectively. Hake opercles differ

Figure 2

Left cleithra from nine species of marine fishes in the Northwest Atlantic: (A) silver hake; (B) red hake; (C) Atlantic cod; (D) haddock; (E) alewife; (F) Atlantic herring; (G) Atlantic mackerel; (H) butterfish; (I) sand lance. Cleithra are presented in lateral view. Abbreviations: pp = posterior process; dp = dorsal process; vp = ventral process; cm = cleithrum measurement; ap = anterior process; Scale bars = 2.0 mm.
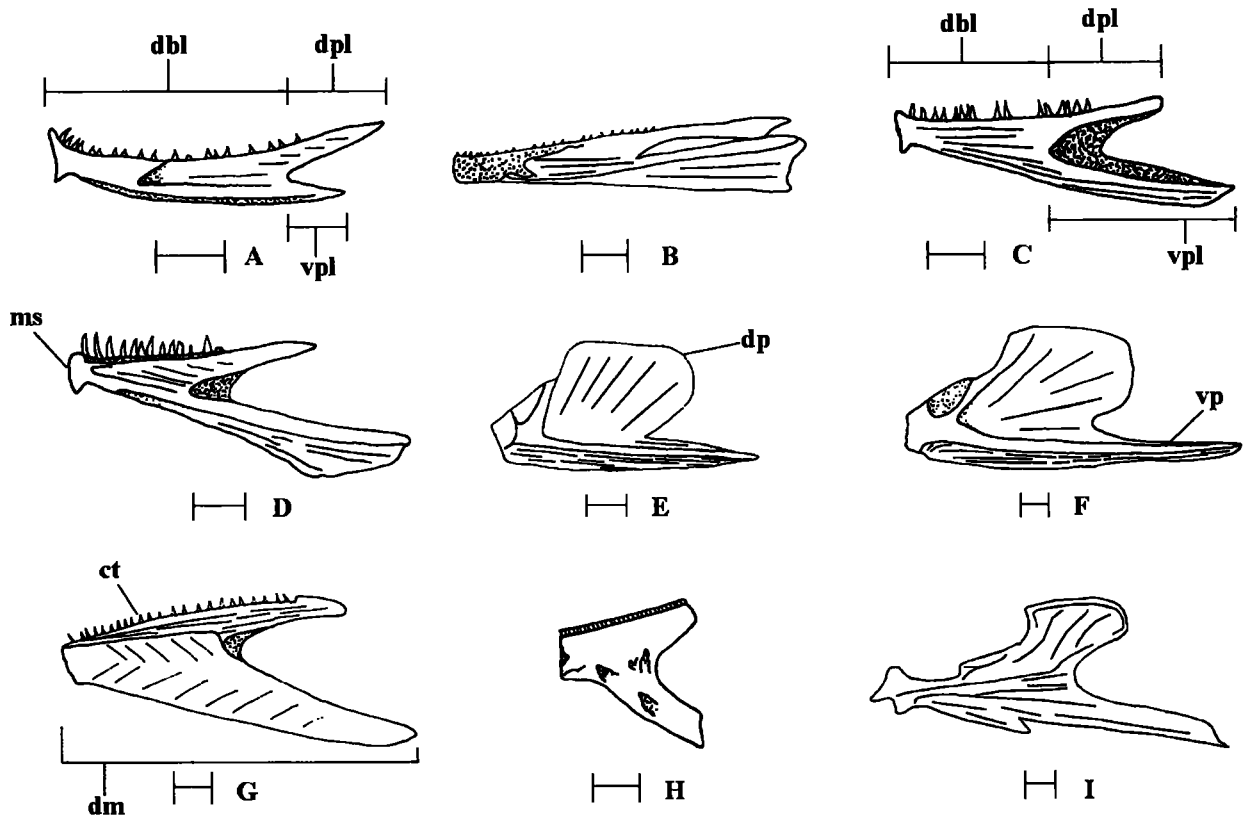
Figure 3

Left dentaries from nine species of marine fishes in the Northwest Atlantic: (A) silver hake; (B) red hake; (C) Atlantic cod; (D) haddock; (E) alewife; (F) Atlantic herring; (G) Atlantic mackerel; (H) butterfish; (I) sand lance. Dentaries are presented in lateral view. Abbreviations: dbl = dentary body length; dpl = dorsal process length; vpl = ventral process length; ms = mandibular symphysis; dp = dorsal process; vp = ventral process; ct = conical teeth; dm = dentary measurement. Scale bars = 2.0 mm.

slightly because the posterior region of the red hake opercle is longer in relation to the body of the opercle than that of silver hake and is also narrower, ending in a sharper point in contrast with the opercle of silver hake. The opercles of Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) share a general triangular shape with the hakes, although it is less pronounced in cod and haddock (Fig. 1, C and D). Opercles of Atlantic cod and haddock can be further separated from hake opercles by the presence of only one prominent ridge, which extends posteriorly from the site of hyomandibular attachment, rather than the two ridges found in hake. There appear to be no consistent, observable differences between the opercles of Atlantic cod and haddock. The opercles of alewife (*Alosa pseudoharengus*) and Atlantic herring (*Clupea harengus*) are not triangular and have a distinct notch that is dorsal to the site of hyomandibular articulation along the dorsal margin, with a pronounced curvature along the posterior margin (Fig. 1, E and F). The opercles of

