Trophic levels of fish species of commercial importance in the Colombian Caribbean

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Abstract: Ecological studies on commercial important fish species are of great value to support resource management issues. This study calculated trophic levels of those Colombian Caribbean fish species whose diet has been locally described. Usable diet data of 119 species resulted in 164 trophic level estimates. An ordinary regression model relating trophic level and fish size was formulated. The regression slope was positive and significantly different from zero ($p<0.05$) suggesting a scaling of trophic level with fish size. Both the list of trophic levels and the regression model should be of help in the formulation of trophic indicators and models of neotropical ecosystems. Rev. Biol. Trop. 59 (3): 1195-1203. Epub 2011 September 01.

Key words: trophic level, fishe size, Caribbean fishes, Colombia.

Quantitative knowledge of diet and hence trophic level of species is a key piece of information in our understanding of functioning of marine ecosystems. If fisheries are to be managed in the context of the ecosystem, a paramount input is the trophic level of the species involved, e. g., Stergiou *et al*. (2007); see Cury *et al*. (2005) and references there in and Vivas-Muñoz *et al*. (2008) for an application. In neotropical waters knowledge of fish diets is not scarce but the determination of trophic levels has been rarely intended.

The present work provides a list of trophic levels on the basis of diets determined locally in the Colombian Caribbean that may be useful as input for diagnostic tools, e.g. the fish in balance index of Pauly *et al*. (2000a), and ecotrophic and fishery models, e.g. ECOPATH type models (Christensen & Pauly 1992, Gascuel 2005). A regression model is proposed that relates size and trophic level as a last resort approach in case of absence of quantitative data of fish diets.

MATERIALS AND METHODS

A bibliographic search was conducted including journals and thesis works developed for the Colombian Caribbean fish species of economic importance (Fig. 1). Those works with quantitative data (percentage weight) were preferred, although a recent approach may allow converting frequency data into percentage weight (Stobberup *et al*. 2009). Unidentifiable stomach material was excluded in percentage weight calculations. When a dietary study reported diets by size ranges, a trophic level was calculated for each size range of fish.

Trophic levels, defined as the sum of the trophic levels of prey weighted by their fraction in the predator´s diet plus one, were estimated using the application TrophLab (Pauly *et al*. 2000b). TrophLab allows for three levels of taxonomic resolution of diets and postulates trophic levels for preys in the diets. Thus for each species a list of the typical

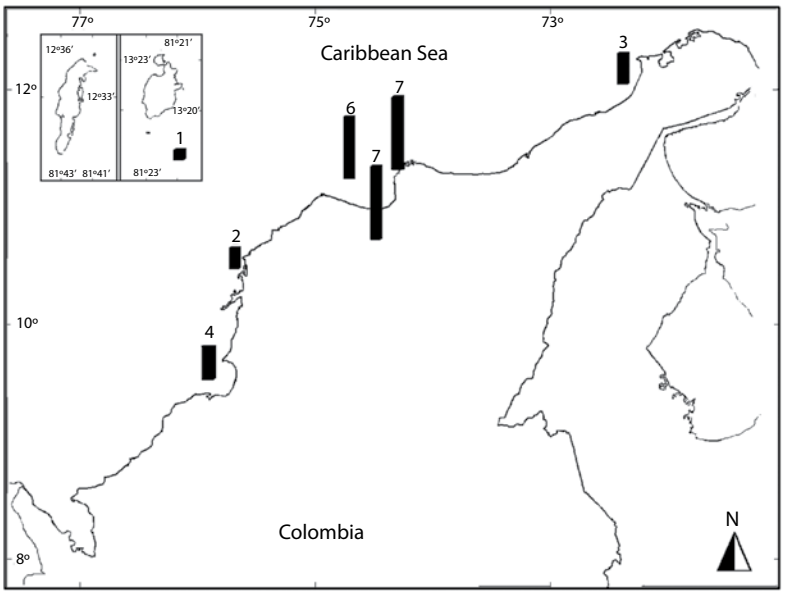

Fig. 1. Spatial distribution of documents on fish diets considered. Numbers on the bars are numbers of documents.

diet was constructed and percentage weight was assigned to items according to constrains in TrophLab.