alewife and Atlantic herring each possess one ridge, extending ventrally from the site of hyomandibular articulation along the anterior margin, and each also has four definable margins. Alewife and Atlantic herring opercles differ mainly in the shape of the dorsal notch—the notch being cup-shaped in alewife, compared with v-shaped in Atlantic herring. In Atlantic mackerel (*Scomber scombrus*), the opercle has a pronounced dorsal curvature with a notch located centrally along the posterior margin (Fig. 1G). The ridge extending from the hyomandibular articulation site is unique to Atlantic mackerel in that it branches out broadly as it extends posteriorly from the articulation site. The opercles of butterfish (*Peprilus triacanthus*) are unique in general shape, resembling a butterfly wing, with four clearly defined margins and a ridge extending ventrally from the hyomandibular articulation site along the anterior margin (Fig. 1H). Sand lance (*Ammodytes dubius*) represent the only species examined here with opercles not possessing ridges along any margins. Sand lance opercles also

Table 2

Least squares regression equations relating measurements of body depth (BD), eye diameter (ED), caudal peduncle depth (CP), and pectoral–fin length (PF) to total length (TL) and fork length (FL) for ten prey species in the Northwest Atlantic. All measurements are in millimeters. s_b = standard error of the regression coefficient; r^2 = coefficient of determination; %PE = mean percent prediction error; n = number of fish measured; Range = size range in total length. Fork lengths were not measured for red hake, silver hake, or Atlantic cod.

Species	Total length				Fork length					
	Equation	s_b	r^2	%PE	Equation	s_b	r^2	%PE	n	Range
Alewife	$TL = 3.881BD + 11.012$	0.073	0.95	4.38	$FL = 3.469BD + 10.856$	0.067	0.98	4.04	137	73–282
	$TL = 24.906ED - 61.344$	0.781	0.88	7.30	$FL = 23.335ED - 57.728$	0.562	0.96	6.13	137	73–282
	$TL = 12.876CP - 1.784$	0.182	0.97	3.53	$FL = 11.348CP + 1.313$	0.163	0.99	3.31	137	73–282
	$TL = 6.840PF + 0.532$	0.100	0.99	3.15	$FL = 5.982PF + 1.785$	0.093	0.98	3.34	66	73–282
Blueback herring	$TL = 4.970BD + 1.439$	0.268	0.91	3.59	$FL = 4.620BD - 1.573$	0.246	0.91	3.66	38	83–134
	$TL = 25.318ED - 35.605$	2.117	0.80	5.33	$FL = 23.792ED - 37.352$	1.865	0.82	5.42	38	83–134
	$TL = 13.684CP + 0.194$	0.752	0.90	3.53	$FL = 12.585CP - 1.782$	0.754	0.89	4.06	38	83–134
	$TL = 7.760PF + 2.935$	0.383	0.92	3.58	$FL = 7.198PF - 0.005$	0.358	0.92	3.79	38	83–134
Atlantic herring	$TL = 4.561BD + 27.341$	0.089	0.97	4.22	$FL = 4.036BD + 26.880$	0.081	0.97	4.17	84	97–295
	$TL = 26.717ED - 51.235$	0.594	0.96	5.08	$FL = 23.633ED - 42.586$	0.537	0.96	5.00	84	97–295
	$TL = 16.303CP - 17.288$	0.296	0.97	4.55	$FL = 14.441CP - 12.792$	0.257	0.97	4.35	84	97–295
	$TL = 7.507PF + 1.533$	0.101	0.99	2.68	$FL = 6.631PF + 4.306$	0.102	0.98	2.95	84	97–295
Atlantic mackerel	$TL = 5.203BD + 37.203$	0.122	0.97	3.67	$FL = 4.641BD + 39.790$	0.118	0.97	3.89	56	158–330
	$TL = 33.706ED - 81.239$	3.027	0.70	10.83	$FL = 30.404ED - 68.847$	2.652	0.71	10.28	56	158–330
	$TL = 40.081CP - 0.837$	0.700	0.98	2.78	$FL = 35.874CP + 5.213$	0.592	0.99	2.61	56	158–330
	$TL = 9.037PF - 1.242$	0.178	0.98	3.02	$FL = 8.068PF + 5.346$	0.172	0.98	3.06	56	158–330
Butterfish	$TL = 2.860BD + 1.650$	0.038	0.98	3.32	$FL = 2.384BD + 5.638$	0.034	0.98	3.57	108	54–193
	$TL = 20.065ED - 21.148$	0.635	0.90	7.48	$FL = 16.700ED - 13.166$	0.544	0.90	7.52	108	54–193
	$TL = 17.960CP + 7.962$	0.290	0.97	3.57	$FL = 14.950CP + 11.046$	0.264	0.97	4.03	108	54–193
	$TL = 3.766PF + 15.966$	0.060	0.98	4.33	$FL = 3.126PF + 18.121$	0.064	0.98	5.54	63	54–193
Sand lance	$TL = 7.308BD + 58.774$	0.455	0.78	6.07	$FL = 7.045BD + 57.497$	0.463	0.76	6.16	75	109–209
	$TL = 49.467ED - 45.022$	4.358	0.64	8.29	$FL = 47.921ED - 43.479$	4.313	0.63	8.45	75	109–209
	$TL = 35.928CP + 8.185$	1.562	0.88	4.32	$FL = 34.923CP + 7.599$	1.575	0.87	4.48	75	109–209
	$TL = 14.993PF - 31.272$	0.934	0.78	6.52	$FL = 14.542PF - 30.374$	0.933	0.77	6.75	75	109–209
Red hake	$TL = 6.398BD + 10.340$	0.210	0.96	7.40					45	108–340
	$TL = 28.474ED - 91.519$	0.860	0.96	6.37					45	108–340
	$TL = 26.384CP - 17.165$	0.627	0.98	5.18					45	108–340
	$TL = 6.885PF - 0.693$	0.146	0.98	3.92					45	108–340
Silver hake	$TL = 6.460BD + 18.219$	0.164	0.94	7.00					95	75–300
	$TL = 21.998ED - 31.654$	0.504	0.95	7.05					95	75–300
	$TL = 22.823CP + 22.881$	0.345	0.98	4.63					95	75–300
	$TL = 4.946PF + 20.269$	0.070	0.99	3.36					60	75–300
Haddock	$TL = 4.199BD + 21.964$	0.173	0.93	5.30	$FL = 4.066BD + 19.660$	0.164	0.93	4.83	47	79–202
	$TL = 20.069ED - 35.473$	1.375	0.83	7.97	$FL = 19.525ED - 36.724$	1.291	0.84	7.87	47	79–202
	$TL = 18.465CP + 16.596$	0.699	0.94	4.90	$FL = 17.922CP + 14.205$	0.638	0.95	4.54	47	79–202
	$TL = 7.367PF - 10.712$	0.260	0.95	4.69	$FL = 7.106PF - 11.430$	0.263	0.94	4.90	47	79–202
Atlantic cod	$TL = 4.249BD + 21.367$	0.133	0.97	4.03					31	52–140
	$TL = 19.393ED - 19.490$	1.053	0.92	7.33					31	52–140
	$TL = 17.999CP + 9.806$	0.480	0.98	3.72					31	52–140
	$TL = 6.728PF + 7.681$	0.185	0.98	3.48					31	52–140

possess only two clearly definable margins and are curved along the entire posterior margin (Fig. 1I).

Cleithra

In higher teleost fishes, the cleithrum is the ventral most bone of the pectoral girdle, which consists of the supracleithrum, the cleithrum, and the postcleithrum. The cleithrum attaches directly to the scapulocoracoid, which articulates with the base of the pectoral fin. Together, the left and right cleithra form the frame of the body wall directly posterior to the branchial cavity. The cleithra of the fishes examined here can be differentiated by their general shape as

well as the numbers, locations, and shapes of the processes. The majority of the cleithra described here have a gently sloping curvature along the dorsoventral axis, whereas others are clearly more sharply curved. Most families examined here possess cleithra with dorsal and ventral processes that end sharply; others possess varying numbers and shapes of posterior and anterior processes.

The cleithra of silver hake and red hake are gently curved along the dorsoventral axis and each has two posterior processes located directly ventral to the dorsal process (Fig. 2, A and B). The ventral process of the red hake ends in a sharper point and is not as broad as that of silver hake, and the posterior processes are broader than those of silver hake. Atlan-

tic cod and haddock have gently curved cleithra with a general shape similar to that of the cleithra of silver and red hake (Fig. 2, C and D). However, the cleithra of Atlantic cod and haddock contain only one posterior process that is broader than the posterior processes of the hake cleithra, and the dorsal processes of Atlantic cod and haddock cleithra end sharply and are much more pronounced than those of the hake cleithra. The main difference between the cleithra of Atlantic cod and haddock is in the shape of the posterior process; the process is distinctly more hook-shaped in Atlantic cod than in haddock. The cleithra of alewife and Atlantic herring are each sharply curved and possess an anterior process located medially along the dorsoventral axis, which is

Table 3

Least squares regression equations relating measurements of opercle length (OP), cleithrum length (CL), and dentary length (DN) to total length (TL) and fork length (FL) for ten prey species in the Northwest Atlantic. All measurements are in millimeters. s_b = standard error of the regression coefficient; r^2 = coefficient of determination; %PE = mean percent prediction error; n = number of fish measured; Range = size range in total length. Fork lengths were not measured for red hake, silver hake, or Atlantic cod.