Ordinary last squares regression was used to relate trophic level with fish size (fish size transformed to natural logarithms as to linearize the relationship). Both maximum length reported and the mean between minimum and maximum length were tested. The last is a crude attempt to give representation of size spectra in the determination of trophic level of a given species. Total length and fork length were transformed to standard length by means of factors obtained from local photographs or from images located in FishBase (Froese & Pauly 2010) with the exception of elasmobranchs and some bony fishes that lack a caudal fin. Only bony fishes were used in the regression analysis.

RESULTS

A total of 164 trophic levels for 119 fish species could be estimated (Table 1). These fishes represent about 20% of marine fishes known to occur in Colombian Caribbean waters (INVEMAR 2010). All fishes of fishery interest are included suggesting a bias towards those fishes. Most fishes have received only one dietary study but some had several (e.g. *Caranx crysus*, *C. hippos*, *Lutjanus synagris*, *Megalops atlanticus*, among others, Table 1). For those fishes with more than one dietary study estimation of trophic level was found to vary, probably due to a combination of different size ranges, with bigger fish tending to have higher trophic levels (see regression analysis below), and varying sample sizes used (Table 1). One additional source of variance is the taxonomic resolution of the original work.

Figure 2 shows the plot of trophic level (TL) vs. mean standard length (SL, plot of trophic level vs. maximum standard length not shown). The slope of both regressions (after transforming size to natural logarithms) is significantly different from zero ($p<0.05$) but the regression trophic level vs. ln (mean standard length) explains more variability in the data: 30% vs. 25% for the other approach. See Figure 2 for the equation.

TABLE 1
Trophic levels of 119 Colombian Caribbean fishes

Species	Trophic Level	Size (mm)	Stomachs	Source
Acanthostracion polygonius	2.33	135-200	10	Navajas (1998)
Acanthostracion quadricornis	2.15	130-180	3	Navajas (1998)
Acanthurus chirurgus	2.36	119-240	16	Navajas (1998)
Albula nemoptera	3.87	200-345	34	Melo (1998)
Albula vulpes	3.71	235-360	11	Melo (1998)
Alectis ciliaris	3.98	255-270	2	Melo (1998)
Aluterus monoceros	2.83	224-355	25	Navajas (1998)
Anisotremus surinamensis	3.68	NR	1	Melo (1998)
Anisotremus virginicus	3.78	208	1	Melo (1998)
Auxis thazard	4.50	229-320	7	Moreno (1986)
Bagre marinus	3.59	225-285	4	Melo (1998)
Bairdiella ronchus	3.78	55-191	623	Torres (1994)
	4.50	NR	3	Jiménez (2008)
Balistes vetula	3.46	168-366	11	Schiller & García (2000)
	3.05	67-370	76	Martínez(1990)
Balistes capriscus	3.39	125-300	179	Duarte & Schiller (1997)
Calamus penna	3.43	205-323	68	Melo (1998)
Calamus pennatula	3.41	235-275	6	Melo (1998)
Caranx crysos	4.30	264-313	3	Melo (1998)
	4.43	179-298	14	Pinilla (1986)
	4.48	306-340	20	Pinilla (1986)
	4.46	349-459	16	Pinilla (1986)
	4.49	157-472	380	Reyes (1999)
Caranx hippos	4.50	280-290	2	Melo (1998)
	4.37	167-250	50	Pinilla (1986)
	4.44	258-500	11	Pinilla (1986)
	4.50	509-792	14	Pinilla (1986)
	4.23	NR	3	Jiménez (2008)
Caranx latus	4.41	194-235	5	Melo (1998)
Carcharhinus signatus	4.44	NR	3	Melo (1998)
Cathorops mapale	3.77	NR	6	Jiménez (2008)
Cathorops spixii	3.67	86-343	108	Santacruz (1989)
	3.28	116-207	41	Melo (1998)
Centropomus ensiferus	4.28	93-160	4	Bustos (2003)
	4.24	NR	8	Jiménez (2008)
Centropomus undecimalis	4.07	75-162	10	Bustos (2003)
	4.40	114-852	223	Sierra (1996)
Chaetodipterus faber	3.12	130-255	60	Melo (1998)
Chaetodon ocellatus	3.51	70-125	8	Navajas (1998)
Chaetodon sedentarius	3.41	110-130	3	Navajas (1998)
Chilomycterus antillarum	3.50	140	1	Navajas (1998)
Chloroscombrus chrysurus	3.59	119-270	38	Melo (1998)
Conodon nobilis	3.88	132-290	103	Melo (1998)
Ctenosciaena gracilicirrhus	3.92	87-190	37	Navajas (1998)
Cynoscion jamaicensis	4.40	NR	8	Jiménez (2008)
	4.49	205-224	3	Navajas (1998)
Dasyatis americana	3.74	670-162 TL	6	Navajas (1998)
Dasyatis guttata	4.02	154-710 DW	19	Mojica (2007)
	3.43	440-1550 TL	16	Navajas (1998)
Diapterus auratus	3.43	200	1	Navajas (1998)
	2.97	61-182	27	Arenas & Acero (1992)
Diapterus rhombeus	2.60	56 -110	79	Arenas & Acero (1992)
Diodon holocanthus	3.36	110-210	25	Navajas (1998)