| Species | Total length | | | | Fork length | | | | | |
	Equation	s_b	r^2	%PE	Equation	s_b	r^2	%PE	n	Range
Alewife	$TL = 9.851OP - 1.119$	0.126	0.99	2.80	$FL = 8.617OP + 0.307$	0.118	0.99	3.15	66	73–282
	$TL = 7.115CL - 3.450$	0.097	0.99	2.80	$FL = 6.217CL - 1.579$	0.097	0.98	3.22	66	73–282
	$TL = 11.610DN - 23.205$	0.163	0.99	3.23	$FL = 10.144DN - 18.824$	0.163	0.98	3.74	66	73–282
Blueback herring	$TL = 10.014OP + 6.641$	0.547	0.90	3.07	$FL = 9.198OP + 4.259$	0.555	0.88	3.46	38	83–134
	$TL = 7.491CL + 0.161$	0.354	0.93	3.09	$FL = 6.893CL - 1.863$	0.362	0.91	3.40	38	83–134
	$TL = 11.743DN - 11.125$	0.653	0.90	2.96	$FL = 10.871DN - 12.840$	0.621	0.90	3.04	38	83–134
Atlantic herring	$TL = 11.732OP - 0.427$	0.168	0.99	2.30	$FL = 10.405OP + 2.028$	0.168	0.98	2.65	71	97–269
	$TL = 8.752CL - 10.804$	0.126	0.99	2.19	$FL = 7.771CL - 7.353$	0.117	0.98	2.41	71	97–269
	$TL = 10.692DN - 17.263$	0.180	0.98	3.02	$FL = 9.495DN - 13.112$	0.164	0.98	3.10	71	97–269
Atlantic mackerel	$TL = 11.114OP + 0.379$	0.179	0.99	2.01	$FL = 9.867OP + 7.462$	0.163	0.99	2.06	44	158–330
	$TL = 7.789CL - 6.990$	0.067	0.99	1.26	$FL = 6.916CL + 0.889$	0.062	0.99	1.27	44	158–330
	$TL = 12.564DN - 30.649$	0.212	0.99	2.53	$FL = 11.148DN - 19.970$	0.201	0.99	2.44	44	158–330
Butterfish	$TL = 7.956OP + 5.184$	0.299	0.92	7.64	$FL = 6.598OP + 9.279$	0.266	0.91	8.48	63	54–193
	$TL = 5.583CL - 27.802$	0.091	0.98	3.23	$FL = 4.653CL - 18.698$	0.081	0.98	3.43	63	54–193
	$TL = 13.643DN + 6.884$	0.484	0.93	7.49	$FL = 11.309DN + 10.725$	0.436	0.92	8.25	63	54–193
Sand lance	$TL = 18.903OP + 25.655$	1.042	0.82	5.46	$FL = 18.352OP + 24.729$	1.044	0.81	5.60	75	109–209
	$TL = 18.487CL - 1.156$	0.719	0.90	3.81	$FL = 17.938CL - 1.228$	0.741	0.89	4.12	75	109–209
	$TL = 20.785DN - 33.880$	0.772	0.91	3.89	$FL = 20.300DN - 34.146$	0.752	0.91	3.92	75	109–209
Red hake	$TL = 27.956OP - 4.679$	0.612	0.98	4.53					45	108–340
	$TL = 9.061CL - 12.185$	0.123	0.99	2.81					45	108–340
	$TL = 13.870DN - 11.769$	0.291	0.98	4.37					45	108–340
Silver hake	$TL = 17.666OP - 11.964$	0.212	0.99	3.20					60	75–300
	$TL = 7.875CL - 5.271$	0.071	0.99	2.57					60	75–300
	$TL = 8.427DN - 5.149$	0.087	0.99	2.63					60	75–300
Haddock	$TL = 23.040OP - 15.425$	1.053	0.91	5.52	$FL = 22.351OP - 16.804$	0.984	0.92	4.78	47	79–202
	$TL = 6.567CL - 2.688$	0.176	0.97	3.25	$FL = 6.215CL - 1.202$	0.258	0.93	4.87	47	79–202
	$TL = 12.348DN - 3.688$	0.496	0.93	5.07	$FL = 11.680DN - 2.075$	0.606	0.89	6.29	47	79–202
Atlantic cod	$TL = 19.019OP + 7.733$	0.705	0.96	5.43					31	52–140
	$TL = 6.590CL + 1.118$	0.101	0.99	2.50					31	52–140
	$TL = 10.458DN - 5.592$	0.181	0.99	2.29					31	52–140

unique among the fishes examined here (Fig. 2, E and F). The shape of the anterior process differs between the two genera of Clupeidae. In alewife, the anterior process is sickle-shaped, whereas in Atlantic herring, the anterior process is more symmetrical, resembling a mushroom. Additionally, the tip of the ventral process is distinctly sharper in the cleithrum of alewife than in the cleithrum of Atlantic herring. Atlantic mackerel cleithra are gently curved and relatively thin and one posterior process is located in the extreme dorsal region of the bone (Fig. 2G). The dorsal process of the Atlantic mackerel cleithrum is relatively small and rounded, whereas the ventral process is broad and does not end sharply as in the cleithra of the gadids. The cleithra of butterfish are only slightly curved along the dorsoventral axis and contain a broad, rounded posterior process. Butterfish cleithra can be distinguished among the families examined here by the presence of a distinctly sharp, thin dorsal process (Fig. 2H). The cleithra of sand lance have a general

Table 4

Independent variables included in stepwise multiple regression models estimating original fish length. Abbreviations for independent variables are those given in Tables 2 and 3. * indicates that forward and backward models were not identical.

Species	Variables included in forward stepwise model	Variables included in backward stepwise model
Alewife	CP, PF, OP, CL	CP, PF, OP, CL
Blueback herring	PF, CL	PF, CL
Atlantic herring	BD, PF, OP, DN	BD, PF, OP, DN
Atlantic mackerel*	CL, DN	CL
Butterfish*	BD, CP, PF, CL	ED, CP, PF, CL
Sand Lance	CP, DN	CP, DN
Red hake	BD, ED, CL	BD, ED, CL
Silver hake*	OP, CL, DN	CL
Haddock	ED, CP, PF, CL	ED, CP, PF, CL
Atlantic cod	BD, PF, CL, DN	BD, PF, CL, DN

Table 5

Least squares regression equations relating measurements (in millimeters) of body depth (BD), eye diameter (ED), caudal peduncle depth (CP), pectoral fin length (PF), opercle length (OP), cleithrum length (CL), and dentary length (DN) to total weight (W) in grams for ten prey species in the Northwest Atlantic. s_b = standard error of the regression coefficient; r^2 = coefficient of determination; %PE = mean percent prediction error; n = number of fish measured; Range = size range in total length.

Species	Equation	s_b	r^2	%PE	n	Range
Alewife	$W = 0.73 \times 10^{-3}BD^{2.940}$	0.041	0.97	10.74	137	73–282
	$W = 2.62 \times 10^{-3}ED^{4.305}$	0.133	0.89	24.00	137	73–282
	$W = 10.18 \times 10^{-3}CP^{3.194}$	0.037	0.98	8.87	137	73–282
	$W = 1.25 \times 10^{-3}PF^{3.229}$	0.053	0.98	11.31	66	73–282
	$W = 2.95 \times 10^{-3}OP^{3.331}$	0.052	0.98	11.73	66	73–282
	$W = 0.81 \times 10^{-3}CL^{3.383}$	0.051	0.99	10.65	66	73–282
	$W = 1.05 \times 10^{-3}DN^{3.739}$	0.055	0.99	10.66	66	73–282
Blueback herring	$W = 0.64 \times 10^{-3}BD^{3.066}$	0.103	0.96	6.83	38	83–134
	$W = 6.68 \times 10^{-3}ED^{4.049}$	0.340	0.80	15.73	38	83–134
	$W = 13.80 \times 10^{-3}CP^{3.061}$	0.154	0.92	9.48	38	83–134
	$W = 3.94 \times 10^{-3}PF^{2.903}$	0.158	0.90	9.88	38	83–134
	$W = 10.40 \times 10^{-3}OP^{2.851}$	0.160	0.90	9.84	38	83–134
	$W = 2.38 \times 10^{-3}CL^{3.027}$	0.139	0.93	8.15	38	83–134
	$W = 3.00 \times 10^{-3}DN^{3.383}$	0.201	0.89	9.96	38	83–134
Atlantic herring	$W = 2.96 \times 10^{-3}BD^{2.734}$	0.033	0.99	8.64	84	97–295
	$W = 7.14 \times 10^{-3}ED^{4.012}$	0.092	0.96	16.58	84	97–295
	$W = 7.96 \times 10^{-3}CP^{3.438}$	0.060	0.98	11.81	84	97–295
	$W = 3.76 \times 10^{-3}PF^{2.935}$	0.065	0.97	12.06	84	97–295
	$W = 10.53 \times 10^{-3}OP^{3.030}$	0.063	0.97	10.01	71	97–295
	$W = 2.20 \times 10^{-3}CL^{3.193}$	0.069	0.97	10.01	71	97–295
	$W = 3.52 \times 10^{-3}DN^{3.210}$	0.084	0.96	12.87	71	97–295
Atlantic mackerel	$W = 2.79 \times 10^{-3}BD^{2.884}$	0.066	0.97	11.73	56	158–330
	$W = 2.20 \times 10^{-3}ED^{4.762}$	0.377	0.75	39.17	56	158–330
	$W = 247.52 \times 10^{-3}CP^{3.373}$	0.061	0.98	9.12	56	158–330
	$W = 1.49 \times 10^{-3}PF^{3.399}$	0.078	0.97	12.07	56	158–330
	$W = 3.90 \times 10^{-3}OP^{3.318}$	0.049	0.99	6.77	44	158–330

continued

butterfly shape that is clearly unique among the families examined here (Fig. 2I).

Dentaries

The dentary is the largest bone of the lower jaw and bears teeth in many fishes. The posterior region of the dentary is attached directly to the angular and articular bones. The left and right dentaries are fused anteriorly at the mandibular symphysis. The dentaries of the fishes examined here can be differentiated by the presence or absence of teeth and by the relative lengths of the body of the dentary and the dorsal and ventral processes.

The dentaries of silver hake and red hake each possess a row of separate conical teeth extending slightly onto the dorsal process. Teeth are curved inwards and spaced relatively far apart (Fig. 3, A and B). The ratios of the lengths of the dorsal and ventral processes to the length of the body of the