TABLE 1 (Continued)
Trophic levels of 119 Colombian Caribbean fishes

Species	Trophic Level	Size (mm)	Stomachs	Source
Elegatis bippinulata	4.24	260-530	42	Posada (2005)
Elops saurus	3.60	305-440	2	Melo (1998)
	4.32	192-715	449	Santos & Arboleda (1993)
	4.35	NR	9	Jiménez (2008)
Eucinostomus argenteus	3.75	70-154	76	Navajas (1998)
	3.29	97-123	11	Arenas &Acero (1992)
Eucinostomus gula	3.58	80-160	63	Navajas (1998)
	3.15	61-101	7	Arenas & Acero (1992)
	3.37	78-101	68	Santacruz (1989)
Eucinostomus harengulus	3.22	94-110	9	Arenas & Acero (1992)
Eucinostomus melanopterus	3.14	80-114	23	Arenas & Acero (1992)
Eugerres plumierii	3.08	94-266	38	Navajas (1998)
	3.09	78-216	155	Arenas & Acero (1992)
Euthynnus alletteratus	4.47	184-643	65	Moreno (1986)
	4.49	240-530	46	Posada (2005)
Fistularia petimba	4.50	105-680	4	Navajas (1998)
Fistularia tabacaria	4.50	636-713	3	Navajas (1998)
Gerres cinereus	3.23	155-255	2	Navajas (1998)
	3.04	62-139	54	Arenas & Acero (1992)
	3.46	65-139	23	Santacruz (1989)
Haemulon album	3.71	320	1	Melo (1998)
Haemulon aurolineatum	3.58	86-235	24	Melo (1998)
Haemulon bonariense	4.26	NR	6	Jiménez (2008)
Haemulon melanurum	3.42	60-235	3	Melo (1998)
Haemulon plumierii	3.82	104-285	155	Rojas & Botero (1987)
	3.27	10-245	5	Melo (1998)
Haemulon steindachneri	3.57	80-285	90	Melo (1998)
Hemicaranx amblyrhynchus	3.80	135-299	2	Melo (1998)
Holocentrus ascensionis	3.47	180-220	7	Navajas (1998)
Isopisthus parvipinnis	4.50	NR	6	Jiménez (2008)
Larimus breviceps	4.38	110-195	14	Navajas (1998)
Lepophidium profundorum	3.92	100-280 TL	72	Santacruz (1989)
Lutjanus analis	4.10	210 a 460	110	Duarte & García (1999a)
	4.04	NR	126	Arévalo (1996)
Lutjanus apodus	4.11	184-334	3	Navajas (1998)
Lutjanus griseus	4.50	426	1	Navajas (1989)
Lutjanus jocu	4.42	260-525	10	Navajas (1989)
Lutjanus mahogoni	4.47	200-225	4	Navajas (1989)
Lutjanus purpureus	3.59	150	1	Navajas (1989)
Lutjanus synagris	3.83	110-320	94	Duarte & García 1999b)
	3.92	87-301	106	Martínez (1990)
	4.00	86-249	91	Santacruz (1989)
	4.10	NR	116	Arévalo (1996)
	4.06	NR	4	Jiménez (2008)
Lutjanus vivanus	3.93	102-290	7	Navajas (1998)
Megalops atlanticus	4.16	305-470	2	Navajas (1989)
	4.13	93-205	101	Cataño & Garzón (1994)
	4.29	206-317	93	Cataño & Garzón (1994)
	4.43	318-495	108	Cataño & Garzón (1994)
Menticirrhus littoralis	4.09	227-244	4	Navajas (1998)
Micropogonias furnieri	3.23	63-325	246	Escobar (1994)
	3.98	167-353	29	Navajas (1998)
Mugil curema	2.00	67-194	276	Bustos *et al*. (2004)
Mugil incilis	2.23	60 -293	15	Velasco (1985)