Table 5 (continued)						
Species	Equation	s_b	r^2	%PE	n	Range
Atlantic mackerel, continued	$W = 0.76 \times 10^{-3} CL^{3.419}$	0.048	0.99	5.97	44	158–330
	$W = 0.99 \times 10^{-3} DN^{3.760}$	0.093	0.98	10.79	44	158–330
Butterfish	$W = 0.18 \times 10^{-3} BD^{3.138}$	0.026	0.99	7.18	108	54–193
	$W = 7.05 \times 10^{-3} ED^{4.076}$	0.113	0.92	24.59	108	54–193
	$W = 94.11 \times 10^{-3} CP^{2.977}$	0.038	0.98	10.79	108	54–193
	$W = 2.14 \times 10^{-3} PF^{2.795}$	0.039	0.99	10.55	63	54–193
	$W = 3.94 \times 10^{-3} OP^{3.232}$	0.098	0.95	21.39	63	54–193
	$W = 0.06 \times 10^{-3} CL^{3.905}$	0.056	0.99	10.83	63	54–193
	$W = 25.57 \times 10^{-3} DN^{3.197}$	0.085	0.96	19.67	63	54–193
Sand lance	$W = 35.99 \times 10^{-3} BD^{2.245}$	0.063	0.95	10.12	75	109–209
	$W = 11.58 \times 10^{-3} ED^{4.925}$	0.372	0.71	20.83	75	109–209
	$W = 95.52 \times 10^{-3} CP^{3.400}$	0.105	0.94	9.35	75	109–209
	$W = 0.19 \times 10^{-3} PF^{4.366}$	0.274	0.78	20.26	75	109–209
	$W = 34.61 \times 10^{-3} OP^{3.017}$	0.177	0.80	18.38	75	109–209
	$W = 5.07 \times 10^{-3} CL^{3.618}$	0.111	0.94	9.84	75	109–209
	$W = 0.93 \times 10^{-3} DN^{4.258}$	0.242	0.81	17.08	75	109–209
Red hake	$W = 2.82 \times 10^{-3} BD^{2.865}$	0.129	0.92	23.72	45	108–340
	$W = 1.26 \times 10^{-3} ED^{4.492}$	0.153	0.95	19.21	45	108–340
	$W = 44.67 \times 10^{-3} CP^{3.286}$	0.091	0.97	15.93	45	108–340
	$W = 1.23 \times 10^{-3} PF^{3.127}$	0.064	0.98	11.85	45	108–340
	$W = 101.46 \times 10^{-3} OP^{3.073}$	0.077	0.97	13.48	45	108–340
	$W = 1.58 \times 10^{-3} CL^{3.261}$	0.042	0.99	7.34	45	108–340
	$W = 7.61 \times 10^{-3} DN^{3.193}$	0.080	0.97	13.75	45	108–340
Silver hake	$W = 2.39 \times 10^{-3} BD^{2.971}$	0.053	0.97	18.47	95	75–300
	$W = 3.11 \times 10^{-3} ED^{4.081}$	0.114	0.93	30.13	95	75–300
	$W = 211.32 \times 10^{-3} CP^{2.647}$	0.037	0.98	13.88	95	75–300
	$W = 2.47 \times 10^{-3} PF^{2.753}$	0.035	0.99	11.11	95	75–300
	$W = 8.67 \times 10^{-3} OP^{3.458}$	0.044	0.99	11.54	95	75–300
	$W = 0.84 \times 10^{-3} CL^{3.354}$	0.045	0.99	12.40	95	75–300
	$W = 1.10 \times 10^{-3} DN^{3.343}$	0.043	0.99	11.61	95	75–300
Haddock	$W = 2.60 \times 10^{-3} BD^{2.736}$	0.079	0.96	11.69	47	79–202
	$W = 3.32 \times 10^{-3} ED^{4.078}$	0.289	0.82	25.98	47	79–202
	$W = 103.33 \times 10^{-3} CP^{2.865}$	0.100	0.95	15.08	47	79–202
	$W = 0.57 \times 10^{-3} PF^{3.523}$	0.123	0.95	14.97	47	79–202
	$W = 23.77 \times 10^{-3} OP^{3.609}$	0.162	0.92	17.41	47	79–202
	$W = 0.92 \times 10^{-3} CL^{3.296}$	0.085	0.97	11.11	47	79–202
	$W = 7.16 \times 10^{-3} DN^{3.298}$	0.140	0.92	17.77	47	79–202
Atlantic cod	$W = 4.89 \times 10^{-3} BD^{2.558}$	0.062	0.98	12.09	31	52–140
	$W = 5.05 \times 10^{-3} ED^{4.042}$	0.233	0.91	25.68	31	52–140
	$W = 67.74 \times 10^{-3} CP^{2.984}$	0.075	0.98	11.67	31	52–140
	$W = 3.30 \times 10^{-3} PF^{2.987}$	0.078	0.98	12.21	31	52–140
	$W = 73.85 \times 10^{-3} OP^{2.983}$	0.119	0.96	16.51	31	52–140
	$W = 1.15 \times 10^{-3} CL^{3.273}$	0.052	0.99	6.96	31	52–140
	$W = 2.48 \times 10^{-3} DN^{3.498}$	0.071	0.99	9.39	31	52–140

dentary of silver hake are much smaller relative to the same ratios for the red hake dentary. In addition, the teeth of red hake are much less prominent, and the ventral process of the dentary of red hake is considerably broader than that of silver hake. Similar to the dentaries of the hakes, the dentaries of Atlantic cod and haddock also possess a row of separate conical teeth that extend slightly farther onto the dorsal process (Fig. 3, C and D). The length of the dorsal process of the dentaries of Atlantic cod and haddock is much smaller than the length of the

ventral process, which contrasts with the dentaries of the hakes. The dentaries of Atlantic cod and haddock can be distiguished by the teeth located just posterior to the mandibular symphysis; the teeth are longer in haddock than in Atlantic cod. Further, the ventral process is considerably broader in haddock than in Atlantic cod. The dentaries of alewife and Atlantic herring each consist of a long, slender ventral process that is considerably longer than the broadly expanded dorsal process, and are toothless (Fig. 3, E and F). The only noticeable difference between the dentaries of the alewife and Atlantic herring is a more gradual incline along the dorsal margin of the dorsal process and a slight hump located anteriorly in Atlantic herring. Similar to the dentaries of the gadids, Atlantic mackerel dentaries possess a row of separate conical teeth (Fig. 3G). However, the teeth of Atlantic mackerel extend well onto the dorsal process, are spaced relatively uniform distances apart, and are not curved inwards. The dentaries of butterfish possess a continuous row of separate teeth that are squared off at the tips, which is a unique feature among the fishes examined here (Fig. 3H). The ventral process of the butterfish dentary extends from the body of the dentary at a considerable angle. In sand lance, the dentaries have a long, thin ventral process that ends sharply and is much longer than the dorsal process, and are toothless (Fig. 3I). The dorsal process of the dentary of sand lance is curved along its margin, similar to the dorsal processes of the dentaries of alewife and Atlantic herring. However, the dorsal process of the dentary of sand lance is much less broad than that found in the dentaries of alewife and Atlantic herring.

Table 6

Independent variables included in stepwise multiple regression models estimating original fish weight. Abbreviations for independent variables are those given in Tables 2 and 3. * indicates that forward and backward models were not identical.

Species	Variables included in forward stepwise model	Variables included in backward stepwise model
Alewife	BD, CP, CL	BD, CP, CL
Blueback herring	BD, CP, PF, CL	BD, CP, PF, CL
Atlantic herring	BD, CP, OP	BD, CP, OP
Atlantic mackerel	OP, CL	OP, CL
Butterfish	BD, CP, PF, CL	BD, CP, PF, CL
Sand Lance	BD, CP, CL, DN	BD, CP, CL, DN
Red hake	CP, PF, CL	CP, PF, CL
Silver hake*	BD, CP, PF, OP	BD, ED, CP, PF, OP, DN
Haddock	BD, CP, CL	BD, CP, CL
Atlantic cod	BD, CP, PF, CL	BD, CP, PF, CL

Table 7

Least squares regression equations relating measurements (in millimeters) of total length (TL) and fork length (FL) to total weight (W) in grams for ten prey species in the Northwest Atlantic. s_b = standard error of the regression coefficient; r^2 = coefficient of determination; %PE = mean percent prediction error; n = number of fish measured; Range = size range in total length. Fork lengths were not measured for red hake, silver hake, or Atlantic cod.

Species	Total length Equation	s_b	r^2	%PE	Fork length Equation	s_b	r^2	%PE	n	Range
Alewife	$W = 2.74 \times 10^{-6} TL^{3.213}$	0.031	0.99	7.12	$W = 3.29 \times 10^{-6} FL^{3.254}$	0.035	0.99	7.82	137	73–282
Blueback herring	$W = 6.24 \times 10^{-6} TL^{2.993}$	0.101	0.96	6.78	$W = 13.78 \times 10^{-6} FL^{2.887}$	0.113	0.95	7.16	38	83–134
Atlantic herring	$W = 4.10 \times 10^{-6} TL^{3.111}$	0.037	0.99	8.10	$W = 4.53 \times 10^{-6} FL^{3.156}$	0.040	0.99	8.33	84	97–295
Atlantic mackerel	$W = 1.09 \times 10^{-6} TL^{3.354}$	0.039	0.99	5.86	$W = 0.85 \times 10^{-6} FL^{3.451}$	0.041	0.99	5.84	56	158–330
Butterfish	$W = 8.14 \times 10^{-6} TL^{3.094}$	0.024	0.99	6.78	$W = 8.43 \times 10^{-6} FL^{3.180}$	0.032	0.99	8.36	108	54–193
Sand lance	$W = 0.32 \times 10^{-6} TL^{3.449}$	0.112	0.93	12.74	$W = 0.41 \times 10^{-6} FL^{3.421}$	0.119	0.92	13.63	75	109–209
Red hake	$W = 4.41 \times 10^{-6} TL^{3.053}$	0.034	0.99	5.75					45	108–340
Silver hake	$W = 1.91 \times 10^{-6} TL^{3.213}$	0.027	0.99	8.96					95	75–300
Haddock	$W = 3.44 \times 10^{-6} TL^{3.186}$	0.063	0.98	7.50	$W = 3.78 \times 10^{-6} FL^{3.196}$	0.080	0.97	9.12	47	79–202
Atlantic cod	$W = 1.99 \times 10^{-6} TL^{3.308}$	0.090	0.99	5.53					31	52–140

Discussion

Each of the morphometric measurements, including those from diagnostic bones, were significantly related to total length, fork length, and weight. Measurements taken from diagnostic bones, especially cleithrum length, appear to be highly reliable predictors of original size for prey fish species in the Northwest Atlantic. Internal hard parts of fishes have historically proven accurate for estimating original sizes of prey fishes recovered from the stomachs of several freshwater piscivores (Knight et al., 1984; Trippel and Beamish, 1987; Hansel et al., 1988). Our results suggest that examination of diagnostic bones should also benefit diet analyses of marine piscivores.