TABLE 1 (Continued)
Trophic levels of 119 Colombian Caribbean fishes

Species	Trophic Level	Size (mm)	Stomachs	Source
Mustelus canis	3.87	265-487	8	Melo (1998)
Myripristis jacobus	3.51	125-155	9	Navajas (1998)
Narcine bancroftii	3.60*	109-594 TL	79	Moreno *et al*. (2009)
Narcine brasiliensis	3.55	240-470 TL	8	Melo (1998)
Ocyurus chrysurus	4.31	75-376	123	Rojas & Botero (1987)
Oligoplites palometa	4.45	56-280	86	Duque *et al*. (1996)
Oligoplites saurus	4.48	60-249	282	Duque *et al*. 1996)
Opisthonema oglinum	2.36	NR	12	Jiménez (2008)
	3.30	34-288	64	Navajas (1998)
Pellona harroweri	3.37	34-91	21	Críales (2003)
	3.67	67-221	15	Navajas (1998)
Polydactylus virginicus	3.90	140-222	19	Navajas (1998)
Pomacanthus paru	2.03	114	1	Navajas (1998)
Pomadasys corvinaeformis	3.35	96-400	44	Melo (1998)
Pomadasys crocro	3.50	NR	1	Melo (1998)
Priacanthus arenatus	3.89	130-290	16	Melo (1998)
Prionotus punctatus	3.74	145-240	2	Melo (1998)
Pristipomoides aquilonaris	4.14	150-200	6	Navajas (1998)
Pseudopeneus maculatus	3.76	69-147	74	Santacruz (1989)
	4.05	104-190	14	Melo (1998)
Rhinesomus bicaudalis	3.14	180-280	2	Navajas (1998)
Rhinobatos percellens	3.70	319-575	24	Melo (1998)
Rhinoptera bonasus	3.59	554	1	Melo (1998
Rhomboplites aurorubens	4.20	150-205	7	Navajas (1998)
Saurida normani	4.46	155-237	3	Navajas (1998)
Scomberomorus brasiliensis	4.45	295-605	11	Navajas (1998)
	4.50	167-583	56	Moreno (1986)
	4.50	NR	5	Jiménez (2008)
Scomberomorus cavalla	4.50	270-946	11	Moreno (1986)
Scorpaena plumieri	3.30	165-224	9	Melo (1998)
Selar crumenophthalmus	3.97	150-257	37	Melo (1998)
	4.13	182-191	23	Pinilla (1986)
	4.09	201-218	57	Pinilla (1986)
	4.30	226-261	13	Pinilla (1986)
Selene brownii	4.38	95-280	39	Melo (1998)
Selene setapinnis	3.60	120-210	8	Melo (1998)
Selene vomer	3.97	145-304	39	Melo (1998)
Seriola rivoliana	4.34	220-260	3	Melo (1998)
Seriola zonata	3.54	255	1	Melo (1998)
Serranus atrabranchus	4.01	70	1	Melo (1998)
Sphoeroides greeleyi	3.09	35-102	337	Londoño (1994)
Sphoeroides testudineus	3.35	52-210	329	Londoño (1994)
Sphyraena barracuda	4.50	>427	51	Bent (2006)
Sphyraena guachancho	4.40	285.443	5	Navajas (1998)
Sphyraena picudilla	4.48	215-362	6	Navajas (1998)
Stellifer griseus	4.50	NR	6	Jiménez (2008)
Stephanolepis setifer	2.62	137	1	Navajas (1998)
Syacium micrurum	3.50	105-130	3	Navajas (1998)
Thunnus atlanticus	4.48	176-748	26	Moreno (1986)
Trachinotus carolinus	3.50	340	1	Melo (1998)
Trachinotus falcatus	3.23	370-393	2	Melo (1998)
Trichurus lepturus	4.47	490-1120 TL	12	Melo (1998)
	4.50	NR	5	Jiménez (2008)
Umbrina broussonetti	4.07	145-210	15	Navajas (1998)

TABLE 1 (Continued)
Trophic levels of 119 Colombian Caribbean fishes

Species	Trophic Level	Size (mm)	Stomachs	Source
Umbrina coroides	3.92	NR	4	Jiménez (2008)
	3.44	131-205	84	Navajas (1998)
Upeneus parvus	4.28	160-175	3	Melo (1998)

Unless otherwise stated size measure is standard length. NR=Not reported, TL=Total length, DW=Disk width. * As reported in Moreno *et al*. (2009).

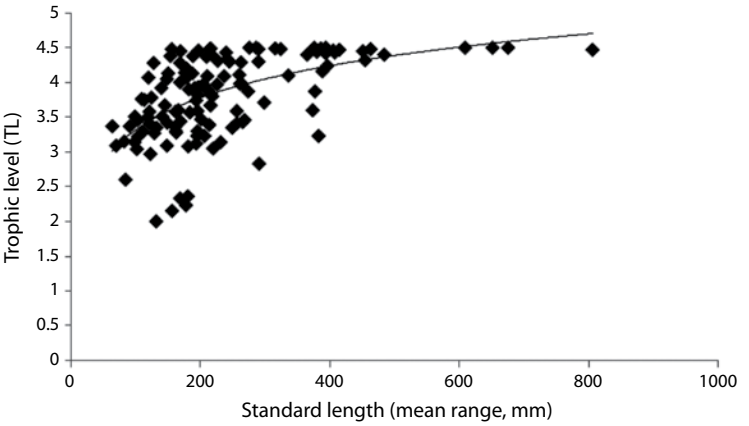

Fig. 2. Relationship between mean range standard length (SL) and trophic level (TL) in some Colombian Caribbean bony fishes. Regression equation was: TL=0.2678+0.6622*ln(mean SL), r^2=0.30, $p<0.05$.

DISCUSSION

Much work remains to be done. Spatial coverage of studies is quite uneven with the bulk of the work done in the central Colombian Caribbean thus spatial cover must be improved as spatial comparisons would be informative. It is unfortunate that a substantial amount of work has not been published as it is contained in gray literature (thesis works). No work has attempted to follow temporal changes in diets and only few have come close to size-based changes in diets. However, our results suggest that trophic level increases with size for a given species (Table 1).

The trophic levels reported here should be viewed with care. Size structure should be taken into account and be given adequate weight in calculations. A weakness in the regression model presented here as a predictive tool is the uneven number of stomachs of fishes size range. Clearly, size is not everything as it explains a relative low percentage in trophic level variation (via a logarithmic relationship), although it may be the single most important factor. For instance, Romanuk *et al*. (2010), using a much bigger data set, found that fish size explained about 20% of fish trophic level variation, while phylogeny explained an additional 17%. Nevertheless, it is hoped that both the trophic level list and the regression presented here turns out to be useful to researchers in the neotropics and elsewhere.

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RESUMEN

Estudios ecológicos de especies de peces importantes comercialmente son de gran valor como insumos en temas de manejo. Aquí se presenta estimaciones del nivel trófico de aquellas especies de peces del Caribe colombiano cuya dieta ha sido descrita localmente. Información utilizable sobre 119 especies resulto en 164 estimaciones de nivel trófico. Se propone un modelo de regresión ordinaria entre el nivel trófico y el tamaño de los peces. La pendiente resultó positiva y significativamente diferente de cero ($p<0.05$) lo cual sugiere una relación moduladora entre el nivel trófico y el tamaño de los peces. Tanto la lista de niveles tróficos como el modelo de regresión, deben ser de ayuda en la formulación de indicadores tróficos y modelos de los ecosistemas neotropicales.

Palabras clave: nivel trófico, talla de peces, peces del Caribe, Colombia.

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