The ability to estimate original length and weight of common prey fishes from a suite of morphometric measurements should result in a considerable increase in the amount of size-specific diet information for several predatory fishes in the Northwest Atlantic. Accurate information on the sizes of prey consumed across temporal and spatial scales is critical in order to calculate predator consumption rates and to determine predator impact on prey populations. Moreover, many piscivorous fishes feed selectively on specific sizes of prey (Juanes, 1994), suggesting that predatory impact may be greatest on a small range of prey sizes. Therefore, knowledge of prey sizes consumed is necessary in order to determine the extent of size-selective feeding patterns in Northwest Atlantic piscivores and their role in structuring marine fish populations. Finally, several authors have demonstrated the importance of body size in determining the outcome of predator-prey interactions among fishes (Werner and Gilliam, 1984, Miller et al., 1988, Stein et al., 1988). More complete information on predator-prey size relationships in the Northwest Atlantic may improve our understanding of the effects of body size on prey vulnerabilities to predation during various life history stages.

Clearly, the estimation of original prey sizes from diagnostic bone dimensions is not as susceptible to measurement error as estimates from external morphological features, where measurements are usually associated with soft tissues. Moreover, external morphology can often be altered during digestive processes, which may cause some or all external features to yield unreliable measurements. However, for recently consumed prey fishes, external morphological measurements may be highly reliable estimators of original prey size and represent a suitable alternative to diagnostic bones. For example, the linear relations of both eye diameter and caudal peduncle depth with total length were found to be reliable for reconstructing original prey lengths of six prey spe-

cies consumed by juvenile bluefish (Scharf et al., 1997). Similarly, Serafy et al. (1996) found the linear relation between eye diameter and total length of red drum to be particularly useful in estimating the size of angled fish. In addition to cleithrum length, maximum body depth and caudal peduncle depth were consistent predictor variables for estimating original weight of prey fishes examined in this paper. Differences in fish condition factor may not be closely correlated with differences in other morphological measurements. Therefore, indices of fish girth, such as body depth and caudal peduncle depth, should be reliable indicators of condition factor and should be most closely related to body weight. Further, the reconstruction of original prey sizes from external morphological measurements has the advantage of being comparatively less labor intensive than dissection and removal of internal hard parts.

The reconstruction of original prey sizes from diagnostic bones or external morphological measurements does, however, have some important limitations. The potential effects of preservatives on bone dimensions need to be considered if stomach contents are stored in a chemical preservative. The fish used in this study were not exposed to preservatives but were frozen and thawed before measured. The use of boiling water to aid in the removal of soft tissue may cause shrinkage and deformation of extracted bones if sufficient time elapses between the boiling process and the completion of bone measurements. However, bone measurements for our analyses were completed immediately after dissection and removal. In addition to the potential effects of preservation, previous studies indicate that estimation of prey sizes from partial remains will likely underestimate the proportion of small prey fish in the diet, because bones and external features of larger prey fish should be more resistant to digestion and be recovered from piscivore stomachs more frequently (Trippel and Beamish, 1987; Hansel et al., 1988). Lastly, allometric relationships may not remain constant with changes in fish size. Therefore, regression equations should not be applied to fish outside the size range used for their generation.

The results of our study indicate that, for the families of fishes examined, the opercle, cleithrum, and dentary represent diagnostic tools that can potentially aid in the identification of prey fishes recovered from the stomachs of Northwest Atlantic piscivores. The diagnostic features unique to each of the three bones appear to perform equally well in distinguishing family taxa from one another. However, within the families Gadidae and Clupeidae, cleithra and dentaries are better suited to illustrate

differences between genera relative to opercles. Newsome (1977) and Hansel et al. (1988) revealed similar findings, demonstrating the limitations of opercles for identifying prey fishes beyond the family level. Moreover, Hansel et al. (1988) found that cleithra and dentaries were more resistant to digestion than opercles or pharyngeal arches, when examining several freshwater fishes, and concluded that, for young prey fish, the cleithrum may be the most reliable bone because of its large size and early development in relation to other diagnostic bones.

None of the three diagnostic bones appear useful for differentiating between the two species of the genus *Alosa* examined in this study. Similarly, Hansel et al. (1988) found that for certain congeneric freshwater fishes, identification was inconsistent and not dependable when opercles, cleithra, dentaries, and pharyngeal arches were used. The size range of fishes used in this study included juveniles and young adults (Table 1) and is typical of size ranges examined in previous studies (Trippel and Beamish, 1987; Hansel et al., 1988). Therefore, for these life stages, opercles, cleithra, and dentaries may be potentially useful as tools for identifying prey fishes to the family and, in some cases, the generic taxonomic level, but likely are not adequate for distinguishing between species of the same genus.

Our descriptions of the diagnostic bones provide a simple means to distinguish prey fishes based on general bone structure. Indeed, there have been more rigorous efforts directed at identifying the systematic relationships among several of the fishes examined in this paper. However, the bone descriptions in this paper were provided as a simple guide for field identification of prey fishes commonly recovered from piscivore stomachs, and thus centered on general overall shape and features that were common to all of the fishes. The differences among the taxa that are outlined here should be readily observable to a large range of workers with varying levels of fisheries training. Therefore, we suggest that the level of analysis and description presented here may compliment existing information and may be ideally suited for identification of prey fishes in field settings.

The bone descriptions and regressions presented in this paper clearly have the potential to increase the amount of dietary information obtainable from stomach contents analyses of Northwest Atlantic piscivores. Further, the generation of a series of regression equations relating measurements from both internal hard parts and external morphological features to original fish size may provide a means to cross reference prey size estimates, thus facilitating the identification of erroneous estimates.

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